SITEKIN: Jurnal Sains, Teknologi dan Industri, Vol. 23, No. 1, December 2025, pp.97- 105
ISSN 2407-0939 print/ISSN 2721-2041 online

Implementation of Remote Steering System on RC Boat Trash Collector Based on Solar Energy

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ABSTRACT

Trash, especially plastic trash in the water, remains a problem in Indonesia since conventional methods are restricted and employ inefficient heavy equipment. Automation-based technological solutions such as the Remote Controlled (RC) Boat Trash Collector are promising and sustainable answers. This research focuses on the design and implementation of a remote steering mechanism for a solar-powered RC Boat Trash Collector. This system is energized by solar panels as a source of renewable energy, a conveyor system for garbage picking, and a Jumper T-Lite V2 2.4 GHz frequency remote control as the main controller. The process of research was conducted by designing, constructing, and testing the performance of the ship, for example, testing the drive motor, servo rudder, conveyor system, and test range control. The test results showed that the steering system responds well with an effective range of up to 300 meters, and the solar panels can extend the vessel's operating time. The conveyor mechanism also performs well in gathering floating debris into a collection bin. By the integration of this system, the RC Boat Trash Collector has proven to be effective, efficient, and environmentally friendly in assisting waste cleaning in bodies of water while being a platform for the implementation of sustainable, renewable energy technology.

Keywords: *RC Boat, renewable energy, remote steering system, solar panels, trash collector.*

Introduction

The Waste, particularly in the waters, has become an environmental crisis that threatens the sustainability of Indonesia's aquatic ecosystems. According to National Waste Management Information System Data, out of 35,015,331.53 tons of waste generated per year, 61.22% or the equivalent of 21.4 million tons of waste, is not effectively managed [1]. This condition is further compounded by the fact that Indonesia is the second largest contributor of plastic waste into the world's oceans, where the accumulation of plastic waste in the waters not only causes pollution of the marine ecosystem and the death of coral reefs but also disrupts ship transportation routes and causes microplastic pollution in the food chain [2]. Handling efforts through conventional methods that rely on direct human labor or the use of excavators have proven to be greatly limited in terms of efficiency, coverage, and safety factors of the workers, especially when implemented on narrow rivers in densely populated residential areas [3]. Faced with this multidimensional challenge, the technology of Remote Controlled (RC) Boats, or remote-controlled trash collector boats, has emerged as a promising innovative solution [4]. This boat is designed to perform semi-autonomous cleaning operations with significantly reduced human labor and increased cleaning area compared to traditional methods that can reach previously unreachable waters. However, in its implementation, existing RC Boat designs still suffer from two fundamental limitations that inhibit their widespread operation: operational endurance and control system reliability.

The limitation of RC Boats concerns operational endurance. Traditional RC boats depend on conventional batteries with limited capacity, which regularly need to be recharged, thus making the duration and continuity of cleaning missions very limited. The integration of solar panels has been proposed as a solution for its sustainable energy provision [5], [6]. However, previous research, such as that by Nevon Projects [7] and other similar projects [6], generally adopts solar panels as an additional charging system, without being balanced by optimization of an integrated energy management system for long-term and sustainable operations (long endurance). The second limitation lies in the domain of control systems. Most designs for RC Boats still use conventional radio frequency technology in the 2.4 GHz band [8], [9], [10], [11]. Although technology is widely adopted, it is inherently burdened by weaknesses in its very fundamentals: limited range and interference by noise, especially when operated in the middle of large waters or cities characterized by high levels of obstruction with high electromagnetic noise. limitedious previous studies have successfully demonstrated the implementation of remote-control systems on various boat models [9], [10], [11], substantive innovations in terms of intelligent control logic, the adoption of superior communication protocols, and optimization techniques to improve responsiveness and maneuverability are still very limited. For example,

RC Boat research still uses a Jumper T-Lite V2 (2.4 GHz) remote control that remains within conventional RF control without much improvement in range and connection stability [11].

Fundamentally, based on the identification of these technological gaps, this research goes beyond merely combining solar panels with a control system and introduces several specific, differentiated innovations to create a superior system. The contribution of novelty in the present research is threefold: First, the integration of a control system based on an ESP-NOW protocol offers a new paradigm in wireless communication for RC Boat applications. Unlike previous conventional RF systems, the ESP-NOW protocol offers a wider range, lower latency, and superior connection stability while offering more efficient power consumption, fundamentally addressing the deep-rooted weaknesses of previous control systems [12] Second, Mechanical Design Optimization and Drive Configuration. This study will implement a specifically optimized conveyor mechanism for surface waste collection, in tandem with a computationally designed thruster configuration to provide more responsive and stable maneuvers, hence greatly differing from conventional designs that rely on passive nets or DC pump systems [7]. Third, there is the Intelligent Hybrid Energy Management Strategy, which implements intelligent control logic to optimize the utilization of solar energy in real time. In this design, solar panels also act not just as chargers but as a power source. It acts as the dynamic primary power source, managed through maximum power point tracking (MPPT) to maximize operational duration critical aspect that is usually overlooked in similar research [5][6].

This research will realize a solar-powered RC Boat Trash Collector with a remote-control system and an integrated conveyor mechanism by implementing this comprehensive innovation package. The developed solution is expected to be not only effective and efficient in cleaning up marine debris but also sustainable, operable with a superior range and reliability, and with minimal risk. This will fill the gap in technology that still remains in developing previous RC trash collectors and will contribute significantly to solving the waste crisis in Indonesian waters.

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Research Methods

1. Tools

The tools used in this research were selected to support the assembly and testing processes. The main tools used are:

a. Soldering iron: For assembling and soldering electronic components.
b. AVO Meter (Multimeter): To conduct electrical tests and ensure the components in the RC Boat Trash Collector remote control system are functioning properly.

2. Materials

In addition to tools, key materials or components are also needed to design and build the steering system. The materials used in designing the remote steering system on the solar cell-based RC Boat Trash Collector are as follows:

a. 1700 kV Brushless Motor
b. 40A ESC (Electronic Speed Controller)
c. MG996R Servo
d. T-Lite V2 Remote Jumper
e. 50 Rpm DC Motor
f. Connecting Cable
g. Receiver

3. Research Design and Methods

The methods applied in this research are designed to answer the research questions in a structured and measurable manner. This research used a quantitative experimental method with systematic work stages, as shown in Figure 1**.**

Figure 1. Research flowchart

This research began with the Preparation Phase; an initial process focused on identifying needs and preparing the necessary components and equipment. This phase involved selecting key materials, such as the remote control, receiver, drive motor, conveyor motor, servo rudder, Electronic Speed Controller (ESC), battery, solar panel, and boat frame. Furthermore, the availability of supporting measuring instruments to be used in the trial process was checked, such as a multimeter, an AVO meter, and a soldering iron. This

preparation aimed to ensure that all components used in the RC Boat Trash Collector Assembly were ready for use and fit for purpose.

The literature review, conducted by collecting, studying, and analyzing various theories and relevant previous research results. The literature reviewed included radio frequency–based remote control systems, RC boat technology design, and the working principles of solar energy utilization through solar cells. This literature review provided a strong theoretical foundation for the research and allowed previous research to be used as a reference in designing a more effective and efficient system. After that, the steering system design was conducted, where researchers began to develop a comprehensive ship control design. This stage included creating an electrical circuit schematic and determining the installation positions for the propulsion motor, conveyor motor, servo, rudder, ESC, battery, and solar panel. This stage also determined the integration method between components to ensure the entire system's coordinated operation, from power distribution and the flow of control signals from the receiver to the ship's movement mechanism and waste conveyor.

The next stage was the steering system implementation, which involved assembling and installing all components according to plan. The previously selected components were installed on the ship's frame, considering aspects of stability, weight, balance, and electrical network security. At this stage, researchers also soldered cables, installed solar panels, arranged the power supply from the battery to the ESC, and designed the conveyor mechanism for optimal operation. After the system was installed, steering system testing was conducted, a crucial step in establishing the vessel's actual performance in the field. This test included measuring the remote control's response speed, the vessel's maneuverability in water, its cruising range based on battery capacity, and the conveyor's effectiveness in collecting surface debris. Furthermore, the stability of the solar panel's energy supply in assisting battery. This test included measuring the remote control's response speed, the vessel's maneuverability in water, its cruising range based on battery capacity, and the conveyor's effectiveness in collecting surface debris. Furthermore, the stability of the solar panel's energy supply in assisting battery charging was evaluated. The measurement data were then recorded for further analysis.

In the data analysis stage, all field data collected were processed using descriptive and comparative methods to assess the system's effectiveness. Analysis was conducted on control, speed, and stability, battery power consumption, the solar panel's contribution to energy security, and the conveyor's success rate in collecting debris. This analysis determined whether the system design met the research objectives or whether improvements were needed. The final stage was drawing conclusions, summarizing the research findings based on the data analysis. This stage clearly outlines the system's advantages and limitations, the RC Boat Trash Collector's effectiveness in addressing marine waste issues, and opportunities for further development. These conclusions serve as the basis for providing technical and practical recommendations for future research, while also emphasizing the research's contribution to supporting environmentally friendly, renewable energy-based technological innovation.

4. How the Trash Collector Works:

The RC Boat Trash Collector is an innovative trash-cleaning vessel that utilizes a combination of batteries and solar cells as its energy source. Two batteries, each with a capacity of 5200 mAh and 2000 mAh, serve as the primary electrical energy storage, which supplies power to the entire system. Solar cells are placed on the top of the vessel to capture sunlight, convert it into electrical energy, and then channel that energy to the batteries. This mechanism not only provides additional energy during operation, but also extends the battery's lifespan, allowing the vessel to operate longer in open waters. Energy from the batteries is then channeled through an Electronic Speed Controller (ESC). This component plays a crucial role in regulating the voltage and current sent to the motors, allowing the motors' speed and direction of rotation to be adjusted according to operator commands.

The propulsion system consists of three motors with different functions. Two motors, located on the port and starboard sides, function as the primary propulsion units for the vessel, generating thrust for forward, backward, and turning. A dedicated auxiliary motor is used to drive the conveyor mechanism. This conveyor functions to collect trash from the water's surface and channel it into a collection container inside the boat, effectively collecting it. All motors are controlled via an ESC connected to a receiver. The receiver receives signals from a 2.4 GHz remote control. These signals are then translated into electronic instructions that control the operation of the propulsion motor and conveyor motor according to the remote's joystick.

In addition to the propulsion system, the boat is also equipped with a steering system in the form of a servo-driven rudder. When the operator moves the joystick left or right, the servo turns the rudder, allowing the boat to change direction as desired. The combination of the two main propulsion motors and the rudder allow the boat to maneuver nimbly, even in narrow or trash-filled waters. Overall, the boat operates in a single cycle: solar cells charge the battery during the day, the battery supplies energy to the ESC, the ESC regulates power distribution to the motors and servos according to the receiver's instructions, and the motors and rudder then propel the boat while the conveyor collects trash. With this system, the RC Boat Trash Collector can operate effectively and be environmentally friendly. Solar power is utilized as a supplemental power source, reducing total reliance on batteries. Furthermore, the 2.4 GHz frequency-based remote control allows the

operator to safely navigate the vessel without direct contact with polluted water. As a result, this vessel not only contributes to the efficiency of waste cleanup efforts in the waters but also serves as an example of the application of renewable energy technology to environmental problems.

Results and Discussion

Control System Design

The RC Boat Trash Collector design uses a remote steering system, namely a Jumper brand remote control, to facilitate operation of the device. The RC Boat Trash Collector is equipped with 15 1 Wp solar cells to supply power for battery charging. Another advantage of the RC Boat Trash Collector is that it uses a conveyor mechanism to collect trash from the surface of the river.

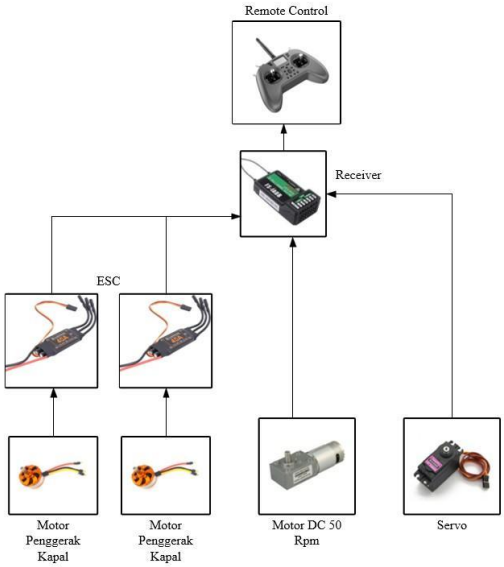


Figure 2. Remote control system design

Two boat drive motors are connected in parallel to form a single output connected to the receiver, thereby simplifying the operation of the motor. The DC motor that drives the conveyor mechanism is also connected to the receiver to increase the efficiency of the conveyor mechanism itself.

Control System Performance Test

The RC Boat Trash Collector performance test aims to determine how much trash can be transported by this RC Boat Trash Collector and to determine the radius of the remote steering system's capability on the RC Boat Trash Collector. The test was conducted on the Bedadung River by transporting waste on the river surface until the RC Boat Trash Collector's tank was full and transporting the waste to a certain distance. This test aimed to determine the waste capacity that could be transported and the maximum distance of remote steering system control on the RC Boat Trash Collector. This testing stage was conducted by controlling the radius distance in increments of 50 meters. The test indicator results can be used to determine the maximum distance for the remote steering system on the RC Boat Trash Collector.

System implementation

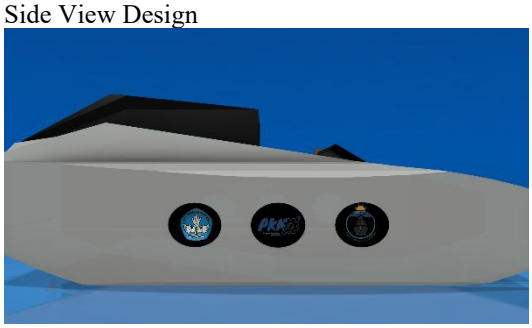
The following is the implementation of the remote steering system on the RC Boat Trash Collector. There are six main components in this study, namely Remote-Control Jumper T -Lite V2, Receiver, Servo MG996R, 1700kv brushless motor, 40A ESC, and 50 Rpm DC motor. The remote control in this research uses three buttons, each of which functions to send data to the receiver as a control button on the remote steering system on the RC Boat Trash Collector.

Figure 3. Remote Control Jumper T-Lite V2

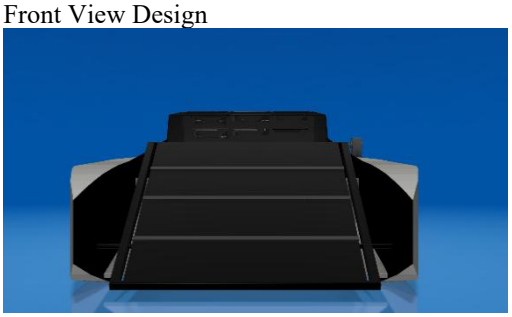
The following is the design of the remote-control system circuit applied to the solar-powered RC Boat Trash Collector:

Overall, View Design

Side View Design

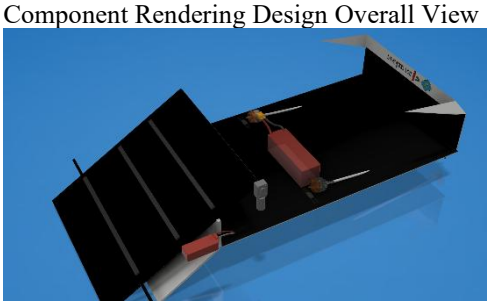


Front View Design

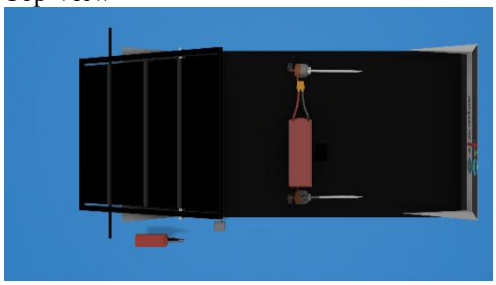


Rear View Design

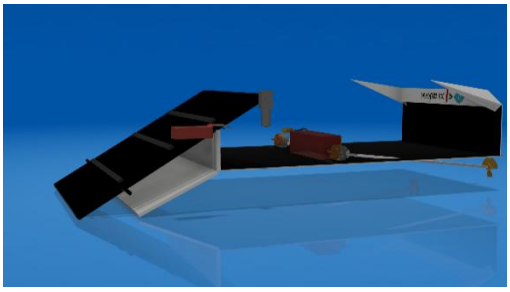
Component Rendering Design Overall View



Component Rendering Design
Top View



Component Rendering Design
Side View



Component Rendering Design
Rear View

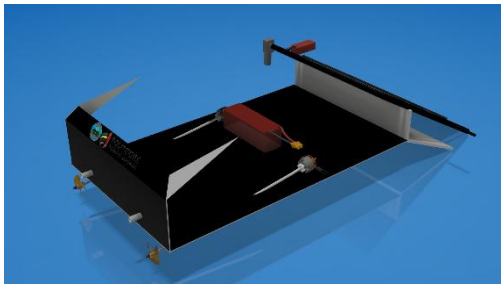


Figure 4. Remote control system circuit design for the RC Boat Trash Collector

The circuit contains electrical energy generated by solar panels, which convert sunlight and are stored in batteries, which serve as the primary power source for the entire system. Power from the batteries is channeled to the Receiver, which receives control signals from the user's remote control. These signals are then transmitted to the Electronic Speed Controller (ESC) to regulate the speed and direction of the Drive Motor, allowing the boat to move forward, backward, or turn. The receiver also sends signals to the Trash Collector Motor, which drives a netting mechanism or conveyor to lift trash from the water's surface. The captured trash is then channeled to the Trash Receptacle at the rear of the boat. With this system, RC Boats can operate independently and efficiently without the need for conventional fuel, thus supporting the principles of renewable and environmentally friendly energy.

1. Servo testing

Servo testing is necessary to ensure the servo functions properly for maneuvering the RC Boat Trash Collector. In this test, the joystick button on the remote control is moved horizontally or along the axis (X), where the boat's programme indicates right and left turn commands.

Table 1. Servo motor test result

No	Joystick position on the axis (x)	Description
1	0	Normal Condition
2	50 to 100	Turn right
3	-50 to -100	Turn Left

Based on the test results conducted on the servo motor, it can be analyzed that the steering system on the RC Boat Trash Collector functions properly according to the commands given via the remote control. The test was conducted by moving the joystick on the horizontal axis (X), which produced three clear operational conditions. The reliability check of the maneuver according to the command shows how the control input via the joystick is mapped to the servo [13]. From the test results, it was found that at a value of 0, the servo was in a neutral or normal condition without giving any turning commands. When the joystick was moved to a positive value (50-100), the servo responded by turning the boat to the right. Conversely, at a negative value (-50 to -100), the servo responded by turning to the left. These results indicate that the programming and calibration between the remote control, receiver, and servo have been conducted correctly, so that the steering system can be relied upon to maneuver the boat during waste collection operations. The measured response accuracy (neutral at 0, right turn on positive signal, left turn on negative signal) is a behavior that can be explained by correct calibration and control [14].

2. Evaluating the Conveyor Mechanism

The buttons on the remote control used to control the conveyor mechanism need to be evaluated to determine whether they function properly in driving the DC motor in the conveyor mechanism.

Table 2. Conveyor Mechanism Test Results

No	Button Position	Description
1	Center	Conveyor off
2	Upward	Conveyor moves clockwise
3	Downward	Conveyor moves counterclockwise

From the results of the tests conducted on the conveyor mechanism, the conveyor control system is working very efficiently and in accordance with the instructions given by remote control. The tests conducted with three button positions all produced a definite and consistent response from the DC motor. In the middle position, the conveyor is in the off state, i.e., the system can stop perfectly without any unwanted movement. When the button is pushed upwards, the conveyor rotates in a clockwise direction, i.e., the DC motor responds well to the forward command. When the button is moved downwards, the conveyor moves in a counterclockwise direction, indicating the ability of the system to rotate in two directions (forward and reverse) as needed.

These results confirm that the programming and interfacing of the remote control, receiver, and DC motor have been included correctly. In addition, the quick and accurate response of the conveyor to button commands indicates that this system is dependable for implementation in waste collection processes by the RC Boat Trash Collector. This study also validated the performance of the conveyor system by checking the speed, stability, and suitability of response to commands from the remote control [15]. Passing this test further confirms that the conveyor mechanism design is optimal and ready to use under field conditions. Like [16], if direction control (forward/reverse) and response to commands can be achieved with the proper design.

3. Evaluating the boat's drive motor

The motor driving needs to be tested to ensure that it can function properly as the drive for the RC Boat Trash Collector. In this test, the joystick button on the remote control is moved vertically or in the direction of the axis (Y), where the boat's condition in the program indicates a forward command.

Table 3. Drive motor test results

No	Joystick axis position (x)	Description
1	0	Stop
2	10 to 100	Move forward

Based on the test results conducted on the drive motor, it can be analyzed that the drive system on the RC Boat Trash Collector functions well and is responsive to commands from the remote control. The test was conducted by moving the joystick on the vertical axis (Y) that controls the forward movement of the boat. The drive system was evaluated properly; if the joystick moved from 0 to 10-100, then the motor responded by moving forward proportionally [9]. The test results showed two clear operational conditions. Proper control is needed when the boat is moving on the water surface. At a value of 0, the drive motor is in a stopped state, indicating that the system can stop the drive system perfectly when not needed. When the joystick is moved in the range of 10 to 100, the driver motor responds by moving the vessel forward. This indicates that the motor speed control system is functioning properly, where an increase in the value on the Y-axis proportionally regulates the forward speed of the vessel. These results indicate that the drive system of this device is ready for use in waste cleaning.

4. Distance testing

This test was conducted to determine the maximum radius that can be controlled by the remote control. The test was conducted at a radius of 50 m - 500 m with the following results.

Table 4. Distance test results

No	Radius (m)	Connection Status	Description
1	50	Present	Can be controlled
2	100	Present	Can be controlled
3	150	Present	Can be controlled
4	200	Present	Can be controlled
5	250	Present	Can be controlled
6	300	Present	Can be controlled
7	350	Weak	Intermittent control
8	400	Weak	Intermittent control
9	450	None	Disconnected control
10	500	None	Disconnected control

Based on the test results listed in the table, the effective range of the remote-control system on the RC Boat Trash Collector can be visualized as follows.

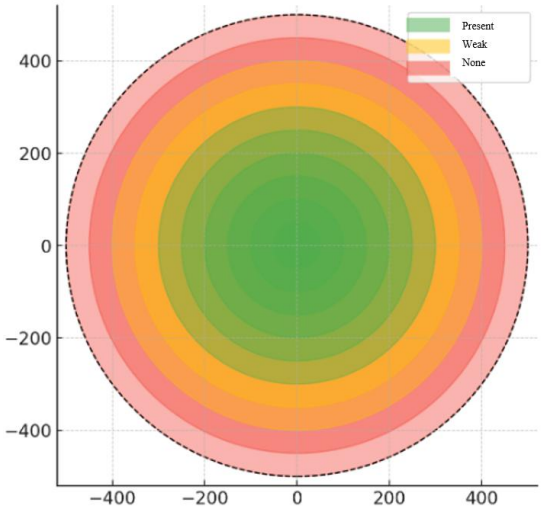


Figure 5. Control area range diagram

The concentric circle map shows the quality of connection varying with the distance in terms of radii from the center of control. In the green area, up to a radius of 300 meters, if one crosses a radius between 350 and 400 meters, the connection begins to weaken and moves into the yellow area. And, at a distance of 450 meters or more, the connection is lost. Between 50 to 300 meters range, the control system exhibits very stable and reliable performance. The receiver and remote control have a solidly established relationship, and the boat is controlled without any distraction or signal loss. This means that at this range, the system is well more than sufficient for water waste collection activities. At 350 to 400 meters, the connection begins to malfunction, and

control gets unstable. This indicates that the signal is received to the effective maximum range of the system. This range must be kept away from because it could cause irregular performances from the vessel, where the process of waste collection may be interrupted and even the vessel at risk if the control is lost halfway in the sea. At 450 meters more, the connection is completely lost. A 400-450 meter range would then be the upper limit of the system. Testing has proven that the remote-control system used has met functional specifications for an RC Boat Trash Collector. The remote operation of connection is evidenced by the quality of the signal, which begins to reduce after a certain distance and makes the control intermittent with the distance approaching the limit [17]. The permissible safe limit of use is under 300 meters to avoid loss of control. A 300-metre useful range would be adequate for most applications for marine refuse collection. Practical and efficient planning of sea surface cleaning trajectories, with a small operating sector [10]. Refuse collection equipment in remote waters with ranges of several hundred meters to a few kilometers suffice and are in common use [11].
The obtained results prove that the RC Boat Trash Collector has met its objectives regarding the development of an efficient, solar-powered, and remote-controlled river trash removal system with appropriate range, be it for Indonesian rivers. Tests on various prototypes have demonstrated the boat's ability to maneuver and efficiently collect waste on the water's surface [18], [19], [20]. Data collected from these tests depicts the integration of all three pillars of innovation mentioned above: the control system, the optimized drive configuration, and the hybrid energy management strategy in overcoming the identified key limitations in current literature. This boat integrates solar panels and batteries as energy sources, enabling it to operate sustainably without relying on external electricity [18], [20], [21]. Thus, the following test results confirm not only the answers to the research questions but also the significant achievement in the stated objectives.

Conclusion

It can be concluded from the design and testing results that the remote steering system in the RC Boat Trash Collector had been successfully implemented by connecting two boat propulsion motors into one output connected to the receiver, making it easier to control with a single button. The control system of the RC Boat Trash Collector consists of three main functions: the propulsion motor, the steering servo, and the mechanism of the conveyor, all of which are stable and accurate when controlled by a radio controller. The effective range of this system is up to 300 meters, which is adequate for cleaning operations in many rivers and lakes in Indonesia. Development Suggestions The following development suggestions are made for further research, such as: (1) Increase battery capacity and efficiency of the solar panel to have longer operating life; (2) Integrate a GPS-based semi-autonomous navigation system to run mapped cleaning routes; (3) Add sensors such as ultrasonic or cameras to enable trash detection automatically and obstacle avoidance; (4) Develop a more adaptive trash collection mechanism for different types and sizes of trash; and (5) Conduct long-term trials in various locations and different water conditions to test the durability and reliability of the system.

Acknowledge

Thank you to the Director and P3M Politeknik Negeri Jember for funding the 2025 PNBP Community Service programme.

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