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IoT-Based Water Quality Monitoring and Management System Empowering Rural Communities for Sustainable Development

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Abstract: This project shows off an IoT-based water quality control system made for use in rural villages. As the need for clean drinking water grows, especially in areas that lack access to it, this method helps address some of the most critical issues in ensuring water safety and quality. The proposed system connects a network of sensors that are strategically placed in the village's water supply system to monitor key parameters, including pH level, turbidity, dissolved oxygen, chlorine levels, temperature, and conductivity. These sensors provide real-time data wirelessly to a central computer, where it is processed and analysed. We use advanced algorithms to identify unusual patterns, predict future events, and detect possible contamination incidents. If the water quality standards are not met, the system sends alarms and messages to the right people so that they may take action quickly and fix the problem. The method also enables those in charge of villages and water management to monitor and control things from a distance, allowing them to address water quality issues before they become problems. To raise awareness and encourage participation among locals, community engagement is stressed. This encourages a group approach to managing water quality. The system's potential for growth and longevity is emphasised, ensuring it remains effective even as village dynamics change and resources become scarce. By using an IoT-based solution, rural villages can make it easier for people to access safe drinking water, reduce health risks, and improve their overall health.

Keywords: Water Quality Management, Relevant Stakeholders, Internet of Things (IoT), Chemical Parameters, Public Health, Water-Borne Diseases, Water Pollution, Clean Drinking, Valuable Insights

Introduction

Water pollution is a major problem around the world that puts people's health at risk and is responsible for a large number of fatalities from diseases spread by water [24]. To solve this challenge, we need more effective and cost-effective ways to monitor water quality in real time. This article proposes a cost-effective approach to utilising the Internet of Things (IoT) for creating a real-time water quality monitoring system [39]. The system's goal is to monitor important physical and chemical factors, such as gas levels, pH, temperature, and humidity, while drinking water is being distributed [28]. This kind of technology could provide us with important information on water quality, enabling us to take steps to ensure drinking water is safe and preserve public health.

An embedded system is a controller programmed and operated by a real-time operating system (RTOS) that performs a specific function within a larger mechanical or electrical system. It often has to deal with the processing limits of embedded systems in real time [25]. It is built into a whole gadget, which usually has both hardware and mechanical pieces. Many of the items we use every day are controlled by embedded systems. Ninety-eight per cent of all microprocessors are made to be used as parts of embedded systems. When compared to general-purpose computers, embedded computers tend to use less power, be smaller, work in a wider range of temperatures, and cost less per unit [34]. This comes at the cost of low processing power, which makes them much harder to program and use. By leveraging the intelligence in the hardware and utilising existing sensors, along with the network of embedded units, you can maximise the resources at both the unit and network levels, and introduce new features that extend beyond the existing capabilities. For instance, smart methods can be made to control power [30]. An embedded processor is usually part of an embedded system. Embedded systems are used in many digital devices, such as microwaves, VCRs, and autos. Some embedded systems come with an operating system. Some are particularly specialised, which means that the whole logic is written as one program [38]. Some gadgets have these systems built in for a specialised purpose other than general-purpose computing.

There are several uses for embedded systems in cars, such as motor control, cruise control, body safety, engine safety, robotics on assembly lines, automotive multimedia, car entertainment, E-commerce access, and mobile devices [26]. Networking, mobile computing, wireless communications, and other related technologies are all examples of embedded systems in telecommunications. Smart cards have embedded systems for banking, phones, and security. Defence, communication, and aerospace are all fields that use embedded systems in satellites and missiles. Image processing, networking systems, printers, network cards, monitors, and displays are all examples of embedded systems in computer networking and peripherals [32]. Digital consumer electronics that include embedded systems are set-top boxes, DVDs, high-definition TVs, and digital cameras.

The Internet of Things (IoT) is a concept that describes situations in which network connectivity and computational power are added to objects, sensors, and ordinary items that aren't usually thought of as computers [36]. This enables these devices to create, share, and use data with minimal human assistance. However, no one definition fits everybody. Technologies that make things possible: For decades, people have thought about how to use computers, sensors, and networks together to keep an eye on and operate equipment. But a few recent movements in the tech business are making the Internet of Things more likely to become a reality for a lot more people [22]. Some of these are Ubiquitous Connectivity, Widespread Adoption of IP-based Networking, Computing Economics, Miniaturisation, and Advances in Data. Connectivity Models: IoT systems utilise multiple technical communication models, each with its distinct features. The Internet Architecture Board talks about four popular ways to communicate: Device-to-Device, Device-to-Cloud, Device-to-Gateway, and Back-End Data-Sharing [31]. These models demonstrate the flexibility of IoT devices in connecting and providing value to users.

IoT devices are made up of both hardware and software. Dedicated hardware components are utilised to connect the interface to the real world and perform tasks that are harder to compute [27]. Microcontrollers run programs that read inputs and control the system. This module discusses the roles of the hardware and software components within the system. It talks about the roles of common hardware parts and how the software and hardware work together through the microcontroller. Often, IoT devices require an operating system to enable communication between the software and the microcontroller. We will talk about what an operating system does for an IoT device and how an IoT operating system is different from a regular one. An IoT ecosystem is made up of smart gadgets that can connect to the internet and use built-in processors, sensors, and communication gear to gather, send, and act on data they get from their surroundings [33]. IoT devices link to an IoT gateway or another edge device to exchange the sensor data they collect.

The data is then either transferred to the cloud for analysis or processed on the device itself. These gadgets can sometimes communicate with other related devices and act based on what they learn from each other. Most of the work is done by the devices themselves, but people can still interact with them [21]. For example, they can set them up, give them instructions, or access the data. The connectivity, networking, and communication protocols utilised by these web-enabled devices are predominantly contingent upon the specific IoT applications implemented [37].

The Internet of Things has many real-world uses, such as consumer IoT, commercial IoT, manufacturing IoT, and industrial IoT [29]. IoT apps can be used in a lot of different fields, such as automotive, telecommunications, energy, and more. For instance, in the consumer market, smart houses with smart thermostats, smart appliances, and connected heating, lighting, and electronic gadgets can be managed from a distance using computers, cellphones, or other mobile devices [35]. Wearable devices with sensors and software may gather and evaluate user data. They can also convey information about users to other technologies to make their lives easier and more comfortable [23]. Wearable gadgets are also utilised for public safety. For example, they can help first responders get to an emergency faster by giving them the best routes to take, or they can keep track of construction workers' or firefighters' vital signs at dangerous locations.

Literature Survey

The current condition of water quality management systems around the world is the result of a complicated mix of environmental, technological, and regulatory factors [15]. This assessment examines key issues and challenges, including varying water quality standards across different areas, limited access to monitoring tools in developing countries, and the increasing impact of climate change on water supplies [2]. Industrial discharge, agricultural runoff, and urban wastewater are still major dangers to aquatic ecosystems and human health. The report also discusses new developments, including the use of advanced sensor networks, big data analytics, and real-time monitoring platforms, to enhance water quality monitoring. Regulatory frameworks are changing to deal with new contaminants, but enforcement is still not consistent. The review emphasises the necessity of amalgamating scientific research, policy formulation, and community involvement to develop adaptable and resilient management systems. To make monitoring techniques more consistent and share best practices, countries need to work together and strengthen their capabilities [5]. Due to increasing environmental demands, the report suggests techniques like ecosystem-based management, better ways to treat wastewater, and specific steps to stop pollution. The results show that we need to take a more comprehensive approach that balances economic growth with environmental protection [9]. This will ensure that future generations have access to safe and clean water, while also mitigating the hazards associated with declining global water quality.

The use of Geographic Information Systems (GIS) and remote sensing technology in water quality management has transformed the methodologies for collecting, analysing, and using spatial and temporal data [8]. This literature review examines the efficacy of geospatial technologies in monitoring diverse water quality measures, including turbidity, chlorophyll concentration, and temperature, at both local and regional levels, by facilitating the mapping of pollution hotspots and the identification of pollution sources [18]. GIS and remote sensing enable people to make informed decisions based on data, allowing them to focus their cleanup efforts. Remote sensing, using images from satellites and drones, lets you keep an eye on things on a large scale all the time. GIS, on the other hand, lets you analyse and visualise complicated datasets in space. The report also discusses problems, including the need for high-resolution data, the challenge of integrating different datasets, and the limitation that some water quality characteristics can't be detected from a distance [14]. There are opportunities to enhance the accuracy and reliability of these technologies by integrating them with ground-based measurements and predictive models [1]. The study also discusses how cloud-based platforms and open-access data repositories can facilitate easier access to geospatial information for policymakers, scholars, and communities. By leveraging the best aspects of GIS and remote sensing, water quality management can become more proactive, flexible, and responsive to emerging threats. This will help protect aquatic resources around the world in a way that lasts.

Recent advancements in molecular approaches have greatly improved the detection and identification of microbial contaminants, diseases, and new pollutants in the evaluation of water quality [11]. This article discusses how tools like polymerase chain reaction (PCR), next-generation sequencing (NGS), and metagenomics can make water testing more accurate, sensitive, and faster. PCR allows for the quick detection of certain diseases at extremely low levels. At the same time, NGS gives a full picture of the composition of microbial communities, making it possible to find both known and new organisms. Metagenomics also lets you study genetic material directly from ambient samples without having to culture them beforehand. These procedures are better than older ones because they cut down on detection times and make diagnoses more accurate [6]. However, there are several challenges, including high costs, the need for specialised knowledge, and the requirement to manage a large amount of complex data. The review also discusses the potential of portable molecular diagnostic technologies for field use, which could revolutionise water monitoring in resource-poor areas [17]. Water quality programs can better deal with contamination events, find pollution sources, and come up with targeted intervention strategies that protect public health and keep ecosystems healthy by combining molecular methods with traditional monitoring and risk assessment frameworks.

Community-based approaches to managing water quality stress the need for local stakeholders to be involved in monitoring, making decisions, and putting conservation measures into action. This review uses case studies from different parts of the world to show how getting people involved in their communities makes them feel responsible for their local water resources. These kinds of programs generally teach people in the community how to gather water samples, read the data, and address pollution problems [4]. Adding local knowledge makes management plans more relevant and acceptable, and it helps to close the gaps between scientific judgements and community needs. The report examines successful projects where communities, NGOs, and government agencies have collaborated to improve water quality and manage resources more sustainably. However, there are still problems, including insufficient funding, inconsistent attendance, and potential disagreements among parties. Building capacity, using low-cost monitoring tools, and including community data in official decision-making processes are all ways to make community-driven activities stronger. These programs help people take an active role in managing water, which leads to long-term environmental stewardship, social cohesion, and management solutions that are culturally appropriate and meet the needs and challenges of different areas.

Emerging pollutants, such as medications, personal care items, and a range of industrial chemicals, are widely acknowledged as a substantial risk to water quality and ecosystem vitality [10]. This literature review examines their prevalence, routes, and potential hazards to human populations and aquatic organisms. Some of the places where these pollutants come from are wastewater treatment plant effluents, agricultural runoff, and improper disposal of domestic items [20]. Analytical techniques, like liquid chromatography-mass spectrometry (LC-MS), have enhanced detection capabilities, allowing researchers to discern minuscule amounts of a diverse array of substances [19]. However, we still lack detailed information on the long-term effects of many new pollutants on health and the environment, particularly when they are combined or used over an extended period. The report emphasises the importance of incorporating monitoring programs for these contaminants into their regular work. It also discusses possible solutions, including the use of advanced wastewater treatment technologies, reducing garbage at its source, and increasing public awareness [16]. To deal with new toxins, scientists, regulators, industry stakeholders, and communities will need to work together to establish rules that are both proactive and flexible. The assessment emphasises that, in the absence of these actions, the continued presence and accumulation of these compounds in water systems may present increasing hazards in the future.

Using artificial intelligence (AI) to manage water quality is a game-changing way to improve monitoring, assessment, and remedial operations [7]. This paper examines the capacity of AI methodologies, such as machine learning algorithms, neural networks, and expert systems, to analyse extensive and intricate datasets for pattern recognition, forecasting water quality changes, and facilitating informed decision-making. AI can combine data from several sources, like sensors in the field, remote sensing images, and lab tests, to make real-time forecast models of how water quality changes over time. These features enable the setup of early warning systems that can identify potential contamination situations before they escalate [3]. The study discusses examples where AI-driven models have successfully identified pollutant sources, enhanced water treatment processes, and managed water resources effectively. Some of the problems include ensuring the data is accurate, clarifying algorithms, and integrating AI systems into the current infrastructure. People are also concerned about the cost of using advanced AI solutions and the level of technical expertise required. Still, there is a lot of potential because AI can make things more efficient, lower the cost of monitoring, and let managers be proactive instead of reactive [13]. As these technologies improve, they could become integral components of comprehensive systems for managing water quality.

Methodology

The current method uses separate water quality monitors in different bodies of water. These sensors can measure things like pH levels, depending on what is needed and the body of water being watched [41]. When the system detects a potential water quality issue, it triggers an alarm. You can send this notice to the right people, such as environmental agencies, water management staff, or the authorities, using GSM notifications on their phones [43]. The suggested cost-effective real-time water quality monitoring system uses Internet of Things (IoT) technology to help protect public health from the serious problem of water contamination.

The system's main job is to monitor important physical and chemical factors like temperature, humidity, pH, and gas levels throughout the distribution of drinking water. This monitoring will enable us to take proactive steps to protect public health and ensure the safety of drinking water [40]. The system will utilise the Blynk app (Figure 1) to simplify monitoring and operation of the water system. The app will let customers see the water quality parameters in real time and control the device from a distance. In particular, the app will have a button that lets you manipulate the wall of the water tank [42]. Clicking the button opens the wall of the water tank, making it easier to manage the water flow.

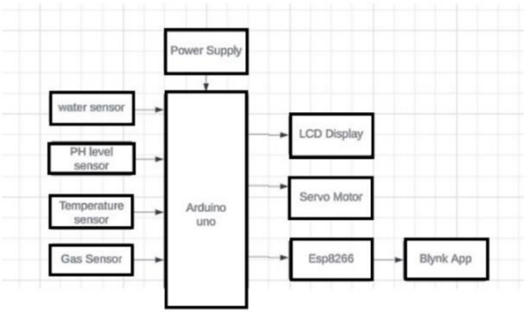

Figure 1. Block Diagram

Results and Discussion

A servomotor is a closed-loop servomechanism that uses feedback about its location to control its movement and final position [53]. A signal, either analogue or digital, that tells the control where to move the output shaft is what it gets as input. An encoder is connected to the motor to give feedback on its speed and position [95]. In the most basic scenario, only the position is measured (Figure 2). The output's measured position is compared to the command position, which is the input to the controller from the outside [69]. An error signal is sent if the output position is not what it should be. This signal then makes the motor turn in either direction, as needed, to move the output shaft to the right position. The motor stops when the error signal gets closer to zero.

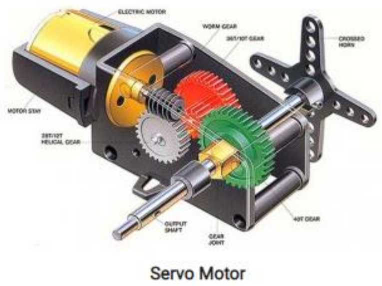

Figure 2. Servo Motor

The most basic servomotors employ a potentiometer to sense simply the position and bang-bang control to move the motor [83]. The motor always spins at maximum speed or stops. This kind of servomotor isn't utilised much in industrial motion control, but it's the basis for the simple and cheap servos that are used in radio-controlled models. More advanced servomotors use optical rotary encoders to measure the speed of the output shaft[2] and a variable-speed drive to change the speed of the motor. [3] Usually used with a PID control method, both of these improvements make it possible for the servomotor to reach its commanded position faster and more accurately, with less overshooting. A servo motor is made up of four parts: a regular DC motor, a gear reduction unit, a position-sensing device, and a control circuit. A gear mechanism connects the DC motor to a position sensor, which is generally a potentiometer [68]. The servo spline sends the motor's output to the servo arm from the gearbox. The gear in a conventional servo motor is usually composed of plastic, while the gear in a high-power servo motor is usually made of metal. A servo motor has three wires: a black wire that goes to the ground, a white/yellow wire that goes to a control unit, and a red wire that goes to a power supply.

The way LCDs work is that when you put an electric current through the liquid crystal molecule, it tends to untwist [58]. This changes the angle of the light that goes through the molecule of the polarised glass and the angle of the top polarising filter. So, a small amount of light can get through the polarised glass through a certain section of the LCD. So, that area will be darker than the others. The LCD operates by blocking light [44]. When making LCDs, a mirror that reflects light is put on the back. An electrode plane composed of indium-tin-oxide is on top, and a polarised glass with a polarising film is on the bottom of the device [94]. A common electrode must cover the whole area of the LCD, and the liquid crystal material must be above it.

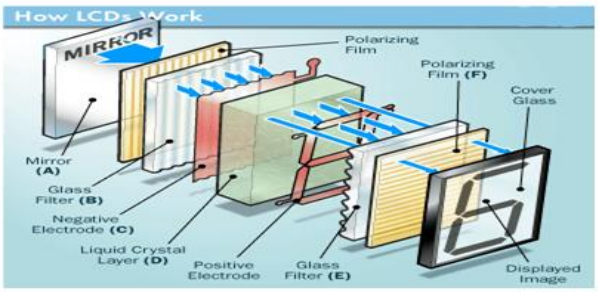

Figure 3. LCD Layer Diagram

The second piece of glass has an electrode in the shape of a rectangle on the bottom and another polarising film on top [93]. It is important to note that both components are retained at right angles (Figure 3). The light will pass through the front of the LCD, be reflected by the mirror, and then be sent back when there is no current. The current from the battery will make the liquid crystals between the common-plane electrode and the rectangular-shaped electrode untwist [59]. So, the light can't get through. It looks like nothing is in the rectangular space.
A gas detector is a safety gadget that finds gases in an area. You can use this kind of technology to find a gas leak or other emissions. It can also connect to a control system so that a process can be

stopped automatically [67]. A gas detector can make an alarm sound for those in the area where the leak is happening so they can flee. This kind of gadget is vital since many gases can harm living things, including people or animals [89]. Gas detectors can find gases that are harmful, flammable, or toxic, as well as oxygen levels that are too low. This kind of device is widely used in business [79]. You can find them in places like oil rigs, where they monitor industrial processes and new technologies like solar. They could be used to put out fires.

Gas leak detection involves using sensors to identify gas leaks that could be hazardous [70]. People are normally warned when these sensors find a harmful gas by sounding an alarm. People can also be exposed to harmful gases while painting, fumigating, filling up with gasoline, building, digging up contaminated soil, working in landfills or going into tight places [52]. Some common types of sensors are photoionization detectors, flammable gas sensors, infrared point sensors, ultrasonic sensors, electrochemical gas sensors, and semiconductor sensors. These sensors can be used for a variety of applications [84]. You can find them in houses, industrial plant fumigation facilities, paper pulp mills, aircraft and shipbuilding facilities, hazardous operations, and wastewater treatment facilities.

Figure 4. Gas Sensor

Electrochemical: Electrochemical gas detectors let gases pass through a porous membrane to an electrode, where they are either chemically oxidised or reduced (Figure 4). The concentration of the gas is shown by how much of it is oxidised at the electrode, which controls how much current is produced. Manufacturers can modify the porous barrier on electrochemical gas detectors to enable them to detect a specific range of gas concentrations [60]. Also, because the diffusion barrier is physical or mechanical, the detector was more stable and reliable over the sensor's lifetime. So, it required less maintenance than other early detection systems [71]. However, the sensors can be damaged by corrosive substances or chemicals, and they may only endure for one to two years before they need to be replaced. [4] Electrochemical gas detectors are utilised in many places, including chemical factories, refineries, gas turbines, subterranean gas storage facilities, and more.

Catalytic bead (pellistor): Catalytic bead sensors are often employed to find flammable gases that could explode when their concentrations are between the lower explosion limit (LEL) and the upper explosion limit (UEL). There are active and reference beads with platinum wire coils on opposite arms of a Wheatstone bridge circuit [96]. These beads are heated electrically to a few hundred degrees C. The active bead has a catalyst that makes it possible for combustible substances to oxidise [50]. This makes the bead even hotter and changes its electrical resistance. The difference in voltage between the active and passive beads is directly related to the amount of all the flammable gases and vapours that are present. A sintered metal frit lets the sampled gas into the sensor [66]. This filter keeps the instrument from exploding when it is taken into an area with flammable gases. Pellistors can measure almost all gases that can burn, but they are more sensitive to tiny molecules that go through the sinter faster. The concentration ranges that can be measured are usually between a few hundred ppm and a few volume per cent [92]. These sensors are cheap and strong, but they need at least a few per cent of oxygen in the air to work. They can also be poisoned or stopped by things like silicones, mineral acids, chlorinated organic chemicals, and sulphur compounds.

Photoionisation: A photoionisation detector (PID) uses a UV lamp with a lot of photons to ionise the molecules in the gas being sampled [72]. If the ionisation energy of the compound is lower than that of the lamp photons, an electron will be released. The current that flows through the compound is directly related to the amount of it present. The most common lamp photon energies are 10.0 eV, 10.6 eV, and 11.7 eV. The 10.6 eV lamp lasts for years, but the 11.7 eV lamp usually only lasts a few months and is only used when there are no other options. You can find a wide range of chemicals in amounts from a few ppb to several thousand ppm [45]. Aromatics and alkyl iodides are the most sensitive compound classes, followed by olefins, sulphur compounds, amines, ketones, ethers, alkyl bromides, and silicate esters; organic esters, alcohols, aldehydes, and alkanes; and H2S, NH3, PH3, and organic acids. There is no reaction to regular air parts or mineral acids [88]. The best things about PIDs are that they are very sensitive and easy to use [85]. The only bad thing is that they don't measure specific compounds. New PIDs with pre-filter tubes have been released that make it easier to find chemicals like benzene or butadiene [54]. People use fixed, handheld, and small clothing-clipped PIDs a lot for monitoring the environment, industrial hygiene, and hazardous materials.

Infrared point: Infrared (IR) point sensors work by using radiation that passes through a specified amount of gas. The sensor beam's energy is absorbed at certain wavelengths, which depend on the gas's properties [73]. Carbon monoxide, for instance, takes in wavelengths between 4.2 and 4.5 µm. This wavelength's energy is compared to a wavelength that is outside of the absorption range [97]. The difference in energy between the two wavelengths is proportional to the amount of gas present. This kind of sensor is useful since it doesn't need to be put into the gas to find it, and can be used for distant sensing [82]. You can use infrared point sensors to find hydrocarbons and other gases that are active in the infrared range, like water vapour and carbon dioxide. IR sensors are often used in places where combustible gases are present and there is a risk of an explosion, such as wastewater treatment plants, refineries, gas turbines, chemical factories, and other places. With remote sensing, you can monitor a large area [61]. Researchers are also looking into using IR sensors to measure engine emissions. The sensor would be able to tell whether there are high quantities of carbon monoxide or other strange gases in the exhaust of a car. It might even be connected to the car's electronic systems to let drivers know.

Infrared imaging: There are both active and passive methods for infrared image sensors [78]. In active sensing, IR imaging sensors usually scan a laser across the scene's field of vision and seek light that bounces back at the absorption line wavelength of a certain target gas [91]. Passive IR imaging sensors look for specific spectral signatures that show the presence of target gases by measuring changes in the spectrum at each pixel in an image [57]. The same kinds of chemicals can be seen using infrared point detectors, but the pictures may help find the source of a gas.

Semiconductor: Semiconductor sensors can detect the presence of gases through a chemical reaction that occurs when the gas comes into contact with the sensor [74]. The most popular material for semiconductor sensors is tin dioxide. When the sensor comes into contact with the gas being monitored, its electrical resistance goes down. In the air, the resistance of tin dioxide is usually around 50 kΩ, but it can be reduced to about 3.5 kΩ when there is 1% methane. This variation in resistance is used to figure out how much gas is in the air [51]. People often utilise semiconductor sensors to find hydrogen, oxygen, alcohol vapour, and dangerous gases like carbon monoxide. Carbon monoxide sensors are one of the most prevalent uses for semiconductor sensors [87]. They are also in breathalysers. Semiconductor sensors operate over a shorter distance than infrared point or ultrasonic detectors because they require physical contact with the gas to detect it.

Ultrasonic: Ultrasonic gas leak detectors are not gas detectors. They pick up the sound that comes from a gas that is under pressure and expands in a low-pressure area through a small hole (the leak). They use acoustic sensors to find changes in the noise level in their surroundings [46]. Most high-pressure gas leaks make sounds in the ultrasonic range of 25 kHz to 10 MHz. The sensors can easily tell these frequencies apart from background noise, which is in the audible range of 20 Hz to 20 kHz. The ultrasonic gas leak detector then sounds an alarm when the background noise changes in an ultrasonic way [75].

Ultrasonic gas leak detectors cannot determine the amount of gas present in the air [65]. The device can still figure out the leak rate of an escaping gas since the ultrasonic sound level changes based on the gas pressure and the amount of the leak. Ultrasonic gas detectors are primarily used for remote sensing applications outside, where the weather can quickly disperse escaping gas before it reaches leak detectors that require direct contact with the gas to trigger an alarm [81]. You can usually find these detectors on oil and gas platforms, gas compressors and metering stations, gas turbine power plants and other places that have a lot of external pipelines.

Holographic: Holographic gas sensors use light reflection to detect changes in a polymer film matrix that contains a hologram [77]. Holograms reflect light at certain wavelengths; therefore, changing their makeup can make them reflect light in a way that shows the presence of a gas molecule. [12] But holographic sensors need light sources like white light or lasers and a person or CCD detector to work.

Calibration: You need to calibrate all gas detectors regularly. Portable gas detectors require more frequent calibration than fixed ones, as they are frequently moved between different environments [62]. A fixed system may require calibration every three months, every six months, or annually, depending on the system's power. A portable gas detector usually has to be "bump tested" every day and calibrated once a month (Figure 5). Most portable gas detectors need a certain type of calibration gas, which the manufacturer can provide [47]. The Occupational Safety and Health Administration (OSHA) in the US may prescribe minimum standards for periodic recalibration.

Water Level Sensor

Figure 5. Water Level Sensor

Several different kinds of liquid-level sensors can find the point level of a liquid. Some types use a magnetic float that moves up and down with the liquid in the container. A reed magnetic switch turns on when the liquid, and by extension, the magnet, reaches a particular level. There is usually a switch at the top and bottom of the container that lets you see the lowest and highest levels of liquid [55]. Many sensors also feature a protective barrier that shields the magnet from damage caused by turbulence or direct contact with the liquid.

The most popular programming language for making electronic devices is Embedded C (Figure 6). Embedded software is linked to each processor in an electronic system. Embedded C programming is an important part of how the CPU does certain tasks. We use a lot of technological equipment every day, like phones, washing machines, digital cameras, and more [48]. Microcontrollers programmed in embedded C make all of these devices operate together. The code in the block diagram above is used to make the LED connected to Port 0 of the microcontroller blink. C code is better than other languages for programming embedded systems [64].

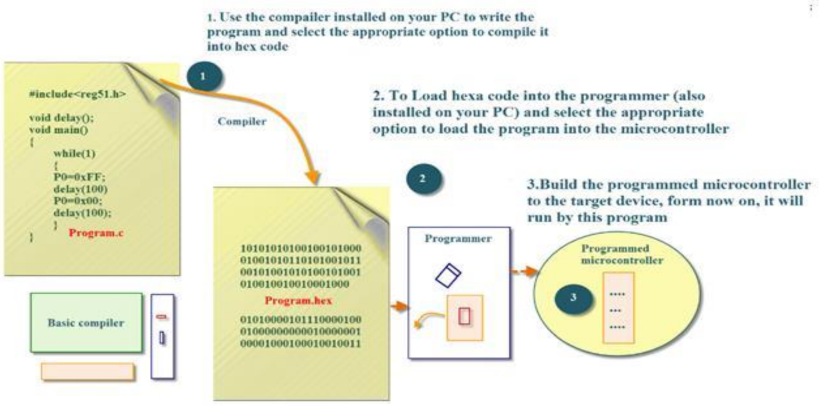

Figure 6. Embedded C

To set up an IoT-based water quality management system for a village, you need to first look at the current water supply infrastructure, such as sources, treatment plants (if any), distribution networks, and storage facilities. You also need to determine the key parameters to monitor per local water quality standards and identify potential sources of contamination [56]. Once the requirements are known, the right hardware parts, including sensors, data processing units, communication modules, and power sources, are chosen [86]. The sensors must be able to measure important things like pH, turbidity, dissolved oxygen, and pollutants. During the system design phase, the architecture is defined, including the best places for sensors, the best ways to send data, the best algorithms for processing data, the best ways to send alerts, and the best ways for users to interact with the system. Scalability, dependability, and power efficiency are all taken into account [80]. When you install hardware, you strategically place and calibrate sensors in the water supply system. You also set up processing units, such as Raspberry Pi or Arduino, and communication modules, like Wi-Fi or GSM, so that data can be collected and sent without any problems.

At the same time, software development makes the tools needed for processing, analysing, visualising, and generating alerts from data. These tools include real-time algorithms and interfaces that make them easy to use [76]. Integration and testing make sure that the hardware and software work together by checking for accuracy, reliability, and responsiveness under different operating situations and by simulating problems to see if they meet the defined standards [63]. After successful testing, the system is put into place in the village's infrastructure. Local staff are trained on how to use, maintain, and repair it, ensuring it is ready to use and properly commissioned. Regular monitoring and maintenance are essential to maintain accuracy and uptime. This includes calibrating sensors, replacing batteries, updating software, and quickly fixing problems, as well as clear rules for handling alerts and responding to incidents [90]. Finally, regular evaluations of how well the system works, based on feedback from stakeholders, can help find ways to make it better and increase its functionality, scalability, and usability [49]. This will help the water quality management solution stay efficient and resilient over time.

Conclusion

For the health of people, aquatic ecosystems, and important water resources, a comprehensive water quality management system is essential. This multimodal method combines monitoring, evaluation, regulation, and remediation strategies to effectively deal with the many sources of pollution that endanger water quality. Using the latest monitoring technology, it is possible to keep an eye on water parameters at all times and find contaminants early, which allows for quick action to stop further damage. Water quality indices and advanced modelling approaches are two examples of assessment tools that can help us understand the general health of a body of water. They can help us identify pollution hotspots and propose targeted management solutions. Regulatory frameworks set strict standards, rules, and enforcement mechanisms to limit the release of pollutants, encourage pollution prevention, and promote responsible water resource management.

Also, proactive remediation steps like building modern wastewater treatment plants, using green infrastructure, and restoring natural wetlands are important for reducing pollution and bringing the environment back into balance. In addition, public education campaigns, community involvement programs, and collaboration among stakeholders are all important parts of a good water quality management system. They help create a culture of environmental stewardship and shared responsibility. By putting these different parts together into a single framework, communities can protect water quality and make sure that current and future generations have access to clean, safe water while also protecting the important ecological services that aquatic ecosystems provide. This comprehensive strategy not only reduces the dangers of water pollution, but it also builds resilience against new problems like climate change and urbanisation. In the long run, it helps protect water resources and the health of both people and the environment.

Future Enhancement

In the future, we can enhance our IoT-based water quality management system in several ways to make it better and easier to use. First, we aim to enhance our system's real-time data assessment capabilities, enabling us to identify water quality issues as they occur promptly. Additionally, incorporating predictive maintenance tools will enable us to anticipate when equipment may fail, ensuring the system remains operational smoothly. Additionally, creating a user-friendly mobile app for villagers will enable them to access real-time water quality data and report issues directly through the app. Adding more sensors to our network and covering a larger area will give us a complete picture of water quality. We also plan to add self-cleaning technologies to make the water cleaner and prevent pollution from accumulating. Additionally, integrating our technology with smart irrigation systems would benefit local farmers by optimising water use in agriculture. Working with government departments to share data and ideas will help make decisions based on evidence and focused actions. Lastly, training and awareness initiatives for the community will give residents the knowledge and skills they need to help keep water sources clean. These improvements will help make sure that everyone in the village has access to safer and healthier water.

References

[1] J. Smith, A. Johnson, and R. Patel, "Implementation of an IoT-based water quality management system for rural communities: A case study," J. Sustain. Dev. Technol., vol. 8, no. 2, pp. 123–136, 2022.

[2] Y. Wang and P. M. Atkinson, "Real-time water quality monitoring using Internet of Things: A review of recent developments," IEEE Internet Things J., vol. 7, no. 1, pp. 1–13, 2020.

[3] S. Akbar and A. Javed, "An IoT-based smart water quality monitoring system," in Proc. Int. Conf. Sustain. Smart Comput. Commun., Singapore, 2019.

[4] S. G. K. Peddireddy, "Advancing Threat Detection in Cybersecurity through Deep Learning Algorithms," FMDB Transactions on Sustainable Intelligent Networks., vol.1, no. 4, pp. 190–200, 2024.

[5] S. G. K. Peddireddy, "Integrating AI for Proactive Network Defense against Emerging Security Vulnerabilities," FMDB Transactions on Sustainable Computer Letters., vol. 2, no. 4, pp. 232–241, 2024.

[6] S. G. K. Peddireddy, "Optimizing Resource Allocation in Multi-Cloud Environments for Cost Efficiency and Scalability," FMDB Transactions on Sustainable Computing Systems., vol. 2, no. 4, pp. 167–177, 2024.

[7] R. Rai, "A brief assessment of kiwifruit cultivation status in Nepal," J. Multidiscip. Sci., vol. 7, no. 1, pp. 46–55, 2025.

[8] A. Nepal, C. Joshi, N. Khatiwada, P. B. Chhetri, R. S. Chhetri, P. Kathayat, B. Mahara, and R. Rai, "Evaluation of the conversion of farming systems and scaling up of agroecological approaches in Nepal," J. Multidiscip. Sci., vol. 7, no. 1, pp. 11–25, 2025.

[9] A. Badarch, R. Rai, and J.-H. Kim, "Estimation and analysis of the impact of habitats and chromosomes on trichome variation in Lilium amabile Palibian," J. Multidiscip. Sci., vol. 7, no. 1, pp. 1–10, 2025.

[10] A. Nepal, K. Koirala, S. Rai, and R. Rai, "Agrobiodiversity integration in farming systems for income generation and livelihood options of smallholder farmers in Nepal: A case study of Bhimphedi Municipality," J. Exp. Biol. Agric. Sci., vol. 13, no. 1, pp. 29–49, 2025.

[11] S. Rai, A. Nepal, S. Basi, T. Dhakal, and R. Rai, "Present status, practices, limitations, and future prospects of organic fruit production in Nepal," J. Exp. Biol. Agric. Sci., vol. 13, no. 1, pp. 1–10, 2025.

[12] R. Rai and J.-H. Kim, "Heterosis and combining ability among promising single cross hybrids in Lilium formolongi Hort. for major growth and flowering traits," Academia Biology, vol. 2, no. 4, 2024.

[13] R. Rai, A. Shrestha, S. Rai, S. Chaudhary, D. K. Acharya, and S. Subedi, "Conversion of farming systems into organic bio-intensive farming systems and the transition to sustainability in agroecology: Pathways towards sustainable agriculture and food systems," J. Multidiscip. Sci., vol. 6, no. 2, pp. 25–34, 2024.

[14] S. Rai and R. Rai, "Advancements and practices in budding techniques for kiwifruit propagation," J. Multidiscip. Sci., vol. 6, no. 2, pp. 11–16, 2024.

[15] S. Rai and R. Rai, "Monkey menace in Nepal: An analysis and proposed solutions," J. Multidiscip. Sci., vol. 6, no. 1, pp. 26–31, 2024.

[16] A. K. Shrestha, S. Chaudhary, S. Subedi, S. Rai, D. K. Acharya, and R. Rai, "Farming systems research in Nepal: Concepts, design, and methodology for enhancing agricultural productivity and sustainability," J. Multidiscip. Sci., vol. 6, no. 1, pp. 17–25, 2024.

[17] S. Rai and R. Rai, "Advancement of kiwifruit cultivation in Nepal: Top working techniques," J. Multidiscip. Sci., vol. 6, no. 1, pp. 11–16, 2024.

[18] S. Chaudhary, A. K. Shrestha, S. Rai, D. K. Acharya, S. Subedi, and R. Rai, "Agroecology integrates science, practice, movement, and future food systems," J. Multidiscip. Sci., vol. 5, no. 2, pp. 39–60, 2023.

[19] R. Rai, V. Y. Nguyen, and J.-H. Kim, "Variability analysis and evaluation for major cut flower traits of F1 hybrids in Lilium brownie var. colchesteri," J. Multidiscip. Sci., vol. 4, no. 2, pp. 35–41, 2022.

[20] V. Y. Nguyen, J.-H. Kim, J.-Y. Kim, and K. N. Jong, "Ecogeographical variations of the vegetative and floral traits in Lilium amabile Palibian," J. Plant Biotechnol., vol. 48, no. 4, pp. 236–245, 2021.

[21] R. Rai and J.-H. Kim, "Performance evaluation and variability analysis for major growth and flowering traits of Lilium longiflorum Thunb.," J. Exp. Biol. Agric. Sci., vol. 9, no. 4, pp. 439–444, 2021.

[22] R. Rai, V. Y. Nguyen, and J.-H. Kim, "Estimation of variability analysis parameters for major growth and flowering traits of Lilium leichtlinii var. maximowiczii germplasm," J. Exp. Biol. Agric. Sci., vol. 9, no. 4, pp. 457–463, 2021.

[23] R. Rai and J.-H. Kim, "Effect of storage temperature and cultivars on seed germination of Lilium × formolongi Hort.," J. Exp. Biol. Agric. Sci., vol. 8, no. 5, pp. 621–627, 2020.

[24] R. Rai and J.-H. Kim, "Estimation of combining ability and gene action for growth and flowering traits in Lilium longiflorum," Int. J. Adv. Sci. Technol., vol. 29, no. 8S, pp. 1356–1363, 2020.

[25] R. Rai, A. Badarch, and J.-H. Kim, "Identification of superior three-way cross F1s, its Line × Tester hybrids, and donors for major quantitative traits in Lilium × formolongi," J. Exp. Biol.

Agric. Sci., vol. 8, no. 2, pp. 157–165, 2020.

[26] R. Rai, J. Shrestha, and J.-H. Kim, “Line × Tester analysis in Lilium × formolongi: Identification of superior parents for growth and flowering traits,” SAARC J. Agric., vol. 17, no. 1, pp. 175–187, 2019.

[27] R. Rai, J. Shrestha, and J.-H. Kim, “Combining ability and gene action analysis for quantitative traits in Lilium × formolongi,” J. Agric. Life Environ. Sci., vol. 30, no. 3, pp. 131–143, 2019.

[28] T. X. Nguyen, S. I. Lee, R. Rai, N. S. Kim, and J.-H. Kim, “Ribosomal DNA locus variation and REMAP analysis of the diploid and triploid complexes of Lilium lancifolium,” Genome, vol. 59, pp. 1–14, 2016.

[29] T. X. Nguyen, J.-Y. Kim, R. Rai, J.-H. Kim, N. S. Kim, and A. Wakana, “Karyotype analysis of Korean Lilium maximowiczii Regal populations,” J. Fac. Agric. Kyushu Univ., vol. 60, no. 2, pp. 315–322, 2015.

[30] S. Kasthuri and A. N. Jebaseeli, “An artificial bee colony and pigeon inspired optimization hybrid feature selection algorithm for Twitter sentiment analysis,” J. Comput. Theor. Nanosci., vol. 17, no. 12, pp. 5378–5385, 2020.

[31] S. Kasthuri and A. N. Jebaseeli, “Review analysis of Twitter sentimental data,” Biosci. Biotechnol. Res. Commun., vol. 13, no. 6 (Special Issue), pp. 209–214, 2020.

[32] S. Kasthuri and A. N. Jebaseeli, “An efficient decision tree algorithm for analyzing the Twitter sentiment analysis,” J. Crit. Rev., vol. 7, no. 4, pp. 1010–1018, 2020.

[33] S. Kasthuri and A. N. Jebaseeli, “Latent Dirichlet Allocation feature extraction with bio inspired pigeon feature selection technique for Twitter sentiment analysis,” Int. J. Adv. Trends Comput. Sci. Eng., vol. 9, no. 4, pp. 6406–6414, Jul.–Aug. 2020.

[34] S. Kasthuri, L. Jayasimman, and A. N. Jebaseeli, “An opinion mining and sentiment analysis techniques: A survey,” Int. Res. J. Eng. Technol. (IRJET), vol. 3, no. 2, pp. 573–575, 2016.

[35] S. Kasthuri and A. N. Jebaseeli, “A robust data classification in online social networks through automatically mining query facts,” Int. J. Sci. Res. Comput. Sci. Appl. Manage. Stud., vol. 7, no. 4, Jul. 2018.

[36] S. Kasthuri and A. N. Jebaseeli, “Social network analysis in data processing,” Adalya J., vol. 9, no. 2, pp. 260–263, Feb. 2020.

[37] S. Kasthuri and A. N. Jebaseeli, “Review on social network analysis in data mining,” Infokara Res., vol. 8, no. 12, pp. 1168–1172, Dec. 2019.

[38] S. Kasthuri and A. N. Jebaseeli, “Study on social network analysis in data mining,” Int. J. Anal. Exp. Modal Anal., vol. 11, no. 8, pp. 111–116, Aug. 2019.

[39] G. Rajarajeswari and S. Kasthuri, “Co-clustering interpretations for feature selection by using sparsity learning,” Int. J. Res. Instinct, vol. 4, no. 1, pp. 30–35, 2017.

[40] T. Ganesh Kannan, S. Kasthuri, and T. Dineshkumar, “A reliable communication and rate control for mobile network through efficient routing protocol,” Int. J. Comput. Sci. Eng., vol. 6, Special Issue 2, pp. 354–357, 2018.

[41] K. V. Deshpande and J. Singh, “Weighted transformer neural network for web attack detection using request URL,” Multimedia Tools and Applications, vol. 83, no. 15, pp. 43983–44007, Oct. 2023.

[42] J. Singh, S. Rani, and V. Kumar, “Role-based access control (RBAC) enabled secure and efficient data processing framework for IoT networks,” Int. J. Commun. Netw. Inf. Secur. (IJCNIS), Aug. 2024.

[43] J. Singh, S. Rani, and P. Kumar, “Blockchain and smart contracts: Evolution, challenges, and

future directions," in Proc. 2024 Int. Conf. Knowledge Eng. Commun. Syst. (ICKECS), Apr. 2024, pp. 1–5.

[44] J. Singh, E. al., "Enhancing cloud data privacy with a scalable hybrid approach: HE-DP-SMC," J. Electr. Syst., vol. 19, no. 4, pp. 350–375, Jan. 2024.

[45] J. Singh, S. Rani, and G. Srilakshmi, "Towards explainable AI: Interpretable models for complex decision-making," in Proc. 2024 Int. Conf. Knowledge Eng. Commun. Syst. (ICKECS), Apr. 2024, pp. 1–5.

[46] G. Sadineni, J. Singh, S. Rani, G. S. Rao, M. J. Pasha, and A. Lavanya, "Blockchain-enhanced vehicular ad-hoc networks (B-VANETs): Decentralized traffic coordination and anonymized communication," Int. J. Intell. Syst. Appl. Eng., vol. 12, no. 1s, pp. 443–456, Sep. 2023.

[47] D. Jadhav and J. Singh, "Web information extraction and fake news detection in Twitter using optimized hybrid bi-gated deep learning network," Multimedia Tools and Applications, May 2024.

[48] S. Jadhav and J. Singh, "Design of EGTBoost classifier for automated external skin defect detection in mango fruit," Multimedia Tools and Applications, vol. 83, no. 16, pp. 47049–47068, Oct. 2023.

[49] K. V. Deshpande and J. Singh, "A systematic review on website phishing attack detection for online users," Int. J. Image Graph., Jan. 2025.

[50] S. Jadhav-Mane and J. Singh, "Mango skin disease detection techniques based on machine learning: A review," Wireless Pers. Commun., vol. 139, no. 4, pp. 1881–1904, Dec. 2024.

[51] R. K. K, P. M, J. Singh, G. Surendra, S. M. Ali, and M. R. B, "BlockStream solutions: Enhancing cloud storage efficiency and transparency through blockchain technology," Int. J. Electr. Electron. Eng., vol. 11, no. 7, pp. 134–147, Jul. 2024.

[52] P. Nasra et al., "Optimized ReXNet variants with spatial pyramid pooling, CoordAttention, and convolutional block attention module for money plant disease detection," Discover Sustainability, vol. 6, no. 1, May 2025.

[53] D. Jadhav and J. Singh, "A review on web information extraction and hidden predictive information from large databases," Multimedia Tools and Applications, May 2025.

[54] S. Devi, O. Yadav, S. Rani, J. Singh, C. Dhavale, and S. Khanvilkar, "Blockchain integration in crowdfunding: A smart contract-based approach to fundraising," in Proc. 2025 7th Int. Conf. Comput. Intell. Commun. Technol. (CCICT), Apr. 2025, pp. 308–312.

[55] J. Singh, S. Rani, S. Devi, and J. Kaur, "A systematic study on recommendation system for e-commerce applications," in Proc. 2025 7th Int. Conf. Comput. Intell. Commun. Technol. (CCICT), Apr. 2025, pp. 221–226.

[56] V. S. A. Anala, A. R. Pothu, and S. Chintapalli, "Enhancing Preventive Healthcare with Wearable Health Technology for Early Intervention," FMDB Transactions on Sustainable Health Science Letters., vol.2, no.4, pp. 211–220, 2024.

[57] V. S. A. Anala and S. Chintapalli, "Scalable Data Partitioning Strategies for Efficient Query Optimization in Cloud Data Warehouses," FMDB Transactions on Sustainable Computer Letters., vol. 2, no. 4, pp. 195–206, 2024.

[58] N. Ansari, G. Singh, R. Singh and Sheetal, "Innovative herbal tea formulation using Holarrhena antidysenterica, Emblica officinalis, and Stevia: Nutritional and phytochemical analysis," J. Neonatal Surg., vol. 14, no. 6, pp. 381-389, 2025.

[59] S. Bala, G. Singh and M. Kaur, "Mindfulness of functional foods in cancer prevention and health promotion: A comprehensive review," Rev. Electron. De Vet., vol. 25, no. 1, pp. 1181-1187, 2024.

[60] S. Bala, G. Singh, R. Arora and Devanshika, "Impact of caffeine consumption on stress management and stamina among university students," Rev. Electron. De Vet., vol. 25, no. 2, pp. 253-259, 2024.

[61] G. Singh and M. Khatana, "Assessment regarding the efficacy of intermittent fasting," Int. J. Res. Anal. Rev., vol. 9, no. 1, pp. 2349-5138, 2022.

[62] G. Singh et al., "Analyze the effects of prebiotics on the immunity of human beings through various clinical studies," Jundishapur J. Microbiol., vol. 15, no. 1, pp. 1167-1177, 2022.

[63] Md H. Rahman, T. Islam, Md E. Hossen, Md E. Chowdhury, R. Hayat, Md S. S. Shovon, M. Alamgir, S. Akter, R. Chowdhury, and A. R. Sunny, "Machine Learning in Healthcare: From Diagnostics to Personalized Medicine and Predictive Analytics," J. Angiother., vol. 8, no. 12, pp. 1–8, 2024.

[64] R. Chowdhury, Md A. H. Fahad, S. M. S. Alam, M. I. Tusher, Md N. U. Rana, E. Ahmed, S. S. Akhi, and Md R. H. Mahin, "Database Management in the Era of Big Data: Trends, Challenges, and Breakthroughs," Pathfinder Res., vol. 1, no. 1, p. 15, 2020.

[65] Md R. H. Mahin, E. Ahmed, S. S. Akhi, Md A. H. Fahad, M. I. Tusher, R. Chowdhury, and Md N. U. Rana, "Advancements and Challenges in Software Engineering and Project Management: A 2021 Perspective," Pathfinder Res., vol. 2, no. 1, p. 15, 2021.

[66] Md A. H. Fahad and R. Chowdhury, "Evolution and Future Trends in Web Development: A Comprehensive Review," Pathfinder Res., vol. 3, no. 1, p. 13, 2022.

[67] A. R. M. T. Islam, Md. N. Uddin, Md. F. R. Joy, R. Proshad, T. Kormoker, A. H. Anik, M. S. Rahman, Md. A. B. Siddique, and M. A. Alshehri, "Tracing sources-oriented ecological risks of metal(loid)s in sediments of anthropogenically-affected coastal ecosystem from northeast bay of Bengal," Mar. Pollut. Bull., vol. 211, p. 117354, 2025.

[68] A. R. M. T. Islam, M. Abdullah-Al Mamun, M. Hasan, M. N. Aktar, M. N. Uddin, M. A. B. Siddique, M. H. Chowdhury, M. S. Islam, A. B. M. M. Bari, and A. M. Idris, "Optimizing coastal groundwater quality predictions: A novel data mining framework with cross-validation, bootstrapping, and entropy analysis," J. Contam. Hydrol., p. 104480, 2024.

[69] Md. A.-A. Mamun, A. R. M. T. Islam, Mst. N. Aktar, M. N. Uddin, Md. S. Islam, S. C. Pal, A. Islam, A. B. M. M. Bari, A. M. Idris, and V. Senapathi, "Predicting groundwater phosphate levels in coastal multi-aquifers: A geostatistical and data-driven approach," Sci. Total Environ., vol. 953, p. 176024, 2024.

[70] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. A. H. Badsha, M. H. Chowdhury, and A. R. M. T. Islam, "Hexavalent chromium removal from aqueous medium by ternary nanoadsorbent: A study of kinetics, equilibrium, and thermodynamic mechanism," PLoS ONE, vol. 18, no. 12, e0290234, 2023.

[71] G. C. Saha, M. A. Hasanath, M. N. Uddin, and M. Hasan, "Sustainable Utilization of Textile Dyeing Sludge and Coal Fly Ash by Brick Production Through Traditional Kilns," Nature Environ. Pollut. Technol., vol. 21, no. 3, 2022.

[72] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. T. Rahman, and M. M. Rashid, "Development and Characterization of Novel Mn–Fe–Sn Ternary Nanoparticle by Sol–Gel Technique," in Advances in Civil Engineering, S. Arthur, M. Saitoh, and S. K. Pal, Eds. Singapore: Springer, 2022, vol. 184, Lecture Notes in Civil Engineering.

[73] M. T. Rahman, G. C. Saha, M. A. Hasanath, and M. N. Uddin, "Potential Use of Dying Sludge, Pet Granules and Fly Ash in Light Weight Concrete Block," in Advances in Civil Engineering, S. Arthur, M. Saitoh, and S. K. Pal, Eds. Singapore: Springer, 2022, vol. 184, Lecture Notes in Civil Engineering.

[74] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. T. Rahman, and M. M. Rashid, "Development and Characterization of Novel Mn–Fe–Sn Ternary Nanoparticle by Sol–Gel Technique," in

Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 29–34.

[75] M. A. Hasanath, M. N. Uddin, and M. Ashraf, "Fabrication of Eco-friendly Water Purifier by Pedaling Energy," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 29–34.

[76] M. A. Hasanath, M. N. Uddin, and G. C. Saha, "Assessment of beverage sludge as agricultural soil," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 254–260.

[77] M. T. Rahman, G. C. Saha, M. A. Hasanath, and M. N. Uddin, "Potential Use of Dying Sludge, Pet Granules and Fly Ash in Light Weight Concrete Block," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 254–260.

[78] M. R. Donthi, S. R. Munnangi, K. V. Krishna, R. N. Saha, G. Singhvi, and S. K. Dubey, "Nanoemulgel: A Novel Nano Carrier as a Tool for Topical Drug Delivery," Pharmaceutics, vol. 15, no. 1, p. 164, Jan. 2023.

[79] M. R. Donthi et al., "Formulating Ternary Inclusion Complex of Sorafenib Tosylate Using β-Cyclodextrin and Hydrophilic Polymers: Physicochemical Characterization and In Vitro Assessment," AAPS PharmSciTech, vol. 23, no. 7, Oct. 2022.

[80] M. R. Donthi, R. Dudhipala, R. Komalla, D. Suram, and N. Banala, "Open Access Preparation and Evaluation of Fixed Combination of Ketoprofen Enteric Coated and Famotidine Floating Mini Tablets by Single Unit Encapsulation System," J Bioequiv Availab, vol. 7, no. 6, pp. 279–283, 2015.

[81] D. Mahipalreddy, D. Narendar, K. Devendhar, S. Dinesh, A. S. Kiran, and B. Nagaraj, "Preparation and Evaluation of Ketoprofen Enteric Coated Mini Tablets for Prevention of Chronic Inflammatory Disease," J. Pharm. Drug Deliv. Res., vol. 04, no. 02, 2015.

[82] M. R. Donthi, R. N. Saha, G. Singhvi, and S. K. Dubey, "Dasatinib-Loaded Topical Nano-Emulgel for Rheumatoid Arthritis: Formulation Design and Optimization by QbD, In Vitro, Ex Vivo, and In Vivo Evaluation," Pharmaceutics, vol. 15, no. 3, p. 736, Mar. 2023.

[83] M. R. Donthi, N. Dudipala, R. Komalla, and N. Banala, "Design and Evaluation of Floating Multi Unit Mini Tablets (MUMTS) Muco Adhesive Drug Delivery System of Famotidine to Treat Upper Gastro Intestinal Ulcers," vol. 3, no. 5, p. 179, 2015.

[84] T. Alekya, D. Narendar, D. Mahipal, N. Arjun, and B. Nagaraj, "Design and Evaluation of Chronomodulated Drug Delivery of Tramadol Hydrochloride," Drug Res. (Stuttg)., vol. 68, no. 3, pp. 174–180, Mar. 2018.

[85] M. R. Donthi, A. Butreddy, R. N. Saha, P. Kesharwani, and S. K. Dubey, "Leveraging spray drying technique for advancing biologic product development–A mini review," Heal. Sci. Rev., vol. 10, p. 100142, Mar. 2024.

[86] R. Rajitha, D. Narendar, N. Arjun, B. Nagaraj, and D. Mahipal, "Colon Delivery of Naproxen: Preparation, Characterization and Clinical Evaluation in Healthy Volunteers," Int. J. Pharm. Sci. Nanotechnology(IJPSN), vol. 9, no. 3, pp. 1–10, 2016.

[87] S. Karnam, M. R. Donthi, A. B. Jindal, and A. T. Paul, "Recent innovations in topical delivery for management of rheumatoid arthritis: A focus on combination drug delivery," Drug Discov. Today, vol. 29, no. 8, p. 104071, Aug. 2024.

[88] M. Choudhari, M. R. Donthi, S. Damle, G. Singhvi, R. N. Saha, and S. K. Dubey, "Implementation of Quality by Design Approach for Optimization of RP-HPLC Method for Quantification of Abiraterone Acetate in Solid Dispersion in Forced Degradation Studies," Curr. Chromatogr., vol. 9, no. 1, pp. 78–94, Nov. 2022.

[89] A. Chahal et al., "Systematic analysis based on Conflux of machine learning and internet of things using bibliometric analysis," Journal of Intelligent Systems and Internet of Things, vol.

13, no. 1, pp. 196–224, 2024.

[90] A. K. Tyagi and S. R. Addula, “Artificial Intelligence for malware analysis,” Artificial Intelligence-Enabled Digital Twin for Smart Manufacturing, pp. 359–390, Sep. 2024.

[91] A. Pati et al., “Artificial Intelligence in improving disease diagnosis,” Artificial Intelligence in Medicine and Healthcare, pp. 24–49, Jan. 2025.

[92] G. S. Nadella et al., “Generative AI-Enhanced Cybersecurity Framework for Enterprise Data Privacy Management,” Computers, vol. 14, no. 2, p. 55, Feb. 2025.

[93] G. S. Sajja and S. R. Addula, “Automation using robots, machine learning, and artificial intelligence to enhance production and quality,” 2024 Second International Conference Computational and Characterization Techniques in Engineering & Sciences (IC3TES), pp. 1–4, Nov. 2024.

[94] N. K. Misra, S. Das, S. Satpathy, S. R. Addula, and M. C. Trivedi, “Covid-19 pandemic: A worldwide critical review with the machine learning model-based prediction,” Journal of The Institution of Engineers (India): Series B, vol. 106, no. 1, pp. 339–349, Sep. 2024.

[95] S. Almotairi et al., “Personal data protection model in IOMT-blockchain on secured bit-count transmutation data encryption approach,” Fusion: Practice and Applications, vol. 16, no. 1, pp. 152–170, 2024.

[96] V. Yadav, “Machine Learning in Managing Healthcare Workforce Shortage: Analyzing how Machine Learning can Optimize Workforce Allocation in Response to Fluctuating Healthcare Demands,” Progress In Medical Sciences, pp. 1–9, Aug. 2023.

[97] V. Yadav, “Machine Learning for Predicting Healthcare Policy Outcomes: Utilizing Machine Learning to Forecast the Outcomes of Proposed Healthcare Policies on Population Health and Economic Indicators,” Journal of Artificial Intelligence & Cloud Computing, vol. 1, no. 2, pp. 1–10, Jun. 2022.