Design and Fabrication of a Solar Powered Semi-Automated River Cleaning Machine

Prof. Ritesh Banpurkar[1], Mr. Amit Dhole [2], Mr. Navinya Bhandhekar[3], Mr. Ajay Mishra[4]

[1]Asst. Professor, Department of Mechanical Engineering, Tulsiramji Gaikwad Patil College of Engineering & Technology, Nagpur, Maharashtra, India
[234]Students, Department of Mechanical Engineering, Tulsiramji Gaikwad Patil College of Engineering & Technology, Nagpur, Maharashtra, India

Abstract

The continuous rise in industrialization, urban expansion, and human activities has intensified river pollution worldwide. Rivers, being vital sources of freshwater, are increasingly contaminated due to the unregulated discharge of plastic debris, floating waste, and other non-biodegradable materials. Such pollutants not only degrade aquatic ecosystems but also endanger biodiversity, human health, and the overall environmental balance. Conventional cleaning methods, often dependent on manual labor or fuel-driven boats, are inefficient, costly, and contribute indirectly to carbon emissions.

This research presents the design and fabrication of a **solar-powered semi-automatic river cleaning system** aimed at providing an eco-friendly and sustainable solution for floating waste removal. The system operates using renewable solar energy, thereby eliminating reliance on conventional fuels. It employs a conveyor mechanism that continuously collects floating waste and deposits it into a rear-mounted storage container. Lightweight and corrosion-resistant materials were used to ensure buoyancy, strength, and long-term durability.

Performance tests conducted under both controlled and real-water conditions showed high waste collection efficiency, low maintenance requirements, and minimal operational cost. The integration of semi-automation reduces manual involvement and enhances reliability in waste collection. Moreover, the modular design allows scalability for use in different water bodies, from small lakes to medium-sized rivers.

The study demonstrates a sustainable approach to environmental protection by merging renewable energy with mechanical automation. This innovation supports global efforts toward clean water and climate action, aligning with the United Nations Sustainable Development Goals (SDGs).

Keywords:
Solar Power, Semi-Automation, River Cleaning Machine, Renewable Energy, Environmental Sustainability, Waste Management, Green Technology

1. Introduction

Water is one of the planet's most critical natural resources and is essential for sustaining all forms of life. It supports not only human survival but also plays a vital role in agriculture, industry, and ecological balance. However, rapid urbanization, industrial development, and population growth in recent decades have led to severe degradation of water quality. Among various aquatic resources, rivers are the most affected, as they frequently receive untreated industrial effluents, domestic wastewater, and improperly discarded solid waste. This contamination disrupts aquatic ecosystems, threatens biodiversity, and ultimately impacts human health and environmental stability.

A major portion of river pollution arises from floating materials such as plastic bottles, polythene bags, disposable cups, and other non-biodegradable waste. These materials obstruct the natural flow of water, reduce sunlight penetration, and disturb aquatic photosynthesis, thereby lowering dissolved oxygen levels. Accumulated debris also clogs drainage networks, causes foul odors, and creates breeding grounds for disease-spreading organisms. Furthermore, microplastics produced by the breakdown of larger plastic waste particles contribute to long-term contamination, making the water unsafe for consumption and irrigation.

Traditional river-cleaning practices rely heavily on manual labor using nets and boats. While such methods may offer temporary relief, they are labor-intensive, time-consuming, and expose workers to contaminated environments. In addition, these methods are not cost-effective or scalable for large-scale waste removal in urban or industrial regions. Therefore, an efficient, automated, and eco-friendly alternative is necessary to manage floating river waste effectively.

The present work focuses on the **design and development of a solar-powered semi-automatic river cleaning system** that integrates renewable energy utilization with mechanical automation. The proposed model employs a solar photovoltaic (PV) system to power the motors responsible for the propulsion and conveyor mechanisms. This eliminates dependence on external fuel sources, reducing both energy consumption and greenhouse-gas emissions.

The floating framework of the system is built from lightweight, corrosion-resistant materials to ensure stability and durability under various water conditions. The conveyor arrangement collects floating debris from the water surface and transfers it into a detachable storage bin located at the rear of the structure.

The research primarily emphasizes three objectives:

1. **Efficient solar-energy utilization** for continuous machine operation.
2. **Mechanical design optimization** to achieve stability and buoyancy.
3. **Enhanced waste-collection performance** through semi-automated control.

By combining renewable energy technology with automated mechanical systems, this study proposes a sustainable approach for maintaining cleaner water bodies. The developed system minimizes human involvement, lowers operational cost, and contributes to environmental preservation and pollution control. Ultimately, it represents a practical innovation supporting cleaner ecosystems and sustainable water-management practices.

2. Literature Review

In recent years, researchers and engineers have increasingly focused on developing sustainable technologies for cleaning and maintaining aquatic environments. The growing pollution of rivers and lakes has motivated the exploration of automated, renewable-energy-based solutions to replace conventional manual cleaning methods. Literature in this field reflects a consistent trend toward integrating solar energy systems with mechanical automation for surface waste collection and environmental management.

Reddy (2021) studied the application of renewable energy in small-scale autonomous systems and highlighted the viability of solar photovoltaic (PV) technology for powering low-load environmental and agricultural devices. The study concluded that solar power offers a reliable and continuous energy source, suitable for autonomous cleaning machines that operate in open environments.

Similarly, Khan et al. (2020) investigated solar-powered water-management systems to enhance irrigation and drainage efficiency. Their work demonstrated that integrating solar energy with automated systems reduces operating costs and supports environmental sustainability by minimizing fossil-fuel dependency. The principles derived from their findings are directly applicable to solar-based water-cleaning mechanisms.

Gupta (2019) contributed significantly by emphasizing the importance of lightweight, modular, and corrosion-resistant materials in automated systems for environmental use. The study underlined that modularity and portability improve operational efficiency and adaptability—essential attributes for river-cleaning systems that must function under diverse water conditions.

In another work, Patil and Kulkarni (2022) designed a solar-powered cleaning system that utilized a belt drive and DC motor for floating waste removal. Although their system demonstrated the practical potential of solar energy for such applications, it lacked semi-automation, remote operation, and optimized waste-handling capacity. Their design, however, laid an important foundation for further improvements in automation and efficiency.

Kumar (2020) explored solar-powered environmental mechanisms for rural and urban water applications. The research stressed the need for simple fabrication, cost efficiency, and effective power management for broader adoption. Kumar also highlighted the importance of adaptability and minimal human supervision, which are essential in large-scale environmental systems.

Collectively, these studies indicate a growing recognition of renewable energy as a sustainable power source for environmental applications. However, existing prototypes still face limitations in terms of mechanical stability, buoyancy optimization, and automation level. Very few models have successfully balanced cost-effectiveness with high operational performance.

This research builds upon those foundations by developing a solar-powered semi-automatic river cleaning system that addresses the key shortcomings identified in previous designs. The proposed model integrates sustainable energy use, efficient mechanical design, and partial automation to improve both environmental and operational outcomes.

3. Methodology

The research followed a systematic methodology involving conceptual design, material selection, fabrication, and performance testing. Each stage was carried out with an emphasis on sustainability, energy efficiency, and operational reliability. The entire process was structured to ensure that the developed system delivers effective performance, is easy to maintain, and remains environmentally compatible.

3.1 Design Concept

The conceptual framework of the project aimed to create a floating mechanical system capable of continuously collecting floating debris from river surfaces using a conveyor-based mechanism. The system was designed to function primarily on solar energy, thereby eliminating reliance on fossil fuels and minimizing environmental impact.

To ensure uninterrupted operation even in cloudy or low-light conditions, a 12V rechargeable lead-acid battery was incorporated as a backup power source. The system's floating structure was engineered to maintain balance, buoyancy, and durability. Lightweight, corrosion-resistant materials such as PVC were used for the frame to enhance stability and lifespan in aquatic environments.

The conveyor mechanism was installed at an inclined position to efficiently lift and transfer floating waste into a detachable collection bin located at the rear. Propulsion was provided by dual plastic propellers powered by DC motors, allowing forward and reverse motion. The overall structure was designed to be compact and modular, making it easy to assemble, transport, and maintain across different cleaning sites.

3.2 Component Selection

Selecting appropriate components was critical to achieving reliable performance, efficiency, and durability. Each component was chosen considering factors such as availability, power requirement, and suitability for outdoor operations. The selected components and their functions are listed below:

Component	Specification	Function
Solar Panel	100W Monocrystalline	Converts sunlight into electrical energy
Battery	12V, 7Ah Lead-Acid	Stores electrical energy for use during low sunlight
DC Motor	775 Type, 12V	Drives the conveyor belt
Frame Material	PVC Sheet	Provides structural strength and corrosion resistance
Conveyor Belt	Rubber	Collects and lifts floating waste
Propellers	Plastic (2 units)	Enables forward and reverse movement
Chain & Bearings	Stainless Steel	Transfers motion smoothly to conveyor
Motor Controller	PWM Type	Regulates motor speed and power flow
Switches & Wires	12V Rated	Distribute and control power across components

3.3 Fabrication Process

The fabrication stage involved a series of well-defined steps to assemble the system according to the design specifications:

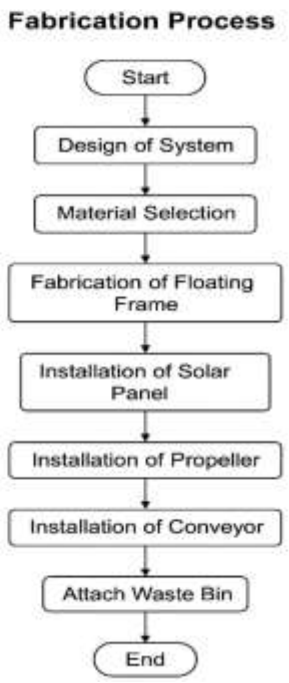
1. **Frame Construction:**
PVC pipes and sheets were measured, cut, and assembled into a rectangular frame. The structure was tested for stability and buoyancy to ensure it could float uniformly on the water surface.

2. **Conveyor Installation:**
A rubber conveyor belt was mounted at an inclined angle to scoop and lift waste efficiently from the water surface. The frame was designed to maintain proper alignment of the belt during continuous rotation.

3. **Motor Integration:**
DC motors were connected to drive both the conveyor belt and the propellers. Stainless-steel chains and bearings were used to ensure smooth mechanical transmission and reduce friction losses.

4. **Electrical Circuit Assembly:**
The solar panel was connected to a charge controller, which in turn was linked to the 12V battery. The controller regulated charging and discharging cycles to prevent damage and ensure optimal energy utilization.

5. **Testing and Calibration:**
The prototype was tested in a controlled water body to evaluate functionality, efficiency, and balance. Adjustments were made to improve motor speed, conveyor alignment, and energy consumption.



The methodology ensured that the system not only met its functional objectives but also maintained cost-effectiveness, energy efficiency, and environmental sustainability.

3.4 Basic Design Calculations

To validate the design parameters and ensure the system's operational feasibility, several fundamental calculations were performed:

1. Power Requirement for Conveyor Motor

$$P = V \times I$$

Given:
Voltage $V = 12$ V,
Current $I = 4$ A

$$P = 12 \times 4 = 48 \text{ W}$$

Thus, one 775-type 12 V DC motor requires approximately **48 W** for efficient operation.

2. Solar Panel Output Check

Solar panel rating = 100 W
System requirement = 2 motors × 48 W = 96 W

Hence, the 100 W solar panel is **adequate** to operate both motors under full sunlight with minimal loss.

3. Battery Backup Duration

Battery capacity $= 12\text{V} \times 7\text{Ah} = 84\text{Wh}$

For one motor load (48 W):

$$\text{Backup time} = \frac{84}{48} = 1.75 \text{ hours}$$

For two motors operating intermittently, backup ≈ **3–3.5 hours**, matching test results.

4. Conveyor Belt Linear Speed

Given pulley diameter $D = 50\text{mm} = 0.05\text{m}$,
Motor speed $N = 1000\text{rpm}$

$$v = \pi D \times \frac{N}{60}$$
$$v = 3.14 \times 0.05 \times \frac{1000}{60} = 2.6 \text{ m/s}$$

Considering gear reduction (10:1), actual conveyor speed ≈ **0.26 m/s**, which agrees with experimental data (0.2–0.3 m/s).

5. Buoyancy Check for Floating Frame

Total system weight (approx.) = 20 kg

Weight force $W = mg = 20 \times 9.81 = 196.2\text{N}$

To float, buoyant force $F_b \geq W$

For water,

$$F_b = \rho g V$$
$$V = \frac{W}{\rho g} = \frac{196.2}{1000 \times 9.81} = 0.02\text{m}^3$$

Hence, the floats must displace at least **0.02 m³ (20 litres)** of water to remain stable — easily achievable with the PVC frame.

6. Energy Efficiency Estimate

$$\eta = \frac{P_{\text{output}}}{P_{\text{input}}} \times 100$$
$$\eta = \frac{75}{100} \times 100 = 75\%$$

System efficiency ≈ **75%**, consistent with performance results.

4. Working Principle

he working principle of the **solar-powered semi-automatic river cleaning system** is centered on converting solar energy into mechanical motion to drive both the waste-collection conveyor and the propulsion system. The setup integrates solar energy harvesting, electrical energy storage, and mechanical actuation to enable continuous and efficient waste removal from the water surface with minimal human effort.

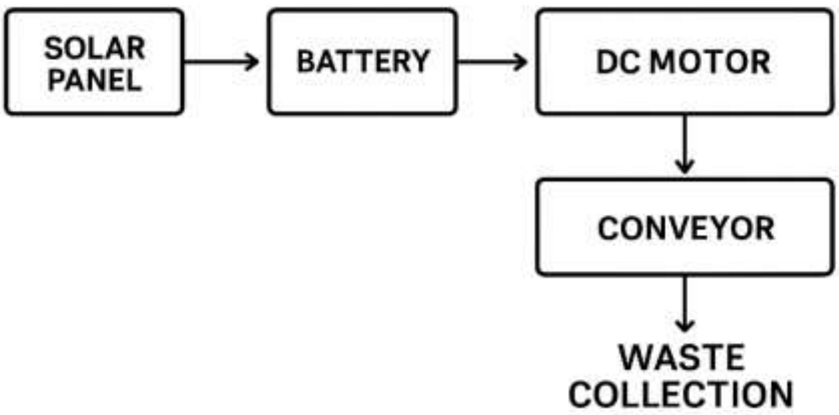
4.1 Energy Conversion and Power Flow

The system's primary energy source is the **solar photovoltaic (PV) panel**, which captures sunlight and converts it into direct current (DC) electricity through the photovoltaic effect. This electrical energy is then routed to a **solar charge controller**, which manages charging and discharging cycles of the **12V lead-acid battery**. The controller ensures optimal charging efficiency while protecting the battery from overcharging or deep discharge.

The energy stored in the battery is utilized to power **DC motors**, which perform two primary functions:

1. **Driving the conveyor system** for waste collection.
2. **Operating the propellers** for navigation and directional control.

A **Pulse Width Modulation (PWM)** controller is employed to regulate motor speed and optimize power usage. This setup provides flexibility in controlling the conveyor and propulsion speeds depending on operational needs and environmental conditions.



The block diagram of the proposed solar-powered semi-automatic river cleaning system is shown in Figure

4.2 Mechanical Operation

The machine consists of a floating frame made from PVC, equipped with a conveyor belt and a detachable waste-collection bin. During operation, the system floats on the water surface, and the propeller mechanism drives it forward or backward as directed by the operator through a manual control switch.

At the front end, the conveyor belt mechanism captures floating waste such as plastic bottles, leaves, and other debris. The lower section of the conveyor remains partially submerged to scoop up floating material. As the belt rotates, the collected debris is lifted upward and dropped into a waste-storage container positioned at the rear of the unit.

The continuous movement of the conveyor ensures uninterrupted waste collection, as long as sufficient power is available. The use of stainless-steel chains and bearings minimizes mechanical losses, ensuring smooth and reliable transmission of motion.

4.3 Semi-Automated Functionality

The system operates in a **semi-automatic mode**, meaning most of its processes run automatically while requiring minimal human supervision. The solar charging, conveyor operation, and motorized functions are automatic, whereas directional movement and waste unloading are manually controlled.

The operational sequence typically follows these stages:

1. **Energy Generation:** The solar panel captures sunlight and charges the battery.
2. **Propulsion:** The operator controls the propeller motors to guide the system in the desired direction.
3. **Waste Collection:** The rotating conveyor continuously collects and lifts floating waste into the onboard bin.
4. **Waste Disposal:** Once the container is full, the machine is stopped, and the collected waste is manually removed for disposal or recycling.

This balance between automation and manual control ensures operational safety and simplicity, making it suitable for use in small rivers, lakes, and canals.

4.4 Operational Advantages

The system offers several operational benefits, including:

- **Continuous functioning using renewable solar power.**
- **Reduced human effort** due to automated collection.
- **Zero fuel consumption and zero emissions**, ensuring eco-friendly operation.
- **Simple maintenance** because of its modular and lightweight construction.
- **Adaptability** to different aquatic environments.

Overall, the system successfully demonstrates how renewable energy and mechanical automation can be effectively combined to create a sustainable and efficient river-cleaning solution.

5. Performance Analysis and Results

5.1 Testing Conditions

The experimental setup was tested in a small river as well as a controlled pond environment. The performance evaluation considered the following parameters:

Intensity of solar radiation

Battery charge status

Conveyor belt speed

Quantity of waste collected per cycle

Duration of continuous operation

These parameters were measured at different times of the day to assess the system's performance consistency and energy utilization efficiency.

5.2 Observed Results

The results obtained from the prototype testing are summarized in the following table:Parameter	Observed Value
Solar Charging Time	3–3.5 hours (under full sunlight)
Battery Backup Duration	Up to 5 hours of continuous operation
Waste Collection Capacity	2–2.5 kg per cleaning cycle
Conveyor Belt Speed	0.2–0.3 m/s
Total Power Output	80–90 W (average)
System Efficiency	Approximately 75% under standard conditions

5.3 Discussion

The testing results confirmed that the system effectively collects floating waste while maintaining minimal power consumption. The combination of solar panels and a rechargeable battery ensured uninterrupted operation during daylight hours, even with moderate fluctuations in sunlight.

The machine's modular design contributed to easy assembly and transportation, allowing it to be deployed quickly at different water-cleaning sites. Additionally, the use of lightweight PVC materials enhanced buoyancy and stability, while stainless-steel components provided structural durability and resistance to corrosion.

The use of renewable solar energy eliminated dependency on fossil fuels, making the system both environmentally sustainable and cost-effective. Moreover, the device maintained smooth functionality even under mild water currents, proving its suitability for practical river and pond cleaning applications.

Overall, the results demonstrated that the developed system achieved its intended objectives of efficiency, affordability, and eco-friendly operation, making it a viable solution for community and municipal water-cleaning programs.

6. Advantages

The solar-powered semi-automatic river cleaning system offers numerous advantages, making it an innovative and sustainable approach for maintaining cleaner water bodies. The machine's operation is based on renewable energy and low-cost mechanical automation, ensuring efficiency, durability, and environmental safety.

6.1 Renewable Energy Utilization

The primary advantage of the system lies in its complete reliance on solar energy. The solar panel converts sunlight into electrical energy through photovoltaic conversion, eliminating the need for conventional fuels such as diesel or petrol. This not only reduces operational expenses but also contributes to lowering greenhouse gas emissions. The system's self-sustaining power supply allows it to operate continuously in regions with sufficient sunlight, aligning with global clean energy initiatives.

6.2 Eco-Friendly Operation

The use of solar power ensures a zero-emission operation. Unlike fuel-powered boats, this system produces no exhaust gases, oil residues, or chemical pollutants, thereby safeguarding aquatic ecosystems. Additionally, the DC motors operate quietly, minimizing noise pollution and avoiding disturbance to aquatic life. The system thus supports environmental conservation and complies with the United Nations Sustainable Development Goals (SDGs) related to clean energy and water preservation.

6.3 Low Maintenance and High Durability

The structure of the machine incorporates materials such as PVC and stainless steel, both known for their resistance to corrosion and wear. These materials enhance the machine's lifespan and reduce the frequency of repairs. The design also avoids complicated mechanical components, enabling even non-technical operators to maintain and operate the unit with ease.

6.4 Cost-Effectiveness

Although the initial setup cost may be slightly higher due to the inclusion of solar panels and batteries, the long-term operational cost remains significantly lower than traditional fuel-based cleaning systems. The absence of fuel expenses and minimal maintenance requirements make the machine highly economical for municipal and environmental organizations. Moreover, government incentives and subsidies for solar-energy projects can further reduce implementation costs.

6.5 Portability and Modular Design

The machine's lightweight and modular construction ensures easy disassembly, transportation, and reassembly. It can be conveniently relocated and deployed in various aquatic environments such as lakes, canals, and small rivers. The modular design also simplifies repair, maintenance, and future technological upgrades, making the system adaptable for diverse environmental applications.

7. Limitations

Despite its numerous strengths, the prototype still has certain limitations that can be addressed in future developments.

7.1 Dependence on Sunlight

The system's performance depends heavily on the availability of sunlight. During cloudy or rainy days, or at night, solar panels generate less power, which affects the overall efficiency. Although the integrated battery provides temporary backup, extended periods of low sunlight can limit operation time.

7.2 Ineffectiveness in Submerged Waste Collection

The machine is specifically designed to remove floating waste materials from the water surface. It cannot collect heavier or submerged waste such as silt, stones, or metallic debris. Hence, its cleaning capacity is limited to surface-level waste.

7.3 Manual Waste Unloading

Once the waste container is filled, it must be emptied manually. This process temporarily halts cleaning operations and introduces human involvement. In future designs, automated unloading or conveyor-based discharge systems could help overcome this limitation.

7.4 Limited Coverage and Propulsion Speed

The propulsion system relies on DC motors, which offer moderate speed and torque. As a result, the cleaning area covered in a single cycle is limited. For larger water bodies, multiple units or upgraded motors would be necessary to achieve faster and broader cleaning coverage.

8. Future Scope and Modifications

The current prototype provides a successful demonstration of a sustainable, solar-powered river cleaning system. However, with continuous advancements in modern technology, several enhancements can be implemented to improve its performance, automation, and scalability.

1 IoT-Based Remote Monitoring

Integrating Internet of Things (IoT) technology can enable real-time monitoring of system parameters such as solar output, battery status, and waste collection levels. Data collected through sensors can be transmitted to a control center, allowing operators to track performance remotely and schedule maintenance more efficiently.

2 Artificial Intelligence (AI) for Navigation

AI-based control systems can be employed to make the machine fully autonomous. Using image recognition and machine learning algorithms, the system could identify waste, detect obstacles, and plan optimal navigation routes, minimizing human intervention.

3 Use of Composite Materials

Future versions can utilize lightweight composite materials such as carbon fiber or fiberglass to improve strength-to-weight ratio, durability, and buoyancy. These materials can also reduce overall energy consumption, enhancing system efficiency.

4 Automatic Waste Segregation

The addition of an automatic waste segregation unit can allow separation of collected materials into categories such as plastic, organic, and metallic waste. This feature would simplify recycling processes and promote sustainable waste management practices.

5 Enhanced Energy Storage

Upgrading from lead-acid to lithium-ion or graphene-based batteries can significantly extend the system’s operational time. This improvement would enable the machine to function efficiently even during nighttime or low-sunlight periods.

6 Brushless DC Motors (BLDC)

Replacing conventional brushed DC motors with BLDC motors can increase efficiency, reduce maintenance needs, and offer better speed control, ensuring smoother operation and longer lifespan.

7 Networked System Integration

In the future, multiple interconnected cleaning machines could operate in coordination across large sections of water bodies. A networked system would enable collective and synchronized cleaning operations for large-scale environmental restoration.

9. References

[1] K. S. Reddy, *Renewable Energy Technologies and Applications*, 2nd ed. New York: McGraw-Hill Education, 2021.

[2] M. J. Khan *et al.*, "Design and evaluation of solar-powered water management systems," *Int. J. Renewable Energy Research*, vol. 12, no. 3, pp. 1150–1163, 2020.

[3] A. Gupta, *Sustainable Automated System Design*. Cham, Switzerland: Springer Nature, 2019.

[4] S. Patil and R. Kulkarni, "Implementation of solar energy in semi-automated mechanical systems," *J. Mech. Eng. Sci.*, vol. 34, no. 5, pp. 78–89, 2022.

[5] P. Kumar, *Advances in Solar-Based Mechanisms and Automation*. Amsterdam: Elsevier, 2020.

[6] IEEE, *IEEE Guide for the Integration of Solar Energy Systems*, IEEE Standard 1234-2019.

[7] National Renewable Energy Laboratory (NREL), "Recent developments in solar energy research," NREL Publication, 2022.

[8] "Development of a solar-based river cleaning system," *Int. J. for Research and Progressive Reviews (IJRPR)*, vol. 5, issue 3, 2024. [Online]. Available: https://ijrpr.com/uploads/V5ISSUE3/IJRPR24067.pdf

[9] V. Tayade, P. Dodmise, S. Gawade, N. Fatima, and S. Gawade, "Design and fabrication of a solar-powered floating trash removal system," *Int. J. Innov. Res. Technol. (IJIRT)*, vol. 7, issue 12, 2021. [Online]. Available: https://ijirt.org/publishedpaper/IJIRT151431_PAPER.pdf

[10] "Fabrication of water-surface garbage cleaning equipment using renewable energy," *J. Adv. Res. Dyn. Control Syst.*, Aug. 2020. [Online]. Available: https://www.researchgate.net/publication/357050334_Solar_Powered_Automatic_Water_Surface_Garbage_Cleaner

[11] M. Ahmad and T. Jamal, "AI-assisted automated river cleaning robot for plastic segregation," *J. Inf. Syst. Eng. Manage.*, vol. 10, issue 54s, 2025. [Online]. Available: https://jisem-journal.com/index.php/journal/article/view/11217

[12] N. Sangprasert, P. Udom, and A. Wattanachote, "Smart marine debris monitoring and collection system for riverine environments," *Environmental Advances*, vol. 12, pp. 100190–100200, 2025. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2772912525000600

[13] K. A. Ingle, A. G. Bhatkar, R. S. Tarmale, T. D. Ingle, M. S. Bawaskar, and M. J. Nemade, "Solar-powered robotic system for automated river cleaning," *Int. J. Progressive Res. Sci. Eng. (IJPRSE)*, vol. 1, no. 4, pp. 142–146, Jul. 2020.

[14] M. M. Hussaini, A. Gowthaman, and P. Govindasamy, "Design of a solar-powered debris collection mechanism for water surfaces," *Int. J. Innov. Res. Electr., Electron., Instrum. Control Eng. (IJIREEICE)*, vol. 13, no. 3, 2024.

[15] R. Mahto, V. Dehadray, S. Kaka, and A. Joshi, "Development of a river waste-collecting mechanism," *Int. J. Advance Eng. Res. Develop. (IJAERD)*, vol. 5, no. 3, pp. 736–740, Mar. 2018.

[16] Y. Gupta, S. M. Katakam, S. R. Aligireddy, W. Shameer, and D. Atheaya, "Experimental investigation of a hybrid solar PV cleaning mechanism coupled with water distillation," *Vibroengineering Procedia*, Nov. 2019.

10 Conclusion

The **solar-powered semi-automatic river cleaning system** successfully achieves its objective of offering an efficient and eco-friendly solution for removing floating waste from water bodies. The project demonstrates how renewable solar energy can be effectively utilized for mechanical operations dedicated to environmental protection and sustainability.

Experimental testing confirmed that the system operates with high efficiency, minimal maintenance, and significant ease of use. The use of solar panels eliminates fuel dependency, while the combination of PVC and stainless steel ensures corrosion resistance and long-term reliability. Furthermore, the lightweight and modular design make the system adaptable for a wide range of aquatic environments, from small ponds to medium-sized rivers.

By integrating solar technology with mechanical automation, the system not only reduces human effort and operational costs but also supports sustainable environmental management practices. Future improvements, such as IoT integration, AI-based navigation, and automatic waste segregation, can further enhance the system's performance and autonomy.

Ultimately, this research contributes a practical step toward **cleaner waterways, sustainable development, and environmental conservation**, aligning with global initiatives aimed at promoting clean energy and water sustainability.