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Water Quality Parameter Guidelines and the Selection of Microcontroller for the Monitoring of Aquaculture System: A Review

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Abstract*: Aquaculture is known as the suitable method for cultivating fish and aquatic animals but there is negative impact on the Aquaculture. This is due to the lack of knowledge on the parameters regarding water quality and the use of manual and traditional fish farming. The aim of this research paper is to provide the proper guidelines for the maintenance of the Aquaculture system to attain the optimum yield. Firstly, the significance, desired limits and the remedies if they deviate from the tolerable limits of particular parameter are mentioned for the set of different parameters. Secondly, the required microcontroller is selected by comparing with the market's best microcontrollers to measure and monitor the parameters, this reduces the time and human intervention in the aqua farming and results in high yields. Subsequently, to mention the desired sensor for the particular parameter that works efficiently and effectively.

***Index Terms*: Aquaculture, Hardness, Microcontroller, Plankton, Temperature, Turbidity.**

I. INTRODUCTION

Aquaculture Systems consume lot of water for the maintenance .In countries like India, which have a huge coastal line spread around 6000 kms can have a huge possibility of growing Aquaculture systems [1].Fish rearing or growing is a major cash crop in food sector and followed across the globe. The cultivation of fish in ponds is done in most of the countries which are situated near water body. But unfortunately the aqua farmers tend to follow the manual or traditional methods for the cultivation of fish which leads to the improper yield and growth [2]. Water is the platform for its life functions such as secretion, metabolism, feeding and development. The quality of water can be known by various factors such as biological, physical and chemical. These factors can indirectly or directly affect the water quality and simultaneously affects its stability and production of fish [3].

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Water quality parameters have certain tolerance limits for the entire class of aquatic animals in which it can perform with high yield [4][5]. Any sudden changes in these parameters can lead to adverse effects on growth and metabolism.

So, it is essential to maintain the excellent water quality parameters for the better growth and existence of fish. The important source of inexpensive, high protein resource is fish. For the increasing population to meet their demands, there should be sufficient supply of fish. To increase the productivity or supply of fish there is a need to maintain the good water quality parameters under the tolerable limits with respect to the certain parameter and the other important thing in consideration is which system or microprocessor to maintain these parameters . The primary objective of this paper is to survey or review the water quality parameters and come to a concise opinion regarding the better and economic parameters for the better growth of aquaculture systems.

II. DISCUSSION

The most important factor influencing the growth and performance of fish is water quality in aquaculture systems. Better water quality leads to better performance and stability of fish which gives high yield or output. By this, aquaculture systems need to understand the requirements of water quality for the maintenance of fish culture [6][7]. This paper discusses the water quality parameters such as water level, temperature, pH, dissolved oxygen, turbidity, salinity, alkalinity, hardness. For the particular water quality parameter the characteristics of that parameter is mentioned. The tolerable limits and the remedies when they are deviated from the desired values are described. However, this paper would contribute the primary guidelines in determining the better water quality parameters for fish farmers to achieve high yields under low cost maintenance.

III. TURBIDITY

Turbidity is one of the primary assessment in measuring water quality [8]. These are huge individual particles practically invisible to our eye. These particles in water has ability to transmit the light in which it generally restricts the entrance of light and ultimately the photosynthesis is reduced which is known as turbidity [9]. These particles are formed in different sizes. Some particles are heavy to settle at the bottom of the pond quickly if the water in the pond is left idle.

The particles settle slowly if they are small in size. Because of these particles, the water in pond is appeared as turbid.The unit of measurement for turbidity is Formazin turbidity unit [10]. This unit is used to measure the amount of concentration in a water sample due to these suspended particles by calculating the input scattered light perpendicular from the sample water. This lighted is collected through photodiode.

Too much of this turbidity results in minimization of sunlight penetrated into the pond which leads to death of fish.

A. Tolerable limits

Scientists suggests that the level of turbidity should be less than 30cms in water to regulate the growth of plankton buds.If the depth is more than 60cms there may be a chance of increase in amount of dissolved oxygen which is harmful to the growth of fishes. The other issue is that when the light penetrates to higher depth, the growth of Macrophytes like plants which results in less formation of plankton. Some scientists suggest that 30 to 80 cm, but there is a problem of high dissolved oxygen levels and if the depth is less than 13cm it causes stress to the aquatic animals. So, for the best intense aquaculture systems the depth should be in the range of 30 to 40 cm [11].

B. Remedies

1) Turbidity in water can be reduced by the method of flocculation or coagulation and these methods are widely used to reduce the turbidity in water [12].

2) Addition of water or alum with Calcium oxide at a rate of 0.02kg per litre and the pond is spilled with $CaSO_4.2H_2O$ (gypsum) in the ratio of 0.2Kg/m3 will reduce the turbidity in pond [12].

C. Sensor

SKU:SEN0189 is the turbidity sensor for Analog inputs manufactured by Dfrobot which is modelled for microcontroller [12].

IV. DISSOLVED OXYGEN

The existence, growth, Mental stability, behaviour, productivity are affected by variation in Dissolved oxygen [13]. Planktons and the atmospheric gases are primary resource of dissolved O2. The main problem is to acquire the required amount of oxygen for the survival of aquatic animals. The shortage of oxygen is due to the poor solubility of O2 in liquids. The solubility is affected by the increase in factors like salinity, Temperature, humidity, concentration of deep emerged plants in water, and nutrients like planktons along with the decrease in atmospheric pressure[14]. The dissolved oxygen amount is also dependent from the sunrise to sunset. The amount of dissolved oxygen is also estimated from the temperature that is commonly known as Winkler's method. This method is popular because the actual dissolved oxygen sensor is expensive. By this method we can estimate the dissolved oxygen easily and economically [15].

A. Tolerable limits

DO in water between 3 to 5 parts per million in water is not desirable. For a better maintenance the range should be equal or above 5ppm. For the essential fish production the level of dissolved oxygen should be greater than 5 ppm which is suggested by scientists. The range of dissolved oxygen depends on the type of fish species. The estimated amount of dissolved oxygen at temperature 50oF should be 11mg per litre, 9mg per litre is measured at 70oF and 8mg per litre is calculated at 90oF [16]. For some species the value of DO may be lower than the estimated results.

B. Remedies

1) The amount of dissolved Oxygen is regulated by aerators and inflators.

2) To reduce the DO, the hot water is passed through the pipes that increases the temperature of the pond.

3) Limiting the fertilizers, animal matter and other natural organic manures can able to maintain the level of DO in aquaculture systems. As the sensors are costly we can estimate the DO using the soft-sensor design algorithm[17].

C. Sensor

DO30G is the Dissolved oxygen sensor for analog inputs manufactured by YOKOGAWA which is suitable for Arduino microcontroller.

V.HARDNESS

Commonly hardness of water is the estimation of amount of dissolved elements like magnesium, calcium. Apart from these elements, the ions like iron, carbonates, aluminium, hydrogen, strontium etc these elements are primary source for the existence of fish in aquaculture systems and helps in formation of their bone and body structure [18].

A. Tolerable limits

The suggested value of hardness of water for aquaculture must in the range of 30-160mg per litre and ppm should be maintained around 20. The amount of calcium carbonate must be in the range of 45-160 mg per litre. If the hardness is less than 20 parts per million then it causes stress to the aquatic animals.

The tolerable limits of hardness varies with the type of fish. For the better aquaculture unit the hardness of water should be in range of 80-160ppm and for some species the tolerance is high [18].

B. Remedies

1) Addition of Zeolite, CaO along with alum to reduce the hardness.

2) To get silt in the pond, avoid the water runoff during the rainfall in the monsoon season [19].

C. Sensor

US8147758B2 is the Water hardness sensor for Digital inputs manufactured by Haier US Appliance solutions.

VI. WATER COLOUR

The objects colour is based on the wavelength of the visible light it reflects where as pure water is in pale blue colour. The colour becomes deeper blue with increase in thickness of the sample. Due to mineral impurities and dissolved gases , the colour varies [20].

A. Tolerable limits

Basically, Zooplankton and phytoplankton are responsible for the water colour. Greenish, light greenish and pale colours are suitable for fish culture where as dark brown colour is harmful. Clear water is unproductive for fish culture.

Brown greenish, bluish - green and green colours contains high plankton population which yields good fish culture [20].

B. Remedies

1) Add 20 to 25 kg of sugar with baker's yeast which turns the colour back to normal.

2) Treatment with dolomite.

3) Apply formalin 5ppm dose in alternative days with change the water colour [20].

C. Sensor

EZO-RGB is the Water colour sensor takes Digital values modelled by Atlas scientific.

VII. PH

pH is a parameter which expresses the acidity or alkalinity in terms of logarithmic scale which varies from 0 - 14 , where 7 indicates the neutral solution. Lower values of ph are determined as acids and higher values are determined as alkaline (Bases) [21]. Basically pH depends upon hydrogen ion concentrate in a solution i.e.,

$$pH = -\log_{10} C, \quad (1)$$

Refer to (1) where C indicates the hydrogen ion concentrate in terms of moles per litre. Fish performs all their activities in water. Change in ph effects the water quality which changes the water chemistry. Extreme values of pH can affect the fish metabolism. Due to intake of this water, growth of the fish will be effected. In case of young fishes the low pH values leads to death and high pH values can cause denaturing of cellular membranes. At low values of pH, high amount of metals are ejected from the rocks which effects the fishes growth[22].Different types of fishes have different range of desirable pH values. The pH values not static as it changes due to various factors such as, number of fishes, amount of water and changes over a day. Typically it rises during the day and drops during the night.

A. Tolerable Limits

Fishes have Salt water fishes prefers a pH of 8 and above, where as fresh water fishes prefers a pH limit from 5.5 to 7.5. Optimum values of warm water pond fishes is from 6.5 to 9 where as in shrimp ponds it varies from 7.8 to 8.5. If pH is below 4, water becomes more acidic and pH greater than 11, water becomes more alkaline which leads to death over a long period. pH value below 4 is called acid death point and greater than 4 is alkaline death point [23].

B. Remedies

1) Add quick lime to maintain the ph value. If pH is greater than 6, use 300 - 650 kg of quick lime per hectare. If pH is less than 5, use 1500 - 2000 kg of quick lime per hectare.

2) If pH values are greater than 8.3 then use 1 to 3 kg of sugar per 1000 sq meter. We can also use organic matter like cow dung to reduce pH values [24].

C. Sensor

SEN0161 is pH sensor for analog inputs produced by Dfrobot.

VIII. TEMPERATURE

Temperature is the measurement of heat present in an object. Depending on Temperature some types of organisms thrive and some diminish in number and size. There is a intense effect of temperature on the life of a cold blooded or Poikilotherm (an organism which cannot regulate its own body temperature) [25]. Poikilothermic animals such as fish, which cannot regulate its own temperature, takes the temperature of their medium of survival. Increase in water temperature leads to the consumption of oxygen caused due to decomposition processes and it is also an important consideration when water contains toxic substances [26]. Many substances (i.e. cyanides, xylene, phenol) becomes more toxic at high temperatures. These toxicities leads to decrease in fish production. For every 18ºF rise in temperature Metabolic rates in fish doubles[27].

A. Tolerable Limits

Based on optimal growth temperatures fishes are categorized into warm water, cool water, and coldwater species. General temperature ranges for coldwater, cool water, and warm water species are 55-65ºF ,65-75ºF and 75-90ºF respectively. On an average the desirable temperature is between 28 -32°C as per 2004 and 24-30°C as per 2007 census for the optimal growth of fishes [27].

B. Remedies

1) Water temperature can be controlled by using water exchange technique or by planting shady trees .

2) To prevent formation of ice build-up mechanical aeration can be used in large areas of the pond.

3) In case of Concrete tanks , temperature can be regulated using heaters or coolers [28].

C. Sensor

Ds18B20 is the temperature sensor for measuring the temperature of water takes digital inputs manufactured by Maxim Integrated solutions.

IX. CO_2

The most important gases in water are oxygen, carbon dioxide, nitrogen and ammonia.

Generally measuring carbon dioxide levels in aquaculture are ignored based on different reasons

1) As it is not easy, many aquaculture facilities ignore the measurement of carbon dioxide levels.

2) Oxygen and ammonia measurement is sufficient for the fish health and performance.

CO_2exist in the water in the form of carbonates and bicarbonates. When CO_2 levels are high in water, the release of CO_2 from the fish decreases. Due to which percentage of CO_2 in the fish remains high. This leads to Hypercapnia. This has intense effect on the health of the fish [29].

A. Tolerable Limits

Fish can tolerate 10 mg/l of carbon dioxide levels. But this varies from species to species.

When DO levels are high, then the limit varies from 5mg/l to 60 mg/l .Tropical fishes have high tolerable level around 100mg/l where as pond fishes has a ideal level less than 9 mg/l. For photosynthetic activities, 5 to 8 ppm of CO_2 is essential. 50 to 60 ppm of CO2 is very harmful for pond fishes [29].

B. Remedies

1) Excess gases can be removed through proper aeration.

2) If organic load is too high in the water, either add more amount of water or remove the organic load by netting.

3) Bases can be added to regulate the CO_2 levels i.e., $CaCO_3$, $NaHCO_3$.

4) Application of $KMnO_4$ at the rate of 2.5 kg per 1 hectare [29].

C. Sensor

In Pro 5000i is the CO_2 sensor to collect Digital data which is modelled for Arduino manufactured by Biotech.

X.PLANKTON

Plankton is a microscopic organism which floats in the sea or fresh water. There are three types of planktons i.e., phytoplankton, zooplankton, bacteria. Phytoplankton is produced by plants and it can perform photosynthetic activities. Zooplankton is produced by animals and is the main source for small fishes which are the source for big fishes. So fish population is directly proportional to plankton abundance [30].

A. Tolerable Limits

Optimum plankton population is 3500 to 4500 nos per litre in pond fish culture.

B. Significance

1) Due to increase in plankton population, optimum fertilization is archived and algal crash is decreased.

2) Phytoplankton produces 10 times more oxygen , which is helpful for respiration of fish.

3) Plankton prevents the growth of Macrophytes which is harmful for fish growth.

C. Remedies

1) Proper water circulation is to be maintained to avoid inedible plankton species.

2) Using herbivores like silver carp, reduces the blue-green algae which is undesirable for fish.

3) When plankton scum's appears, light penetration and DO levels decreases, which are to be maintained with $CuSO_4$ [30].

XI. SELECTION OF MICROCONTROLLER

Microcontroller is a combination of microprocessor and i/o devices which helps to perform various tasks. Microprocessor is a integrated chip that performs all the functions done by central processing unit of computer. Microcontrollers helps to perform many activities in various fields . It has wide range of uses. They are highly economical.

Microcontrollers like Arduino UNO, Arduino MEGA, Raspberry pi, PLC are used.

Arduino UNO is open source microcontroller board based on ATmega328P microcontroller .It has 14 digital and 6 analog pins. It is programmable using Arduino IDE. This is first type of arduino boards. It is highly user friendly having a clock speed of 16MHz and flash memory of 32kb. It costs around 5 dollars. Arduino MEGA is microcontroller board based on ATmega2560. It has 54 digital and 16 analog pins. It is also programmable using Arduino IDE. It has a clock speed of 16mhz and flash memory of 256kb. It is around 15 dollars. Arduino type microcontroller can run one program at a time [31].

Raspberry pi is microcontroller based on BCM2837B0. It has 40 general i/o pins. This uses Linux operating system which has the ability to run multiple programs. But this is highly complicated to use. It has 1.6GHz of clock speed. It is around 35 dollars. Programmable logic controller know as PLC is real time controller which is highly specialized for rough real time situations. It has various digital inputs. It is also known as industrial controller for various activities like robotic devices, manufacturing process. It is highly flexible. It's inputs can be varied from few tens to thousands. They are highly profound for their extended ranges, high immunity to electrical noise and storage. PLC software is used to create and edit the program's in a ladder-style logic.

In case of fish culture various parameters like temperature, turbidity, water level, etc., should be measured. Raspberry pi is the microcontroller with high speed and can do multiple tasks which is better compared to other microcontroller but it needs lots of coding and complex language where as Arduino is simple to code and easy to execute but it performs one task at a time. PLC is highly durable in extreme temperature where air supply and cooling systems cannot be places. They have a large lifespan which extend up to couple of decades. But this take lot of time to execute given instructions [32].

Various microcontrollers have various specifications which are highly durable in different fields.

For fish culture, various parameters are to maintained but all the parameters are easy to be monitored compared to heavy industrial measures. In ponds high temperatures and strain on microcontroller is not recorded, so PLC is not suggestible due to its slow processing and complex structure. Raspberry pi is much faster but it needs lots of coding and much complicated to use compared to other microcontrollers. It can be used when we need to design a robot which need to perform various operations with at most accuracy but this level of complexity is not needed in case of managing few parameters. Arduino mega has many i/o parameters with low complexity coding and fast processing which is much deserved for regulating few parameters in case of fish culture. So, Arduino mega is better choice compared to others due to it's speed and ease of coding.

XII. CONCLUSION AND FUTURE SCOPE

In this paper, the considered parameters like Dissolved oxygen, Temperature, pH are important parameters to maintain the Aquaculture system. The required sensor for these water quality parameters are suggested.

If the sensors are not available then the remedies are provided for each and every parameter. Secondly, for monitoring these parameters the desired microcontroller is Arduino mega selected by comparing the advantages and disadvantages with other microcontrollers. It can further extended to find the better IoT device to send and receive the data accumulated from the parameters through microcontroller.

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