**AQua: An Energy-Efficient Water Quality**

**Monitoring and Recording System**

A Research Paper

Presented to:

**Dr. Cristina Dadula**

Adviser in ECE 170 - Capstone Project 1

In partial fulfillment of the Requirements

In ECE 170 - Capstone Project 1

Daligdig, Arianne Dale O.

Fuentespina, Jane T.

DECEMBER 17, 2021

**Chapter I**

**Introduction**

Aquaculture is one of the most booming industries in many nations globally, as demand for fish and fish-prepared foods grows every day. In 2018, 179 million metric tons of fish were produced, of which 82 million were produced by aquaculture (FAO, 2020). In the Philippines during the first quarter of 2020, the volume of harvests from the aquaculture farms reached 525.24 thousand metric tons. It decreased by 0.2 percent from the 526.05 thousand metric tons produced during the same period in the previous year (PSA, 2021). In Mindanao specifically in Region 12, about 2,869.78 metric tons were produced from aquaculture fisheries in the 2nd quarter of 2020 and this is about 15.2 percent lower compared to the catch of 3,382.20 metric tons in the same quarter last year (PSA-SOCCSKSARGEN, 2020).

With this, the aquaculture industry is facing many problems; and it is due to the sudden climatic fluctuation that leads to changes in water quality parameters. According to BFAR-PHILMINAQ, the fish perform all its physiological activities in the water – breathing, excretion of waste, feeding, maintaining salt balance, and reproduction. Thus, water quality is the determining factor in the success or failure of an aquaculture operation. The continued degradation of water resources due to anthropogenic sources necessitates an improvement in sites for aquaculture using water quality as a basis. At present, aqua farmers rely on manual testing to determine water conditions; and it consumes time and produces inaccurate readings because water quality parameters may alter with time.

These problems being faced by the Philippine government stem from a lack of clear responsibilities, overlapping institutional boundaries, duplication of work, and a lack of coordination among involved institutions. All water quality monitoring programs in the country are constrained somehow by available laboratory facilities, instruments, transportation, and human resources; and may collect data primarily through direct sampling or limited water quality parameters. (Japitana et al., 2018) Specific information about water conditions, which is required to develop management strategies, is particularly scarce. (Deutsch et al., 2005)

With this, the researchers proposed a study that builds a portable and energy-efficient on-site water quality monitoring and recording system that can deliver real-time data to the aqua farmers and government officials and record the current environmental status of the aquaculture sites for further analysis. This project will help prevent the water parameters from fluctuating to a dangerous level that affects the mortality rate of the organism. Also, this will help in addressing the decline of the production of fish in selected aquaculture sites in Mindanao, Philippines.

**Statement of the Problem**

This research is conducted to provide an automated system of monitoring and recording water quality using Arduino.

Specifically, this research aims to answer the following questions:

1. How accurate are the readings of the sensors used when exposed to a wide range of conditions?
   1. Acidic and basic for pH and oxidation reduction potential
   2. Hot and cold for temperature and dissolved oxygen
   3. Saline and non-saline for total dissolved solid
   4. Turbid and clear for turbidity
2. Is the AQua effective in terms of:
   1. Speed and range of data transmission
   2. Power efficiency

**Objectives**

General

The main objective of this research is to develop a real-time water quality progress report for water treatment ensuring a safe natatory environment for aquaculture using Arduino.

Specific

This research project aims to achieve the following:

1. Design and construct the AQua device using Arduino Uno.
2. Monitor and measure the water pH, temperature, dissolved oxygen, total dissolved solids, oxidation reduction potential and turbidity using available sensors at remote places.
3. Assess the accuracy of the results when applied to a wide range of water conditions.
4. Avail local power supply to sensor nodes using solar energy and collect the data from various sensor nodes and send it to base stations by a wireless channel which are connected using Wireless Sensor Network technology like Zigbee.
5. Simulate and analyze the quality parameters for quality control using ThingSpeak and publish the corresponding record over the web for public information and further assessment of water resources.

**Significance of the Study**

Aquaculture is the practice of raising, reproducing, and harvesting aquatic organisms in a controlled natatory environment such as seas, lakes, rivers, ponds, and streams. The expansion of this industry is essential to addressing food production, restoration of threatened and endangered species populations, wild stock population enhancement, the building of aquariums, fish cultures, and habitat restoration. Since it is popular at the farm level, it provides increased rural employment and livelihood. Associated with its rise, however, are compounding problems brought by poor water quality. Thus, our project aims to aid in the rapid transmission of water parameter data to specified local government officials and specialists, that is to say, critical in the water treatment decision-making and action-taking process.

**Scope and Delimitations**

This project's main objective is to create an onsite and energy-efficient IoT-based water quality monitoring and recording system using an Arduino Uno. It focuses mainly on the sensor's and device's accuracy in contrast to typical laboratory equipment and the speed and range of data transmission via Zigbee module interface. Only the pH, temperature, total dissolved solids, dissolved oxygen, redox potential and turbidity of the water will be measured by the device. The study's threshold values are solely based on Department of Environment and Natural Resources' (DENR) standard levels. This device is solely for determining the water quality of aquaculture industries in selected sites in Mindanao.

**Theoretical Framework**

**Chapter II**

This chapter presents the related literature cited to support the variables used in the study. The information was gathered from the following: e-journals, internet and other unpublished materials.

**Related Literatures**

**Aquaculture**

Aquaculture is the world's fastest-growing food-production sector. It is the practice of raising, breeding, and harvesting aquatic animals and plants in controlled aquatic environments such as oceans, lakes, rivers, ponds, and streams. It also has inherent features that make it one of the most cost-effective and low-impact methods of producing high-quality protein for humans. Compared to traditional animal agricultural methods, these advantages include a significantly higher food conversion efficiency. All systems, on the other hand, must provide the same ecological functions, such as maintaining an acceptable culture temperature, ensuring enough oxygen levels, and removing dangerous waste products (Tidwell and Bright, 2018; Schramm and Grist, 2021).

According to C. E. Boyd (2013), aquaculture is the practice of raising aquatic animals and plants in controlled and managed environments. While aquarium keeping, water gardens, and sport fish ponds are examples of aquaculture for aesthetic or recreational purposes, the majority of aquaculture is used to produce aquatic plants and animals for human consumption. Rural farmers in developing countries use aquaculture to provide food for their families. Fish and other aquatic species are also produced for domestic and international markets all around the world.

Aquaculture has a long history in the Philippines, and it encompasses a wide range of species and farming technologies in a variety of environments. Seaweed, milkfish, tilapia, shrimp, carp, oyster, and mussel farming account for the majority of production. Aquaculture contributes greatly to the country's food security, employment, and foreign exchange revenues. Aquaculture is increasing at a far quicker rate than commercial fishing. However, the worldwide position of the Philippines in aquaculture output has decreased progressively from 4th place in 1985 to 12th place now. Only a little more than 1% of worldwide farmed fish output is now produced in the Philippines, down from 5% earlier. (FAO,2022)

**Fishkill**

According to the BFAR, fishkill is defined as the "massive destruction of fish stocks in a specific area due to unacceptable or toxic water quality conditions in a specific aquatic environment." Some cases are caused by human activities, but natural causes account for roughly half of all cases worldwide. Some of the most common reasons include algal blooms and the related water quality issues, such as low oxygen or toxin development (Vera-ruiz, 2021).

Fish deaths can be caused by a variety of reasons, including: Changes in salinity, temperature, acidity levels, dissolved oxygen levels, and considerable algal development are all environmental elements to consider natural events, such as a component of the species' life cycle; insecticides, chemicals, and sewage are examples of pollutants; and seasonal illness outbreaks in fish populations are caused by parasites and pathogens. Fish deaths can occur as a result of one or more variables, generally in combination, and testing might take some time to complete. Due to the rapid changes in environmental conditions and the limited time available to obtain quality samples, the cause of many fish death occurrences is unknown.("Fish kills", 2022)

**Solar Energy**

Solar energy can be harvested from artificially created or naturally occurring light. The efficiency of this technology is determined by the type of photovoltaic (or solar) cell used. Thin film, mono-crystalline, and poly-silicon photovoltaic cells are examples of solar cells. It's worth noting that mono-crystalline technology is often used due to its high energy conversion efficiency, which is typically less than 25%. (Olatinwo and Joubert, 2018).

**ThingSpeak Server**

ThingSpeak is an IoT data collection platform used for analyzing, examining, and visualizing water quality sensor values that have been uploaded to the cloud, such as pH, turbidity, voltage, temperature, moisture, distance, and so on. The data collector collects data from edge node devices and also allows for data modification for historical data analysis in a software environment. The user must first log in using his or her server's credentials. The core component of ThingSpeak activity is the channel, which has data fields and a status field. Data is updated, analyzed, and interpreted with MATLAB code when a ThingSpeak channel is created, and the data is reacted to with tweets and other notifications ( Das and Jain, 2017; Simitha and Raj, 2019)

ThingSpeakTM is a cloud-based IoT analytics tool that lets you gather, visualize, and analyze live data streams. You can see the data that your devices have sent to ThingSpeak right away using ThingSpeak. You may do live analysis and analyze data as it arrives in ThingSpeak thanks to the ability to execute MATLAB® code. ThingSpeak is frequently used for IoT systems that require analytics, such as prototyping and proof-of-concept. You may store and analyze data in the cloud without establishing web servers with ThingSpeak, and you can generate complex event-based email notifications depending on data coming in from your connected devices. ("ThingSpeak for IoT Projects", 2022)

**Water Parameters**

Depending on the intended water parameters of interest, chemical, physical, and biological aspects of water can all be analyzed or monitored. Temperature, dissolved oxygen, pH, conductivity, ORP, and turbidity are just a few of the water quality metrics that are commonly measured or monitored.

*Dissolved Oxygen*

Because it is linked to breathing, dissolved oxygen is the most crucial factor in maintaining fish survival. Low quantities of dissolved oxygen can degrade the quality of refined water, disrupt growth, and put the body at danger of illness. Diffusion from the atmosphere into the water, as well as diffusion from algae photosynthesis in the water, provide dissolved oxygen. The efficiency with which the diffusion process from air to water was carried out has an impact on water quality. The concentration of dissolved oxygen must be increased. The greater the water quality, the higher the dissolved oxygen concentration (Mahasri et al., 2018; Omer, 2019).

*Oxygen-reduction Potential*

The ability of a lake or river to cleanse itself or break down waste products such as pollutants and dead plants and animals is measured by its oxidation-reduction potential (ORP). When the ORP value is high, the water contains a lot of oxygen. Bacteria that break down dead tissue and pollutants will be able to work more efficiently as a result. The greater the ORP rating, the healthier the lake or river is in general. Even in healthy lakes and rivers, however, as you move closer to the bottom sediments, there is less oxygen (and thus lower ORP values). This is because numerous bacteria in the sediments are working hard to break down dead tissue, and they consume a lot of the oxygen available (Sallenave, 2013).

*pH*

Extremely low or extremely high pH water is fatal. Only a few organisms can survive in water with a pH of below three or beyond eleven, and most fish will die if the pH is below four or above ten. Water that is somewhat acidic (low pH) can diminish the number of hatched fish eggs, irritate fish and aquatic insect gills, and damage membranes (Omer, 2019).

*Temperature*

The temperature of water is one of its most basic properties, and many other factors rely on it for accuracy. We can use temperature data to monitor thermal loading or discharge, as well as measure changes in the thermocline, which has an impact on the health of aquatic animals and critters. Many aquatic organisms are harmed by high temperatures because less oxygen dissolves in the water, clouds prohibit plants from creating enough oxygen through photosynthesis, and calm breezes inhibit turbulence and mixing of atmospheric oxygen with surface water. Warmer water has a lower oxygen solubility, which reduces oxygen delivery. Furthermore, because larger fish demand more oxygen than smaller fish, they usually perish first (Sallenave, 2013).

*Total Dissolved Solid*

Total dissolved solids (TDS) are the sum of all ion particles less than 2 microns, according to the Fondriest Environmental Learning Center (2019). (0.0002 cm). All of the disassociated electrolytes that make up salinity concentrations, as well as other substances such dissolved organic matter, are included. TDS is roughly equal to salinity in "clean" water. TDS can comprise organic solutes (such as hydrocarbons and urea) in addition to salt ions in wastewater or contaminated environments. Excessive total dissolved solids can be hazardous to fish and fish eggs depending on their ionic characteristics.

*Turbidity*

Suspended particles can block or harm fish gills, reducing disease resistance, growth rates, egg and larval maturation, and the efficacy of fish capture methods. Higher turbidity boosts water temperatures, which limits the amount of accessible food, because suspended particles absorb more solar heat. As a result, the concentration of dissolved oxygen (DO) can be lowered since warm water carries less dissolved oxygen than cold water (Omer, 2019).

**Water Pollution**

Pesticides, heavy metals, and hydrocarbons, among other potentially dangerous compounds, are frequently introduced into the aquatic environment. When huge amounts of pollutants are released, there may be an immediate impact, as seen by large-scale abrupt mortalities of aquatic animals, such as fish kills caused by agricultural pesticide contamination of waterways. Lower discharge levels could lead to a buildup of contaminants in aquatic creatures. Immunosuppression, impaired metabolism, and damage to the gills and epithelia are some of the end effects, which can occur long after the pollutants have gone through the environment (Demeke, and Tassew, 2016)

Water pollution occurs when chemicals contaminate water sources, rendering it unfit for drinking, cooking, cleaning, swimming, and other uses. Chemicals, garbage, bacteria, and parasites are examples of pollutant types. Pollution in all sorts ultimately finds its way into the water. Pollution from the air lands on lakes and seas. In an underground stream, a river, and eventually the ocean may all be affected by pollution from land. Consequently, rubbish thrown on an empty lot might harm a water source in the long run. ("Water Pollution", 2022)

**Wireless Sensor Network Technology**

Recent technologies in wireless communications and electronics have brought the vision of Wireless Sensor Network (WSN) into reality which have increased the growth of low cost, low power and multi-functional sensors that are small in size and can communicate in short range. Each node consists of microcontrollers, memory and transceiver. The microcontrollers are used to execute tasks, data processing and assist the functionality of other components in the sensor node. For the memory, it is mainly used for data storage while the transceiver acts from the combination of transmitter and receiver functions. Natural phenomena data such as temperature, light, sound and pressure are collected by sensors and then transmitted to a server. These battery powered nodes are used to monitor and control the physical environment from remote locations. In the past few years, the applications of Wireless Sensor Network have been widely used and applied in medical, military, industrial, agricultural and environmental monitoring (Mohd, 2011).

In order to collect data about the surrounding environment, wireless sensor networks (WSNs) are made up of interconnected sensor nodes that interact wirelessly. Nodes are often low-power and distributed in a decentralized, ad hoc manner. Although WSNs have acquired a lot of traction, resource restrictions in memory, compute, battery life, and bandwidth have placed some major limitations when it comes to establishing security. Privacy, control, and availability are all targets of a variety of assaults. (Patil & Chen, 2017)

**Zigbee Module**

ZigBee is a standard protocol that combines the physical Radio Frequency (RF) layer with the IEEE 802.15.4 physical radio specification and operates in unlicensed bands such as 2.4 GHz, 900 MHz, and 868 MHz [4,8]. Except for the GSM modem network, this project utilised the 2.4 GHz ISM frequency band for all nodes. ZigBee's smart, cost-effective, and energy-efficient mesh network is defined by the core ZigBee specification. It's a self-configuring, self-healing system of redundant, low-cost, very low-power nodes that allows ZigBee to have its distinctive flexibility, mobility, and ease of use. WSN futures will also have an energy-saving coverage due to its tiny size and battery life dependence, which is limited to be powered. As a result, the 'active' and 'hibernation' nodes will aid in power conservation (Nasirudin et al, 2011)

igbee offers low-cost, low-power wireless network implementation on a large scale. It can run for years on affordable batteries, making it ideal for a variety of monitoring and control applications. Zigbee technology is making substantial progress in a variety of areas, including smart energy/smart grid, AMR (Automatic Meter Reading), lighting controls, building automation systems, tank monitoring, HVAC management, medical devices, and fleet applications. ("What Is Zigbee Wireless Mesh Networking?", 2022).

**Chapter III**

The goal of the research is to develop an onsite and energy-efficient water quality monitoring and recording system with a notification system. To accomplish this, the development was divided into 4 parts: (1) The designing of the device, (2) the assembly of the main circuitry, (3) the construction of the device chassis, and (4) the accuracy tests.

**System Design and Layout**

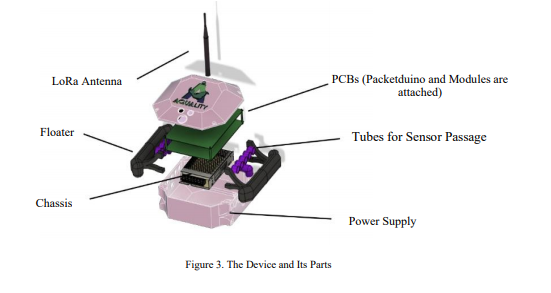
The sensors, the microcontroller (Arduino Uno), the base station (ThingSpeak), the Zigbee module, and the solar power supply are the five primary components of the AQua device. The pH sensor, temperature sensor, TDS sensor, dissolved oxygen sensor, oxidation-reduction potential sensor, and turbidity sensor are the sensors used in this study. The data collected by the sensors is sent to the base stations by a wireless sensor network technology called Zigbee. The quality parameters acquired are then simulated and analyzed for quality control using ThingSpeak and publish corresponding records over the web for public information and further assessment of water parameters.

Figure 2. Block Diagram

Figure 2 shows the whole block diagram of the study. The power supply gives power to the Arduino, sensors, and Zigbee module. The sensors are the pH sensor, temperature, dissolved oxygen sensor, TDS sensor, oxidation reduction potential sensor and turbidity sensor. The Zigbee module will be used to connect the nodes and base station. The data obtained by various sensors on the node side will be sent to the base station where the data can be displayed in a visual manner and analyzed using ThingSpeak.

**Construction and Assembly**

The AQua device contains six sensors (namely the pH sensor, the temperature sensor, the total dissolved solids sensor, dissolved oxygen sensor, oxidation-reduction potential sensor, and the turbidity sensor) which are connected to one main microcontroller (Arduino Uno) together with the Zigbee module. The case of the device is box-shaped and will be made out of acrylic due to its low cost material, water resistance ability, and well-known availability. It houses all the main parts of the device. The two tubes on each side function as a floating device. The pipes on each side are outlets for the sensor and are covered by mesh to avoid fish eating the sensors or bumping into them. Figure 3 shows the inspiration of the AQua device related to its illustration and its parts.



**Device Accuracy Tests**

The collected data was compared against the traditional way of data gathering for each parameter to ensure that the results were credible. To be considered accurate, each datum obtained by the gadget must be within 5% of the traditional method's test findings (Alave et al, 2020).

**References:**

Alave, E. N. L., Lim, H. A. G., Ronquillo, J. L., & Tugade, M. M. (2020). PORTABLE ARDUINO-BASED INTEGRATED WATER QUALITY ANALYZER WITH REAL-TIME DATA TRANSMITTER.

Boyd, C., 2013. Reference Module in Earth Systems and Environmental Sciences. Elsevier.

Das, B., & Jain, P. C. (2017, July). Real-time water quality monitoring system using Internet of Things. In 2017 International conference on computer, communications and electronics (Comptelix) (pp. 78-82). IEEE.

Demeke, A., & Tassew, A. (2016). A review on water quality and its impact on fish health. International journal of fauna and biological studies, 3(1), 21-31.

Deutsch, W. G., Busby, A. L., Orprecio, J. L., Bago-Labis, J. P., & Cequina, E. Y. (2005). Community-based hydrological and water quality assessments in Mindanao, Philippines. Forests Water & People in the Humid Tropics, 134-149.

FAO. (2020). STATE OF WORLD FISHERIES AND AQUACULTURE 2020 : sustainability in action. Food & Agriculture Org.

FAO Fisheries & Aquaculture. (n.d.). Www.fao.org. Retrieved January 7, 2022, from <https://www.fao.org/fishery/en/countrysector/naso_philippines>

Fish kills. (2022). Retrieved 7 January 2022, from <https://www.fish.wa.gov.au/Sustainability-and-Environment/Fisheries-Science/Aquatic-Animal-Health/Pages/Fish-Kills.aspx>

FISH KILL: Why do they occur? (2021, January 6). Manila Bulletin. <https://mb.com.ph/2021/01/06/fish-kill/>

Fisheries Situation Report, January to arch 2021 | Philippine Statistics Authority. (n.d.). Psa.gov.ph. Retrieved December 15, 2021, from <https://psa.gov.ph/content/fisheries-situation-report-july-september-2021-0>

Fondriest Environmental, Inc. (2014). Conductivity, Salinity & Total Dissolved Solids - Environmental Measurement Systems. Environmental Measurement Systems. <https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/>

Mahasri, G., Saskia, A., Apandi, P. S., Dewi, N. N., & Usuman, N. M. (2018, April). Development of an aquaculture system using nanobubble technology for the optimation of dissolved oxygen in culture media for nile tilapia (Oreochromis niloticus). In IOP Conference Series: Earth and Environmental Science (Vol. 137, No. 1, p. 012046). IOP Publishing.

Mohd. Ezwan Jalil. (2011). Positioning and Location Tracking Using Wireless Sensor Network (Doctoral dissertation, Universiti Teknologi Malaysia).

Nasirudin, M. A., Za'bah, U. N., & Sidek, O. (2011, September). Fresh water real-time monitoring system based on wireless sensor network and GSM. In 2011 IEEE Conference on Open Systems (pp. 354-357). IEEE.

Olatinwo, S. O., & Joubert, T. H. (2018). Energy efficient solutions in wireless sensor systems for water quality monitoring: A review. IEEE Sensors Journal, 19(5), 1596-1625.

Omer, N. H. (2019). Water quality parameters. Water quality-science, assessments and policy, 18.

Patil, H., & Chen, T. (2017). Wireless Sensor Network Security. Computer And Information Security Handbook, 317-337. doi: 10.1016/b978-0-12-803843-7.00018-1

Sallenave, R. (2013). Understanding and preventing fish kills in your pond. NM State University, Cooperative Extension Service.

Schramm, D., & Grist, C. (2021). BUILDING SITE SELECTION TO CONSERVE ENERGY BY OPTIMIZING TOPOCLIMATIC BENEFITS: A Possible Use for Computer-Based Data Manipulation and Mapping Systems. In Energy Resources and Conservation Related to Built Environment (pp. 308-318). Pergamon.

Simitha, K. M., & Raj, S. (2019, June). IoT and WSN based water quality monitoring system. In 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA) (pp. 205-210). IEEE.

SOCCSKSARGEN REGION’s 2nd QUARTER 2020 FISHERIES PRODUCTION UP BY 23.0 PERCENT | Philippine Statistics Authority SOCCSKSARGEN Region. (2020). Psa.gov.ph.<http://rsso12.psa.gov.ph/article/soccsksargen-region%E2%80%99s-2nd-quarter-2020-fisheries-production-230-percent>

ThingSpeak for IoT Projects. (2022). Retrieved 7 January 2022, from <https://www.mathworks.com/products/thingspeak.html>

Tidwell, J. H., & Bright, L. A. (2019, January 1). Freshwater Aquaculture (B. Fath, Ed.). ScienceDirect; Elsevier. <https://www.sciencedirect.com/science/article/pii/B9780124095489106189>

Water Pollution. (2022). Retrieved 7 January 2022, from <https://www.hsph.harvard.edu/ehep/82-2/>

What Is Zigbee Wireless Mesh Networking?. (2022). Retrieved 7 January 2022, from <https://www.digi.com/solutions/by-technology/zigbee-wireless-standard>

‌