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Design and Implementation of Solar Power and an IoT-Based Pisciculture Management System

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Authors' contributions

All the authors contributed to the whole project, but the author MHB gave the idea including literature review section of the manuscript.

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Method Article

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ABSTRACT

Introduction: Pisciculture means fish farming for commercial purposes in a pond or in an artificially created fish tank. Proper care is needed for optimum fish yields.
Aims: The present research aims to design, simulate, implement, and test a low-cost pisciculture monitoring system to get the environmental status of a fishing pond where aquatic plants and fishes reside. The objective of this work is to produce high-quality and high yields of fish in the pond keeping the standard or prescribed states of the pond water.
Study Design: The factors that affect the pond environment are flow rate, p^H level, oxygen level, temperature, humidity, etc. To get high yields of fish from a pond, these factors must be within a specified level. If the values of these parameters go below or above the prescribed level then the

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water loses its quality and thereby fishes find it very difficult to survive in that pond because each water quality factor affects the health conditions of fish. Therefore, it is necessary to monitor these parameters.

Place and Duration of Study: Department of Electrical and Electronic Engineering, Southeast University (SEU) between June 2021 and April 2022.

Methodology: In this work, we have designed an automated microcontroller, IoT, and solar power-based water quality monitoring system for a fishpond. The automated system restores the values of these factors automatically when any of these factors fail to maintain their level in the pond.

Results: After testing the prototype of the system, we found that the designed system is performing very well and showing different parameter values in the LCD screen as outputs.

Conclusion: The system is in expensive and therefore, may be employed in practice.

Keywords: Pisciculture; microcontroller; p^H sensor; solar power; turbidity and temperature sensor; water level; internet of things.

1. INTRODUCTION

The Internet of Things (IoT) is a system that connects any physical objects to the internet and publishes the data or information of such objects to the web via the internet as such, they can either be automated or controlled or monitored without any wired connections. The physical objects gather data from the surroundings through sensors, send it to the cloud database, and solve the problems or instruct other devices what to do [1]. It has become very important in the modern-day society because objects are required to be connected to the digital world [2].

Currently, fish farming in Bangladesh is a commercially viable business venture because of the huge of amount protein intake (60% of animal protein) by the people of this country from fish [3-5], and new technologies in fish farming are being evolved [6]. Besides, a good portion of the Gross Domestic Product (GDP) of Bangladesh now depends on fish farming, over 3.5%, according to a survey by the Fisheries Resources Survey System (FRSS) [7]. According to the FAO report of the year 2018, Bangladesh was ranked third in inland open-water capture production and fifth in the world’s aquaculture production [7]. In Bangladesh, the fisheries division earned the highest GDP growth rate (5.52%) as compared to the other agricultural areas [8]. Fish production in Bangladesh has raised from 20 kg/person in 2010 to 25.5 kg/person in 2019 [9]. Besides, above one-fourth (that is, 25.72%) of the total agricultural GDP is contributed by the fisheries sector [7]. However, due to the lack of proper care and maintenance, many fishes die during the fish cultivation process every year [10]. It has been estimated that hundreds of thousands of fish die every month before they are caught by the fishermen from the ponds due to the contaminated water [11-13]. This occurs due to the under preparation of the ponds by the fish farmers because of their lack of essential knowledge [14-15]. Besides, Bangladesh is one of the highest malnutrition rates countries in the world. It has been estimated that the economic loss of malnutrition in Bangladesh is around US$ one billion each year excluding the healthcare cost for treating malnutrition and other causes [16]. Bangladeshi fishes are rich in protein and mineral contents, like sodium, potassium, calcium, magnesium, iron, zinc, etc. [17]. Thus, fishes are a suitable source of high-quality protein and valuable omega-3 fatty acids for our health. Recently, the World Fish Center has adopted a new approach, coined as community-based fish culture, where fish are produced during the rainy season in a community field but the same one is used for rice production during the dry season [18-19]. This approach needs extensive research on soil and water quality monitoring to get a high yield of rice and fish production [20].

To address the above-mentioned issues, we aimed to design a smart system that would detect the water quality and take appropriate measures automatically if the quality factor parameters fall behind recommended values because the main factor influencing the attainment of aquaculture is the water quality, which is measured by the physical and chemical quantities. These are turbidity, color, odor, alkalinity, acidity, dissolved oxygen level, temperature, humidity, salinity, level from the floating point, and humidity, etc. of the pond water. At every moment, through an automated process with the use of an Arduino microcontroller, these parameters will be monitored. In this work, we used an Arduino microcontroller because it is a very low-cost controller [21-25]. Besides, we used solar power to make it more economical because the use of solar renewable energy will reduce its operating cost [26]. We used the IoT technology to make it a smart system [25]. The system can determine the condition of the pond for the specific fish. It can also control the water quality parameters via a smart-mobile application based on a cloud database. The test results were found very satisfactory.

2. LITERATURE REVIEW

In 2012, at an international conference, the authors presented a simple wireless sensor network-based real-time water level and water quality monitoring system for the fishing pond. This device is mainly used with the RGB sensor. Their system uses mobile applications and sensors to determine the temperature, p^H, and water level of the pond water remotely using the internet [27].

In 2012, another research group developed an IoT-based system for pond monitoring to control ponds at different locations under a centralized common network. The system uninterruptedly reads and controls various parameters that are important for the breeding and growth of the fish, such as p^H, dissolved oxygen, temperature, natural foods, etc. The system has a central monitoring and control panel from where the values of various parameters are observed and based on that appropriate predictive decisions can be made intelligently [28].

At present, researchers around the world are using the IoT technology to monitor water levels, detect leakage, and auto-refill tanks automatically whenever there is a requirement [29].

In 2018, a research group developed and implemented a water quality monitoring system for aquaculture using Raspberry Pi, Arduino microcontroller, multiple sensors, cameras, and mobile Android Apps. The monitoring parameters of water were temperature, p^H, electrical conductivity, and color. Sensors and cameras collected required parameter values and images by the Arduino and the acquired data and images were processed by the Raspberry Pi and then stored in a server [30].

A research group published a work on the design and implementation of an automatic monitoring and governing system for Bio-floc fish farming by measuring the water quality parameters that include p^H, level of the dissolved oxygen and solids, temperature, water level, etc. They also used an IoT-based App to monitor the water parameters and regulate the actuators through the internet using smart-phone [31].

Another group of researchers presented a paper on a WEMOS-D1 microcontroller-based water quality observing system, such as p^H, oil layer, water level, temperature, etc. to have effective growth of fish in the pond. They also identified the behavior of fish to determine the food requirements of the fish [32].

For wireless network data transmission, one of the most important wireless system standards (such as, IEEE802.11b, IEEE802.11a, or IEEE802.11g) should be adopted so that the highest possible data transfer rates (for example, from 11 Mbps to 54 Mbps) are possible achieve for getting the error free data transfer [33].

Some species of fishes are found in the Recirculating Aquaculture System (RAS) to have a controlled interface between the fishpond organisms and natural situation to have enormously stylish waste controlling mechanisms in the fish farm. This is requires an IoT-based solution for proper management [34-35].

Climate Information Services (CIS) are needed to inform fish farmers about the climate change and its impact on fish yield. This service should be made available and accessible at an affordable cost to them [36]. This can be made possible using IoT-based solution, too.

3. PROBLEM STATEMENTS AND OBJECTIVES

In this work, we designed a water quality monitoring and control system. For this purpose, we will use various sensors to detect the status of water quality automatically by using an Arduino microcontroller. We will use a soil sensor, p^H sensor, turbidity sensor, ultrasonic sensor, feed sensor, temperature sensor, GSM module, potentiometer, air pump, water pump, turbine, LCD screen, power supply ICs, solar panel, buck converter, resistors, capacitors, LEDs, etc.

The specific objectives of this research are to-

- Check the turbidity condition, p^H value, dissolved oxygen level, temperature, humidity, height, etc. of pond water.

- Adjust the values of those parameters in water.
- Get the notification for each parameter via SMS.
- Create a proper environment for pisciculture.

If such system can be implemented then fish farmers would be benefitted at low cost by getting higher fish yields from their fishponds. This would also help the country to become self-sufficient in fish production and thereby earn foreign currency by exporting fishes abroad.

4. HARDWARE DESIGN AND IMPLEMENTATION

The system architecture shows the arrangement of components and sub-systems or objects in the system. The conceptual design of the system is completed and then simulated to get its real-time behavior. Therefore, to get a complete system of the conceptual design, a block diagram is drawn for the hardware design process of the whole system. The block diagram shows how different components are connected with various input and output terminals of the system. This diagram also refers to what happens from input to output. The block diagram of our proposed system is demonstrated in Fig. 1. Fig. 1 represents three main blocks where the left side blocks are for giving input signals to the microcontroller and the right side blocks are there to receive the output signals. In the middle, there is an Arduino Uno microcontroller and Node MCU.

The left side blocks are for various sensors that collect various information from the water body individually and send the corresponding electrical pulses to the microcontroller that reads those signals in the digital format from its input ports. Then microcontroller processes the received signals according to its programming instructions and then sends the appropriate action signals to its output ports. Here, we used a pH sensor to measure the p^H value of water. We also used here a feeding system for fish to monitor the position of the feed. For this purpose, we used here an LDR with a resistor to find the actual conditions of the feed every second. We used a turbidity sensor to measure the turbidity of water for ensuring its cleanliness. To control the percentage of dissolved oxygen in the water, we used an air pump so that air can be pumped into the water from the bottom to the upper parts of the pond. Another important part of our system is the temperature measurement sub-system that can measure the water temperature regularly from three different levels of the water, viz. lower, middle, and surface. When the temperature rises above 40^0C then it will send a notification that the temperature is high using the GSM module. However, the GSM module is employed here for multiple purposes, like making calls, and sending notifications based on several sensor data. To provide electrical energy to operate various parts

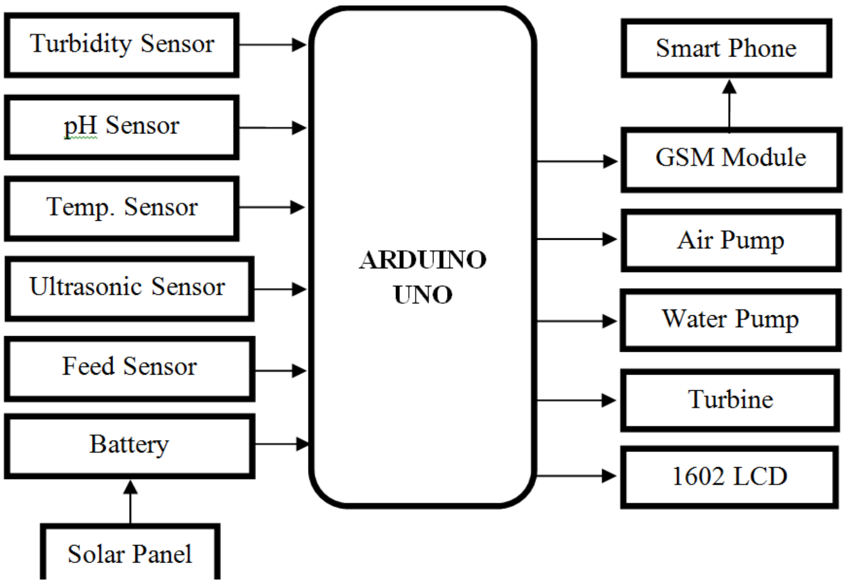

Fig. 1. Block diagram of a pisciculture system

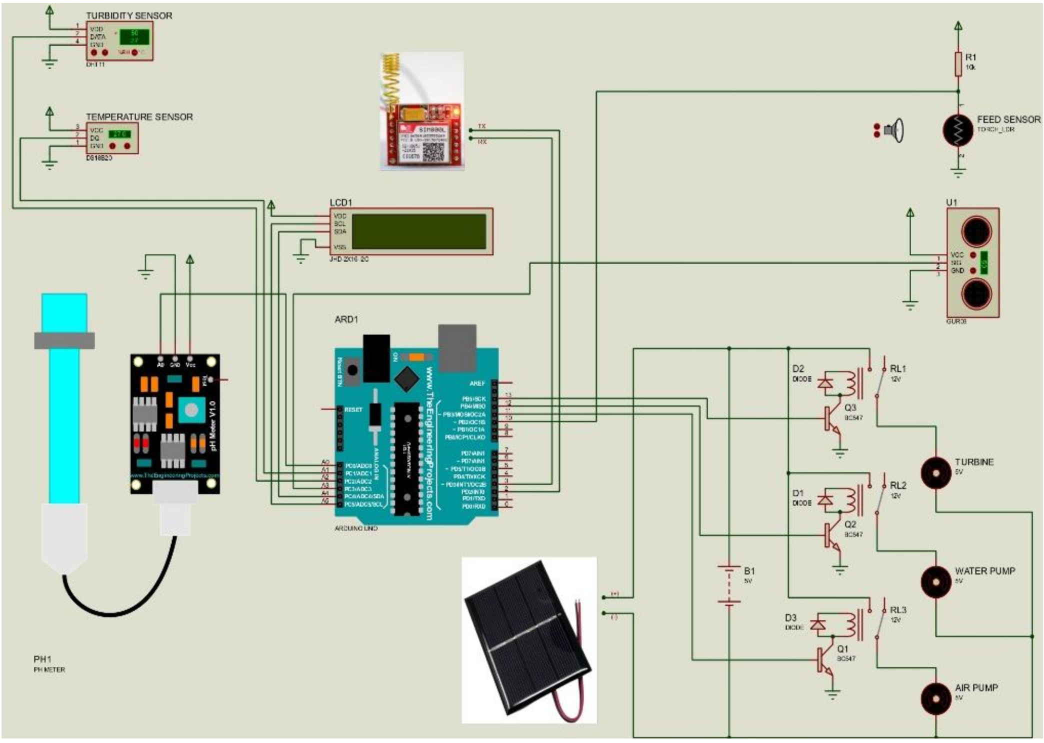

Fig. 2. Circuit diagram of a pisciculture system in Proteus

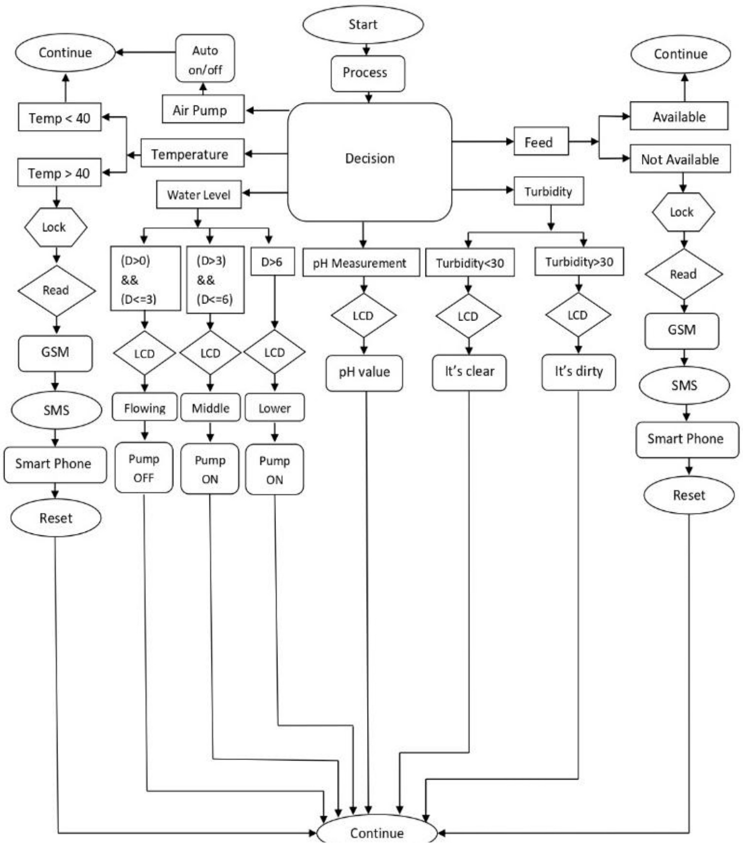

Fig. 3. Flowchart of a pisciculture system in Proteus

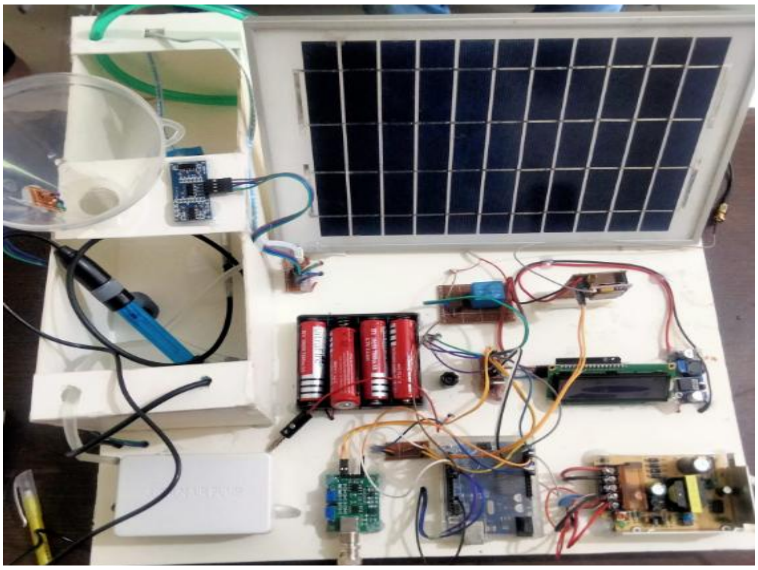

Fig. 4. Real-time designed image of the pisciculture system prototype

of the complete system, we used a solar panel to reduce its operating cost. Besides, we used a switched-mode power supply (SMPS) to work during no sunlight conditions. However, during the sunlight, it will charge the power bank to store electrical energy, also. To save the data of various sub-systems, the data are sent through the gateway to the cloud via mobile applications. Not only that, 16 characters by 2 lines LCD is used here to show all the values of this system instantaneously using the serial port of the microcontroller.

From the conceptual block diagram of Fig. 1, a circuit diagram of the system is developed using the Proteus software. The circuit diagram is shown in Fig. 2 where various images of each component are used. The interconnections of each element are shown, also in this diagram with the necessary pin connections. Fig. 2 represents the hardware pins connected to the Arduino Uno microcontroller, the main unit of the designed system. The supply pins of various sensors are connected to the Arduino Uno microcontroller board's power supply so that the input data reference is the same for all input and output pins. The output pins are connected to the digital pins and analog pins of the Arduino Uno.

The assembly program is developed for the Arduino Uno using the Integrated Development Environment (IDE) and then this code is used in the microcontroller for simulations. To develop the code, we used the flow chart, which is self-explanatory as shown in Fig. 3. The developed code is also used for the real-time prototype implementation of the system.

After the successful simulation of the system, we realized a prototype of the hardware system as shown in Fig. 4. Then we tested and evaluated the system performance by taking various data from the system.

5. RESULTS AND DISCUSSION

After implementing this system, we tested the system by applying various input conditions and some output results that we observed on the LCD screen are shown in Figs. 5-12. Figs. 5-6 show that the system is ready for displaying the output results of its operation. First, it will welcome everyone to this system.

Fig. 7 shows that the system has available feeds for the fish if the system senses that enough feeds are there. On the other hand, if the system senses that there are not enough feeds available then it will show feed the result as “Not available”. After that, we can see the value of the p^H sensor in Fig. 9 to confirm that the water is good in terms of this data. We know that if the p^H value of water is in the range of 6.5-9 then it is suitable for pond fish farming and if it is > 9.5 then it is inappropriate for the fish [37].

Fig. 5. Displaying the welcome texts of the pisciculture system prototype

Fig. 6. Displaying the system name of the pisciculture system prototype

Fig. 7. Displaying the feed's availability of the pisciculture system prototype

Fig. 8. Displaying the feed's non-availability of the pisciculture system prototype

Fig. 9. Displaying the p^H value of the pisciculture system prototype

Fig. 10. Displaying the temperature value of the pisciculture system prototype

We also monitored the temperature of the pond water, and it was found slightly above 32^{0}C as displayed in Fig. 10. This is one of the most important parameters to be monitored to maintain the water quality. Based on the culture period, the optimum temperature range for a high yield of fish is recommended by the researchers as 28-34^{0}C [38].

Then we can see the turbidity of the water. It will show two stages of the water, that is whether the water is clear or dirty. We used here drinking water in our prototype model so it showed the turbidity of water as clear as shown in Fig. 11.

We can monitor the level of water in three stages, such as low-level, mid-level, and high-level. We use a small amount of water to test our system, so it is showing “Low level” on the LCD screen as shown in Fig. 12.

We monitored the p^H level of water on different dates at two particular times in the day and evening. Then it is sent to the mobile Apps that showed it in two different plots of a graph as shown in Fig. 13. Similarly, the system sent the water temperatures on different dates at two particular times in the day and evening, and the graph is shown in Fig. 14. Fig. 15 shows the turbidity of water at two different times of the day on different days. However, the water level collected from the ultrasonic sensor is shown at different times on a particular day in Fig. 16. The LCD data and other environmental monitoring system data confirm all the data displayed on various plots as shown in Figs. 13-16.

A breakdown of the component cost of the completed system is shown in Table 1. It shows that the total cost is slightly higher than six thousand Bangladeshi Taka (BDT6,025.00), which is equivalent to fifty-nine US Dollars (US$59.00), approximately [39].

Fig. 11. Displaying the turbidity of the pisciculture system prototype as clear

Fig. 12. Displaying the water level of the pisciculture system prototype as low

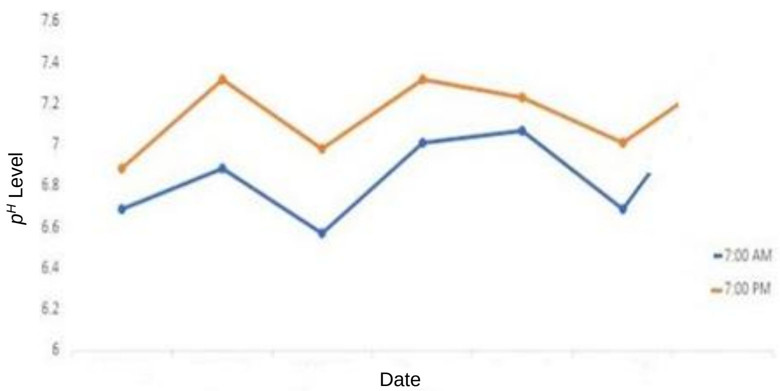

Fig. 13. Plot of the p^H levels of water on different dates and time

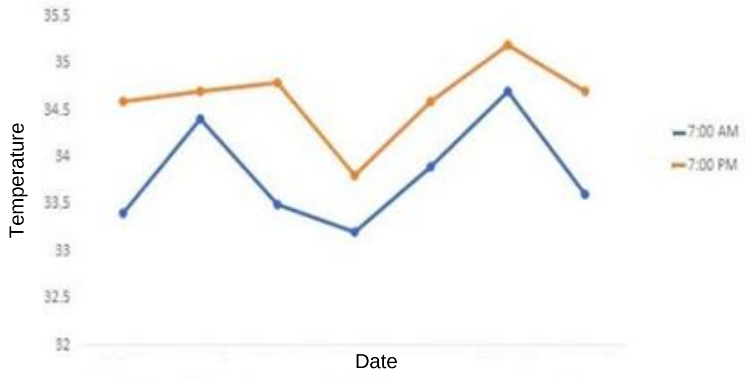

Fig. 14. Plot of the water temperature on different dates and time

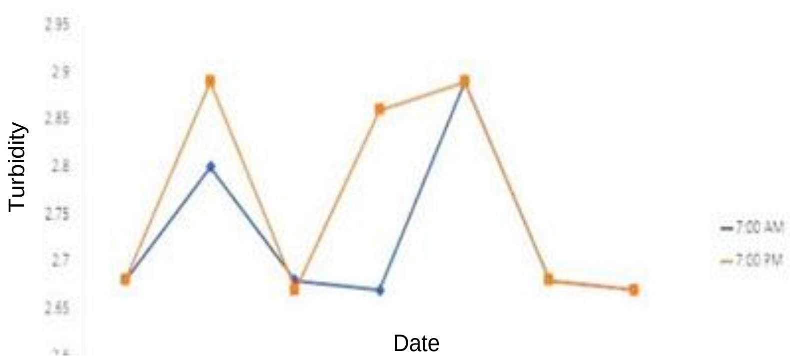

Fig. 15. Plot of the water turbidity on different dates and time

Table 1. The design cost of a microcontroller, solar power, and an IoT-based pisciculture system

SN	Equipment name	Model	Quantity	Price (BDTK)
1	Arduino UNO	Atmega16U2	1	570.00
2	16*2 LCD Display	HD44780	1	120.00
3	Adaptor module	I2C Interface	1	80.00
4	GSM Module	SIM800l	1	250.00
5	Relay Module		1	50.00
6	Buck Converter	LM2596	1	60.00
7	Solar Panel		1	400.00
8	DC Water Pump		1	50.00
9	Mini Air Pump		1	185.00
10	LDR Sensor Module		1	80.00
11	Turbidity sensor		1	220.00
12	pH sensor	Indion C0042	1	3,160.00
13	Temperature sensor	DS18B20s	1	180.00
14	Battery	Dry Cell	4	130.00
15	4 cell Battery case		1	40.00
16	Voltage regulator	LM7805	1	250.00
17	Ultrasonic Sensor		1	150.00
18	Connecting wire		20	50.00
Total Amount of BDTK				**6,025.00**

Fig. 16. Plot of the water level at different times of a day

6. CONCLUSION

The proposed fishpond monitoring system is an IoT-based system that can monitor the water quality parameters in real time. The system can respond suitably and automatically through various actuators once, the value of a particular parameter goes out of the recommended ranges of the agriculture scientists. Thus, the proposed system can help the fish farmers to produce more fish by providing optimum parameter values of the water quality. The owner of the pond can learn about the environment of his/her cultivated pond and various parameters of the water. He/she can take the necessary steps to manage his/her fishpond remotely through the Android application. Our test and evaluation of the system's performance confirmed its functionality.

Finally, this research work will bring about a breakthrough in fish farming in Bangladesh. This system can be scaled up to manage multiple fishponds from one smartphone with multiple systems. The power consumption of the system is minimized by the use of a solar panel and thus making it cost-effective. If a close circuit camera along with several motion sensors is used with this system then the real-time video monitoring of the system can also be done to prevent theft cases. This enables fish farming a more profitable and viable aquaculture business. As a future scope of this work, ammonia sensors, solid waste sensors, toxic or poisonous gas detection sensors, etc. could be added to the existing system to have a wider range of application areas of this system. Besides, all parameters may be measured quantitatively instead of qualitatively. A digital image processor with a suitable may be added to the system to identify the fish diseases in the pond. A digital signal processor based system may be employed instead of a microcontroller-based system to have more features [40].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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