International Journal on Theoretical and Applied Research in Mechanical Engineering

ISSN: 2319-3182

Volume 12 Issue 1 (2023) | Pages: 29-32

Advances in Solar-Powered Remote-Controlled Floating Lake Cleaners: A Review of Surface Debris Harvesting Technologies

Mahesh Borse[1], Dilip Singh[2], Manjunath Nimbalkar[3], Ashwini Admane[4*]

[1,2,3,4]Dept. of Mechanical Engineering, Indira College of Engineering and Management Pune, India

*Corresponding Author: ashwiniphalke65@gmail.com

Peer Review Information

Type: *Article*
Received: *03 May 2023*
Revised: *27 May 2023*
Accepted: *22 June 2023*
Published: *26 July 2023*

Abstract

Surface contamination in freshwater bodies caused by unmanaged floating solid wastes such as polyethylene packaging, PET bottles, beverage cans, and organic debris presents severe ecological, economic, and public health threats. Conventional remediation techniques rely primarily on manual netting, which exposes operators to hazardous environments, or heavy fossil-fuel-powered skimmers that incur high operational costs and introduce secondary carbon emissions. To address these challenges, recent research has focused on small-scale, solar-powered, remotely operated surface harvesting vessels. This paper presents a comprehensive review of the design principles, structural considerations, powertrains, and debris intake mechanisms utilized in floating lake cleaning technologies. It highlights the integration of twin-pipe PVC catamaran hulls, 70°C inclined chain-conveyor collection assemblies, auxiliary clearing arms, and Bluetooth-based propulsion controls powered by photovoltaic solar panels paired with energy storage units. Structural safety criteria, buoyancy margins, power autonomy, and financial feasibility are synthesized to outline current capabilities and future development vectors in automated freshwater maintenance.

Keywords: Review; Floating Lake Cleaner; Solar Photovoltaic Energy; Catamaran Hull; Debris Harvesting; Surface Water Remediation; Wireless Automation.

How to Cite This Article

Borse, M., Singh, D., Nimbalkar, M., & Admane, A. (2023). *Advances in solar-powered remote-controlled floating lake cleaners: A review of surface debris harvesting technologies*. *International Journal on Theoretical and Applied Research in Mechanical Engineering,* 12(1), 29–32.

Introduction

Rapid urbanization, industrial expansion, and inadequate waste disposal practices have severely impacted urban and rural freshwater bodies across developing nations. Low-velocity aquatic ecosystems—including lakes, ponds, drainage channels, and stagnant reservoirs—frequently serve as endpoints for floating solid wastes. This accumulation blocks water flow, generates foul odors, degrades aquatic ecosystems, causes animal mortality through plastic ingestion, and exacerbates urban flooding during high-rainfall events.

Traditional remediation relies either on direct manual labor or heavy industrial skimmer watercraft. Manual surface cleaning exposes municipal personnel to pathogenic waterborne vectors, toxic chemicals, and hazardous sewage gases. On the other hand, heavy fuel-driven skimmers require substantial capital investment, deep operating drafts, and ongoing fuel expenditures, while posing risks of oil spills and greenhouse gas emissions.

Consequently, research has shifted toward renewable energy-driven, low-draft, remote-controlled surface harvesting systems. Utilizing photovoltaic (PV) solar energy combined with battery storage, these systems drive mechanical conveyor belts to collect floating waste automatically or via wireless remote controls. This review evaluates the structural, mechanical, and electrical configurations of solar-powered floating lake cleaners, examining their operational dynamics, design criteria, economic impacts, and technological developments.

Overview of Surface Debris Harvesting Approaches

Efforts to clean freshwater surfaces have evolved through several technological generations:

- Manual Shoreline & Boat Netting: Requires direct human intervention using hand nets or rake attachments. While low in initial cost, it is labor-intensive, slow, inefficient for micro-debris, and hazardous to operator health.
- Fossil-Fuel Powered Skimmer Vessels: Large barges equipped with diesel-driven conveyor belts and hydraulic arms. Although capable of high payload capacities, their deep draft prevents operation in shallow or narrow water zones, and their fossil-fuel engines introduce secondary pollution.
- Hydropower-Driven Fixed Collectors: Stationary installations placed in flowing rivers or drainage channels that harness current kinetic energy or water wheels to scoop debris. These systems are highly efficient in flowing channels but ineffective in stagnant ponds or lakes.
- Pedal- and Human-Powered Watercraft: Low-cost floating collectors using pedal-driven paddle wheels or manual cranks. They eliminate fuel costs but cause operator fatigue over prolonged cleaning cycles.
- Solar-Powered Autonomous & Remote Surface Harvesters: Modern hybrid vessels combining photovoltaic energy, rechargeable battery banks, low-draft catamaran hulls, and chain or belt conveyor harvesters. They offer zero operational emissions, quiet operation, shallow-water maneuverability, and worker isolation from hazardous water conditions.

Key System Components and Structural Mechanisms

Hull Configuration and Buoyancy Architecture

The hull architecture determines vessel stability, draft depth, and payload capacity. Catamaran (twin-hull) configurations using Polyvinyl Chloride (PVC) cylindrical pontoon pipes are widely preferred over monohull designs for small-scale surface harvesters. Pontoons provide high roll stability, a low center of gravity, minimal hydrodynamic drag, and low displacement draft, enabling operation in shallow shoreline margins.

Conveyor and Intake Mechanism

The waste harvesting system typically employs a inclined conveyor mechanism positioned at the forward bow of the vessel.

- Incline Angle: An inclination angle around 70 ℃ relative to the waterline optimizes the balance between horizontal scoop reach into the surface debris layer and vertical lifting height into the collection hopper.
- Chain-Sprocket Assembly: Roller chain mechanisms equipped with L-shaped collection flappers or perforated scoops provide positive mechanical engagement, preventing waste slippage during vertical elevation.
- Auxiliary Mechanical Clearing Arm: Positioned near the conveyor entrance, a clearing arm or guide plate prevents floating items from jamming against the bow frame and directs scattered waste into the conveyor path.

Solar Photovoltaic and Energy Storage Powertrain

To maintain zero direct carbon emissions, modern designs use a hybrid solar-battery electrical architecture:

- Photovoltaic Array: Onboard solar panels convert solar radiation into direct current (DC) electrical power to continuously recharge the energy storage system during daytime operation.

- Energy Storage Unit: Rechargeable sealed lead-acid or lithium-ion battery banks buffer variations in solar irradiance and supply steady power to the conveyor gear motors and propulsion thrusters.
- Drive Motors: Permanent Magnet Direct Current (PMDC) gear motors are selected for conveyor drives due to their high torque output at low rotational speeds, enabling reliable lifting of wet waste payloads.

Wireless Control and Propulsion

Maneuverability is achieved through dual rear thrusters or submerged propeller units driven by independent DC motors. Differential thrust control allows differential steering without complex mechanical rudders. Wireless control interfaces such as Bluetooth modules or Radio Frequency (RF) transceivers allow operators to direct navigation, speed, and harvesting functions safely from the shoreline over distances up to 50 meters.

System Architecture

The overall functional layout and energy-material flow of a solar-powered remote-controlled floating lake cleaner is illustrated in Fig. 1.

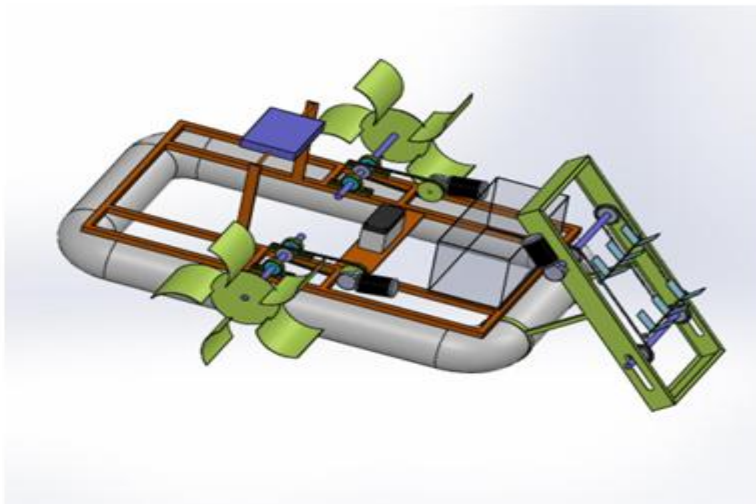

Fig. 1. *System architecture schematic of a solar-powered floating lake cleaner*

Design Considerations and Structural Reliability

Evaluating the structural reliability of surface cleaning watercraft involves several core mechanical considerations:

- Torsional & Bending Rigidity of Drive Shafts: Transmission shafts driving conveyor sprockets must be sized to withstand peak torsional moments induced by clogged waste loads without exceeding allowable shear stress limits of carbon steel materials (e.g., C45 grade).
- Welded Joint Structural Integrity: Chassis frames constructed from mild steel (MS) square tubing rely on fillet welded joints. Stress calculations must confirm that direct shear stresses on weld throats remain well below allowable endurance limits under maximum payload conditions.
- Flapper & Sprocket Fatigue Resistance: Collection flappers subjected to cyclic bending loads as they lift surface debris must maintain stresses below yield limits to prevent permanent deformation or weld fatigue failure.
- Hydrostatic Flotation Equilibrium: The total buoyant force generated by the displaced volume of the submerged pontoon hulls must significantly exceed the combined dead weight of the vessel frame, electrical components, and maximum rated garbage load. This ensures a high factor of safety against capsize or sinking under choppy surface conditions.

Environmental, Economic, and Operational Evaluation

Environmental and Safety Benefits

- Zero Direct Emissions: Utilizing solar energy eliminates fossil fuel combustion, preventing secondary carbon emissions, exhaust smoke, and potential fuel leaks in sensitive aquatic ecosystems.
- Operator Safety: Remote wireless control isolates personnel from direct exposure to contaminated water, hazardous biological waste, foul gases, and sharp floating debris.
- Ecosystem Restoration: Continuous removal of non-biodegradable plastics and organic waste reduces water stagnation, improves

dissolved oxygen levels, and prevents ingestion of synthetic materials by aquatic fauna.

Economic Feasibility

Compared to large commercial skimmers requiring high capital outlays and dedicated maintenance budgets, small-scale solar floating cleaners can be fabricated using readily available industrial materials (such as standard PVC piping, mild steel tubing, commercial chain drives, and standard solar panels). Fabrication costs remain exceptionally low, making them accessible for municipal water boards, local park authorities, private resorts, and agricultural pond operators.

Challenges and Future Research Directions

Despite their advantages, solar-powered floating harvesters face several operational constraints that guide future research:

1. Payload and Heavy Debris Limits: Compact conveyor drives are designed primarily for light surface waste (e.g., plastics, bottles, foliage). Submerged logs, heavy silt, or dense macro-debris require higher torque transmissions and larger hull structures.
2. Solar Energy Reliance: System runtime during overcast, rainy, or night conditions depends entirely on battery storage reserves. Integrating higher-efficiency solar cells and smart power-management sleep modes can extend operational autonomy.
3. Autonomous Navigation & Target Recognition: Current systems rely on manual remote control. Future developments aim to incorporate Computer Vision (CV) with Artificial Intelligence (AI) object-detection algorithms, GPS waypoints, and LiDAR/Ultrasonic sensors for fully autonomous debris tracking and obstacle avoidance.
4. Automatic Shoreline Unloading: Most current prototypes require manual emptying of onboard collection hoppers. Implementing automated tipping hoppers or dedicated dockside transfer conveyors will enable fully automated waste management loops.

Conclusion

Solar-powered remote-controlled floating lake cleaners represent a practical, economical, and sustainable alternative for freshwater surface remediation. By combining lightweight PVC catamaran pontoon hulls,70 ℃ inclined chain-conveyor mechanisms with L-flappers, and auxiliary clearing arms, these systems effectively harvest floating plastics, cans, and organic matter without secondary carbon emissions or worker exposure to hazardous environments. Structural analyses from literature demonstrate high safety margins across drive shafts, welded joints, chain sprockets, and pontoon buoyancy capacities. Future integration of autonomous GPS navigation, AI-driven debris detection, and automated shoreline dumping will further enhance operational efficiency, supporting sustainable global aquatic ecosystem management.

Acknowledgment

The authors acknowledge the guidance of faculty members, project coordinators, and institutional leadership at Indira College of Engineering and Management, Savitribai Phule Pune University, for supporting research in eco-friendly mechanical design and environmental remediation systems.

References

1. B. Rai, "Pollution and conservation of Ganga river in modern India," *International Journal of Scientific and Research Publications*, vol. 3, no. 4, pp. 1–4, Apr. 2013.
2. Y. Sharma, R. Helmer, and I. Hespanhol, "Case study I: The Ganga, India," *United Nations Environment Programme, Water Supply & Sanitation Collaborative Council and World Health Organization*, 1997.
3. P. Das and K. R. Tamminga, "The Ganges and the GAP: An assessment of efforts to clean a sacred river," *Sustainability*, vol. 4, no. 8, pp. 1647–1668, 2012.
4. R. Patil, R. Itnare, S. Ahirrao, A. Jadhav, and A. Dhumal, "Study of river harvesting & trash cleaning machine," *International Journal of Innovative Research in Science & Engineering*, vol. 2, no. 3, pp. 422–431, Mar. 2016.
5. W. Jianlong, "Point sources of pollution: Local effect and its control," in *Encyclopedia of Life Support Systems (EOLSS)*, Vol. II, Technology for Water Pollution Control, Beijing, China: Tsinghua University, pp. 1–10.
6. W. Radhuber, "Trashrack cleaning: The past, the present, the future," in *Proc. 15th International Seminar on Hydropower Plants*, Vienna, Austria, 2008, pp. 1–16.
7. J. E. Shigley, *Mechanical Engineering Design*, 6th ed. New Delhi, India: Tata McGraw-Hill, 2005.
8. R. S. Khurmi and J. K. Gupta, *A Textbook of Machine Design*, 1st ed. New Delhi, India: S. Chand Publishing, 1979.
9. T. Bevan, *The Theory of Machines*, 3rd ed. New Delhi, India: CBS Publishers & Distributors, 2005.
10. P. L. Ballaney, *Theory of Machines and Mechanisms*, 24th ed. New Delhi, India: Khanna Publishers, 2005.
11. V. B. Bhandari, *Design of Machine Elements*, 18th ed. New Delhi, India: McGraw-Hill Education, 2003.
12. PSG College of Technology, *Design Data: Data Book of Engineers*, Coimbatore, India: Kalaikathir Achchagam, 2003.