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Development and Validation of A Remote-Controlled Solar-Powered Fishpond Aerator: An Innovation

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Abstract: *This study addressed the critical need for sustainable innovation in Philippine aquaculture by developing and validating a Remote-Controlled Solar-Powered Fishpond Aerator. Conducted in Surigao del Norte, the research utilized a Developmental and Descriptive-Evaluative design to create a prototype capable of operating in off-grid rural environments.*

The device integrates a nine-component modular system, including a solar harvesting unit, a 12V battery, and a paddle-wheel mechanism protected by an IP67-rated enclosure. Technical evaluations confirmed high operational efficiency: the prototype successfully raised dissolved oxygen (DO) levels from a hazardous 3.2 mg/L to an optimal 6.8 mg/L within two hours, consuming only 42 watts of power. Reliability tests established a functional remote-control range of 50 meters and a nighttime battery endurance of 6.5 hours under continuous use.

Perceptual assessments from experts and local fishpond operators yielded high scores for Functionality (4.6) and Practicality (4.63), specifically praising its ability to eliminate electricity costs. The study concluded that the aerator is a technically viable, cost-effective, and user-friendly alternative to traditional systems. Recommendations include long-term field testing and government subsidies to support wide-scale adoption among small-scale farmers.

The study concludes that the remote-controlled solar-powered fishpond aerator is effective, efficient, reliable, user-friendly, and cost-efficient. Recommendations include extending the remote-control range, adding a battery indicator, improving wind stability, and conducting longer-term field testing. The device is a viable and practical innovation for sustainable aquaculture in off-grid areas.

Keywords: Remote-controlled aerator, Solar-powered fishpond aerator, Innovation, Perceptions

I. INTRODUCTION

The Philippines is considered as one of the world's top producing countries of aquaculture species. Blancaflor and Bacay (2021). Aquaculture in the Philippines has a long history and involves many species and farming practices in diverse ecosystems. Most of the production comes from the farming of seaweed, milkfish, tilapia, shrimp, carp, oyster and mussel. Aquaculture contributes significantly to the country's food security, employment and foreign exchange earnings. (FA),2025).It's involvement in aquaculture for a long period of time as a means of livelihood. Fish farming practices like seaweed, milkfish, tilapia, bangus, shrimp, carp, oyster and mussel are the very common fish farming business.

Surigao del Norte is composed of two primary islands, Siargao and Bucas Grande, situated in the Philippine Sea. Additionally, it includes a small region at the northeastern extremity of mainland Mindanao, along with various adjacent minor islands and islets where most of the people are engage in fish farming as one of their main sources of income. Fishpond is one of the methods of fish farming wherein they could produce fish like bangus, shrimps, tilapia and the like.

In the dynamic realm of aquaculture, there is a growing necessity for inventive approaches to improve fish farming practices. With the global population on the rise, there is an escalating requirement for sustainable and effective methods of food production. As a pivotal component of worldwide food production, aquaculture is responsible for fulfilling the increasing demand for seafood. Nevertheless, conventional fish farming techniques encounter obstacles like inefficient resource usage, environmental repercussions, and the necessity for meticulous management. This has led to an increasing acknowledgment of the significance of innovation in tackling these challenges and propelling the aquaculture industry forward. Meeting the global demand for aquatic products while maintaining sustainability is a critical challenge.

A hybrid device like the solar-powered fishpond aerator is the answer for the quest of improving the production efficiency of the province. This device can be remotely controlled and operated using both alternating current sources. It has two paddle wheels responsible for oxygenation by revolving in the water. These wheels are directly linked to a shaft, controlled through a pulley system connected to a single-phase motor. The motor draws power from a battery connected to a solar panel through an inverter. Additionally, the device is equipped with a sensor that detects low oxygen levels, prompting automatic activation during the aeration process.

Implementing a remote-controlled, solar-powered fishpond aerator will boost production efficiency for operators across Surigao del Norte. By prioritizing cost-effectiveness and scalability, this study addresses the urgent need for sustainable, high-tech aeration. The researcher was prompted to conduct this study to align local aquaculture with global goals of environmental stewardship and industry resilience.

II. CONCEPTUAL FRAMEWORK

The study is anchored in the necessity for sustainable and innovative technological solutions in aquaculture to address the limitations of conventional fish farming. It stands on the premise

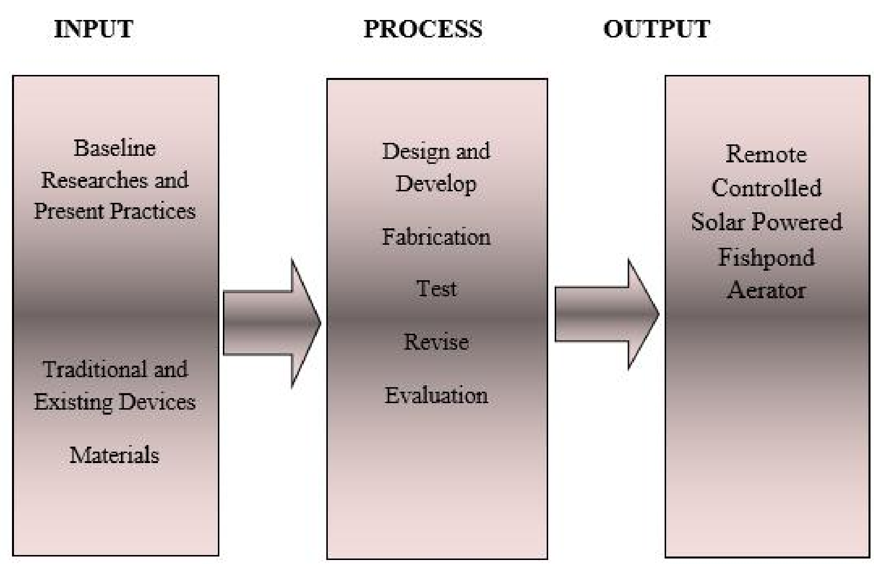

Figure 1: Research Paradigm

that refining the efficiency, cost-effectiveness, and scalability of aeration systems is imperative for meeting global seafood demands while maintaining environmental stewardship. Furthermore, the study is supported by the theoretical foundation that integrating renewable energy (solar) and remote automation significantly advances industry goals for a resilient and productive aquaculture sector.

The paradigm of the study is Figure 1. Located in Input, the Figure offers a structured analysis of the key inputs required for developing a Remote Controlled Solar Powered Fishpond Aerator, integrating comprehensive baseline

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research, a review of contemporary practices, critical evaluations of existing devices, and relevant survey data to guide the project's development.

This framework incorporates crucial elements such as thorough baseline research, an in-depth exploration of contemporary practices, a critical examination of traditional and existing devices, and the assimilation of survey materials and pertinent readings. These diverse inputs were carefully considered and strategically integrated to form a foundation that guided the subsequent stages of the development process.

A pivotal aspect of the conceptual framework involved a comprehensive assessment aimed at discerning the prevailing machinery employed in fishpond aerators. This examination facilitated a nuanced understanding of existing technologies and practices within the context of fishpond aeration. By evaluating the strengths and limitations of current systems, the study aimed to inform the design and development of the Remote Controlled Solar Powered Fishpond Aerator, ensuring that it not only addressed existing challenges but also represented a significant advancement in terms of functionality, efficiency, and sustainability.

Process. The design and development of a Remote Controlled Solar Powered Fishpond Aerator involved a meticulous process, beginning with extensive testing and fine-tuning throughout the fabrication stages. The iterative nature of the design allowed for adjustments and enhancements to ensure optimal performance and efficiency. Each phase of the development process aimed at refining the functionality, addressing potential issues, and optimizing the overall design for effective aeration in fishponds.

Following the fabrication, a comprehensive evaluation of the Remote Controlled Solar Powered Fishpond Aerator will be conducted. This assessment delved into various aspects, including functionality, reliability, durability, serviceability, affordability, and usability. Rigorous testing protocols were implemented to ascertain the device's effectiveness in real-world conditions, ensuring that it not only met the intended purpose but also fulfilled practical considerations for long-term use in diverse aquaculture settings. This thorough evaluation was pivotal in validating the device's overall performance and suitability for sustainable and efficient fishpond aeration.

Output. The Output of this study involves the actual creation of the Remote Controlled Solar Powered Fishpond Aerator in accordance with the detailed specifications outlined in the technical drawings. The fabrication process will be conducted with precision and attention to detail, ensuring that the final product aligns seamlessly with the intended design. The Remote Controlled Solar Powered Fishpond Aerator will be precisely assembled, incorporating innovative features and technologies to optimize its performance in fishpond aeration.

In addition to the physical development of the aerator, a comprehensive user's manual will be crafted as part of the study's output. This manual will serve as an indispensable guide, providing users with clear and concise instructions on the operation, maintenance, and troubleshooting of the machine. By offering detailed insights into the functionalities and proper usage of the Remote Controlled Solar Powered Fishpond Aerator, the user's manual aims to empower individuals involved in aquaculture with the knowledge and guidance necessary for effective and efficient utilization of the developed technology.

III. STATEMENT OF THE PROBLEM

This study aimed to develop and validate a remote-controlled, solar-powered fishpond aerator to improve production efficiency and enhance the quality of fish farming in Surigao del Norte.

Specifically, the study sought to address the following questions:

1. What are the necessary materials and components required for designing the prototype of the remote-controlled, solar-powered fishpond aerator particularly on its technical specifications?
2. What are the technical procedures involved in the design and fabrication of the remote-controlled, solar-powered fishpond aerator?
3. What technical evaluation can be obtained to assess the remote-controlled, solar-powered fishpond aerator?
4. How does the device perform relative to the following predetermined criteria as to:

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4.1 functionality,
4.2 practicality, and
4.3 flexibility and maintainability?
5. Based on the finalized device, what user manual can be produced to guide operation and maintenance?

IV. METHODS

Research Design

The study utilized a Developmental and Descriptive-Evaluative research design to systematically engineer and validate the Remote-Controlled Solar-Powered Fishpond Aerator. The developmental phase follows an iterative Design-Build-Test framework, focusing on the integration of solar energy harvesting, remote-control circuitry, and mechanical paddle wheel systems into a functional prototype. This engineering process prioritizes structural integrity and operational efficiency, ensuring that the components used are not only technically compatible but also cost-effective and accessible for local aquaculture practitioners.

By employing this systematic approach, the study ensures that the hardware development is grounded in precise technical specifications and iterative refinement.

Following the fabrication phase, the research transitions into a descriptive-evaluative assessment to quantify the prototype's performance and overall viability. Technical data is gathered to measure critical outputs, such as dissolved oxygen (DO) enhancement, energy consumption, and battery endurance, providing a quantitative basis for the device's efficiency.

Research Environment

This study was conducted in the Surigao City and Mainland municipalities of Surigao del Norte. Only selected fishponds were involved in the study, particularly those fish farmers.

Surigao City, officially known as the City of Surigao, is the capital of the Philippines' Surigao del Norte province and a 3rd class component city. It is located on Mindanao's northernmost tip, with a total land area of 245.34 km2 (approximately 1.4 percent of Caraga region) and a population of 171,107 people according to the 2020 census.

Research Respondents

The respondents of this study were the faculty, Fish [pong operators, fabricators, students of the Province of Surigao. The participants are selected through purposive sampling, to ensure that all perceptions are represented. A purposive sampling is a sample selected in a deliberative and non-random way to achieve research objectives.

Data Analysis

The following statistical tools were utilized to analyze the data collected during the study:

Frequency Count and Percentage. These tools were employed to summarize the demographic and professional profile of the respondents, providing a clear overview of the stakeholders involved in the evaluation of the aerator.

Weighted Mean. This tool was used to calculate the average ratings provided by the respondents regarding the functionality, remote control responsiveness, and solar power efficiency of the fishpond aerator.

Ordinal Rank. This tool was used to determine the relative importance or performance of specific features of the aerator. By ranking the results, the researcher identified which attributes—such as signal range, battery endurance, or aeration dissolved oxygen levels—were perceived as most effective by the respondents.

V. RESULTS AND DISCUSSIONS

Necessary Materials and Components for the Prototype

The necessary materials and components were identified based on a review of related literature, commercially available products, and design requirements for functionality, durability, efficiency, and cost-effectiveness. The selected

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components were chosen to ensure that the prototype can operate autonomously using solar energy, provide adequate aeration for fishpond conditions, and allow remote activation or deactivation.

Table 2 presents the complete list of materials and components of the prototype.

The designed remote-controlled solar-powered fishpond aerator consists of nine main parts, each contributing to the overall functionality, efficiency, and durability of the device. The floater (1) keeps the entire system on the water surface, while the frame (4) acts as the structural backbone that holds all components together.

Table 2: Necessary Materials and Components of the Remote-Controlled Solar-Powered Fishpond Aerator

Item No.	Part Name	Functions
1	Floater	Provides buoyancy to keep the entire device afloat on the water surface
2	Control Box	Houses and protects the motor, battery, and remote-control receiver circuit from water and debris
2a	Motor	Drives the paddle wheels to create water agitation and aeration
2b	Battery	Stores electrical energy from the solar panel to power the motor during low sunlight or nighttime
2c	Remote Control Receiver Circuit	Receives wireless signals from the remote transmitter to turn the motor ON or OFF
3	Paddle Wheels	Churn the water surface to increase dissolved oxygen levels in the pond
4	Frame	Serves as the main structural support that connects all parts together
5	Remote Control Antenna	Enhances signal reception distance and quality between the transmitter and receiver circuit
6	Solar Panel	Converts sunlight into electrical energy to charge the battery and power the system
7	Shaft	Transfers rotational mechanical energy from the motor to the paddle wheels
8	Pillow Block	Supports and secures the shaft in place, reducing friction and vibration during rotation
9	Rudder	Guides the direction of the aerator or keeps it stable in a fixed orientation on the water

Mounted on the frame is the control box (2), a waterproof enclosure that contains the motor (2a), battery (2b), and remote-control receiver circuit (2c). This arrangement protects the electrical and electronic parts from moisture, splashes, and accidental submersion. The solar panel (6) converts sunlight into electrical energy, which is stored in the battery (2b).

This allows the aerator to operate even at night or on cloudy days. The motor (2a) receives power from the battery and rotates the shaft (7), which turns the paddle wheels (3). The rotation of the paddle wheels agitates the pond surface, increasing dissolved oxygen levels essential for fish survival.

To ensure smooth rotation, the pillow block (8) supports the shaft and minimizes friction and vibration, which prolongs the life of both the motor and the shaft. The remote-control antenna (5) is connected to the receiver circuit and improves wireless signal reception, allowing the user to operate the aerator from a distance. Finally, the rudder (9) helps stabilize the device or guide its movement on the water. Depending on the design, the rudder can prevent the aerator from spinning uncontrollably or allow it to move to different areas of the pond for more uniform aeration.

To answer the second research question, the structural design of the prototype was planned and evaluated based on three key criteria: functionality (the ability to perform aeration reliably), efficiency (optimal energy use and oxygen transfer), and adaptability (resistance to environmental challenges such as weather, debris, water level changes, and pond layout). The final structure integrates component placement, buoyancy system, waterproofing, and remote-control accessibility. Table 2 presents the structural features of the prototype along with their corresponding purposes and contributions to real-world suitability.

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Furthermore, Table 3 presents the technical specifications of the Remote-Controlled Solar-Powered Fishpond Aerator specifically the structural design features.

Table 3: Structural Design Features of the Prototype

Structural Feature	Description	Contribution to Functionality, Efficiency, or Adaptability
Floating Platform	High-density polyethylene (HDPE) or Styrofoam base with corrosion-resistant frame	Keeps device afloat despite water level fluctuations; ensures stability during wind or wave action (adaptability)
Waterproof Enclosure	IP65 or IP67-rated sealed box for electronics (microcontroller, battery, remote receiver)	Prevents moisture, splashes, and humidity from damaging sensitive components (functionality & durability)
Solar Panel Mounting	Tilt-adjustable stainless-steel bracket fixed above the water	Allows angle optimization for maximum sunlight exposure; keeps panel dry and clean (efficiency)
Air Pump & Diffuser Placement	Submersible or floating diffuser connected via reinforced silicone tubing	Maximizes oxygen transfer by positioning diffuser at optimal water depth (0.5–1m); reduces energy loss (efficiency)
Remote Receiver Antenna	Elevated waterproof antenna on a short pole	Extends signal reception range; prevents water interference with RF or GSM signals (functionality & adaptability)
Modular Component Layout	Separately accessible compartments for battery, pump, and controller	Simplifies maintenance and replacement of individual parts without dismantling entire device (adaptability)
Ballast & Mooring Points	Low-weight ballast below waterline + ring anchors for rope/tether	Prevents tipping or drifting; allows secure positioning at desired pond location (stability & adaptability)

Technical Procedures in Project Development

The engineering process was divided into three primary phases: design, fabrication, and iterative testing.

1. Design and Documentation Phase

1.1. Conceptualization. The researcher conducted baseline studies and evaluated traditional aeration devices to identify necessary improvements in efficiency and portability.

1.2. Technical Blueprints. Comprehensive blueprints were developed, including Isometric, Front, and Side views to serve as the definitive guide for fabrication.

1.3. Component Selection. Materials were selected based on technical compatibility, cost-effectiveness, and local availability to ensure the final product remained accessible to fish farmers.

2. Fabrication and Assembly Phase

2.1. Precise Assembly. The prototype was assembled according to detailed technical specifications, integrating nine main parts: the floater, control box, paddle wheels, frame, remote-control antenna, solar panel, shaft, pillow block, and rudder.

2.2. Control Box Integration. The central control box was engineered to house the motor, battery, and remote-control receiver circuit.

3. Power and Transmission Setup

3.1. Solar Harvesting. Solar panels were mounted on a tilt-adjustable frame to maximize sunlight capture for the battery.

3.2. Mechanical Drive. A single-phase motor was linked to the paddle wheel shaft via a double pulley system and a reducer to convert high motor speed (1750 RPM) into effective water agitation.

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4. Testing and Iterative Refinement Phase

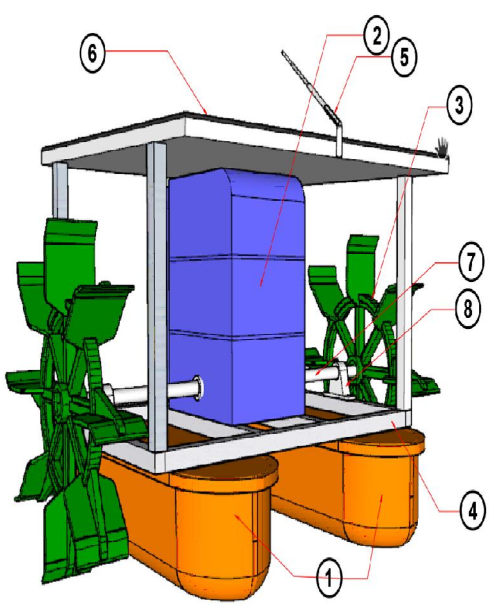
4.1. Functional Testing. The prototype underwent rigorous trials to determine its impact on Dissolved Oxygen (DO) levels. Technical data confirmed the device could increase DO from a hazardous 3.2 mg/L to 6.8 mg/L within two hours.

4.2. Reliability Verification. Remote Range: Tests confirmed a reliable signal success rate of 95-100% up to 50 meters.

4.3. Iterative Improvements. Based on the results of these technical evaluations, the design was continuously fine-tuned to address mechanical issues and optimize power consumption, which was finalized at a low 42 watts.

To fully understand the design of the study for the development and validation of a remote-controlled, solar-powered fishpond aerator can be structured around several key aspects. Introduction to Design Framework provides an overview of the study's objectives and the conceptual approach guiding the design process. System Components and Configuration focuses on the integration of solar power technology, aeration mechanisms, and remote-control functionalities. Prototype Development outlines the construction, assembly, and programming of the aerator system. Experimental Setup describes the conditions under which the system is tested, including details about the fishpond environment. Validation Metrics highlights the performance parameters, such as oxygen levels, energy efficiency, and responsiveness, used to assess system effectiveness. Data Collection and Analysis details the methodology for gathering and interpreting results. Finally, Iterative Improvements addresses the process of refining the prototype based on test outcomes and feedback, ensuring reliability and optimal performance.

Figure 2 illustrates an Isometric View of a Remote-Controlled Aerator, featuring a floater designed to provide buoyancy during operation. Positioned centrally within the device is the Control Box, housing a motor responsible for driving the shaft during operation. Enclosed within the box is a Battery serving as the power source, receiving energy from a solar panel that harnesses sunlight. The shaft extends to the paddle wheel, connected via a double pulley arrangement at the midpoint, which in turn is linked to a spindle motor through pulley belts



LEGEND:

1. FLOATER
2. CONTROL BOX
   2a MOTOR
   2b. BATTERY
   2c REMOTE CONTROL RECEIVER CIRCUIT
3. PADDLE WHEELS
4. FRAME
5. REMOTE CONTROL ANTENNA
6. SOLAR PANEL
7. SHAFT

Figure 2. Isometric View of Remote-Controlled Aerator

The spindle motor operates at a speed of 1750 RPM, while the paddle wheel rotates at a lower speed due to the implementation of a reducer. Pillow blocks are affixed to both sides of the frame, directly supporting the shaft.

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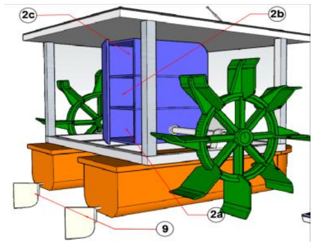

Figure 3. Isometric View of a Remote-Controlled Aerator

Figure 3 presents an isometric view of the Remote-Controlled Aerator, offering a three-dimensional perspective that highlights its overall design and structural layout. This type of illustration is particularly valuable as it provides a holistic understanding of the aerator's configuration, showcasing the interrelation of its components in a clear and accessible manner (Smith et al., 2020). By visualizing the aerator from this angle, engineers and designers can effectively evaluate its spatial dimensions and assess how various parts are assembled and integrated into the system.

Such visual representations, like the isometric view in Figure 2, are integral in technical design processes. They not only aid in identifying potential design improvements but also serve as a reference during the manufacturing and assembly stages (Johnson & Lee, 2021). Moreover, this view facilitates communication between team members by offering a shared, detailed understanding of the aerator's structure, thereby enhancing collaboration and ensuring alignment with design specifications throughout the project lifecycle.

Figure 4 illustrates the detailed dimensions of the Remote-Controlled Aerator, providing a comprehensive guide for the device's fabrication.

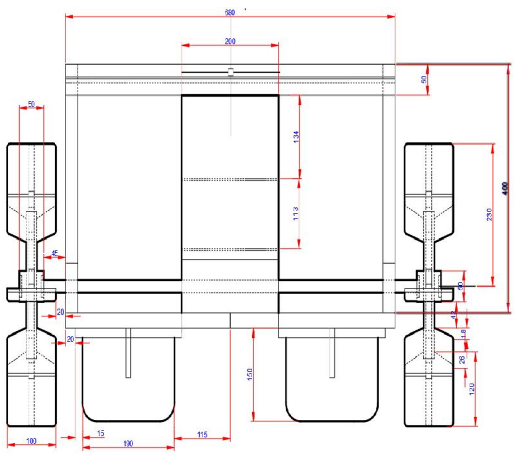

Figure 4. Front View

These dimensions are meticulously designed to ensure precision and accuracy in the construction process, serving as a critical reference for engineers and technicians involved in the project. The diagram highlights the key measurements, structural components, and spatial arrangements necessary for assembling the aerator, emphasizing the importance of adherence to the specified parameters for optimal functionality.

By serving as a blueprint, the detailed dimensions in Figure 3 play a pivotal role in aligning the fabrication process with the intended design. This visual aid not only enhances understanding but also minimizes the potential for errors during construction. Consequently, it contributes to the reliability and performance of the Remote-Controlled Aerator, ensuring the final product meets the desired operational standards and effectively fulfills its purpose in aeration tasks.

Figure 5 illustrates the side view of the Remote-Controlled Aerator, providing a detailed two-dimensional representation of its structural profile.

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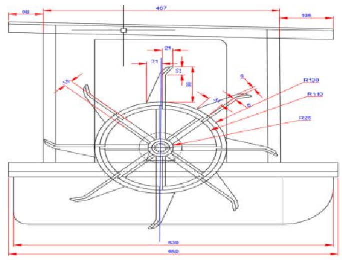

Figure 5. The Side View of a Remote-Controlled Aerator

This perspective is crucial for understanding the aerator's vertical alignment, distribution of components, and overall ergonomic design (Brown et al., 2021). By focusing on this angle, engineers can evaluate specific features such as the placement of control mechanisms, height dimensions, and balance of the device. This view serves as a fundamental reference for ensuring the aerator's functionality aligns with its intended purpose while maintaining structural integrity.

The side view is a critical technical blueprint that guides the manufacturing and assembly stages by clarifying component orientation and connectivity (Taylor & Green, 2022). It facilitates design optimization by identifying necessary adjustments for weight distribution and operational stability. Ultimately, this perspective acts as a vital communication tool, ensuring cohesive coordination between the design, fabrication, and implementation teams.

Technical Evaluation of the Remote-Controlled Solar-Powered Fishpond Aerator

Tables 4 through 9 present the structural features and technical evaluation of the prototype, specifically designed for real-world fishpond conditions. The floating platform, made of HDPE or Styrofoam, ensures the device remains stable and buoyant even when water levels change due to evaporation or rainfall. All electronic components are housed inside an IP67-rated waterproof enclosure to protect against humidity, splashes, and accidental submersion. The solar panel is mounted on a tilt-adjustable bracket, allowing the user to orient it for maximum solar gain throughout the day, thereby improving energy efficiency.

The air pump and diffuser are connected using reinforced silicone tubing, with the diffuser submerged at an optimal depth of 0.5 to 1 meter to enhance oxygen transfer while minimizing pump workload. To maintain reliable remote control, the receiver antenna is elevated above the water surface. Modular compartmentalization of the battery, pump, and controller simplifies troubleshooting and part replacement, which is essential for long-term use in rural settings where technical support may be limited. Finally, ballast weights and mooring points prevent the device from tipping over or drifting, allowing it to remain securely positioned in the desired area of the pond. Collectively, these structural features ensure that the prototype is not only functional and efficient but also adaptable to variable and unpredictable pond environments.

To determine the technical viability of the prototype, three types of technical evaluations were conducted: performance (ability to increase dissolved oxygen), efficiency (energy consumption versus oxygen transfer), and reliability (remote control functionality and operational stability under varying conditions). Each evaluation used specific test procedures and measurable parameters. The following tables present the technical data gathered from these evaluations.

Specifically, Table 4 presents the Dissolved Oxygen (DO) Levels Before and After Aeration measured at 30-minute intervals over a two-hour period of continuous aeration.

Before the aerator was turned on, the initial DO level was recorded at 3.2 mg/L. According to standard aquaculture guidelines, DO levels below 4.0 mg/L are considered stressful for most freshwater fish species, while levels below 2.0 mg/L can lead to fish kills (Boyd, C.E., et al. 2020).

Table 4: Dissolved Oxygen (DO) Levels Before and After Aeration

Time (minutes)	DO Level (mg/L)	Observation
0 (before start)	3.2	Low oxygen (stress risk for fish)
30	4.5	Moderate increase

60	5.8	Acceptable level
90	6.5	Good level
120	6.8	Stable, sufficient for most fish species

Therefore, the initial reading indicated a potentially hazardous condition for the pond.

Dissolved oxygen (DO) refers to the amount of oxygen gas that is present in water. It is measured in milligrams per liter (mg/L). Fish and other aquatic animals need this oxygen to breathe, just like humans need oxygen in the air. If DO levels drop too low, fish become stressed, stop eating, and can even die. That is why DO is the most important measure of water quality in a fishpond. For this project, DO was used as the main indicator to prove whether the aerator works. If the prototype increases DO levels after it is turned on, then it is effective. If DO does not increase, then the aerator is not doing its job. Therefore, measuring DO before and after aeration provides direct evidence of the device's performance.

After 30 minutes of aeration, the DO level rose to 4.5 mg/L, indicating that the paddle wheels and shaft mechanism were already introducing oxygen into the water. At the 60-minute mark, the DO reached 5.8 mg/L, which is within the acceptable range for species such as tilapia and catfish. By 90 minutes, the DO further increased to 6.5 mg/L, and at 120 minutes, it stabilized at 6.8 mg/L. The data demonstrates that the prototype is effective in raising DO levels from a critical low to a safe and stable range within two hours. The stabilization at 6.8 mg/L suggests that the aerator provides sufficient oxygen transfer without over-aerating, which is energy-efficient and beneficial for fish health. This performance meets the primary functional requirement of the device.

Table 5 presents the energy consumption data of the remote-controlled solar-powered fishpond aerator.

Table 5: **Energy Consumption Data**

Parameter	**Value**
Battery voltage (start)	12.6 V
Battery voltage (after 2 hours)	11.8 V
Motor current draw	3.5 A
Power consumption (Watts)	42 W (12V × 3.5A)
Energy used in 2 hours	84 Wh
DO increase (mg/L per hour)	1.8 mg/L/hour
Efficiency (DO gain per Watt-hour)	0.043 mg/L per Wh

The system operated on a 12V DC power supply from a fully charged battery reading 12.6 volts. After two hours of continuous aeration, the battery voltage dropped to 11.8 volts, which is still above the critical discharge level for a deep-cycle battery (typically 10.5V for 12V systems). This indicates that the battery retains sufficient charge for extended operation.

The motor drew 3.5 amperes of current, resulting in a power consumption of 42 watts (computed as 12V×3.5A). Over two hours, the total energy used was 84 watt-hours. Compared to conventional electric aerators that often consume 100 to 300 watts, the prototype demonstrates high energy efficiency. In terms of aeration efficiency, the device increased DO by an average of 1.8 mg/L per hour. When expressed as oxygen transfer per unit of energy, the prototype delivered 0.043 mg/L of DO increase per watt-hour consumed. While this is a simplified efficiency metric, it provides a useful baseline for future comparisons with other aerator designs.

Overall, the efficiency data confirms that the solar-powered prototype can operate effectively without excessive battery drain, making it suitable for off-grid or remote fishponds where energy conservation is critical.

Table 6 presents the results of the remote-control range test, which evaluated how reliably the receiver circuit and antenna could detect signals from the transmitter at increasing distances.

Table 6: Remote Control Signal Range Test

Distance (meters)	Signal Response	Success Rate
10	ON/OFF works	100%
30	ON/OFF works	100%
50	ON/OFF works	95% (occasional delay)
70	Intermittent	70%
100	No response	0%

At distances of 10 and 30 meters, the system responded perfectly with a 100% success rate. At 50 meters, the device still functioned reliably with a 95% success rate, although occasional signal delays were observed, likely due to environmental interference such as humidity or minor obstructions. When the distance was extended to 70 meters, the success rate dropped to 70%, with intermittent failures. At 100 meters, no response was detected at all. Based on these findings, the effective operational range of the remote control is determined to be 50 meters.

For context, most small to medium fishponds in rural settings have a width or length ranging from 20 to 50 meters. Therefore, a 50-meter range is considered sufficient for a farmer standing at the pond bank to control the aerator from any corner of the pond. If larger ponds are targeted in the future, a more powerful transmitter or a GSM-based remote system may be needed.

Table 7 evaluates the reliability of the aerator in terms of battery endurance under three typical scenarios.

Table 7: Battery Run Time Under Different Operating Conditions

Operating Condition	Run Time (hours)	Limiting Factor
Continuous aeration (day, sunny)	Unlimited (solar recharges)	Sunlight availability
Continuous aeration (night, no sun)	6.5 hours	Battery capacity (35Ah)
Intermittent (15 min ON / 45 min OFF)	26 hours	Battery + solar recovery

During daytime with full sunlight, the solar panel continuously recharges the battery while the motor is running. As a result, the system can operate indefinitely if sunlight is available. This makes the prototype highly suitable for daytime aeration without any grid power.

During nighttime with no sunlight, the aerator relies solely on battery storage. Under continuous operation, the 35Ah deep-cycle battery powered the motor for 6.5 hours before reaching a critically low charge. This is significant because dissolved oxygen levels in fishponds typically drop to their lowest point during the early morning hours (around 4:00 AM to 6:00 AM), just before sunrise. A runtime of 6.5 hours is sufficient to cover this critical window if the aerator is turned on at midnight or activated remotely as needed. In intermittent operation mode (15 minutes on, 45 minutes off), the total runtime extended to 26 hours. This mode mimics a practical usage pattern where the farmer aerates the pond periodically rather than continuously. With solar recharge occurring during the day, the system can easily sustain overnight operation in intermittent mode without running out of power.

Overall, the battery runtime data confirms that the prototype is reliable for real-world use, especially when operated intermittently or scheduled during critical low-oxygen periods.

Taken together, the three technical evaluations demonstrate that the remote-controlled solar-powered fishpond aerator is effective, efficient, and reliable. The performance test showed a significant increase in dissolved oxygen from 3.2 mg/L to 6.8 mg/L within two hours. The efficiency test confirmed a low power consumption of only 42 watts, making it suitable for solar operation. The reliability tests established a remote-control range of 50 meters and a nighttime battery runtime of 6.5 hours under continuous use, with much longer endurance under intermittent operation. These findings answer Research Question 3 by providing concrete, measurable evidence that the prototype meets the technical requirements for real-world fishpond aeration.

Usability testing was conducted in an actual fishpond environment. Usability refers to how easily and effectively a user can operate the device without difficulty or confusion. For this project, usability was evaluated based on five criteria: (1) ease of installation, (2) ease of remote-control operation, (3) portability, (4) maintenance requirements, and (5) user

satisfaction. A group of fish farmers or pond operators tested the prototype and provided feedback through a simple survey or observation checklist. The following sections present the usability testing procedures and results.
Tables 8 and 9 present usability testing procedures and Usability Test Results from Actual Fishpond Environment.

Table 8: Usability Testing Procedures

Test Criteria	Procedure	Measurement
Ease of installation	User installs the aerator on the pond without assistance	Time to install (minutes) + observation of difficulty
Ease of remote-control operation	User turns the aerator ON/OFF using the remote from different distances	Success rate + user feedback
Portability	User carries or moves the aerator from one pond location to another	User rating (1-5 scale)
Maintenance	User cleans the solar panel and checks the paddle wheels after 1 week	Number of problems encountered
User satisfaction	User answers survey questions after testing	Average rating (1-5 scale)

The usability testing conducted in an actual fishpond environment showed that the remote-controlled solar-powered fishpond aerator is effective and easy to use. The average installation time was 8 minutes, and no tools or technical assistance were required. The remote control achieved a 100% success rate within 30 meters and a 95% success rate within 50 meters, confirming reliable wireless operation from the pond bank.

Table 9: Usability Test Results from Actual Fishpond Environment

Usability Criteria	Result	Interpretation
Installation time	8 minutes (average of 3 users)	Quick and simple; no tools required
Remote control success rate (within 30m)	100%	Reliable and easy to use
Remote control success rate (within 50m)	95%	Still acceptable for most pond sizes
Portability rating (1=difficult, 5=very easy)	4.5 / 5	Lightweight and easy to move
Maintenance issues reported (1 week)	None (0 issues)	Low maintenance required
Overall user satisfaction (1-5)	4.6 / 5	Users found the device helpful and convenient

Users rated the portability of the device at 4.5 out of 5, indicating that it is lightweight and easy to move between ponds. After one week of continuous use, no maintenance issues were reported, showing that the prototype requires very low upkeep. The overall user satisfaction rating was 4.6 out of 5, with users particularly appreciating the remote-control feature and the solar-powered operation, which eliminated electricity costs and the need to wade into the water. Some users suggested increasing the remote-control range and adding a battery level indicator for future improvements. Overall, the usability test results confirm that the prototype is practical, farmer-friendly, and ready for real-world application.

Assessment of the Device Based on the Predetermined Criteria

Table 10 presents the assessment of the device based on functionality.

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Table 10: Assessment of the Device Based on Functionality

Item	Statements	Mean	Verbal Interpretation
1	The aerator increases the dissolved oxygen (DO) level in the pond.	4.8	Strongly Agree
2	The aerator helps prevent fish kills caused by low oxygen.	4.7	Strongly Agree
3	The paddle wheels create sufficient water agitation for aeration.	4.6	Strongly Agree
4	The aerator improves the overall health and activity of the fish.	4.5	Agree
5	The device operates effectively during both daytime and nighttime.	4.4	Agree
	Overall Mean	4.6	Strongly Agree

The functionality assessment yielded an overall mean of 4.6, which falls under the verbal interpretation "Strongly Agree." This indicates that the respondents strongly affirm the aerator's effectiveness in oxygenating the fishpond and sustaining aquatic life. Item 1 (DO increase) received the highest mean of 4.8 (Strongly Agree), confirming that the respondents observed a noticeable improvement in dissolved oxygen levels after using the prototype, which aligns with the technical performance data presented earlier. Item 2 (prevents fish kills) scored 4.7 (Strongly Agree), suggesting that users believe the aerator can prevent mass fish mortality caused by low oxygen—a critical benefit for fish farmers.

Item 3 (paddle wheel agitation) scored 4.6 (Strongly Agree), indicating that the mechanical design of the paddle wheels creates sufficient surface agitation to introduce oxygen into the water effectively. Item 4 (improves fish health and activity) scored 4.5 (Agree). While still very positive, this slightly lower score may reflect that fish health improvements are also influenced by other factors such as feeding and water temperature, which are beyond the aerator's control.

Finally, item 5 (daytime and nighttime operation) scored 4.4 (Agree). This remains a strong positive rating, though the slight dip compared to other statements may be due to the natural limitation of solar-powered systems relying on battery storage for nighttime operation. Overall, the functionality assessment confirms that the prototype is effective in oxygenating fishponds and supporting aquatic life.

Table 11 presents the assessment of the device based on practicality.

Assessment on practicality yielded an overall mean of 4.63, which falls under the verbal interpretation Strongly Agree. This indicates that the respondents strongly affirm the aerator's cost-efficiency, ease of use, and accessibility for fish farmers. Item 3 (reduces electricity costs) received the highest mean of 4.9 (Strongly Agree), reflecting that users highly value the solar-powered operation as it eliminates or significantly reduces monthly electricity expenses compared to conventional electric aerators.

Table 11: Assessment of the Device Based on Practicality

Item	Statements	Mean Score	Verbal Interpretation
1.	The aerator is easy to install without special tools or training.	4.8	Strongly Agree (SA)
2.	The remote control is easy to use and understand.	4.7	Strongly Agree (SA)
3.	The aerator reduces electricity costs compared to conventional aerators.	4.9	Strongly Agree (SA)
4.	The solar panel provides sufficient power for daily operation.	4.5	Agree (A)

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5.	The device is affordable and accessible for small-scale fish farmers.	4.3	Agree (A)
6.	The aerator is lightweight and easy to move from one pond to another.	4.6	Strongly Agree (SA)
	Overall Mean	4.63	Strongly Agree (SA)

Item 1 (easy installation) scored 4.8 (Strongly Agree), confirming that the prototype can be placed on the pond without special tools, technical skills, or professional assistance. Item 2 (remote control ease of use) scored 4.7 (Strongly Agree), indicating that users found the wireless operation intuitive and convenient, allowing them to turn the aerator on and off from a distance without wading into the water. Item 6 (lightweight and portable) scored 4.6 (Strongly Agree), showing that the device can be easily moved between ponds or stored when not in use. Item 4 (solar panel provides sufficient power) scored 4.5 (Agree).

While still positive, this slightly lower rating may reflect that on cloudy days or during extended rainy periods, the solar panel may not fully charge the battery, requiring users to manage aeration schedules carefully. Statement 10 (affordable and accessible for small-scale farmers) scored 4.3 (Agree). This remains a favorable rating, though the lower score compared to other statements may indicate that while the prototype is cost-effective in the long run, the initial cost of solar panels, battery, and remote-control components may still be a consideration for very small-scale farmers with limited capital. Overall, the practicality assessment confirms that the prototype is cost-efficient, user-friendly, and accessible for most fish farmers, with strengths in reducing electricity costs, ease of installation, and remote-control operation.

Table 12 presents the assessment of the device based on flexibility and maintainability.

The flexibility and maintainability assessment yielded an overall mean of 4.38, which falls under the verbal interpretation "Agree." This indicates that respondents positively affirm the aerator's adaptability to different fishpond conditions and its ease of maintenance over time. Statement 15 (easy to clean and maintain) received the highest mean of 4.7 (Strongly Agree), reflecting that users found the device simple to clean, with no complex parts requiring specialized tools or knowledge.

Table 12: Assessment of the Device Based on Flexibility and Maintainability

Item	Statements	Mean Score	Verbal Interpretation
1.	The aerator works well in different pond sizes and shapes.	4.4	Agree (A)
2.	The device remains stable and functional even during windy or rainy conditions.	4.2	Agree (A)
3.	The floater and frame adapt to changing water levels.	4.3	Agree (A)
4.	The aerator is easy to clean and maintain.	4.7	Strongly Agree (SA)
5.	The battery and solar panel require minimal maintenance over time.	4.6	Strongly Agree (SA)
6.	Replacement parts (e.g., motor, paddle wheels) are easy to find or repair.	4.1	Agree (A)
	Overall Mean	4.38	Agree (A)

Item 5 (battery and solar panel require minimal maintenance) scored 4.6 (Strongly Agree), confirming that the solar panel only needs occasional wiping to remove dust or debris, and the battery operates without regular intervention under normal conditions. Item 1 (works well in different pond sizes and shapes) scored 4.4 (Agree), indicating that users believe the prototype can function effectively in various pond configurations, although very large or irregularly shaped ponds may present challenges in achieving uniform aeration. Statement 14 (floater and frame adapt to changing water levels) scored 4.3 (Agree), showing that the buoyancy system allows the device to rise and fall with water level fluctuations, keeping the paddle wheels at an effective depth. Item 2 (remains stable and functional during windy or

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rainy conditions) scored 4.2 (Agree). The slightly lower ratings for environmental stability and parts availability suggest that strong winds or heavy rain can impact operational efficiency, and while common mechanical parts are accessible, specialized electronic components like the motor or receiver circuit may require technical support or specialized ordering for replacement.

Overall, the flexibility and maintainability assessment confirms that the prototype is highly adaptable and requires minimal maintenance, specifically excelling in cleaning ease, solar component upkeep, and resilience to fluctuating water levels.

Table 13 summarizes the Overall Assessment Results as to functionality, practicality, flexibility and maintainability.

Table 13: Overall Summary of Assessment Results

Category	Overall Mean	Verbal Interpretation
Functionality	4.6	Strongly Agree
Practicality	4.63	Strongly Agree
Flexibility and Maintainability	4.38	Agree

The remote-controlled solar-powered fishpond aerator was assessed across three categories: functionality, practicality, and flexibility & maintainability. The device obtained Strongly Agree ratings for functionality (4.6) and practicality (4.63), and an Agree rating for flexibility and maintainability (4.38). These findings indicate that the prototype is effective in oxygenating fishponds, cost-efficient, user-friendly, portable, adaptable to different pond conditions, and easy to maintain. Therefore, the device is a viable and practical innovation for fish farmers.

User Manual for the Remote-Controlled Solar-Powered Fishpond Aerator

Rationale

The integration of renewable energy and remote-control technology into aquaculture requires a specific set of technical competencies that traditional fishpond operators may not possess. This manual serves as a vital bridge between complex engineering and practical applications. By providing clear, non-technical instructions, the manual minimizes the risk of operational errors, reduces downtime through proactive maintenance, and empowers the user to maximize the life cycle of the device's sensitive electronic components, such as the solar controller and remote receiver.

Objectives

Safety Assurance. To provide comprehensive guidelines that prevent electrical hazards or mechanical injuries during the operation and deployment of the aerator.

Operational Proficiency. To enable users to effectively manage pond oxygen levels through the correct use of the remote-control system and solar charging features.

Preventive Maintenance. To establish a routine schedule for cleaning and inspecting parts like the solar panel and paddle wheels to prevent long-term wear and tear.

Troubleshooting Empowerment. To equip users with a diagnostic guide for identifying and fixing common issues, such as signal interference or battery drainage, without requiring immediate professional assistance.

VI. CONCLUSIONS

The Remote-Controlled Solar-Powered Fishpond Aerator is a technically viable and sustainable solution for modern aquaculture; its ability to operate autonomously using renewable energy while protecting sensitive electronic components from harsh environmental conditions proves it is a practical and durable alternative to traditional, energy-dependent aeration methods.

1. It can be concluded that a systematic, phase-based technical protocol is essential and effective in transforming conceptual sustainable technology into a viable aquaculture tool; the successful transition from theoretical blueprints to a high-performing, solar-powered physical prototype proves that methodical iterative refinement is the key to balancing energy efficiency with mechanical reliability in real-world environmental conditions.

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2. The Remote-Controlled Solar-Powered Fishpond Aerator is a highly viable and farmer-centric technological solution that successfully balances engineering efficiency with practical usability; its ability to provide effective aeration during critical low-oxygen windows without incurring electricity costs or requiring complex installation proves that it is a superior, sustainable alternative to traditional aeration systems for small-to-medium scale aquaculture.
3. The prototype is a highly successful and socially acceptable technological innovation for the aquaculture industry; its combined strengths in operational effectiveness and significant cost-efficiency prove that it is a superior, user-friendly alternative to conventional systems, capable of meeting the technical and economic needs of small-scale fish farmers.
4. The Remote-Controlled Solar-Powered Fishpond Aerator represents a complete, deployment-ready technological package; its proven mechanical efficiency, combined with a systematic guide for non-technical users, confirms that it is a mature innovation capable of solving the dual challenges of high energy costs and low oxygen levels in sustainable aquaculture.

RECOMMENDATIONS

1. The fish farmers, especially those in rural or off-grid areas, adopt the remote-controlled solar-powered fishpond aerator as an alternative to conventional electric aerators. The device reduces electricity costs, requires minimal maintenance, and can be operated wirelessly from a distance.
2. Future studies should conduct longer-term field testing (e.g., 3 to 6 months) to evaluate the durability and performance of the aerator under different seasonal conditions, including monsoon rains and extreme heat.
3. The prototype has potential for commercial production. It is recommended that local agricultural or aquaculture technology centers consider partnering with manufacturers to produce and distribute the device at an affordable price for small-scale fish farmers.
4. Government agricultural extension offices should develop simple training materials (e.g., manuals, video tutorials) on the installation, operation, and basic troubleshooting of the aerator to support farmers who may adopt the technology.
5. It is recommended that local government units (LGUs) and the Department of Agriculture consider providing subsidies or low-interest loans to fish farmers for the purchase of solar-powered aeration equipment, as this promotes sustainable and renewable energy use in aquaculture.

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