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SMART MONITORING AND CONTROLLING SYSTEM TO ENHANCE FISH PRODUCTION WITH MINIMUM COST

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ABSTRACT

Fish production has significant impacts to several factors in many countries for example it affects the economic especially countries that include seas and rivers and in influence the individual health as it is one of the high nutrients food. In addition to, increasing fish production may participate in overcoming the poverty issue in the world. This paper proposed smart system to monitor and control fish pond by using six different sensors to monitor the dissolved oxygen in water, water temperature, pH, turbidity, TDS and water level sensor. The Arduino platform is used and the two Arduino Uno devises is employed as microcontrollers. Further, the proposal employed servo motor in order to regularly feed the fish. The system has the ability of collecting the sensors reading regularly to perform the proper task. In addition to, sending alert SMS to the fish farmer when critical situations occur by using GSM model. The results were promising because maintaining the fish environment in healthy conditions will affect positively in fish production in terms of number and size.

Keywords: *Fish Ponds, Fish Production, Dissolved Oxygen Sensor, Turbidity Sensor, Arduino Uno Microcontroller.*

1. INTRODUCTION

Testing the water quality is a significant task of environmental monitoring. Poor of water quality affects aquatic life and the surrounding ecosystem too [3].

Usually, water includes a specific level of oxygen in free (O_2) and non-compound forms of oxygen. Dissolved oxygen (DO) means the level of free oxygen in water. It is a significant factor in measuring water quality since it is play a vital role in life of organisms within the water body. In the study of lakes known as limnology, dissolved oxygen is regarded as an essential parameter which comes after the water itself. If the level of dissolved oxygen too high or too low, can harm aquatic life and influence water quality [1] [2] [3].

The sources of dissolved oxygen in water are limited and includes: first, it enters through the air, second from wind and wave action; and third by photosynthesis [4].

Monitoring water quality particularly dissolved oxygen may assist researchers to determine impacted factors on fish health and growth. The recorded measurements can also help to meet environmental standards [1] [4].

Since thousands of years, the fish farming is takes place in whole world. Usually, fish raising is achieved in natural or by man via ponds. Today, the fish farming enters the aquaculture industry. In particular, when the new technologies offer various tools and equipment in water quality monitoring and controlling. Hence the raising fish get benefits from recent technology by measuring DO in ponds using hand-meter or automatic systems. Other water criteria can be measured such as water temperature and pH, in order to control the water quality and improve the fish production [20].

From other hand, the Food and Agriculture Organization (FAO) aims to eradicate hunger, provide food security and overcome malnutrition. Fisheries and aquaculture significantly contribute in achieving food security and providing livelihoods of many of people [21].

In addition to, Fish production plays a very important role in many countries' industry. Further, fish is essential in the daily food of many people because it is regarded as energy-yielding nutrients

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[20]. Producing a healthy and high quality of fish required rising them in standard quality of water and providing them good nutrition [23].

This research employed the recent technologies of remote monitoring and controlling sensing system to increase the fish farm production. In this research, a smart system has been proposed, which is used several types of sensors and controller. In addition to, implement an application which may be applied on mobile phone or personal computer. The proposal has the abilities of remote monitoring and controlling fish farm to maintain its healthy conditions. Accordingly, the fish production is increasing. The proposal offers seamless approach for the fish farmer to monitoring and controlling fish farm and he/she can interfere in real time when critical situation occurred.

The rest of this paper will structured as follows: Section 2 outlines the related work. Section 3 presents the causes and effects of water pollution on fish. Water quality criteria explained in section 4. Proposed system detailed in section 5. Section 6 presents the conclusion.

2. RELATED WORK

Few researchers have been paid attention to the importance of monitoring water characteristics that influence fish production. The following explore some of these researchers' efforts in this field:

Authors in [17] presented the significance of measuring the oxygen dissolved concentration in stationary waters. This paper showed that the oxygen dissolved concentration can be measured by displaced oxygen probe inside water with a speed greater than 0,3 m/s.

In [25] system is proposed to monitor fish farm. Only two parameters were measured to monitor the fish farming which are temperature and pH sensors. The suggested system architecture consists of microcontroller, ZigBee network and sensors and the National Instruments LabVIEW is used for graphical user interface. This system were only display the sensed data when it is above the value of threshold.

The authors in [26] suggested an automatic system to testing water properties in ponds. This system consists of sender and receiver where sender uses four sensor to monitor the water characteristics (temperature sensor for inside water and outside water, pH sensor, and humidity sensor). Sender side send sensed data via GSM to receiver, which is analyzing the received data in PC, and send alert message to mobile farmer phone upon analyzed results.

All the aforementioned researches are measured water characteristics and some of the analyzing these measurements and send alert message to concerned person.

In [27] the authors proposed system which is based on Arduino platform. Proposal aims alerting fish farmers to take the possible preventive procedures. Ultrasonic sensor, pH sensor, Dissolved Oxygen sensor and thermistor are applied in the proposed system which can be used in two modes: Auto mode and Manual mode. The proposal describe the system as prototype and did not presented any measurements that explain the causes and results.

The authors in [28] suggested monitoring system that based on web-based application and mobile application and aimed to support decisions made. This system monitors conductivity, temperature, dissolved oxygen and turbidity. In addition to, deploying UAVs to capture image to the lake area for observation purposes such as quantify density in fish cage, water hyacinth coverage and disaster damage. This system is a monitoring system which its function is collecting data and decision-making since its controls only aerator.

The author in [29] presented a transmitter device that measures and analyzes the Water quality data conditions including pH, turbidity and temperature. This research aimed assisting fish farmers from monitoring their fish pond easily and interfering when it's required.

In [30] the author developed a control and monitoring system instead of marine ecosystem. The aim of the proposed system was to help aquarists from maintaining healthy water parameters in their tanks. The proposed system controls and monitors the pH, Dissolved Oxygen, Temperature and Salinity parameters. PiLeven microcontroller used for controlling, monitoring and communication to slave sensors. In addition to utilizing Raspberry Pi microprocessor as computer interface. This system is nearly same as the proposed system by authors in [27].

The aforementioned researches proposed system to monitor the fish pond. They monitor limited conditions of fish farm such as Dissolved Oxygen, Temperature, and pH. They ignores other important conditions such as turbidity, TDS and water level. Whereas, the proposed system takes into its considerations all the significant conditions that may affects the fish health. In addition, the proposal has the ability of remote controlling,

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while all the aforementioned researches did not haves this feature.

3. CAUSES AND EFFECTS OF WATER POLLUTION ON FISH

There are many physical and chemical factors impact the aquatic environment. The following details the primary causes of harm to fish in fish culture installations that most frequently recorded [5]:

1. **The Water Temperature**
   The body temperature of fish is the same as (or 0.5 to 1°C above or below) the water temperature which they live in because they are poikilothermic animals. The water temperature effects the fish metabolic rate and it is closely associated to it. As the water temperature is getting higher, the metabolism is getting greater. Increasing the water temperature means approaches to the optimum values of water temperature within the normal range. Water temperature directly affects the reproduction and growth of fish [5].

2. **The Water pH**
   As Fish live in water, they perform all their vital activities in water such as breathe, feed and grow, excrete wastes, and reproduce. All these activities affects the pH level in water. For fish, the optimal pH range is within 6.5 - 8.5 [5]. Low and high pH level harms fish especially the young fish in immature stages because they are extremely sensitive to pH levels. The young fish may die when the pH level is below 5 [6].
   In addition, fish may produce an extra amount of mucus on the skin and covers of gill to overcome the effect of a low or high water pH. Very low or high water pH values cause harm to tissues of fish, especially the gills. In post mortem, skin and gills examination shows excess mucus amounts, which are often-containing blood. Further, Water pH also has important impact on the toxic action of a number of other factors such as ammonia on fish [5] [16].

3. **Dissolved oxygen (DO)**
   There two resources of oxygen in water from air from the photosynthesis of aquatic plants. While, the action that removed the oxygen from the water is the aerobic degradation of organic substances, bacteria and the respiration of all the organisms live in the water. The amount of dissolved oxygen in water often determines the number and types of fish living in it. A number of factors control the fish requirements of oxygen requirements for instance the temperature, pH, and CO2 level of the water, in addition to the metabolic rate of the fish. Usually, when individual weight of fish is increasing, oxygen requirements per unit weight is significantly declining. [1] [2] [3] [4].
   From other hand, pollution is the most factors that responsible on reduction the oxygen concentration in the water, which caused by biodegradable organic substances such as waste waters from agriculture, the food industry, and public sewage. Oxygen concentration in water plays vital role for fish and its deficiency causes asphyxiation and death for fish [5] [7] [16].

4. **Ammonia**
   Ammonia pollution of water caused by organic origin such as (domestic sewage, agricultural wastes, or the reduction of nitrates and nitrites by bacteria in anoxic waters) or by inorganic origin such as (industrial effluents from gas works, coking plants and power generator stations). Ammonia is present in water by two forms a molecular (nondissociated) which is (NH_3) and in the ion (dissociated) (NH_4^+). The pH and temperature of the water influence the ratio between these two forms of ammonia. Non-dissociated ammonia is more toxic to fish than dissociated because it can readily diffuse across the tissue barriers [5] [9] [15] [16].

5. **Nitrites and nitrates**
   In the water, nitrite concentration is associated with ammonia concentration. As known, the nitrite has toxic action on fish. The nitrite ions increases methaemoglobin and results in reducing the oxygen transporting capacity of the blood. When the level of methaemoglobin in fish blood is more (70–80%), they lose their orientation and become unable to response to stimuli. Nitrite toxicity influenced by pH, dissolved oxygen, and water temperature.
   From other hand, the toxicity of nitrates to fish is regarded very low. Hence,

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mortalities have only been occurred in the case of exceeded the nitrates concentrations 1000 mg per liter [5] [10] [11] [15] [16].

6. **Water hardness**
Water hardness includes two major types which are general hardness (GH), and carbonate hardness known as alkalinity too (KH). General hardness represents the measurement of positive ions in the water which includes calcium (Ca^{2+}), magnesium (Mg^{2+}) and, iron (Fe^{+}). These ions are not exist in the atmosphere so rainwater has low water hardness whereas high concentration of GH exists in water sources like limestone-based aquifers. General hardness does not have health effects on the water organisms [18].
Carbonate hardness, represents the measurement of the buffering capacity of water which includes carbonates ($CO3^{2-}$) and bicarbonates ($HCO3^{-}$) dissolved in water. KH has a unique relationship with pH that deserves further explanation. Normally, high concentration of carbonate hardness of about 150–180 mg/litre is found in water sources such as limestone bedrock wells/aquifers have. In water, pH level influenced by Carbonate hardness. KH takes the role of buffer to the lowering the level of pH. Rapid changes in pH are stressful to the entire water organism so the role of KH buffering is significant. Adequate level of KH maintains the water from becoming more acidic. If water has no carbonates and bicarbonates. The pH will be rapidly reduced in the water. Hence, KH is essential to overcome the acidification, which is caused by the nitrification process [18].

7. **SuperSaturation with Dissolved Gas**
When the pressure of the dissolved gas is more than the atmospheric pressure, the supersaturation with dissolved gas occurs. In acute cases, the dorsal and caudal fin may be influenced, and bubbles can be visible between the rays of fin. In severe cases, blockage of the major arteries and large bubbles are obviously seen between all of the fins rays of all the fins, which results to rapid death [5] [8].

8. **Hydrogen sulphide (H_2S)**
When the water is polluted, the hydrogen sulphide occurs from the decomposition of proteins. H_2S is also exists in industrial effluents resulted from paper pulp plants, and tanneries. The impact of hydrogen sulphideis range from high to very high toxic on fish [5] [12].

9. **Carbon dioxide**
The carbon dioxide has direct and indirect toxic action on fish. The indirect action represented by influencing the water pH, causing its values rise to toxic levels. In addition to, changes in pH influence the toxicity of dissociated and non-dissociated forms of H_2S and ammonia. When CO_2 is excessed or absence of free, a direct adverse effect occurs. In waters, free CO2 may reach harmful levels when oxygen content is low. This occurred in cases of intensive biodegradation is taking place, or where high density of fish are kept or transported [5] [13] [14] [16].

10. **Turbidity**
It is optical property of water which reflect the water ability of transmitting the light so it's measured the water clarity. Turbidity restricts penetration of light and limit photosynthesis and it is caused by many factors for instance particles of suspended clay, plankton organisms' dispersion, particulate organic matters and colored material in water [24].

11. **Water Color**
Usually, the water color in pond reflects the predominant phytoplankton species. Any changingin phytoplankton flora or densities will change the watercolor or its intensity. Often, the color of water is changing suddenly and this attributed to mass phytoplankton mortality. This occurs in two cases: when the phytoplankton reaches the reproductive cycle peak, or when suddenly the physicochemical environment conditions change and become disadvantageous to phytoplankton. This is caused by a drastic salinity or changing in water temperature, shortage in nutrients, or vast grazing of zooplankton [31].

12. **Total Dissolved Solids (Salinity)**
Total Dissolved Solids (TDS)affects the concentration of dissolved oxygen. Water ability of dissolve oxygen is decreasing when its salinity increasing. Freshwater saturated with Oxygen and salinity saturated has different ration of oxygen from sea water. For instance at 25ºC freshwater contains 8.26 mg/L of oxygen

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whereas at the same temperature and pressure sea water contains 6.72 mg/L of dissolved oxygen [32].

4. WATER QUALITY CRITERIA

In fish farming, controlling the water quality directly affects the fish production in term of size and number. As mentioned earlier, there are many water criteria that must be taken into consideration to maintain high quality of water. Water quality criteria such as Temperature, dissolved oxygen and pH are influence fish production. Dissolved oxygen, pH, temperature, total nitrogen (includes: ammonia, nitrite and nitrate) and water hardness represent the most water criteria that influence fish production in an aquarium. These criteria are influenced each other in addition to be influenced by many other factors such as surrounding environment [18] [19]. Table 1 shows required and critical measurements of these criteria [24].
Maintaining the water criteria within the above ranges will raise productivity and benefits of economic. In addition to achieving the sustainable fish culture and aquaculture via assisting the farmers in maintaining ecofriendly ponds environment [22].

5. PROPOSED SYSTEM

In general, the proposed system consists of many components as described in the block diagram presented in figure 1 and figure 2.
Figure 2 shows the sensors of pH, TDS, DO and temperature in addition to presenting solutions to each critical sensed data. Where these solutions representing by GSM SMS, TDS filter, water pump and heater. Figure 2 shows servo motor feeding with the sensors of turbidity, and water level sensor. In addition to, presenting solutions to each critical sensed data. Where these solutions representing by filter and GSM SMS.
In order to describe each component with its implementation in the proposed system, this section will be divided into two subsection: The components of proposed system and system implementation.
Figure 3 shows the procedure of the proposed system. The proposed system continues gathering, calculating and testing the sensors readings regularly, in order to perform the required action(s) based on the sensed data.

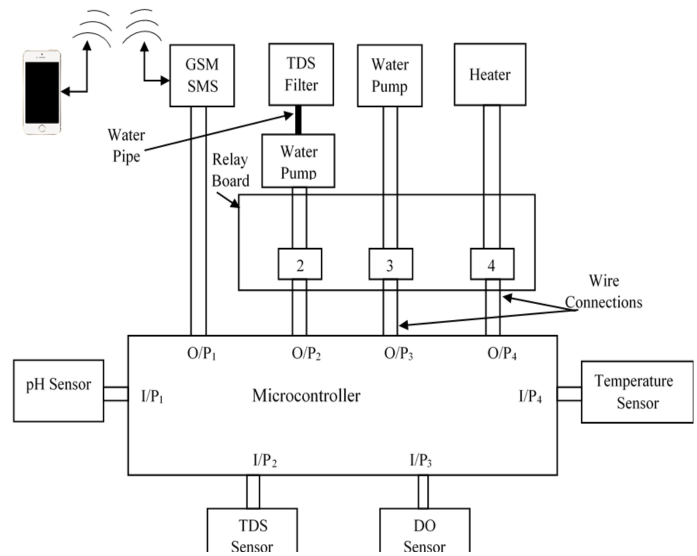

Figure 1. The Block Diagram of Proposed System with pH, TDS, DO and Temperature

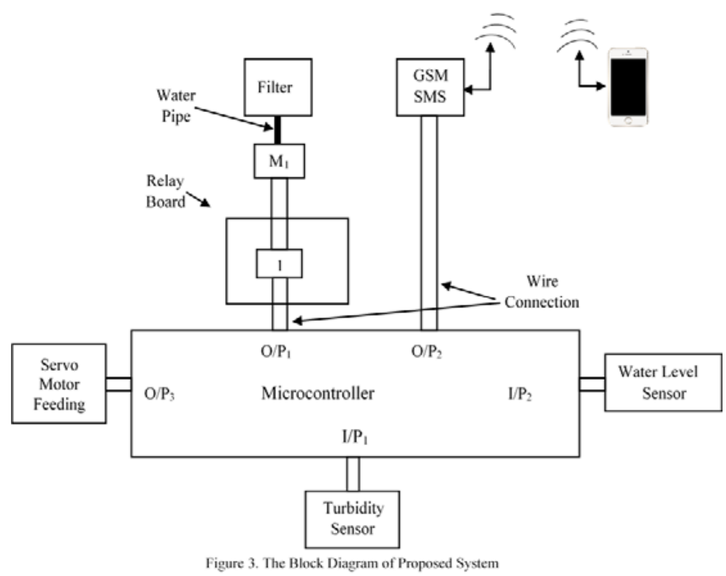

Figure 2. The Block Diagram of Proposed System with Servo Motor Feeding, Turbidity and Water Level Sensors

A. Components of Proposed System

The proposed system used Arduino platform to illustrate all its components. The following explains the used components:

1. **Microcontroller**: Two Arduino Uno's are used as a microcontroller which are based on the ATmega328.The proposed system requires using two microcontroller

because of the Arduino Uno is limited to 14 digital I/O pins and 6analogue input pins, so the proposed system used two Arduino Uno's. The role of each microcontroller is controlling, processing and analysing the input signals from sensors.Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs (sensors) and turn it into an output (activating a motor or publishing something online). The board can be controlled by sending a set of instructions to the microcontroller on the board.

These instructions are written using Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

2. **Relay**: A Relay is a switch that is electrically operated. Electromagnet is used by many relays to mechanically operate the switch and provide electrical isolation between two circuits. Two Arduino cannot control high volt n amp, but a relay can do this job, which is the sole design of it. So the relay is used as switch to control high power devices. Relay circuits are used with 5 v, supply at specific time. The relay is connected to Arduino board for controlling. Relay in figure 1 and 2 were connected to digital microcontroller output pin 2,3,4 in figure 1 and output pin 1 in figure 2 that used to control TDS filter, water pump, heater and Turbidity filter respectively.
3. **pH Sensor:** The employed PH sensor is (SKU: SEN0161)that it used to measure the acidity or alkalinity of a solution and it used with Arduino controller. The measuring range of this sensor is 0-14 pH. This pH electrode needs to be calibrated before using it by putting it into the standard solution (KCL3N solution) whose pH value is 7.00. After calibrated pH sensor, it is connected to A0 (analogue input pin).When pH value is out of the required range the microcontroller sends SMS warning massage to ponds operator via GSM.
4. **TDS Sensor**: TDS sensor of type (SKU: SEN0244) and Arduino analog electrical conductivity sensor (EC meter) which used to measure the water conductivity and convert it to TDS. The sensor is connected to Arduino microcontroller in order to sense TDS value. After calibration process (using conductivity solution like KCL with conductivity =1413us/cm).TDS sensor is connected to A1 (analogue input pin). When the sensed value is out of required range the microcontroller switches on TDS filter via relay.
5. **DO Sensor:** Analog dissolved oxygen sensor from (Atlas Scientific Kits) is used to measure the DO in water with range from 0.01 to +35.99 mg/L. When the oxygen value reduced in ponds the microcontroller energizes the air pump (via relay) to supply ponds with the oxygen. The sensor kit is connected to A2 (analogy microcontroller inputs).
6. **Temperature Sensor:** Water proofed digital sensor type DS18B20 is used and its range is from 25 to -28 C°. The function of this sensor is sensing the water temperature to maintain it within the required range. A heater and axial fan are used to increase and decrease the water temperature respectively. When the sensed value is larger of required range the microcontroller switches on heater via relay. When the sensed temperature is above 28 C°, Adriano microcontroller provide pulse width modulation (PWM) signal (as a digital output) to control speed of the fan (12v,150ma D.C. Brushless, 2,400 r.p.m) with maximum air flow of 75 CFM (cubic feet per minute). In order to boost the output current of microcontroller, a N-P-N (2N2222) transistor, 12v, 250 ma D.C. power supply is used for this purposed.
7. **Turbidity Sensor:** The used turbidity sensor is (SKU: SEN0189) which consists of turbidity probe and turbidity circuit to derive data to the microcontroller. Turbidity represents the total amount of particles in the water and this feature controls waters visibility. Hence, turbidity is considered as the optical property of water and optical devices are used to determine the turbidity. When the amount of suspended solid increases, the water's turbidity level (and cloudiness or haziness) increases. When the sensed value is larger of required range the microcontroller switches on filter via relay.

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8. **Water Level Sensor:** The ultrasonic ranging module HC - SR04 sensor is used to measure the water level and it consists of ultrasonic transmitters, receiver and control circuit. The principle of this sensor is based on detecting pulse signal bac which has been automatically sent eight 40 kHz.If the signal back, the time is calculated by using the following equation: Distance = (high level time * velocity of sound (340M/S) / 2.The measured distance is in centimeter. When the water level is less than the required, (for instance 3 cm) the microcontroller switches on a water pump via relay in order to increase the water level.
9. **GSM:** The used GSM board is of typeSIM900that is connected to microcontroller by using Arduino board to enable it from sending and receiving SMS with fish farm condition based on collected and processed data.SIM900 shield has a modem and transfers processed data to the GSM network by connect the modem to subscriber identification module (*SIM*) card that placed in GSM board (low level communication). The SIM900modem need 12v,1A, in order to operate reliable. The baud rate of GSM board is set is to 19200 symbols per second. The transmitter of Arduino Uon pin TX is connected to the GSM receiver pin RX. While the receiver of Arduino Uon pin RX is connected to transmitter pin TX of GSM.
10. **Servo Motor: a servo motor type (**mg996r) includes gears and a shaft that can be precisely controlled. It allows the shaft to be positioned at various angles, usually between 0 and 180 degrees. It is possible to place a small cylindrical container carrying fish food by changing the angle of its rotation from where the food is carried out through small openings at a descent rate commensurate with the quantity of food supposed to be provided as well as the appropriate time and predetermined daily feeding schedule that can be ensured through the program in the microcontroller.

B. System Implementation

Aquarium with volume of(60*30*30) including 6 golden fish live in it which are in different size as show in figure 4, were used to implement the proposed system. The test focused on measuring the vital factors that influenced the fish health by using the aforementioned sensors.

The conductivity electrode, which is use the analog connection line, is connected to the BNC connector on the EC meter board as described in figure 1. Where the EC meter board is connected to the analog pin 1 of the Arduino controller.

The temperature sensor is connected to the connecting terminal of the sensor adapter. Then the digital connection line should be used, the terminal sensor adapter is connected to the digital pin2 of the Arduino controller. When the Arduino controller switched on, a blue LED on board will be on. Figure 5 shows the microcontroller, relay and sensors of TDS with temperature.

Figure 6 shows a sample of Arduino controller output before the calibration process.

The serial monitor of the Arduino IDE displays information of temperature, voltage, conductivity and so on. The output of electrode is "No solution!" because it's not calibrated yet. Thus, the conductivity electrode and temperature sensor must be calibrated before using by insert them in calibration solution, stir the solution for some time and wait for the stable readings. The sensor can be applied if the conductivity reading on the serial monitor is close to the solution's conductivity. Figure 7 shows a sample of Arduino controller output before the calibration process.

The TDS sensor is placed in aquarium water atoned measured TDS value. If TDS reading is more than 500, the microprocessor operates the water pump by sending order to relay. Water pump filter the water through the TDS filter.

The turbidity, pH, temperature, and dissolved oxygen sensors is connected to microcontroller as shown in figure 1 and 2. Based on the sensed temperature the microcontroller will take the proper action by switching on the heater or axial fan upon temperature sensor reading.

Figure 8 shows the readings of the turbidity, pH, temperature, TDS and dissolved oxygen sensors.

This proposal aims maintain healthy life conditions for fish farm or pond by offering remote monitoring and controlling facilities. In monitoring process, it periodically read the sensed data from the used six sensors. In controlling process, it takes the required action when a critical event is happened for example the temperature is getting cold. In this situation the proposal turns on the heater by used relay.

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Turbidity:11.3 mgpl Ph value: 7.87
Temperature 18.19 Deg C Dissolved Oxygen :6 mgpl TDS=280  ppm

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Temperature 18.19 Deg C Dissolved Oxygen :6 mgpl TDS=280  ppm
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Figure 8. Some the Sensors Readings

6. CONCLUSION

This research aims maintain healthy conditions in fish farm to increase the fish production. This has been achieved by designing and implementing a low cost smart system to monitor and control the fish farm remotely. The research studied the significant factors that affects the vital signs of fish such as TDS, turbidity, pH, temperature, and dissolved oxygen. The optimal ranges of the aquarium environment factors were specified. The Arduino platform was used to implement the suggested system as this platform provides several sensors including the required sensors in this proposal. In addition, Arduino platform is low cost and efficient. The implemented system employed six sensors which are TDS, turbidity, pH, temperature, and dissolved oxygen and water level. In addition to, employing servo motor feeding to feed the fish. When one of the sensed value is out of desired range, the control takes the proper action. For example if the sensed temperature < 12C^{o}. The controller turns on the heater. The proposed system has the ability of sending SMS message to the fish farm owner when required. Hence, the owner can interfere immediately and when it required. Implementing this system enables the owner of fish farm from monitoring and controlling his/her farm remotely. This system has been proposed to be implemented in Iraq. Further, it can be developed to monitor and control large fish farms not only individual fish farms.

From other hand, the proposed system needs to overcome the issue of power consumption in used sensors.

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Table 1. The Required and Critical Measurements of Water Criteria

Water Criteria	**Acceptable Range**	**Desirable Range**	**Critical**
Temperature	15-35 (^{0}C)	20-30 (^{0}C)	<12 , >35 (^{0}C)
Dissolved Oxygen	3-5 (mg L^{-1})	5 (mg L^{-1})	<5 , >8 (mg L^{-1})
pH	7-9.5	6.5-9	<4 , >11
Ammonia	0-0.05 (mg L^{-1})	0 - <0.025 (mg L^{-1})	>0.3(mg L^{-1})
Nitrite	0.02 – 2 (mg L^{-1})	<0.02 (mg L^{-1})	>0.2 (mg L^{-1})
Nitrate	0-100 (mg L^{-1})	0.1-4.5 (mg L^{-1})	>100, < 0.01 (mg L^{-1})
Alkalinity	50-200 (mg L^{-1})	25-100 (mg L^{-1})	<20 , >300 (mg L^{-1})
Hardness	>20 (mg L^{-1})	75-150 (mg L^{-1})	<20 , >300 (mg L^{-1})
H_2S	0-0.02 (mg L^{-1})	0.002	Any detectable level
CO_2	0-10 (mg L^{-1})	<5 , 5-8 (mg L^{-1})	>12 (mg L^{-1})
Turbidity		30-80 (cm)	<12 , >80 (cm)
Water color	Pale to light green	Light green to light brown	Clear water, Dark green &Brown

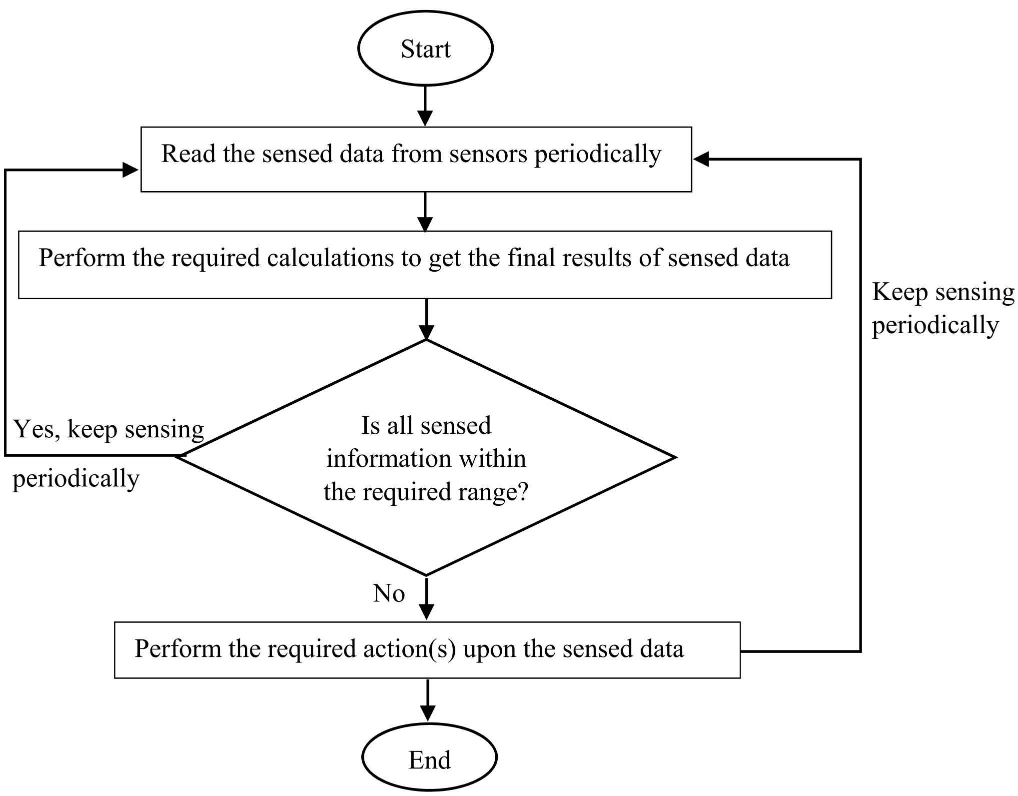

Figure 3. The procedure of the proposed system

Figure 4. Aquarium Plot with Implemented Sensors

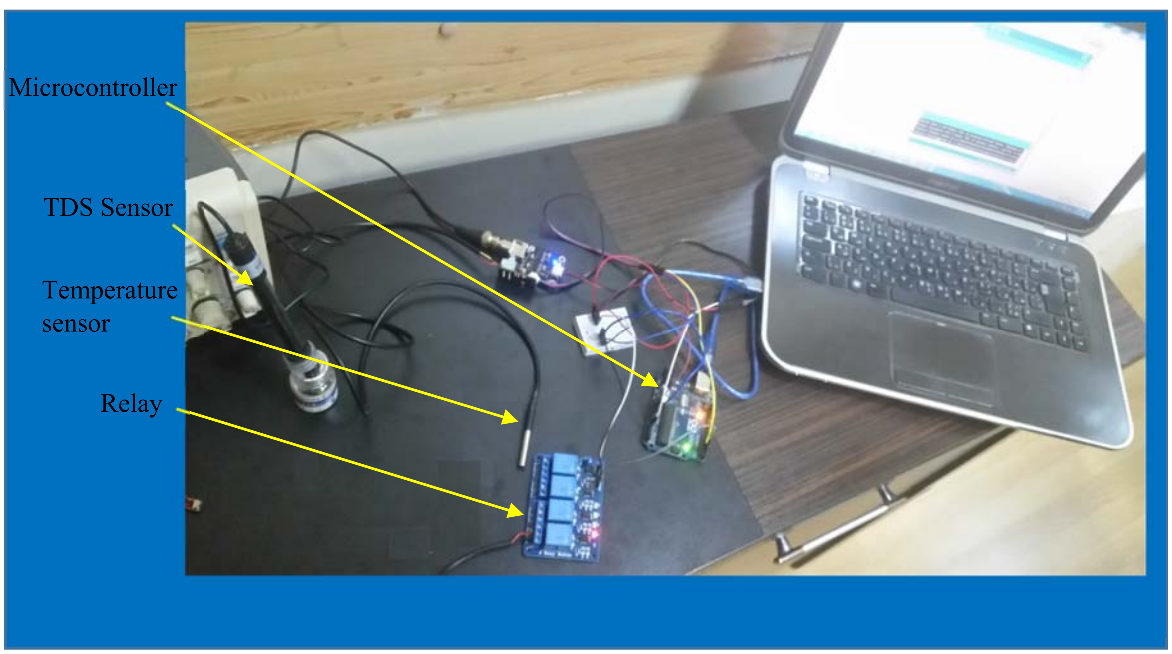

Figure 5. Part of the Proposed System

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```
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.37^C    EC:No solution!
Analog value:0    Voltage:0mV    temp:26.31^C    EC:No solution!
```

Figure 6 . Sample of Arduino Controller Output

```
Analog value:43    Voltage:209mV    temp:23.19^C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19^C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19^C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19^C    EC:1.41ms/cm
Analog value:43    Voltage:209mV    temp:23.19^C    EC:1.41ms/cm
```

Figure 7. Sample Of Arduino Controller Output After Calibration Process