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Internet of Things Based Water Quality Monitoring System Model for Fish Farming in Bangladesh

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ABSTRACT

In this study, an Internet of Things (IoT) based water quality monitoring system model is proposed for periodically monitoring the water condition of fisheries from the perspective of Bangladesh. Although Bangladesh is a leading country in fisheries, but it fails to produce in its full potential due to lack of technology and mismanagement. Traditional farming methods are still prevailent widely, while some farms use basic electric devices like water wheel aerators, manual pH meters and DO (Dissolved oxygen) meters for improvement but these tools are inadequate for effective water quality monitoring. Consequently, the water quality of fisheries declines and hence fish production hampers. This study aims to develop an IoT based water quality monitoring system model with user-friendly solutions for the farmers to enhance sustainability of fisheries. To develop such a model, multiple models were studied, and suitable ones were identified. Afterward, applicable sides of different models were identified and combined. Finally, some new features like expert suggestion, government aid and control, user-friendly application, multilingual and voice mode, flood and disaster alert, weather forecast etc. were introduced to make the model suitable. The proposed model working procedure is kept simple for ease in implementation and maintenance. Firstly, sensors monitor certain parameters such as water temperature, pH, DO and water level of the pond in central monitoring zone. The collected data is sent to the central server for analysis, which is afterward transmitted to mobile devices to monitor the water quality and take necessary actions based on the suggestions of fisheries' experts.

1. Introduction

Bangladesh has excellent fish culture potential in its vast water resources. The fisheries sector plays a significant role in the national economy in terms of nutrition, income, employment and foreign exchange earnings. This is one of the significant export-earning sectors, which contributes to the national GDP and the foreign exchange earnings of the country [1]. Despite its importance, the fisheries sector faces challenges related to water quality, which directly impacts fish health, production rates, and profitability. The motivation for this study arises from the growing need to improve the sustainability and efficiency of aquaculture in Bangladesh.

2. Literature Review

This part comes up with a well explained literature review about the current scenario of fish farms in Bangladesh and the technological involvement in fish production, which basically focuses on the business of the fish farming sector in Bangladesh.

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2.1. Recent scenario of fish farming projects in Bangladesh:

The fisheries sector has been uniformly getting bigger in Bangladesh, growing 45.03 lac metric tons of fish in 2019-20, according to statistics from the Department of Fisheries (DoF). In 2019–20, almost 11.65% were Rui and 15.46% were other inland fish. There is a great opportunity to maximize production, although there are also some noticeable barriers which need to be checked out. The study [10] explained about the implementation of water quality monitoring system to increase fish quality. Another study [11] explained real time water quality, smart fishing and IoT implementation on fisheries industries, another study [12] discussed the method about measuring two parameters (pH factor and temperature) to check water quality. Bangladesh lag behind other nations due the lack of expertise to adopt technological advancements. To overcome this issue, the authors [13] also developed water quality monitoring system considering low cost and integrated mobile application in their proposed system model.

2.2. Implementation of Technologies in fish farming:

In the last 2–3 decades, digital technologies have been successfully applied to the fisheries production and monitoring systems. A smart monitoring system is characterized by a variety of sensors and devices: DO sensors, IoT technologies, pH sensors, temperature sensors, big data analysis, smartphone applications, and more. The study explained a detailed description of digital sensors and systems to get an advanced aquaculture system [14]. In the studies [15], which provide a description of several technological advancements and their adoption in aquaculture, although the technology is applied in large-scale fish farming projects worldwide, the Bangladeshi fish production sector still lags behind in adopting such technological implementation and lags sustainability. Nevertheless, there is ample scope for applying IoT in fisheries. For instance, producers have the capability to monitor water quality continuously. Continuous access to monitored data reduces the time and effort required for manual monitoring. By maintaining continuous checking, producers can establish effective working patterns and enhance the sustainability of their farming operations. Espinosa-Faller and Rendón-Rodríguez [16] have devised a Zigbee system in a recirculation setup for remote data collection. Similarly, Sung, Chen, and Wang [17] are employing Zigbee technology for improved communication in developing a cost-effective system for remote water quality monitoring. This study has checked out a monitoring system for potential implementation in fish farms. Real-time monitoring data assists producers in managing DO levels effectively.

For growing healthy fish and survival, the DO parameter is critical, and with continuous data monitoring, the producers can switch on the oxygen generator when necessary. The next step is to collect the monitored data and scan it with some other data, such as temperature scales, water quality checks, and water levels at different times. In addition, some studies combined an automatic signal with the continuous monitoring system. The study [3] developed a system to measure the DO level continuously and switch on the generator to supply enough oxygen in the pond on the basis of monitored data. The study [18] successfully advanced complex real-time monitoring with an automation system in south China. This system can identify various parameters (DO level, temperature, pH level checking, water level, nitrate turbidity, salinity).

In the last decade (2011–2020), many studies have developed various systems about sustainable fish farming projects. Yet, in the issue of evaluated projects, only a few numbers successfully developed a prototype, whereas the other studies either produced a frame, made their results through experiments, or through IoT simulations. Important parameters are the most experimented with: DO level, pH level, and temperature. Some of the literature above provides a possible technological solution. The [6] study described the economic impact of IoT use in Indian fish farms. They figured out a considerable cost decrease in the need for electricity, energy, and medicine. The use of the new technological adaptation has reduced labor costs considerably. Producers can monitor conditions instantly and perform the required remedy. Through the implementation, there is no need to visit physically, especially at night or during any kind of adverse weather.

There is a remarkable lack of adaptation to the new technological advancements in Bangladeshi fish farms. In this circumstance, this paper studies the implantation of these new technologies from the perspective of Bangladesh. The paper introduces the causes of wasting energy and low productivity. This study overcomes those issues by adapting these technological advancements for further improvements and to increase productivity as well as profitability.

2.3. Issues arising in integrating technologies in Bangladeshi fish farming project:

A comprehensive study has displayed the environmental, infrastructural, political, and technological issues hampering the business of fishing in Bangladesh. These include, for example:

i. Lack of planning and appropriate systems.

ii. Connectivity limitations in rural areas, power supply limitations, and adverse environmental conditions.

iii. Social issues: The authors [19] highlighted the difficulties faced by fisheries industries from Bangladesh perspective, which is usually a mode of survival rather than a means of making a profit.

iv. Absence of suitable methods and financial constraints, the majority of fisheries in Bangladesh rely on basic technology. Farmers are habituated to

use chemicals hazardously for both water quality and the pond ecosystem.

v. All the above concerns are intensified by the general preservation of fish farms and the lack of convenience in such digital devices, which results in farm owners resisting the acceptance of modified systems and the implementation of updated devices. However, a little literature has been found on how Bangladeshi fisheries can benefit from relevant digital systems and technologies. This paper aims to fill this gap by exploring various strategies to enhance the profitability and sustainability of fisheries businesses. The study seeks to collect data on various parameters through the proposed central monitoring zone. This information will then be presented through a user-friendly application. This research project suggests taking an effective approach to Department of Fisheries, Bangladesh (DoF), where decisions are reached through collaborative efforts with businessmen based on informed insights. Additionally, this study also suggests that DoF should take initiatives to collaborate with local farmers and organizations, to identify, adapt, and implement the proposed system.

Table 1: Summary of Literature review (cont.)

Ref. no.	Considered factors							Implementation
	IoT	DOM	App	TM	pH	CMS	WF	
[3]	√	√						Automation, Wireless network
[4]		√		√	√	√		Decision-making method, Real Time Monitoring
[15]	√	√		√	√			Wireless network
[18]	√			√	√			Automation
[20]	√					√		WAN
[21]	√	√	√	√	√			Wireless network
[22]	√	√	√	√	√			Real Time Monitoring
[23]	√	√	√	√	√			Remote monitoring system
[25]				√	√			Wireless network
[26]	√			√	√			Real Time Monitoring
[27]	√							Software- based decisions
This study	√	√	√	√	√	√	√	Wireless network, Aquaculture 4.0.

The summary of the literature review is presented in Table-1, where the findings of fourteen research articles are summarized. These review findings are presented based on seven important factors which are closely related to water quality monitoring system. It is seen that only two articles covered the continuous monitoring system (CMS) [4, 20] and three articles covered mobile app-based monitoring system [21, 22, 23]. It is also seen that nobody considered these seven factors simultaneously at a time. Besides, it is also noticed that nobody considered weather forecasting (WF) yet in their model. So there is a huge scope of work in this area. In this study seven factors are considered simultaneously. This is the prime novelty of the proposed study. The Continuous monitoring system (CMS) of this study is different from prevailing ones since it has central monitoring zone which makes it cost-effective and simple structured. Although three other studies [21, 22, 23] covered Mobile app-based monitoring, this study has made it easier for common people to use and introduced expert suggestion service. Moreover, the introduction of weather forecasting in aquaculture is unique to this study.

3. Research Methodology

This study aims to develop an IoT-based fish farm and quality monitoring system and to adopt it systematically for solving existing problems from the perspective of Bangladesh. Three phases are carried out to conduct this study [29]. These phases are planning stage, conducting stage and reporting stage.

3.1. Planning stage

The preliminary phase of conducting a systematic literature review begins with the planning phase. The planning phase consisted of formulating research questions, developing a search strategy related to the topic, identifying quality evaluation criteria, and creating a data abstraction system.

3.1.1. Review questions

This section contains public motivation review questions that need to accomplish the aim of the study, offering an in-depth analysis of the emerging area of IoT-based fish farm monitoring and finding sustainable solutions of relevant issues. Some lists of research questions (RQs) are here with the required motivation factors.

RQ1: What is the effect of water quality on the profitability of fisheries?

Motivation: In fisheries, poor pond water quality can cause disease outbreaks, reduced growth and mortality of fisheries which finally decreases overall yield and profitability.

RQ2: What are the problems with traditional water quality monitoring systems?

Motivation: Existing traditional water quality monitoring systems are manually operated so it is slow and inefficient.

RQ3: Why is an IoT based water quality monitoring system required?

Motivation: IoT based water quality monitoring systems can enable smart farming and eradicate the limitations of traditional water quality monitoring systems. Moreover, it can increase production volume.

RQ4: Why are the existing IoT based water quality monitoring systems of developed countries not applicable in Bangladesh?

Motivation: The existing IoT based water quality monitoring systems of developed countries are not applicable in Bangladesh because they are not cost-effective and complex structured. Since most of the farmers of Bangladesh are not technologically sound, a system should be designed prioritizing their needs.

RQ5: What is the contribution of the proposed system model to the environment?

Motivation: This system model is for enhancing the aquatic environment since it results in reduced waste of chemicals, fish feed etc. It does not have any harmful effects on the environment.

3.1.2. Development of search strategy

While developing a search strategy, it is essential to create a well-structured set of keywords to search for data online. A search strategy involves searching online databases, identifying relevant keywords and phrases, and formulating search queries. The strategy depends on the selected database. Science Direct and Scopus are the selected databases searched for the strategy. Required keywords: appropriate keywords are found for the strategy: “IoT-based fish production,” “fisheries,” “water quality monitoring,” “sustainable fish farming". Query: The query was planned to apply the appropriately selected digital database for keywords, (“Technology implementation in fish farming,” “water monitoring system,” “IoT-based fish farms," and “Usage of IoT in fisheries”).

3.1.3. Define selection criteria

Selection criteria would be executed after selecting the relevant literature based on the query questions. The execution of both inclusion and exclusion criteria must be present, including inclusion, comparing cases, experiments, and exclusion. Such as qualitative methodology and observational planning. This section would help to match the area of the literature review.

3.1.4. Inclusion and exclusion criteria

In this section, inclusion and exclusion criteria have to be executed for the adjusted systematic literature review (SLR). That would properly describe as mentioned below.

Inclusion criteria:

English language articles have first priority.

i. The studies include water monitoring systems and applications of IoT in fish production.
ii. The studies which have been published in reputed international journals.
iii. Recent years in publications of the studies.
iv. Approaches visual based data and provides terms of accuracy.

Execution criteria:

i. Articles published in any other languages except English.
ii. Poster abstract and conference studies will be excluded.
iii. Diverged from the field and unfocused research topic.
iv. The study in which full PDF is unavailable.

3.1.5. Quality assessment criteria (QAC)

Table 2: Quality assessment criteria

Item	Score	Description
QAC1	0	No
	0.5	Partially, Objectives fulfilled.
	1	Yes, appropriately.
QAC3	0	No
	0.5	Partially, but unclear and scope of using IoT is not very specific.
	1	Yes, completely.
QAC4	0	No
	0.5	Partially, but not on observing the view.
	1	Yes, discussed.
QAC5	0	No.
	0.5	Partially, but not very specific.
	1	Yes, appropriately discussed sensors.

QAC1: Are the issues discussed in papers related to the main themes?
QAC2: How well defined is the methodology?
QAC3: Does the paper discuss the area of fisheries?
QAC4: Does the study discuss the system and technology used in water monitoring systems?
QAC5: Does the study properly explain the sensors for IoT based fish farming?
The QAC has been established to check the actual quality of studies. Each study could be evaluated according to the QAC that has been given in the Table 2. Each answer stands for yes, partially, no and a numerical value has been added. The score of a particular study can be executed through adding the value for the answer against a QAC.

3.1.6. Data extraction strategy

After sorting out the relevant studies which allow QAC, information needs to be extracted. In Table 3, indexing data items to find out the relevant studies and exclude unclear data and their complexity in the studies.

Table 3: Item specification table

Item no.	Item specify	Description	Relevant Question
1	Publisher	Finding Appropriate channels	RQ1
2	Year of publication	Finding recent studies.	RQ2
3	Keywords application	Choosing domains for research studies.	RQ3
4	Technology	Finding Advanced technologies.	RQ4
5	IoT	Finding sensors to accelerate research studies.	RQ5

3.2. Conducting stage

After meeting QAC for a different database, SLR has been executed, and found relevant studies about the implementation of IoT in fish production and the adaptation of technologies for higher efficiency. Some studies that were selected after passing QAC would also serve as a guideline for data extraction and incorporation. At this stage, the details of the SLR process will be discussed

3.2.1. Search process

According to the domains (i.e., “IoT-based fisheries, “water monitoring systems,” “the Internet of Things,” “fisheries," and “sustainable fish farming”) related to our studies, have been performed on several channels. The procedure was done by only sorting out the last ten years' publications.

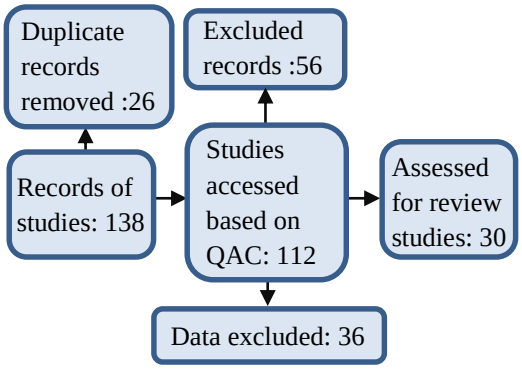

Figure 1: Sequence of sorting relevant studies.

Only relevant scholarly articles on the adaptation of technologies were selected for SLR accomplishments as illustrated in Figure (1).

3.2.2. Selection of studies

By searching all those domains on several channels, a lot of research studies were explored as it contains keywords domains. All the studies were explored, duplicate studies were removed, and inclusion and exclusion criteria were applied to get relevant papers for review. A total of 138 studies were selected for further guidelines and review planning.

3.2.3. Data exclusion and synthesis

The QAC explained in the quality assessment criteria Table 2 was applied to the total number of selected studies. But, in most of the studies, the data didn't clearly match, as they didn't mention the usage of IoT and technology adaptation in fisheries. Among all the studies, 30 studies allowed QAC after data extraction and synthesis.

3.3. Reporting stage

After selecting all the studies, the data was extracted. And after sorting, all the acquired data is shown in this section.

RQ1 was about the effect of water quality on the profitability of fisheries. Maintaining optimum water quality is essential for the profitability of fish farms. Investments in monitoring systems and technologies can help farmers continuously monitor water quality parameters, ensuring healthy and productive fisheries. Poor damages fish health, growth rates, and overall productivity, ultimately impacting the profitability of fish farms.

RQ2 is related to the problems in traditional water quality monitoring systems. Traditional systems in Bangladesh face several challenges. Firstly, it suffers from limited coverage, Moreover, the reliance on manual sampling methods results in infrequent data collection, leading to gaps in information and delayed responses to water quality issues. Additionally, the high costs associated with traditional monitoring, including manpower and resources, pose financial constraints on expanding coverage. Furthermore, the lack of real-time data availability hampers decision-making. Overall, addressing these challenges requires modernizing infrastructure, adopting advanced technologies, and improving public awareness.

RQ3 was about the reason for the IoT based water quality monitoring system required. IoT-based water quality monitoring systems could provide real-time data, continuous monitoring of pond water, timely detection and response to water quality issues, which are crucial for fisheries health and sustainability. IoT systems are cost-effective in the long term, reducing manual labor cost and operational expenses.

RQ4 is related to finding out the reason why existing IoT based water quality monitoring systems of developed countries are not applicable in Bangladesh. The economic and environmental conditions in Bangladesh differ from those in developed countries, requiring modified monitoring approaches. Another limitation is unreliable power supply and internet connectivity issues hinder the deployment and operation of IoT systems. Economic constraints also make it challenging to afford the initial investment associated with advanced IoT technologies.

RQ5 related to the contribution of the proposed system model on the environment. The proposed model helps in reducing waste of energy, manpower, chemicals etc.

4. Model Implementation

4.1. System Design

The system utilizes a microprocessor signal processing unit to process the incoming signals from sensors. It also incorporates server and NB-IoT (Narrowband Internet of Things) technology. The primary benefits of this system include low power consumption, cost-effectiveness, enhanced adaptability, improved stability, user-friendly operation, and overall performance enhancement. An advanced fish farm is shown in Figure (2).

Figure 2: IoT based advanced fish farm in developed countries.

A central monitoring zone consists of a monitoring container with sensors, water pump, automatic watering system, internet connection (preferably Wi-Fi) etc. The monitoring container houses all the sensors in it. Pond water will be collected from each pond periodically using a programmable automatic

watering system which flows water to the container at a given frequency and then water is returned to the pond after the allotted time. Then water from another pond flows into the monitoring container. In this way water quality monitoring data is collected periodically. Between draining water from the first pond and flowing water from the second pond inside the container, there is a clearance time for maintaining higher accuracy of sensors. Then sensors send data to the central server where it is analyzed automatically and then the condition of water is uploaded into the server which can be observed in mobile apps and/or websites. The setup of existing water quality monitoring system in developed countries which is comparatively more complex structured than the proposed model shown in Figure (3).

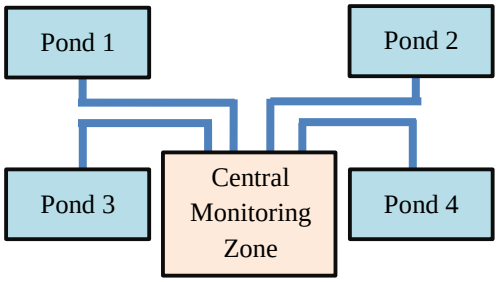

Figure 3: Proposed water quality monitoring system layout.

4.1.1. Central Monitoring Zone

A central monitoring zone is set up adjacent to the ponds for monitoring water quality of multiple ponds as illustrated in Figure (4). It should be set up in such a location so that the required number of connecting water pipes is minimized. It can be placed at the junction of multiple ponds to eliminate excess connection cost. Moreover, it reduces the installation cost since there is no need for installing sensors in every pond rather only one set of sensors is enough for monitoring the water quality of multiple ponds discreetly and periodically. It also enables automation in the fish farm, so water quality can be monitored throughout the year and even in adverse weather conditions. Furthermore, this reduces human effort.

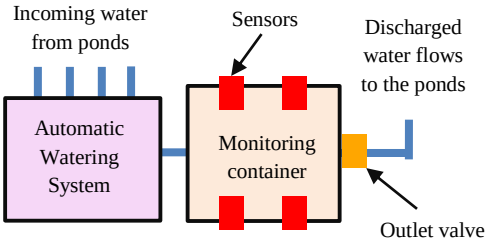

Figure 4: Central monitoring zone layout.

The monitoring container is a container that houses all the sensors. Its main purpose is to hold pond water for a certain period when the sensors will take measurements. After the measurement period is over, pond water flows out through the outlet valve. Since a pH meter cannot be immersed in water for long time, a container is designed to periodically immerse the pH meter in pond water and then drain out after monitoring. In this way, a pH meter can be protected using a monitoring container.

4.1.2. Temperature Sensor

Temperature sensor is used for measuring water temperature which affects both physical and chemical properties of water and so it is a vital parameter in fish farming. Gases like oxygen dissolve less in warmer water and degrade the condition of pond water. Temperature highly influences biological activity and growth of fishes. For any deviation from ideal temperature ranges for growth and survival the physiology of fish degrades consequently.

4.1.3. Dissolved Oxygen (DO) Sensor

DO concentration is the primary water quality indicator. Generally, higher DO levels indicate better water quality. Since fish intake dissolved oxygen (DO), so the amount of DO is vital in fishpond. Insufficient dissolved oxygen impacts the survival rate of fish.

4.1.4. Water Overflow Sensor

In fish farming, the water overflow sensor system enhances water level control for efficient management. This system replaces traditional water level switch indicator with floating balls which is not accurate enough. The new sensor can identify low, medium, and high-water levels. Moreover, it can measure if there is any possibility of overflow. It is more economical than traditional floating switches. Only this sensor is placed inside the pond. During flood or rainy season, it notifies users based on their location if water level exceeds the desired level.

4.1.5. pH Sensor

The pH value expresses the acidity or alkalinity of a solution by measuring acidity or alkalinity of water. It plays a critical role in aquaculture, affecting both water quality and the health of fish. Fish farms produce excrement, leading to increased water acidity. Optimal pH for fish growth is 6.5 to 8.5. Extreme pH levels harm fish, causing sickness, growth stagnation, and increased mortality. Algae affect pH due to photosynthesis (day) and respiration (night). Excessive fish/shrimp excrement reduces oxidation efficiency [4].

4.1.6. Networking Device

In this system, a networking device is required to send sensor data from fish farms to the central server and monitor the condition of water. A dedicated networking device such as Wi-Fi, modem, WAN etc. is required for uninterrupted data transfer. Wi-Fi is the more economic option among them. For remote villages modem can be used since Wi-Fi connections are rare. And for large farms with high financial capabilities can use WAN (Wide Area

Network) like LoRaWAN for supreme internet connection. LoRa transmission module.
A power backup is required for uninterrupted networking since load shedding is eminent in Bangladesh. Instant Power Supply (IPS) is a solution to this problem. In remote areas, where electric supply is not available, solar panels or generators can be used.

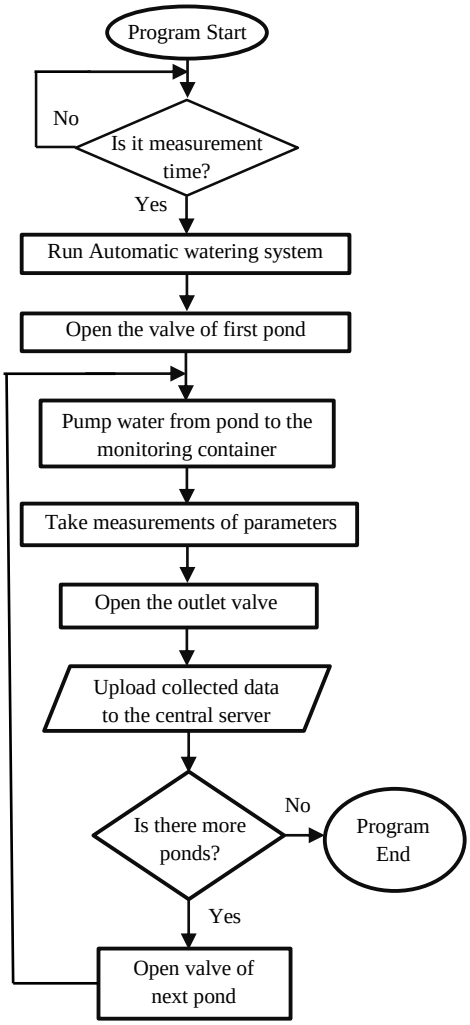

Figure 5: The flow chart of integrated architecture.

4.1.7. Integrated Architecture

The architecture of the system model illustrated in Figure (5) is relatively simple compared to existing systems. Firstly, the automatic watering system device signals the pump to supply water from a pond to the monitoring container. After some time, water flows inside. Secondly, the sensors measure pH, DO, temperature etc. Thirdly, the discharge valve opens, and water is drained out. Then readings are uploaded to the central server via myRIO [30] for further analysis. Finally, according to the allotted range of parameters the condition of water is determined and updated which can be monitored by a registered user through smartphone or website. In this way, the water quality of a pond can be monitored. If a farmer has multiple ponds, then after draining water from the first pond the automatic watering system device closes the valve of the first pond inlet and opens the inlet of the next pond and signals the pump to supply water from another pond to the container. Similarly, the water quality is monitored for other ponds in a cyclic manner [4].

4.2. Mobile application interface

The mobile app is designed for fish farmers while prioritizing simplicity, multi-languages and user-friendly options. It also has voice mode so that illiterate or less educated farmers can also use it. There is always an option of calling the local government agricultural officer for any query. The primary key for the data set is the mobile number of users, so there is no hassle of remembering excess information. The mobile application should have different interfaces for different stages. Firstly, the app is required to be installed in a smartphone. Secondly, the user needs to select his mobile number for registration. Thirdly, the user should fill up the form with the necessary information. Then he should fill up the form for every pond. After completing registration, the user will get an appointment from the local agricultural officer and in the presence of the officer the user profile will be verified and linked to the central server. Afterward, the data is processed, and water quality is determined which is uploaded to the central server. Finally, the user can monitor the condition of his pond water using smartphone.

Figure 6: App interface for registration in both languages.

Figure 7: App interface for poor condition of pond water.

The weather forecast options should be monitored and updated to the central server regularly by the government officials. In times of natural disasters, emergency alarm notifications, preventive measures and other necessary aids should be provided for the

safety of fisheries. Flood and cyclone are the natural disasters that harm the fisheries sector every year in Bangladesh. Since both flood and cyclone can be predicted at least 3–4 days earlier so losses due to these disasters can be minimized if the fish farmers can be alarmed early and proper precautions are taken.

Figure 8: App interface of weather forecast during unfavorable conditions in both languages.

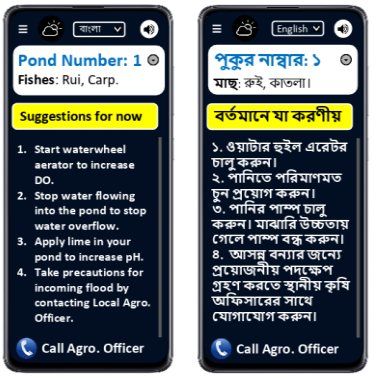

Figure 9: App interface of auto-generated suggestions.

In-app interfaces shown in Figure (6-8) with different colored texts have different meanings. Green color signifies good or ideal condition, yellow color signifies medium or satisfactory condition and red color signifies harmful condition of pond water.

4.3. Proposed model set up cost

The cost for setting up a central monitoring zone is shown in Table 4 according to the online marketplaces without shipping charges in Bangladesh dated on 01.05.2024. It might vary with place and time. The costs do not include installation cost and other variable costs.

Table 4: Cost table for a central monitoring zone.

Components	Price (BDT)
Temperature sensor	135
Water level sensor	3235
Dissolve Oxygen sensor	6424
pH sensor	108
Networking device	3000
Automatic Watering System	3125
Pipe and fittings	8000
Instant Power Supply (IPS)	25000
Others	2500
Total	51527

The cost for setting up a central monitoring zone is approximately BDT 51,527.00, which is affordable for most of the fish farmers in Bangladesh.

4.4. Comparative advantages of the system

The advantages of the system compared to existing systems are given below:

i. Cost-effectiveness: All the parts were selected so that they can meet the desired function at a lower price. The monitoring container is introduced to replace the expensive robotic arm.

ii. Improved efficiency: The system measures parameters periodically and minimizes human effort, cost etc. Thus, it helps to increase the overall efficiency of fisheries.

iii. User-friendly mobile application: The mobile application is designed for both the educated and uneducated fish farmers. With multiple languages and voice mode users can get the most out of it.

iv. Increased profitability: This system utilizes the costs to return maximum output. It can reduce maintenance costs and energy costs to a great extent. It also contributes to enhancing aquatic conditions for maximizing growth of fish and reducing the chance of diseases of fish. If water quality can be kept in ideal condition the production can be maximized. Thus, overall profitability can be achieved by this system if maintained properly.

4.5. Suggestions for implementing this system in Bangladesh:

The proposed water quality system model is designed to enable advanced fish farming throughout Bangladesh. For implementing this system certain points should be followed which are as follows:

i. The government should take the initiative to provide enough subsidies for availing the necessary equipment to the common farmers at affordable price and implement this system in their fish farms.

ii. The DoF should take the responsibility to set up and control the central server because most of the farmers of Bangladesh lack technical skills, and funds to set up their own server.

iii. The DoF should appoint experts for respective fields like mobile application management, weather forecasting, emergency helpline, Agriculturist etc. while implementing the system.

iv. The Local Agricultural Officers should be trained to assist farmers in smart farming.

v. The mobile app should also be developed in cooperation with the ICT ministry, incorporating all the facilities mentioned above.

vi. At first, this system should be implemented in selected ponds in a division for analyzing its regional effect in different parts of the country. Then regions with the best outcomes should be noted down and required planning should be done while focusing on these regions for spreading this system.

5. Result and discussion

5.1. Result

It was found that existing systems were not feasible for fisheries sector of Bangladesh since they were not economical, complex structured etc. So, an efficient water quality monitoring system model has been developed in this study from the perspective of Bangladesh. Several parameters such as, pH, DO, temperature, water level etc. will be monitored through the integrated mobile application. The mobile application was designed with special features for ease in understanding and operation by the farmers.

This system reduces waste of capital, energy, manpower, chemicals, sensors etc. The existing systems use separate monitoring setup for each pond, but this system has central monitoring system to monitor water of multiple pond water so fewer components and manpower are required. Hence, loss of capital, machinery, electric energy and manpower is reduced. Farmers can monitor the water condition regularly and apply chemicals like lime to increase the pH of water. The correct dose of chemicals is suggested by experts so loss of chemicals could be reduced.

5.2. Discussion

This study introduces an IoT-based water quality monitoring system designed specifically for fish farming in Bangladesh, addressing both resource limitations and environmental challenges. The proposed system demonstrates notable advantages in terms of accessibility, cost-effectiveness, and inclusivity compared to existing solutions.

5.2.1. Comparison between the Proposed and Existing System Models

The existing systems introduce water quality monitoring using IoT, but the design and functionality differ significantly. This system is designed from the perspective of Bangladesh, focusing on cost-effectiveness and local resource constraints. The system by Chen et al. [4] emphasizes high automation with advanced technologies like robotic arms and LoRaWAN, targeting fish farms in Taiwan. The proposed system focuses on DO, pH, temperature, and water levels, which are critical for aquaculture in Bangladesh's climate and economic context. While Chen et al**.** includes similar parameters but adds advanced features like a robotic arm for cleaning pH sensors. The proposed system implements a central monitoring zone for multiple ponds to minimize the costs and optimize layouts. But the existing system [4] uses submersible pumps and robotic arms for centralized water quality checks, which increases complexity and costs**.** The proposed system also prioritizes user-friendliness through a mobile application collaborated with government institutions. In the existing system [4], there is a similar inclusive design. This study also focused on affordability and scalability for widespread adoption, especially in resource-limited rural areas while the existing model relies on expensive components like robotic arms and advanced technologies. The existing system [4] requires frequent calibration and maintenance of sensors and robotic arms, increasing overall maintenance costs. The study integrates weather forecasting and disaster alerts, a critical feature for disaster-prone regions like Bangladesh while other papers does not include similar features specifically aimed at disaster mitigation. The incorporation of weather alerts addresses real-world challenges, making it more robust for adverse weather conditions and minimize loss. While the system offers a sustainable framework, certain challenges must be addressed, including the reliance on continuous power supply and stable internet connectivity may cause difficulties in rural areas.

6. Conclusion and future work

Through reviewing the literature, it becomes obvious that there is a noticeable lack of research concerning the integration of advanced technologies like IoT in the local fisheries sector. Consequently, this paper attempts to bridge this gap. This study also highlights the potential benefits of IoT implementation in fish farming practices in modern systems. The suggested model also integrates the mobile application with the central monitoring zone. It is hoped that the DoF will consider the proposed model for implementation, inspire local owners and train them to adopt the proposed system. The literature review also emphasizes ongoing efforts to enhance sustainability within the fisheries industry, with modern digital technologies being recognized for their positive impacts across various aspects of fish farming projects. Through a combination of relevant studies and problem identification, this research certifies these findings within the Bangladeshi context.

This research constitutes one of the initial experiments within the Bangladeshi context. Within the Bangladeshi context, Further studies on the efficiency of these technologies will contribute to future improvements in the field. A limitation of this study is that the research was done without data as there is currently no similar system in Bangladesh, limiting the scope for data collection hence it is not possible to provide scientific justification with practical data for the proposed system. This system is a regional modification of the prevailing systems of other countries like that of [4]. It’s one of the main advantages over the other systems is cost effectiveness and simple structure. These two factors are vital from the perspective of Bangladesh for adapting new technology. From the point of view of farmers, this system can minimize loss in fisheries business by availing expert support, total monitoring of the water quality, flood and disaster alert etc. Due to above reasons, this system could be feasible for the fisheries of Bangladesh.

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Notations for Table 1:

IoT: internet of things implementation
DOM: DO measurement system
App: Mobile app-based monitoring
TM: Temperature measure
CMS: Continuous monitoring system
DOF: Department of Fisheries, Bangladesh
WF: Weather forecasting
pH: pH measure