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A SYSTEM TO IDENTIFY THE CHEMICAL INDICATORS OF WATER WITH UNMANNED SURFACE VEHICLE

Zow Afshan[1]
Sherin Zafar
Safdar Tanweer

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A B S T R A C T

The protection of the water's quality is an essential component of the planning, control, prevention, and preventative actions that must be taken to reduce the pollution of the water and the deterioration of aquatic habitat. Monitoring the water's quality on a consistent basis is an essential activity that contributes to keeping track of the hydrological particulars of any body of water. Many surviving systems and methods have been shown to be ineffective in achieving the same purpose, and only a small handful of other conventional methods have shown a remarkable outcome that has helped to reinstate and keep up water resources from piles of nutrients and organic composites that cause quality degradation. However, the figures collected from all corners of the world suggest that there is an immediate demand for an upgrade in the monitoring system for water quality. Based on the findings of the survey, the concept presented here entails the suggestion of a unique system that is able to maintain tabs on the quality of water, hence assisting the ongoing pollution control trends.. In this paper, a methodical approach is suggested for collecting the parametric quality indicators, most of which are chemical, which then leads to the production of a characteristic drawing for each of the variables relevant to the specific water resource that is the subject of the observation. The information that was gathered is, to put it another way, coupled with clouds. The suggested approach eliminates the most significant drawbacks of the present techniques, which results in an increase in the effectiveness of monitoring water quality and a reduction in water pollution.

1. INTRODUCTION

One essential resource is water. All of humanity can be adequately and adequately served by the current quality. Many people think that water is among the most precious gifts that God has given to mankind. (V. Mounika et al., 2021) The characteristics and dispersion of the problem, however, are what cause the scarcity

[1] Corresponding author: Zow Afshan
Email: afshanzow@gmail.com

and sustainability issues (..Vor ¨ osmarty et al, 2018). All life on Earth depends on water. But there are freshwater shortages in many countries (Min-Allah et al., 2021 . As a species, we have been striving to make the most efficient use of this priceless asset. In order to meet the varying demands of humans for water in terms of both quantity and quality (Pasika et al., 2020), an accessible pathway is crucial. Many bodies of freshwater have been depleted due to industrialization (Pourshahabi et al.,2020). The drinking of water that is polluted causes a great deal of human illness. The primary cause of the water scarcity is pollution, which is in turn caused by natural resources such as acid rain, human waste, and industrial discharges. (Aswin Kumer et al, 2021). The changes in water quality parameters have been the subject of numerous international studies on pollution and water quality. Water bodies can be safeguarded from contamination and additional loss if the tracking procedure is exact, economical, and self-governing, as we can deduce from the framework. The first stage in managing water resources is to check water quality. (Chowdury et al.,2019).

There have been tremendous technological and aesthetic shifts in water monitoring equipment recently. To get the most out of your data collection efforts, you need to do acute monitoring of your water resources (Wijeyaratne et al., 2020). The project to monitor water quality identifies the causes of problems and controls potential solutions. You can save time during information gathering, convert it, and put it all together usefully using an embryonic study that uses the reports that are at hand (Sithole et al.,2019). A reconnaissance survey is required in the preparation stage to identify various waste sources and all side stream contributions to pollution, water extraction, and uses. If a led and executed topographic or geographic study is carried out, this might be effective (Shakhari et al.,2019).

Manual sampling of water from a variety of locations and depths is still the standard method for water quality testing. Multiple locations around the body of water are monitored by electronic sensors (Shriram K. Vasudevan et al.,2021). Nevertheless, these approaches are excessively expensive and labor-intensive. Our plan is to eliminate water waste by utilising the USV, strategically placing sensors, and implementing self-operating data collection.

The issue statements, susceptible designs utilised for water quality inspections, and demand for their adjustment are covered in the beginning portion of this paper. The literature review on water contamination and its many manifestations, as well as the critical importance of monitoring, is presented in Section 2. In Section 3, we will compare and contrast the existing approaches. We covered the proposal's AIM in Section 4. Section 5 delves into the technique, highlights the benefits of the proposed system, and discusses its limits. Section 6 details the suggested framework. A strategy that is broken down into years is covered in Section 7. Section 8: We have completed our task and provided our plans for the future. A reference list is included in the last section.

2. LITERATURE SURVEY

The daily discharge of sewage and other industrial and agricultural waste into the world's water is 2 million tonnes, which is the same as the weight of all 6.8 billion humans (Waste, H. et al, 2010). According to the United Nations, yearly wastewater production amounts to around 1,500 km3, which is equivalent to six times the water contained in all the world's rivers combined. (Source: UN WWAP 2003).

The US Environmental Protection Agency (EPA) reports that out of all the lakes, streams, and bays in North America, 44% are not clean enough for swimming and fishing, 64% are not clean enough for lake acres, and 30% are not clean enough for estuaries and bays (Davis, W.S., et al., 2021). The overall water quality crisis in China is described as 'average' in the 2015 condition of the environment report. The situation with groundwater contamination is dire, and it has been getting worse every year since 2011. 'Bad' to'very bad' was the 2014 classification for groundwater. Additionally, the percentage of groundwater that was deemed "very bad" increased from 15.7% in 2013 to 16.1% in 2014. Since 2013's level was 28.3%, 2014's level of water "unfit for human touch" increased to 28.8% (Sarkar, Santosh Kumar. et al., 2007). A third of India’s total population lives in the heavily populated Ganga basin. Eight states in India are effectively drained by the entire Ganga basin system. Based on data collected between 1997 and 2013, the average BOD level trend is approximately 12 mg/litre (Finkelstein, J.Z., Codebo et al., 2010).

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The Matanza-Riachuelo River (MRR) is known as the Slaughterhouse River in South America. Every day, the river receives an average of 82,000 cubic metres of industrial garbage. Large petroleum operations release 8.3 metric tonnes of oil into the river daily. The butcher, tannery, and dairy sectors are responsible for dumping skin, internal organs, and blood into the river, which accounts for 21% of the pollution. Of the total pollution, 14% comes from the food and beverage business, 11% from paper mills and the textile industry, and 7% from metallurgy, which is the process of extracting metals from their ore. The remaining portion (Ahammed et al.,2016) consists of a mix of sewage, pesticides, and urban garbage. In January 2014, researchers in Bangladesh found that the Buriganga River had an average dissolved oxygen value of 1.8 at 5 of 9 locations, with 4 of those locations having no dissolved oxygen at all.

The blood oxygen saturation (BOD) limit in water is 2-6. According to a January 2007 survey conducted by the BUET Civil Department, the BOD in Buriganga at Hazaribagh is 28 (Utami.et al.,2016) . Among the most contaminated rivers in the world, the Citarum River flows through Indonesia. The condition is a result of the massive amounts of unprocessed industrial and residential waste that are discharged into the river. People release 400 metric tonnes of manure from cattle into the verge daily. Up to 280 metric tonnes of industrial trash and 25,000 cubic metres of domestic rubbish are sent there daily to the Citarum River (Albanese, et al.,2013). Both of these are contributing to the Citarum River's pollution and sedimentation problems. Tragically, the upper Citarum River stream contains 46,000 hectares of crucial land. While river pollution is a problem across Europe, the Sarno River in southern Italy—close to Pompeii and Naples—is often thought to be the dirtiest river in the continent. The river is almost unspoiled in its upper sections close to Mount Sarno, but it gets increasingly polluted as one descends in altitude, eventually becoming coated in greasy scum and chemical foam. Polycyclic aromatic hydrocarbons (PAHs) in the Bay of Naples are thought to originate in the Sarno River, which is heavily polluted by urban trash, agricultural and industrial waste, and other forms of urban runoff (Beretta-Blanco.et al.,2021) In reality, PAHs constitute the bulk of organic contaminants. Roughly 30 percent of Australia's 246 river basins were evaluated in the Australian Water Resources Assessment 2000 (NLWRA, 2001). It evaluated 43 basins, or roughly two-thirds of those that were assessable, and found significant nutrient exceedances, mostly of nitrogen and phosphorus. Extremely polluted rivers, like the ones listed, require robust technical assistance to reduce pollution and prevent more harm (Cordes Erik. et al.,2016). In the event of an emergency, it is critical to have a quality water watch in place to protect against radiation, oil spills that cause erosion, and floods (P. Chawla, et al.,2021)

The study highlights the importance of water quality monitoring procedures, which are a global problem and not limited to the Indian subcontinent. As a result, keeping an eye on the water quality is crucial, and if needed, cleaning the water to make it safer for aquatic life and humans.

3. AVAILABLE METHOD

Here we are discussing the available methods

Manual Methods

People in underdeveloped countries, such as India, often use containers to manually collect water samples from various parts of the body. After collecting water samples, they are submitted to a lab for analysis. There, a battery of tests is run to determine the water's pH, conductivity, dissolved oxygen (DO), turbidity, chloride, temperature, and more. After some time has passed (around one week), the relevant authorities will receive the reported measured results. Down below, you can see the detailed workflow of the manual monitoring approach.

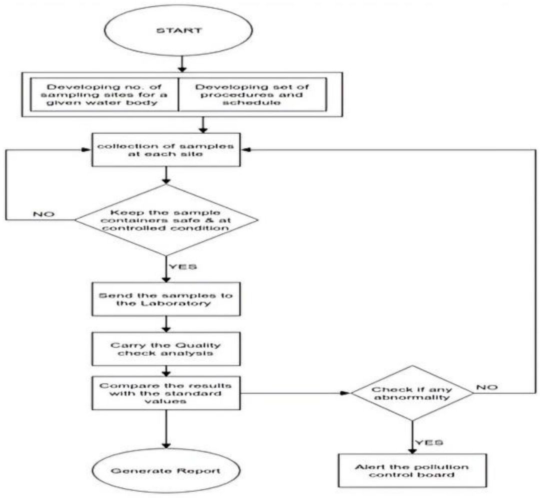

Figure 1. Functional flow of Manual monitoring method

But this methodology suffers from certain limitations that need to be addressed. The notable limitations are:

a) Water sample collection does not cover the entire stretch of the water resource, thus making the results unreliable.
b) The cost incurred for analysing the quality is high and would really soar higher if the entire lake had to be monitored completely.
c) The data collected does not reflect the water quality in real time since the results were not obtained immediately.
d) The entire process is time-consuming as it involves manual collection from different parts of the water resource.
e) The chances of human errors in the water sample collection are always a point of concern. Certain points in the water resource may be missed or could be a duplicate sample of the previous points, redundantly.

Hence, the manual methods suffer from a lot of shortcomings that are to be addressed by any proposed alternate techniques.

Electronic sensor monitoring

Due of its high cost, this approach is applied selectively to specific bodies of water. At specific locations along rivers in India, such as the Yamuna and the Ganga, it is utilised. Data is collected at regular intervals and uploaded to the Internet from sensors installed at various sites around the lake. By gathering data in real-time, the electronic sensor approach overcomes the drawbacks of the conventional manual method. Thus, the water quality monitoring system aids in continuous and remote monitoring of water quality through the usage of a wireless sensor network. A hierarchical topology underpins the system's design; it divides the monitoring process into four main domains, with each domain forming a cluster of wireless sensor nodes that are responsible for sensing, data collecting, processing, and communication. Here is the electronic sensor model's workflow for your better understanding.

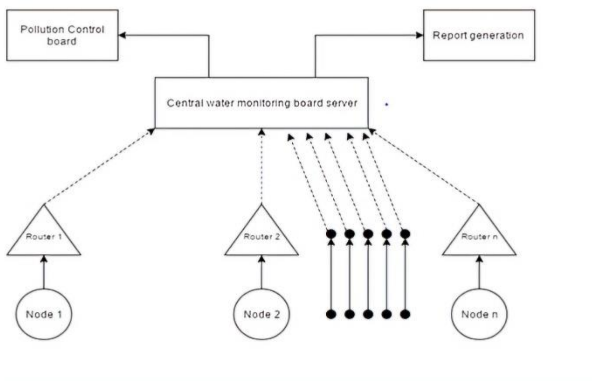

Figure 2. Real-time sensor node method

This method, despite being real-time, also has its limitations.

a) The problem with this technique is that the sensors used in this process are very expensive and are installed at a deeper level in the river, which makes the system less significant. As per the information provided by the Ministry of Water Resources, the total cost incurred towards installing the sensors in 10 locations is approximately 5.61 crores in Ganga, Yamuna, and its tributaries [http://pib.nic.in/newsite/PrintRelease.aspx?relid=106835].
b) Monitoring the monitoring equipment and the maintenance of the sensors is also challenging and expensive.
c) The parameters monitored in this method are pH, turbidity, electrical conductivity (EC), temperature, dissolved oxygen (DO), dissolved ammonia, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates, and chlorides as per the required frequency through sensors and are updated every two hours. One such sample report is presented below in Fig. 3, which is taken from the unit installed at the Ganga River in Kanpur. The report claims that all the measured parameters are at acceptable levels. But Ganga still remains polluted. This drives us to propose a method and a technique to accurately monitor water resources, even at the surface level.

Figure 3. A snap shot of Real Time Water Quality Monitoring data from River Ganga and Yamuna

a) Sensors that are driven by a power source may need replacement if they malfunction. This process may incur additional costs.
b) Though this water sensor network can acquire and serve data in real time, most of the sensors will lack mobility as they are fixed in their positions.
c) Natural disasters like floods and aquatic animals' movements in the water bodies may damage the sensors placed in the bodies.

4. AIM

a) To develop a model that helps in the smart collection of all the data required for analysing the water quality and to depict the results with high accuracy. The proposed model can cater to any category of water body without delay or additional cost.
b) To reduce the difficulty in covering the entire stretch of water body for taking water samples to assess the water quality.
c) This model also aids in designing and developing pollution prevention and management strategies while presenting the results in real time through the to-be-developed mobile and web applications.

5. DETAILED METHODOLOGY

Advancements in fields like data analysis, unmanned surface vehicles (USV), machine learning, and IOT in the bygone era made it possible for us to monitor the quality of water without permanently installing the sensor nodes. Here, we propose a novel engineering technique to track and monitor the various parameters of water (pH, dissolved oxygen, temperature, conductivity, etc.). So, for a given water source, our solution provides the end user with a detailed report of the contamination status over the entire stretch of the water source. Our solution provides the collection of all the data required for the analysis of any water body using water sensors mounted on an autonomous boat. The entire process is accomplished through four modules:

1. Data collection and communication
2. Cloud and data analytics
3. Data visualisation and presentation
4. Water status report generation

The entire process involved in the proposed methodology and its Architecture diagram is shown in the diagrams below:

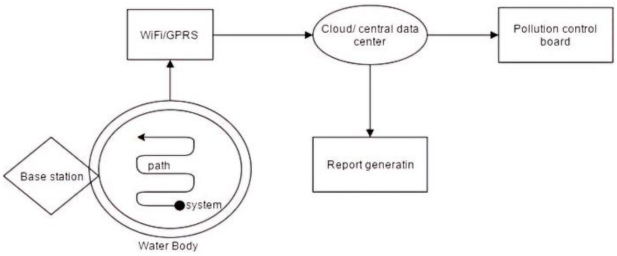

Figure 4. Schematic diagram of system operation flow

The working principle of the proposed approach is explained below:

a) The multi-parameter water sensors are mounted on the autonomous boat. The selection of the sensors is based on parameters like sensitivity, cost, accuracy, latency, etc.
b) The points where the water samples are to be taken and analysed are chosen at random, and their GPS coordinate positions are fed into the system. It is ensured that the sample points are taken well, covering the entire stretch of the water body.
c) To locate the sample points in the water body, a microcontroller unit in the boat interfaces with a GPS module for navigating it to the desired location and also for guiding through its navigation path. To increase its sophistication and reduce the number of peripherals, compact micro-computing units like Arduino and Raspberry Pi shall be utilised.
d) At various points along the water body, the water parameters measured are acquired with the help of a microcontroller and other sensors mounted on the boat.
e) The data collected during the course of navigation is sent to the cloud via Wi-Fi, GPRS, or GSM modules for analysis and prediction.
f) In the cloud, the geo-tagged sensor data is stored as a history of the corresponding water body.
g) To analyse the data in the cloud, machine learning techniques like clustering and regression are used to generate a hypothesis over the data log that was initially collected. Using the analysed data, the algorithm plots the choropleth map of that water body.
h) The generated choropleth maps are also stored in the cloud. The concentration map could be easily interpreted by any end-user.
i) The end-user can get updates and information on the water body via the developed applications for mobile and web platforms.
j) Continuous monitoring of the water body of concern over a period of time helps to optimise the hypothesis function generated; the prediction becomes more accurate as time passes.
k) Finally, one can detect the parameter trend and generate the choropleth map for future conditions as well (after 6 months or one year).

The final prototype model built will have the following features:

a) More stable than rugged water flow.
b) More payload capacity.
c) Data collection, transmission, and navigation units are isolated to enhance better troubleshooting

Advantages Of The System:

a) The model that is being offered here will make it easier to cover the whole length of a body of water in order to assess the water's quality.
b) The system that is being proposed operates in real time without any lag at all.
c) The model that has been suggested is capable of accommodating all kinds of water bodies at no extra expense.
d) The model provides assistance in the process of creating and implementing pollution prevention and management plans while simultaneously showing the findings in real time via mobile and online apps that are still in process of being created.

Conditions Limiting:

a) A big problem with using IoT in the water management business is the potential for it to be hacked.
b) If they wish to reap the benefits of IOT, certain public and commercial water management organisations will need to allocate additional resources to the development of cyber security technologies and training.
c) Placing an excessive amount of reliance on these automated processes may increase the risk of experiencing harm owing to faulty programming.

6. PROPOSED SYSTEM

The proposed model is a combination of three different subsystems interacting with each other during functioning. The three different sub-systems are:

1. Navigation Unit
2. Data collection & IoT Unit
3. Power Supply Unit

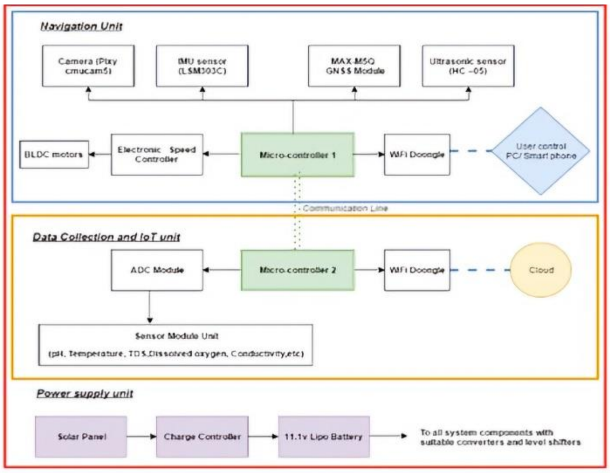

Figure 5. Proposed Architecture of the Water Quality Assessment model

Navigation Unit

This unit consists of components that aid in the navigation of the system with semi-autonomous capability. The navigation unit shall be built with the following components:
BLDC and ESC: brushless outrunner with electronic speed controller; this forms the throttle unit of the system.

Microcontroller: Tentatively, a Raspberry Pi shall be used, which acts as the central point that takes care of all the processes in the navigation unit.

Wireless Dongle: This is used to control and monitor the system status online. Status like location, speed, and battery of the boat can be obtained.

Camera, IMU, GNSS, and ultrasonic sensor—these assist in the localization and mapping of the system that helps in implementing semi-autonomous features for the boat.

Data collection and IoT unit

This sub-system contains all the necessary sensors and communication modules. This subsystem functions all the time, collecting water quality data like pH, temperature, DO, turbidity, etc. All the real-time collected data is then synchronised to the cloud or main server, which acts as the data center. Once the data is sent to the cloud, the data is analysed.

Machine learning will have its major share and contribution towards this proposed system. The learning algorithms used on the dataset collected help in predicting and evaluating the quality of water. Machine learning approaches like clustering and regression will be used on the dataset. The time series data collected from a lake at different latitude and longitude positions will form the vector. Clustering algorithms will be applied to cluster these vectors. As each clustering algorithm will have varying accuracy levels on the data, the dataset will be tested against multiple clustering algorithms, and the best algorithm that gives maximum accuracy for this dataset will be chosen[22]. Applying regression to the same dataset will result in an equation that can be mapped to the clustered sample for further analysis[23]. Combining clustering techniques with regression not only tells how many lakes are toxically affected in a region but also helps predict how soon the lake's toxicity is likely to increase[24].

Power Unit

This unit powers the whole system with suitable level shifters at the different places required. The main source of power here is a lithium polymer battery. The secondary source is solar energy, which is used to recharge the main source, which is LiPo batteries. The entire workflow of the proposed architecture is pictured below.

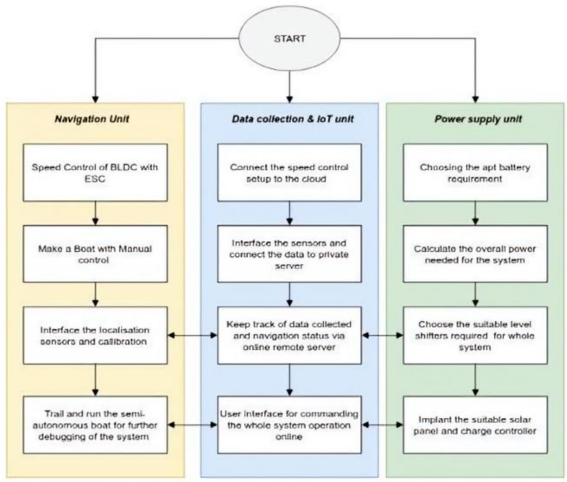

Figure 6. Workflow of the proposed system

7. YEAR WISE WORK PLAN

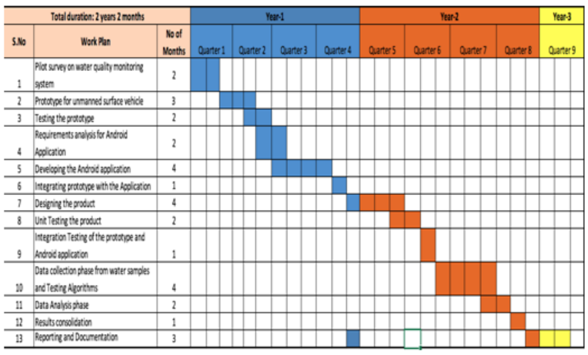

Figure 7. Gantt chart showing the year wise work plan
*Note: Interim report will be created at the end of the first year

Minimum required tenure of the proposed system

A minimum of 1-year is required to build the initial beta-model of the product and the Android application.

Practical relevance/utility of the proposed system

As per the current quality status of different water bodies in India, the need for maintenance and monitoring is at the very least required. The CPCB (Central Pollution Control Board) needs enough data to frame pollution control strategies. Presently, there is no proper water quality monitoring system available in India that can provide sufficient quality data for any particular water body. In this proposed system, the system we propose does the following functions:

a) Physical, chemical, and biological parameters with geo-tag
b) The system is mobile, so it can reach all distinct locations on a water body, giving us the advantage of obtaining data diversely.
c) Further, data analysis and machine learning techniques are applied to get relevant inferences in terms of pollution origination, spread of pollutants, choropleth map of each parameter, and also forecasting of the trend of quality parameters.
d) The system can be used for multiple water bodies as it is portable, autonomous, and mobile.

Expected and other physical outcomes of the proposed system

a) Scheduled status report of each water body. (Daily/weekly/monthly)
b) Choropleth map of each quality parameter.
c) Caution messages to pollution control board with details of the casualty.
d) The system has the ability to suck water sample and store in small containers if required for special cases orstudies.

Agencies which can utilize the results of the proposed system

a) CPCB
b) State and Central water board authorities.
c) Siruthuli (NGO)
d) Seghal Foundation
e) other research purposes

Techno-commercial feasibility of the Proposed system

The prototype that is planned to be developed can be used multiple times and will require minimum or no maintenance. Also, the prototype shall be developed in such a way that it can be used for any water body. The cost incurred in building the system will come down when making the product on a mass scale. It is also to be noted that with this prototype in place, one can avoid spending money on analysing the water samples manually.

Modalities for replication of the outcomes

The prototype can be made into a product and will become economically more viable and feasible. Also, the government or the water bodies may lease the boat (product or system) for quality monitoring, and charges can be made based on the area covered (Rs or sq m). One should also note that the proposed system will completely eliminate the need for manual quality monitoring.

Standardization of the design parameters for technology and preparation of protocols / prototypes for achieving reliable and replicable processes

a) The hardware and the raw materials opted for for building the product shall be of the best quality, makingsure that the system will not fail in the task.
b) The software that is going to be written will be ensured for quality, throughput, and accuracy.
c) The algorithms chosen will be the best fit based on the literature and field trials.

Cost–benefit analysis in terms of physical outputs and environmental benefits

a) The proposed system will avert the unnecessary delay and cost incurred in deploying and maintaining theexisting water quality assessment models.
b) The system shall provide the results with higher accuracy, which is not feasible in the current models.
c) Reduces the difficulty in covering the entire stretch of water body for taking water samples to assess the quality.
d) The results thus obtained shall be utilised in pinpointing the changes or trends that appear in water bodiesover a period of time.
e) Regular monitoring of water bodies will also identify any existing problems or issues that may possiblyarise in the future.
f) It also aids in designing and developing pollution prevention and management strategies in the long term.
g) The developed model will help us check whether the pollution prevention norms comply with the required standard.

4. CONCLUSION

Ensuring that the water quality is examined regularly is absolutely crucial. Manual Techniques are laborious and slow, and their validity and coverage are debateable. While advancements in nodal networks techniques have facilitated the systematisation of machine control, these systems are not without their drawbacks, such as extremely high initial investment and challenging maintenance requirements. One possible answer to the issues highlighted in this study is an unmanned surface vehicle (USV) system. The proposed system (USV) will be built using sensors and the IoT. Without human intervention and with great accuracy, USV will gather all the metrics related to water quality management, eliminating any issues that may have been present. The proposed system is an affordable and well-organized real-time gadget since it can function fully under severe and flawless conditions.

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Zow Afshan
Jamia Hamdard,
New Delhi,
India
afshanzow@gmail.com
ORCID 0009-0000-7233-7962

Sherin Zafar
Jamia Hamdard,
New Delhi,
India
sherin.zafar@jamiahamdard.ac.in
ORCID 0000-0001-6656-1095

Safdar Tanweer
Jamia Hamdard,
New Delhi,
India
safdartanweer@jamiahamdard.ac.in
ORCID 0000-0002-4525-4771