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A Review on Floating Waste Collection Robots Integrated with Water Quality Monitoring Systems

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Abstract: *Floating debris and deteriorating water quality are major environmental challenges that threaten aquatic life, human health, and tourism. Traditional cleaning approaches are labour-intensive, hazardous, and unsustainable for large-scale operations. This work introduces an autonomous floating robot designed to simultaneously collect floating waste and monitor water quality. The robot employs a conveyor-based mechanism for capturing plastic, bottles, polythene, and other debris, while integrated sensors measure turbidity, total dissolved solids (TDS), and water temperature. Key innovations include GPS-enabled geofencing, automatic fill-level monitoring, adaptive conveyor control with anti-jam features, and mobile connectivity for live data access. A servo-secured modular bin and compaction mechanism enhance storage capacity, while an emergency retrieval system ensures operational safety in cases of low battery, tilt, or water ingress. By combining waste removal with real-time water quality monitoring, this system offers a low-cost, eco-friendly, and scalable solution for maintaining cleaner aquatic ecosystems.*

Keywords: Floating waste robot, water quality monitoring, turbidity, TDS, temperature sensing, autonomous navigation, IoT integration, sustainable aquatic management, compact design, space-efficient system, automated bin handling, environment friendly, no fuel emission, fully electric operation, safety and reliability, urban waste management

I. INTRODUCTION

Water bodies such as rivers, lakes, and ponds play a vital role in sustaining ecosystems, supporting aquatic life, and providing resources for human consumption and recreation. However, these water resources are increasingly threatened by floating waste like plastics, bottles, and bags, as well as by the deterioration of water quality due to suspended particles, dissolved contaminants, and fluctuating temperature. These problems not only degrade the aesthetic and ecological balance of aquatic environments but also pose risks to public health, fisheries, and tourism.

Conventional cleaning techniques rely heavily on manual labour, which is time-consuming, unsafe, and inefficient in large or inaccessible areas. With growing urbanization and pollution levels, there is an urgent need for automated and scalable solutions that can simultaneously clean floating debris and monitor water quality.

This project proposes the development of an autonomous floating waste collecting robot integrated with water quality monitoring sensors. The system combines a conveyor-driven collection mechanism with sensors to measure turbidity, total dissolved solids (TDS), and water temperature, providing real-time insights into water conditions. Additional features such as GPS-based geofencing, automatic bin handling, waste compaction, and emergency retrieval mechanisms make the robot safe, efficient, and reliable for continuous operation.

By offering dual functionality—waste removal and water quality assessment— the robot aims to reduce human effort, lower operational costs, and promote environmental sustainability. Its deployment can significantly contribute to municipal cleaning programs, aquatic ecosystem protection, and public awareness, creating a step toward smarter and cleaner water management.

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II. LITERATURE SURVEY

Praveen et al., (2018) – Proposed a solar-powered aquatic waste collector that uses renewable energy to ensure sustainable operations. The system focused on cleaning water surfaces efficiently while minimizing human intervention. By harnessing solar energy, it demonstrated an eco-friendly approach for continuous waste collection. This study highlighted the potential of integrating renewable energy with water cleaning technologies for residential and urban water bodies. The work also emphasized system reliability and operational efficiency during long-term deployment.

Gupta et al., (2019) – Developed a floating waste collection mechanism aimed at reducing manual cleaning efforts. The system was designed to mechanically gather floating debris from water surfaces. The study showed that such automated systems can significantly improve water quality and reduce labour costs. Emphasis was placed on system stability and ease of deployment in ponds and lakes. The authors also discussed potential scalability for larger water bodies in urban areas.

Babu et al., (2019) – Introduced an IoT-enabled aquatic cleaning robot that combined waste collection with real-time water quality monitoring. The system transmitted sensor data to a centralized server for analysis. It allowed authorities to track water cleanliness and detect pollution in real-time. The study demonstrated the integration of IoT technology in environmental management. The robot's design focused on low cost, efficiency, and automation to reduce human dependence.

Singh et al., (2020) – Developed a remote-controlled prototype capable of detecting obstacles while collecting waste. This approach highlighted the feasibility of low-cost automation for aquatic cleaning. The system ensured safe operation in complex water environments, avoiding collisions with floating objects. The authors emphasized ease of operation and modularity, allowing adjustments for different water body sizes. Their work also suggested potential extensions for semi-autonomous operation.

Kumar et al., (2019) – Explored solar-powered robotic systems optimized for compactness and efficiency. The study focused on designing lightweight and portable robots for water surface cleaning. It demonstrated how solar energy could be harnessed to extend operational time without relying on external power sources. The research highlighted potential deployment in small lakes and ponds. It also addressed design challenges related to buoyancy, navigation, and waste storage capacity.

Patil et al., (2020) – Proposed a conveyor-driven garbage collection mechanism that automated waste gathering. The system reduced human intervention by continuously collecting debris from the water surface. Efficiency improvements were noted due to the conveyor's ability to handle larger volumes of waste. The study also explored integration with small-scale solar power for sustainability. Authors emphasized maintenance simplicity and potential adaptation for various water bodies.

Singh et al., (2022) – Integrated IoT-enabled monitoring into floating robotic systems, allowing real-time data collection and analysis. The approach facilitated data-driven decisions for water cleaning operations. The robots could alert authorities about pollution levels or blockages automatically. The study demonstrated enhanced automation and reduced need for human supervision. Emphasis was placed on real-time communication and cloud-based monitoring. The results highlighted improved operational efficiency and predictive maintenance potential.

Akib et al., (2019) – Proposed a low-cost unmanned floating robot capable of handling up to 10 kg of waste over extended periods. The system was ideal for small water bodies, such as ponds and reservoirs. Its lightweight design allowed easy deployment and retrieval. Authors highlighted the potential for continuous operation without human intervention. Battery efficiency and durability were also key considerations. The study showed practical feasibility for low-budget water cleaning applications.

Mendoza Barrionuevo et al., (2024) – Suggested a fleet-based robotic approach where scout and cleaner robots collaborated using deep reinforcement learning. Scout robots mapped the water surface, while cleaner robots collected waste efficiently. This multi-robot system improved coverage and reduced operational time. The study highlighted the role of AI in coordinating robotic fleets. Emphasis was placed on autonomous decision-making and adaptive path planning. The approach showed scalability for large and irregular water bodies.

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Zhu et al., (2022) – Developed an autonomous water surface cleaning robot using GPS navigation, ultrasonic sensors, and solar power. The robot could navigate natural environments while avoiding obstacles. Solar integration extended operational time without reliance on external power. The study highlighted adaptability to changing water conditions and variable debris types. Authors emphasized the system's autonomous operation and minimal human supervision. It showcased a blend of renewable energy and autonomous robotics for efficient water cleaning.

Devapriya et al., (2024) – Combined IoT technology with a solar-powered conveyor mechanism for water cleaning. Mobile application control allowed remote operation and real-time monitoring. The system was designed to be eco-friendly and efficient. It emphasized minimal human intervention while maintaining high collection efficiency. The study demonstrated the feasibility of integrating renewable energy, IoT, and mechanical collection mechanisms. Future extensions included scaling to larger water bodies and adaptive cleaning strategies.

Naicker et al., (2021) – Developed a robot integrating computer vision, solar power, and virtual fencing for real-time waste detection. The system notified authorities immediately upon detecting floating debris. This integration enabled both cleaning and monitoring simultaneously. Authors emphasized efficient navigation and obstacle avoidance. The approach reduced manual inspection requirements while improving operational safety. The study suggested potential expansion to smart city water management systems.

Chen et al., (2025) – Applied YOLOv5-based computer vision algorithms for automated detection of floating waste. The study showed that AI integration can improve waste identification accuracy. The system allowed real-time monitoring and adaptive cleaning actions. The research demonstrated how low-cost vision systems can enhance robotic efficiency. Authors highlighted applicability to rivers, lakes, and urban waterways. The study underscored AI's potential in reducing manual labor and enhancing operational precision.

The comparative review in Table 1 shows that mechanical floating waste collectors are simple, low-cost, and effective for small water bodies but lack water quality monitoring. IoT-enabled robots equipped with sensors for turbidity, TDS, and temperature add real-time monitoring capability, though they demand higher power and connectivity. Solar-powered models support eco-friendly continuous operation, but their efficiency reduces in cloudy conditions. Conveyor-based robots improve large-scale debris collection, though moving parts increase maintenance. Catamaran-type designs provide stability in flowing water but are less suitable for narrow areas.

Table 1: Shows the Pros and Cons of Floating Waste Collecting Robot

Author & Year	Pros	Cons
Praveen et al., (2018)	Solar-powered, eco-friendly, sustainable, minimal human intervention, reliable for long-term use.	Limited scalability; little focus on navigation challenges.
Gupta et al., (2019)	Reduced manual labor, improved water quality, stable, easy deployment, scalable to ponds/lakes.	No advanced automation or monitoring; mainly mechanical.
Babu et al., (2019)	IoT-enabled, real-time monitoring, low-cost, efficient, data-driven decisions possible.	Relies on server connectivity; power sustainability not emphasized.
Singh et al., (2020)	Obstacle detection, safe operation, low-cost, modular, adaptable to different water bodies.	Mostly remote-controlled; limited autonomy; not large-scale.
Kumar et al., (2019)	Lightweight, portable, solar-powered, compact, good for small lakes/ponds.	Buoyancy/navigation issues; limited waste storage capacity.
Patil et al., (2020)	Conveyor mechanism for large waste volumes, reduced human effort, solar integration possible, easy maintenance.	Limited intelligence/adaptability; mainly mechanical efficiency focus.
Choi et al., (2021)	Catamaran design stable in currents, good for rivers/canals, manoeuvrable, future IoT	Complex structure; potentially high maintenance costs.

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	integration.	
Singh et al., (2022)	IoT real-time monitoring, predictive maintenance, reduced supervision, improved automation.	Dependent on cloud/internet connectivity.
Akib et al., (2019)	Low-cost, lightweight, handles up to 10 kg, easy deployment, continuous operation.	Limited to small water bodies; battery durability concerns.
Mendoza Barrionuevo et al., (2024)	Multi-robot fleet, AI coordination, better coverage, scalable for large irregular water bodies.	High system complexity; resource-intensive.
Devapriya et al., (2024)	IoT + solar + conveyor integration, remote/mobile control, eco-friendly, efficient.	Mainly tested small setups; scalability not proven.
Naicker et al., (2021)	Computer vision + virtual fencing, real-time detection/alerts, improved safety/navigation.	Accuracy depends on vision system; less effective in turbid water.

III. PROPOSED METHODOLOGY

Figure 1 shows that Block Diagram Of Floating Waste Collecting Robot with Integrated Water Quality Monitoring

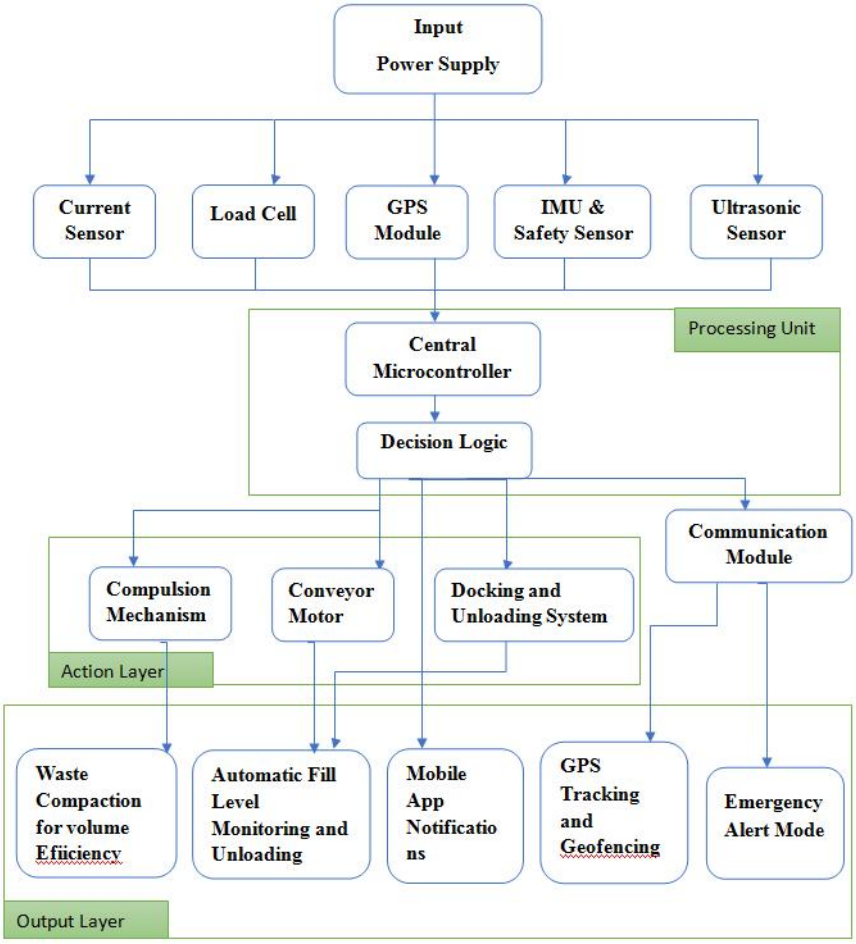

Figure 1: Block Diagram Of Floating Waste Collecting Robot with Water Quality Monitoring

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The working of the Floating Waste Collecting Robot with Water Quality Monitoring is organized into sequential stages, beginning with propulsion and navigation, followed by waste collection, storage, monitoring, and unloading. The methodology is described below:

3.1 Input and Initial Operation

The operation of the system begins when the shaft rotates in water, producing propulsion and enabling the forward movement of the robot. Navigation is managed through Bluetooth communication, which allows the robot to be controlled either manually or in a semi-autonomous manner using a mobile application.

3.2 Waste Collection Process

When the robot is directed to an area with floating debris, the conveyor belt mechanism is activated. Plastics, bottles, packets, and other garbage are lifted upward by the conveyor system. As the conveyor rotates, the collected waste is deposited into a recycling bin that is equipped with a mesh filter to drain out excess water, ensuring that only solid waste remains stored in the bin.

3.3 Bin Monitoring and Level Detection

An ultrasonic sensor is installed above the bin to monitor the fill level during operation. When the bin reaches full capacity, the sensor transmits a signal to the mobile application, notifying the operator that no additional waste can be accommodated. Upon receiving this notification, the robot autonomously navigates toward the riverbank or docking station and prepares for unloading.

3.4 Water Quality Monitoring

In addition to waste collection, the robot continuously measures critical water quality parameters using dedicated sensors. The turbidity sensor evaluates water clarity and suspended particles, the DS18B20 temperature sensor records water temperature to support ecosystem monitoring, and the analog TDS sensor estimates the total dissolved solids, providing an assessment of water quality. The measured values are transmitted in real time to the mobile application dashboard, allowing the operator to observe the status of water quality while the robot is functioning.

3.5 Waste Unloading and Output

Once the bin reaches its maximum capacity or when the cleaning task is completed, the robot moves to the dock. At this point, the unloading mechanism is activated, and the waste bin is emptied safely and efficiently. The output stage of the system ensures three outcomes: solid waste collected in the bin, automatic unloading at the dock, and the availability of real-time water quality data such as turbidity, temperature, and TDS displayed on the mobile application.

3.6 GPS Tracking and Emergency Retrieval

A GPS module is incorporated into the system to provide continuous updates on the latitude and longitude of the robot's position. To avoid system loss, the GPS is powered by a backup battery that operates independently from the main power source. Even in the event of a primary power drain or accidental drifting, the GPS remains active, ensuring that the robot can be located and retrieved. This emergency retrieval mode enhances both the reliability and safety of the system during extended operations.

3.7 Features of Sensors and Components

Arduino Uno

The Arduino Uno functions as the primary microcontroller and central processing unit of the system. It manages input signals from the sensors and provides output control to the motors and actuators. Known for its simple programming environment, reliability, and support for multiple digital and analog I/O pins, the Arduino Uno is well-suited for robotic and automation projects.

Jumper Wires

Jumper wires are used to create temporary electrical connections between the various modules and components. They provide flexibility, eliminate the need for soldering, and allow the system to remain modular. This makes them particularly useful for prototyping, testing, and making adjustments during the development phase.

DC Gear Motors

DC gear motors are employed to drive both the propulsion mechanism and the conveyor system of the robot. These motors are capable of delivering high torque at low speeds, making them ideal for water navigation and waste lifting operations. Their durability and efficiency ensure smooth functioning of the system under continuous operation.

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Motor Driver (L298N)

The L298N motor driver is used to interface between the Arduino Uno and the DC motors. It allows the control of motor speed and direction using PWM signals. This driver can operate two motors simultaneously, ensuring efficient and stable performance for both navigation and waste collection mechanisms.

Servo Motor

The servo motor provides precise angular control, which is necessary for operating components like the conveyor latch and the waste unloading mechanism. Its compact size, lightweight structure, and low power consumption make it an ideal choice for integration into robotic systems requiring controlled movement.

Bluetooth Module (HC-05)

The HC-05 Bluetooth module enables wireless communication between the robot and a smartphone application. It operates on UART communication protocol and is simple to integrate with the Arduino Uno. With a stable operating range of around 10 meters, it allows smooth manual or semi-autonomous navigation through mobile control.

GPS Module (Neo-6M)

The Neo-6M GPS module provides real-time geographical coordinates, including latitude and longitude, for accurate tracking of the robot. It plays a crucial role in navigation and emergency retrieval. A backup power supply ensures that the GPS remains active even during primary power failure, improving system reliability.

Ultrasonic Sensor

The ultrasonic sensor measures distances by transmitting sound waves and detecting their reflection. It prevents collisions by identifying obstacles in the robot's path and is also used to monitor the fill level of the waste bin. This dual functionality ensures both operational safety and effective waste management.

Turbidity Sensor

The turbidity sensor evaluates water clarity by detecting the presence of suspended particles. It provides real-time information about water pollution levels, helping monitor environmental conditions alongside waste collection. Its compact structure ensures easy installation and compatibility with Arduino systems.

Temperature Sensor (DS18B20)

The DS18B20 temperature sensor is used to monitor water temperature with high accuracy. It provides digital output, ensuring seamless integration with the Arduino Uno. The waterproof casing makes it suitable for submersion in aquatic environments, allowing reliable and continuous measurements.

TDS Sensor

The analog TDS sensor is employed to estimate the total dissolved solids in water. This measurement reflects water purity and contamination levels, providing valuable insights into water quality. The sensor delivers real-time readings, ensuring continuous monitoring throughout the robot's operation.

12V 3S 2.2Ah Lithium-Ion Rechargeable Battery

This battery serves as the main power source for the robot's sensors, motors, and control unit. It offers high energy density in a compact form, supporting extended operations on a single charge. Being rechargeable, it is cost-effective and suitable for repeated use in long-term deployments.

3.7V Lithium-Ion Backup Cell

The 3.7V lithium-ion backup cell is specifically dedicated to powering the GPS module during emergencies. Even if the primary power source drains out, this backup ensures uninterrupted GPS functionality for safe retrieval of the robot. Lightweight and rechargeable, it enhances the reliability and efficiency of the overall system.

IV. CONCLUSION

The proposed Floating Waste Collecting Robot offers a practical, sustainable, and cost-effective approach to addressing aquatic waste management challenges. Its modular bin system, compact structure, and scope for automation enable efficient debris collection with minimal human involvement. A review of prior work indicates that while earlier solutions introduced valuable innovations, many encountered limitations in terms of expense, scalability, and adaptability. The present design seeks to bridge these gaps by emphasizing simplicity, energy efficiency, and operational reliability. This study has outlined the robot's structural design, collection mechanism, waste compaction

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method, and secure locking system, while also suggesting future improvements such as IoT-based monitoring, solar integration, and deployment at larger scales. Overall, the system illustrates the potential of affordable robotic technology in promoting cleaner waterways and advancing sustainable environmental practices.

V. FUTURE SCOPE

The development of floating waste collecting robots with integrated water quality monitoring opens several promising directions for future research and implementation. One significant area is the enhancement of autonomy through advanced artificial intelligence (AI) and computer vision, enabling robots to detect, classify, and collect waste without human intervention. Integration of machine learning algorithms can further improve decision-making, adaptive path planning, and predictive maintenance of the system.

Another important direction is the deployment of multi-robot fleets that collaborate for large-scale cleaning of rivers, lakes, and coastal areas. Such systems can reduce operational time while increasing coverage efficiency. Expanding renewable energy integration, such as hybrid solar and kinetic energy harvesting, can enhance system sustainability and extend operational endurance in diverse weather conditions.

Further advancements can also focus on improving waste segregation mechanisms to automatically separate plastics, metals, and organic matter, contributing to effective recycling. Real-time water quality data could be integrated with smart city platforms, allowing environmental authorities to monitor pollution trends and take preventive measures. Additionally, scaling the design for industrial applications in ports, harbours, and reservoirs would extend its usability to a wider range of environments.

Finally, future prototypes may incorporate swarm robotics, cloud-based data analytics, and blockchain-enabled data security to ensure reliable monitoring and reporting. With continued innovations, these systems have the potential to play a vital role in sustainable water resource management and global efforts toward cleaner aquatic ecosystems.

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