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Oilfield Residuals Recovery and Waste Mitigation Program (ORRWMP)

[1]Muhasin K M, [2]Anfal Manaf C M, [3]Jibin Tojo, [4]Athul Krishna, [5]Mohmed Yaseen.

[1]Assistant Professor, [2]Student, [3]Student, [4]Student, [5]Student.

[1]Mechanical Department of Engineering,

KMEA Engineering College, Edathala

Abstract: The Oilfield Residuals Recovery and Waste Mitigation Program (ORRWMP) focuses on reducing water pollution caused by oil spills and floating waste. The project develops a multipurpose, solar-powered vessel that simultaneously removes oil contaminants and surface debris like plastics and garbage using conveyor-based collection systems.The belt-type oil skimmer works on the principles of adhesion and specific gravity. A polyurethane belt, which is oil-attracting and water-repelling, rotates through contaminated water and collects oil on its surface. Scraper blades then remove the oil into a storage container while the belt continues the cleaning cycle. Alongside oil removal, a separate conveyor collects floating solid waste.This integrated system improves water quality, protects aquatic life, reduces manual labor and safety risks, and is suitable for rivers, lakes, ponds, and other slow-moving water bodies.

Keyword: Oil skimmer, Water pollution, Floating waste, Solar powered vessel, Waste mitigation.

I. INTRODUCTION

Water bodies such as rivers, lakes, and seas are essential for ecosystems, freshwater supply, transportation, and human livelihood. However, they are increasingly polluted by oil spills and floating solid waste like plastics, bottles, and packaging materials. Oil contamination spreads rapidly on the water surface, reducing oxygen exchange, blocking sunlight, and harming aquatic organisms. At the same time, floating waste damages habitats, obstructs waterways, and contributes to microplastic pollution.

Conventional cleaning methods are often labor-intensive, time-consuming, and unable to handle both oil and solid waste efficiently at the same time. To address this issue, the Oilfield Residuals Recovery and Waste Mitigation Program (ORRWMP) proposes a boat-type oil skimmer with an integrated waste collection system. The system is designed to recover floating oil residues and collect debris such as plastic bottles and bags in a single operation.

The project aims to develop a safe, cost-effective, and eco-friendly solution suitable for rivers, lakes, and coastal or industrial areas. By reducing pollution loads and improving water quality, the system helps protect aquatic life, support sustainable environmental practices, and minimize manual cleaning efforts.

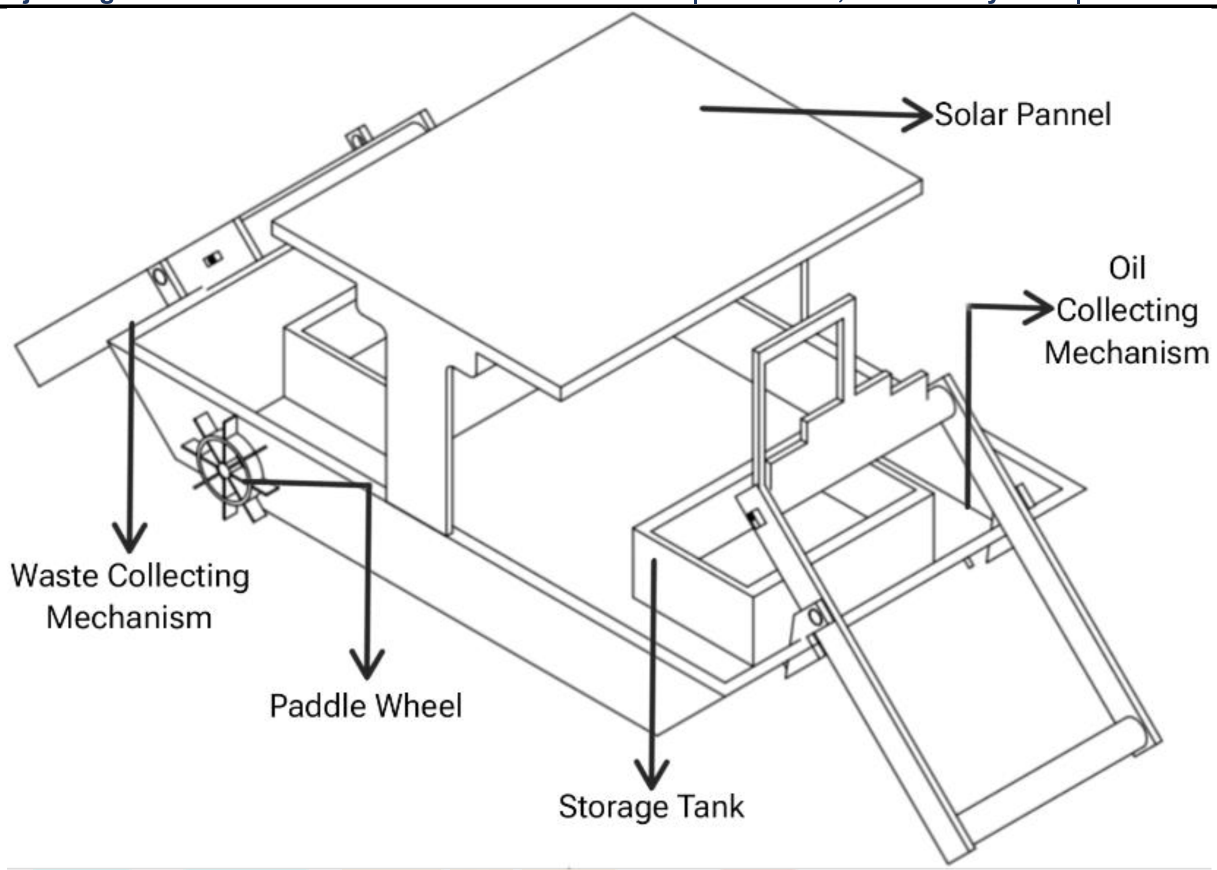
II. DESIGN

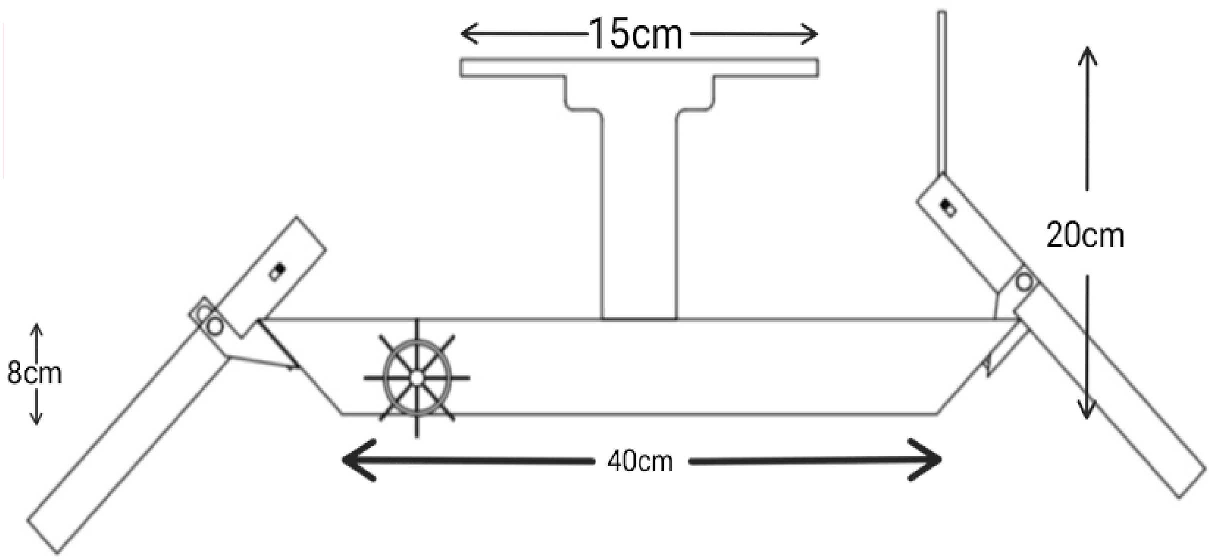
2.1 Design of Body

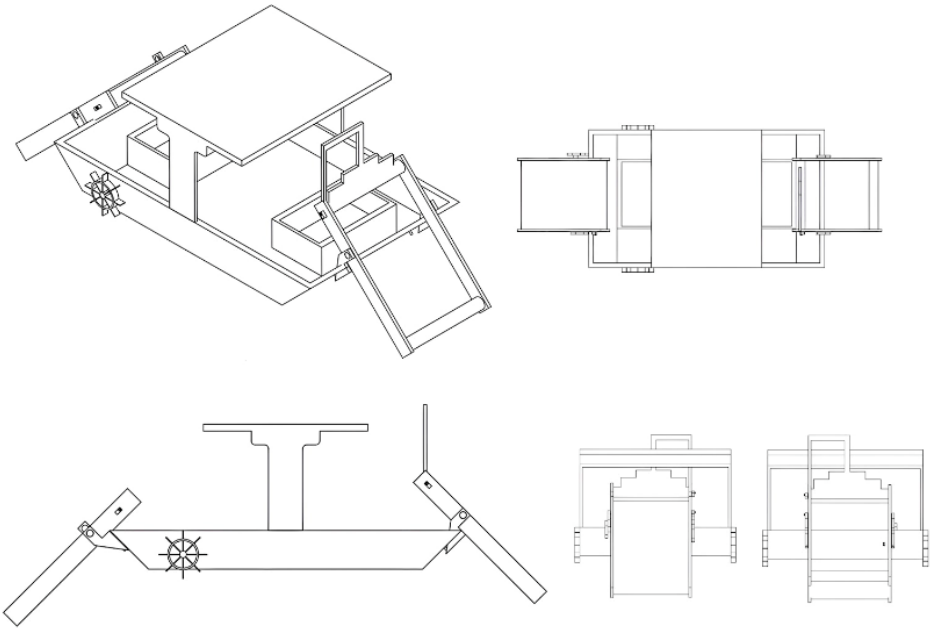
The Oil Contaminants and Plastic Waste Collection Vessel is a solar-powered, dual-purpose system designed to clean aquatic environments by removing floating plastic waste and surface oil contaminants. The vessel uses a forward-facing ramp with two integrated collection mechanisms that operate simultaneously.

A conveyor belt system collects floating debris such as plastic bottles, bags, and other waste materials, transporting them into a storage compartment inside the vessel. Alongside this, a belt-type oil skimmer made of hydrophobic material selectively absorbs oil from the water surface while repelling water. The collected oil is then scraped off into a separate storage tank.

The vessel is powered by solar panels that charge an internal battery system, enabling sustainable and eco-friendly operation. An electric propulsion system, such as a paddle wheel or propeller, allows the vessel to move efficiently across water bodies. Overall, the design provides an effective, autonomous solution for reducing both oil and plastic pollution in rivers, lakes, and other aquatic environments.


Solar Pannel
Oil
Collecting
Mechanism
Waste Collecting
Mechanism
Paddle Wheel
Storage Tank


15cm
20cm
8cm
40cm



2.2 Calculations

Total Mass, m = 5kg
Weight Of the System, W = mg
= 5×9.81= 49.05N

Buoyant Force, F = Density of water × Gravity × Volume of water displaced
= 1000×9.81×0.018 = 176.58N

Since Buoyant force (176.58N) > Weight of the system (49.05N), the system will float.

Centre of Buoyancy, B = Immersion Depth/2
Immersion Depth, d = W/pgA
= 49.05/1000×9.81×0.12 = 0.041m

Centre of Buoyancy, B = 0.041/2 = 0.02m

Moment of Inertia, I = BL3/12
= 0.3×0.43/12
= 0.0016m4

Metacentric Height, BM = I/V
= 0.0016/0.018
= 0.089m

Centre of Gravity, G = H/2
= 0.15/2
= 0.075m

Distance between B and G, BG = G - B
= 0.075 - 0.02
= 0.055m (5.5cm)

Metacentric Height, GM = BM - BG
= 0.089 - 0.055
= 0.034m (3.4cm)

Since GM > 0 , system will stable.

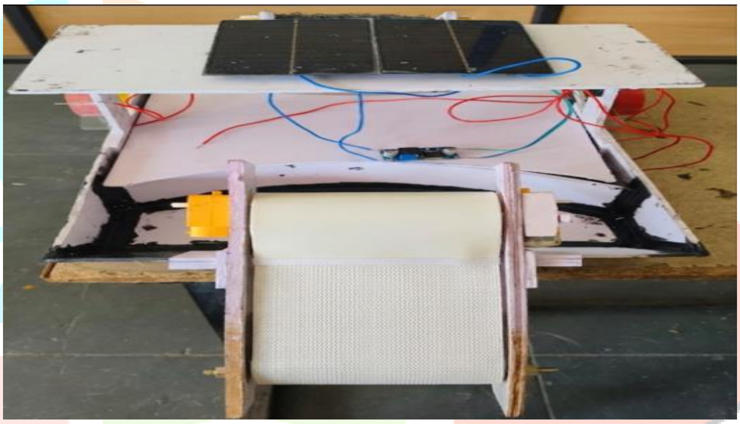
III. FABRICATION

Vessel Hull Structure:

The hull material used as "Form board" in the context of boat building is typically PVC (Polyvinyl Chloride) Foam Board. This is a closed-cell, rigid structural foam often used as the core in a composite sandwich construction, where it is laminated between layers of materials like fiberglass and epoxy resin. It is highly favored for marine applications because it provides an exceptional strength-to-weight ratio, making the vessel lightweight and buoyant. Crucially, its closed-cell structure makes it highly waterproof and impervious to moisture absorption, preventing the rot and corrosion issues associated with traditional materials, ensuring the boat's durability in the aquatic environment.

Belt-Type Oil Skimmer Mechanism:

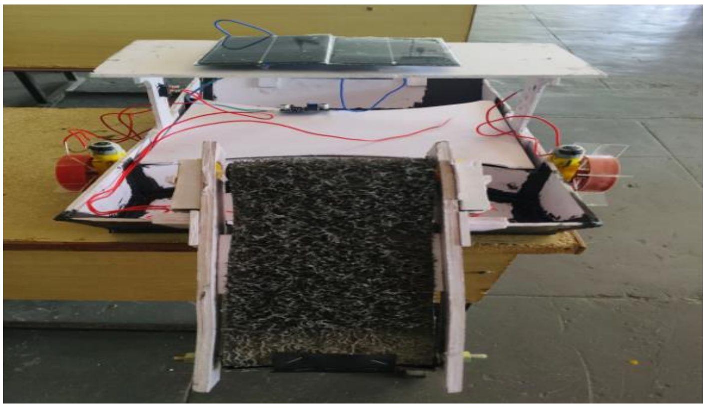
The belt-type oil skimmer system operates by exploiting the physical properties of oil and water. A rotating Polyurethane belt, which is oleophilic (oil-attracting) and hydrophobic (water-repelling), dips into the contaminated water. As the belt moves, it adheres the oil floating on the surface while repelling the water. When the belt completes its rotation, it passes through scraper blades or rollers located above the water line. These components effectively scrape or squeeze the collected oil off the belt's surface, directing the recovered contaminant into a dedicated collection tank. The clean belt then re-enters the water to repeat the process, enabling continuous and efficient removal of oil.



Oil Skimmer Mechanism

Belt-Type Waste Collecting Mechanism:

Modern waste collection mechanisms often utilize a conveyor-based system to automate the sorting and transport of debris. At the heart of this setup is a durable polymer belt, chosen for its flexibility and resistance to the harsh chemicals or moisture often found in refuse. This belt is tightly looped around a series of rollers, which provide the necessary tension and structural support to keep the surface flat and stable during operation. To drive the entire assembly, a high-torque BO motor (Battery Operated motor) is connected to the primary roller; this motor converts electrical energy into the mechanical rotation needed to pull the belt forward. As the motor turns, the polymer belt glides over the rollers, efficiently carrying collected waste from an entry point to a designated storage bin with minimal manual intervention.



Waste Collecting Mechanism

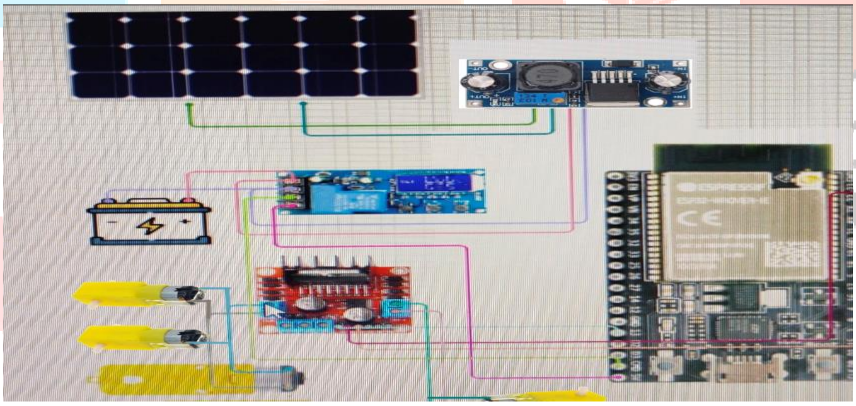
Propulsion System:

A paddle wheel propulsion system works quite a bit like a rowboat, but on a much larger and mechanical scale. It consists of a large wheel fitted with several flat boards, called paddles or floats, arranged around its outer edge. As the engine (or motor) turns the wheel, these paddles dip into the water and push backward. Because of Newton's third law of motion—every action has an equal and opposite reaction—the water pushes back against the paddles, forcing the entire vessel forward. Historically, these systems were popular because they were simple to build and worked well in shallow waters where modern propellers might get stuck or damaged. You usually see them in two styles: stern-wheelers, where the wheel is at the very back, or side-wheelers, where a wheel is mounted on each side of the boat. While they aren't as efficient as modern screw propellers in rough seas, they provide excellent maneuverability in calm rivers and lakes.

Paddle Wheel Mechanism

Electric Circuit System:

The system is a solar-powered electric circuit designed for an environmental cleanup vessel. Two 6V solar panels charge a 3.7V 5000mAh Li-Po battery, while an LM2596 buck converter regulates voltage for stable operation. A 30-pin ESP32 microcontroller controls the system and communicates with an L298 motor driver, which operates two 200 RPM BO motors for propulsion and four 100 RPM BO motors for the oil skimmer and waste collection mechanisms. Jumper wires connect all components, and a 2-way switch controls system power, enabling efficient and autonomous cleanup operations.



Electrical Circuit Diagram

Final Assembly

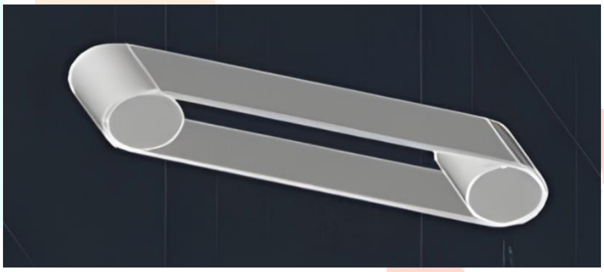
The final assembly of your ORRWMP (Oilfield Residuals Recovery and Waste Mitigation Program) prototype marks the transition from individual components to a functional, solar-powered environmental solution. This stage involves integrating the dual-function recovery systems—the belt-type oil skimmer and the conveyor system—onto the main vessel chassis, ensuring both are positioned for optimal contact with the water's surface. A critical step is the electrical synchronization, where the solar panels are linked to the battery storage and motor controllers to provide sustainable power to the collection mechanisms. Once the mechanical linkages are secured and the vessel is balanced for buoyancy, the prototype stands as a complete, autonomous unit ready to tackle oil and solid waste contamination in aquatic environments.

Final Fabrication

COMPONENTS

Conveyor

A Conveyor system consists of two main parts which are the conveyor belt and roller. The conveyor mechanism is controlled by using a motor driver circuit. This mechanism collects all floating garbages and oil contaminates from water. The conveyor is driven with the help of 2 DC motors with 100 rpm.



Conveyor Belt With Roller

Solar Panel

The most useful way of harnessing solar energy is by directly converting it into electricity by means of solar photo-voltaic cells. It consists of photovoltaic cells, which can be used to generate electricity through photovoltaic effect. This energy is used to charge the batteries and the output is given to DC regulators. In recent years photo-voltaic power generation has been receiving considerable attention as one of the more promising energy alternatives. The reason for this rising interest lies in PV's direct conversion of sunlight to electricity and the nonpolluting nature. In this system two 6V 10W polycrystalline solar panels is used.

Solar Panel

BO Motor

BO motor is a lightweight DC geared motor that provides good torque and RPM at lower voltages. It can run at approximately 100 and 200 RPM when driven by a single Li-Po cell, making it ideal for battery-operated lightweight robots. It operates with minimal or no lubrication due to its inherent lubricity. This motor set is inexpensive, small, easy to install, and well-suited for use in mobile robot cars, commonly used in 2WD platforms. In this project, we use six DC motors—four BO motors with 100 RPM to drive the both conveyor systems and two BO motors with 200 RPM to power the water wheel. 1.2 kg-cm torque, single-phase operation, a 6mm shaft diameter, 125g weight, and a frequency of 50/60Hz. This combination of motors ensures efficient power distribution and functionality in our project.

BO Motor

Lithium Polymer Battery

A Lithium-Polymer battery is a type of rechargeable battery composed of cells in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and back when charging. In this project we use an 3.7 V Lithium - Polymer battery.

Lithium Polymer Battery

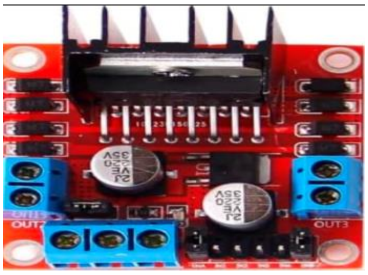
ESP32 Development Board With 30 Pin

The ESP32 30-Pin Development Board, specifically the DOIT DevKit V1 variant, is a high-performance, low-power microcontroller designed for Internet of Things (IoT) applications. At its heart lies the Dual-core Tensilica LX6 microprocessor, which can reach speeds of up to 240 MHz. This dual-core architecture is a significant advantage, as it allows one core to manage wireless connectivity background tasks while the other executes your primary application code, ensuring smooth performance even during heavy data transmission. With 520 KB of internal SRAM and 4 MB of flash memory, it provides ample space for complex scripts and local data storage.

ESP32 Development Board with 30 Pin

L298 Motor Driver Circuit Board

The L298N is a versatile dual H-bridge motor driver module designed to control the speed and direction of two DC motors or one stepper motor by acting as an interface between a low-power microcontroller and high-power motors. It operates by receiving logic signals to switch internal transistors, enabling it to handle motor voltages up to 35V and peak currents of 2A while providing features like an onboard 5V regulator and a heavy-duty heatsink to manage heat dissipation. Because it allows for independent control of two channels via Pulse Width Modulation (PWM), it is a staple component in robotics for driving wheeled platforms and actuators.



L298 Motor Driver Circuit Board

LM2596 DC-DC Buck Converter Step Down Module

The LM2596 DC-DC Buck Converter is a popular and versatile step-down voltage regulator module capable of driving a load up to 3A with high efficiency. It operates by taking a higher input voltage (typically between 4.5V and 40V) and reducing it to a lower, stable output voltage (ranging from 1.23V to 37V), which is adjustable via an on-board multi-turn potentiometer. Unlike traditional linear regulators that dissipate excess energy as heat, the LM2596 uses switching technology—specifically operating at a frequency of 150 kHz—to minimize power loss and reduce the need for large heat sinks. Its ease of use, integrated protection features like thermal shutdown and current limiting, and compact size make it a go-to component for DIY electronics, battery-operated devices, and prototyping power supplies for microcontrollers.

LM2596 DC-DC Buck Converter Step Down Module

Jumper Wire

A jumper wire is an electrical wire with a connector or pin at each end, designed to create temporary electrical connections between components on a breadboard or other prototype circuits. These wires are essential for testing and debugging because they allow for quick, solderless connections that can be easily rearranged as a circuit design evolves. They typically come in different lengths and colors to help organize complex layouts and are categorized by their connectors: male-to-male (with pins on both ends), female-to-female (with sockets), or male-to-female, depending on whether they are plugging into a breadboard or connecting directly to sensors and microcontrollers.

Jumper Wire

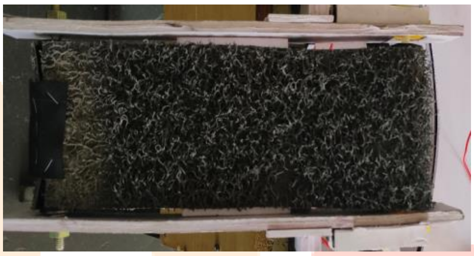
Polyurethane (PU) Belt

Polyurethane (PU) belts are versatile power transmission and linear positioning components known for their exceptional wear resistance and high tensile strength. Unlike traditional rubber belts, PU belts are manufactured from thermoplastic polyurethane, which makes them highly resistant to oils, greases, and many chemicals, ensuring a longer service life in harsh industrial environments. They are often reinforced with steel or aramid cords to prevent stretching, making them ideal for high-precision applications like 3D printers, CNC machinery, and synchronized conveying systems. Additionally, their clean, non-marking surface is a significant advantage in industries such as food processing and pharmaceuticals, where hygiene and product integrity are critical.

Polyurethane Belt

Polymer Belt

Polymer belts used in waste recovery are typically crafted from modular plastic links or high-strength reinforced polymers like polyurethane. These belts offer a distinct advantage over metal because they are naturally buoyant and corrosion-resistant, which is vital for long-term submersion in varied water conditions. Their lightweight nature minimizes the load on the drive motors—a critical factor for solar-powered systems where energy efficiency is paramount. Additionally, the smooth surface of the polymer prevents organic growth from sticking as easily as it might to metal, and the modular design allows for quick repairs; if one section is damaged by a sharp object, you can simply swap out a few links rather than replacing the entire conveyor.



Polymer Belt

Form Board

Foam board, also known as foam core, is a lightweight and easily cut material commonly used for mounting photographic prints, as backing for picture framing, and in 3D modeling. It consists of three layers: an inner core of polystyrene foam laminated between two outer sheets of paper (typically clay-coated or kraft paper). Because of its rigid structure and high strength-to-weight ratio, it is a favorite among architects and engineers for building prototypes and structural scales. While it is incredibly versatile and provides a smooth surface for adhesives and markers, it is generally intended for indoor use, as the paper layers can warp or delaminate when exposed to moisture.

Form Board

IV. RESULT AND DISCUSSION

The developed prototype boat was tested to check its performance in water. The tests were conducted to evaluate the buoyancy, oil collection, waste collection, and leakage test of the system.

Buyancy Test

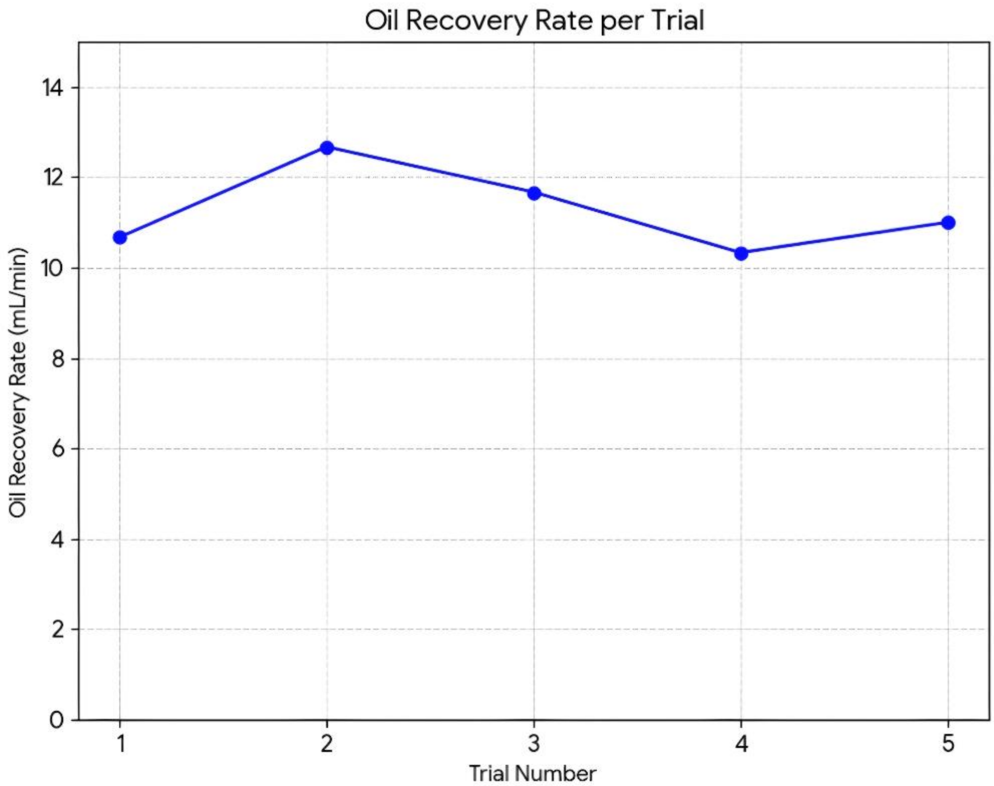
To verify whether the prototype can float safely under full operating load.
Parameters,

- Prototype length = 40 cm
- Prototype width = 30 cm
- Hull width = 9 cm
- Total loaded mass = 3.5 kg
- Water type = Freshwater

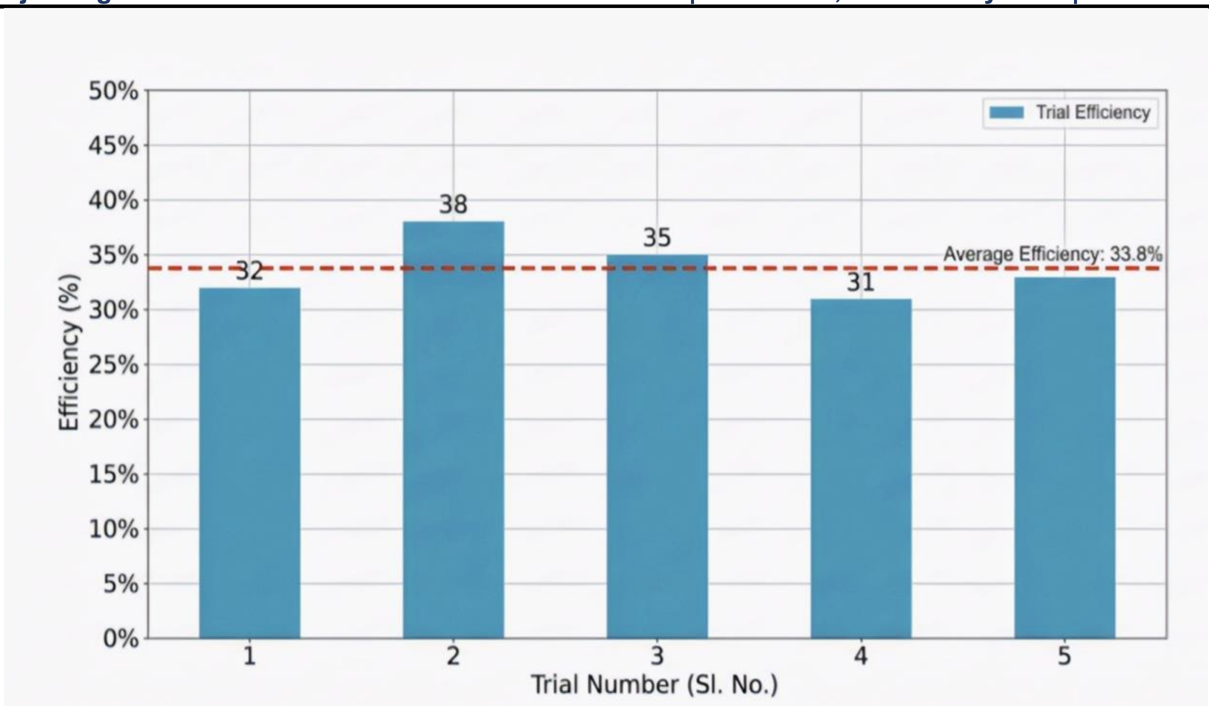
Trial NO.	Total Load (kg)	Draft (cm)	Freeboard (cm)	Floating Condition
1.	5	2	7	Stable
2.	5.3	2.1	6.9	Stable

Oil Collection Test

Trial No.	Time	Oil Added (mL)	Oil Collected (mL)	Oil Recovery Rate (mL/min)	Efficiency (%)
1.	3	100	32	10.67	32%
2.	3	100	38	12.67	38%
3.	3	100	35	11.67	35%
4.	3	100	31	10.33	31%
5.	3	100	33	11	33%



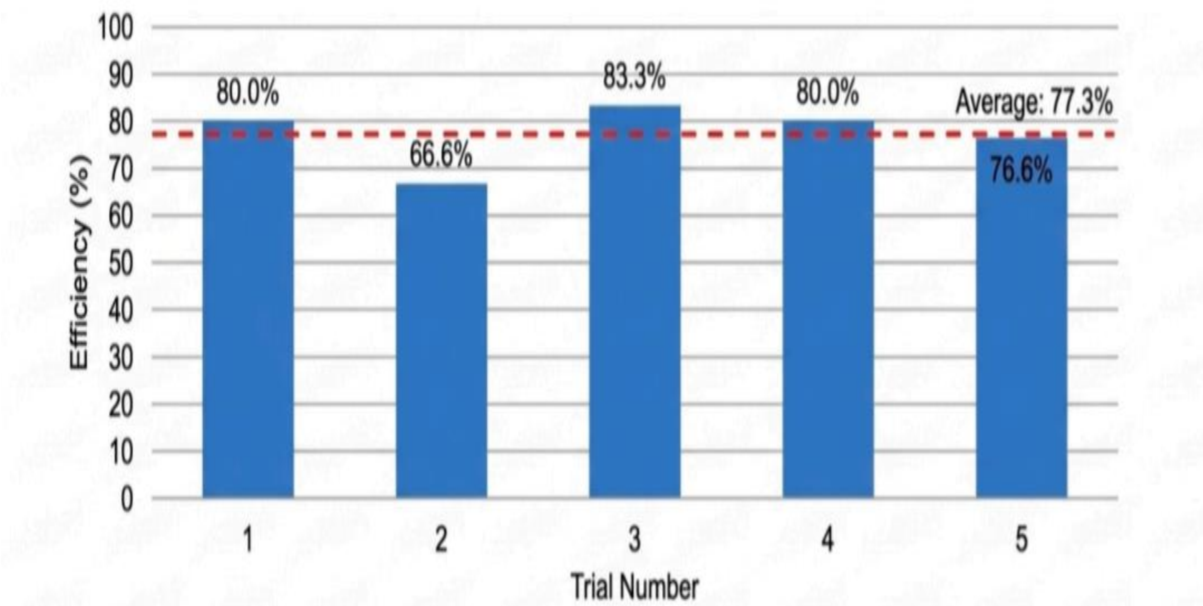
The graph shows the oil recovery rate across five trials. The recovery rate increased from about 10.7 mL/min in Trial 1 to a peak of around 12.7 mL/min in Trial 2. After that, it gradually decreased through Trials 3 and 4, reaching the lowest point near 10.3 mL/min, before slightly increasing again in Trial 5 to about 11.0 mL/min. Overall, the results show small fluctuations with Trial 2 having the highest recovery efficiency.



The bar graph shows the efficiency percentage for five trials. Trial 2 recorded the highest efficiency at 38%, while Trial 4 had the lowest at 31%. The average efficiency across all trials is about 33.8%, indicated by the red dashed line. Overall, the efficiencies vary slightly around the average, showing fairly consistent performance throughout the trials.

Waste Collection Test

Trial No.	Time	Waste Added (g)	Waste Collection (g)	Efficiency (%)
1.	3	30	24	80%
2.	3	30	20	66.6%
3.	3	30	25	83.3%
4.	3	30	24	80%
5.	3	30	23	76.6%



The graph shows the efficiency percentages for five trials. Trial 3 achieved the highest efficiency at 83.3%, while Trial 2 had the lowest at 66.6%. Trials 1 and 4 both recorded 80% efficiency, and Trial 5 showed 76.6%. The average efficiency across all trials is 77.3%, represented by the red dashed line. Overall, the results indicate generally high and consistent efficiency levels.

Leakage Test

SI No.	Test Duration (min)	Water Leakage Observed	Approx. Water Ingress (mL)
1.	10	No Visible Leakage	0
2.	20	No Visible Leakage	0
3.	30	No Visible Leakage	0

DISCUSSION

The developed prototype successfully demonstrated the basic functionality of an autonomous/semiautonomous surface cleaning system. The catamaran hull provided adequate buoyancy and stability for carrying the battery, skimmer mechanism, and waste collection units. The paddle wheel propulsion offered controlled low-speed movement suitable for oil skimming and floating waste collection. The polyurethane belt skimmer showed moderate oil recovery performance, while the conveyor system was effective in collecting lightweight floating waste. Minor structural and waterproofing limitations were observed, mainly due to the low-cost foam board construction, but these can be improved in future iterations using stronger materials and better sealing techniques.

V. CONCLUSION

The present project, “Oilfield Residuals Recovery and Waste Mitigation Program(ORRWMP)”, was successfully completed. The main objective of the project was to design and fabricate a low-cost prototype capable of collecting floating waste materials and recovering oil from the water surface.The developed prototype was designed using a catamaran hull structure to provide better buoyancy and stability. The system was equipped with a paddle wheel propulsion mechanism for movement, a polymer belt system waste collection unit, and a polyurethane belt oil skimmer for oil recovery. The boat was powered using a battery-operated electrical system, with provision for solar charging.The fabricated model was tested for buoyancy, oil collection, waste collection, and leakage test. From the test results, it was observed that the prototype was able to float safely, move effectively in water, and perform the intended waste and oil collection functions. The use of low-cost materials and easily available components made the prototype economical and suitable for academic demonstration purposes.Although the system is a small-scale prototype, the project successfully demonstrates the practical possibility of using such a mechanism for surface water cleaning applications. The developed prototype can be further improved in terms of automation, efficiency, and durability for real-world implementation.Thus, the project was found to be technically feasible, economically simple, and functionally successful for small-scale floating waste and oil skimming operations.

VI. FUTURE SCOPE

A solar-powered Oil Skimmer with Water Trash Collector has a bright future ahead of it, with lots of room to grow, develop, and use in other settings. The following are some possible directions for further development:

1. Improved Technology Combining Machine Learning and AI.

- Use cutting-edge algorithms to improve navigation, avoid obstacles, and gather oil and waste more effectively. AI is also useful for recognizing oil and different kinds of garbage.
- IoT Connectivity: Implement Internet of Things (IoT) technology to enable remote operation and data analysis through real-time monitoring and data sharing.

2. Adaptability and Personalization.

- Modular Design: Create modular parts that can be altered to meet the unique requirements of various bodies of water, including dimensions, oil type, debris types, and environmental factors.
- Fleet Operations: Establish mechanisms that enable the simultaneous deployment of several units, enabling more effective cleaning of greater regions.

3. More Wide-Ranging Uses.

- Urban Waterways: Modify the technology to be used in urban areas, where littering and stormwater runoff pollution are common.
- Along the coast and Marine Environments: Address more extensive problems with marine debris by extending the application to oceans and coastal regions.

4. Cooperation and Alliances.

- Public-Private Partnerships: Work together with private businesses, NGOs, and governments to finance and carry out projects in different areas.
- Community Involvement: Encourage a sense of ownership and accountability for nearby water bodies by including local people in the collectors' upkeep and operation.

5. 5.Investigation and Advancement.

- Environmental Impact Studies: Investigate how well the collectors work to enhance biodiversity and water quality in impacted areas.
- Material Innovation: Investigate making the collectors more environmentally friendly by using sustainable materials in their manufacture.

6. Regulation and Policy.

- Policy Influence: Utilize the oil collector's and garbage collector's data to inform national and local waste management and water quality regulations.
- Regulatory Compliance: Make sure the technology complies with environmental laws and guidelines encouraging its implementation in different jurisdictions.

7. 7.Worldwide Development.

- International Projects: Increase the use of solar-powered oil and water trash collectors in developing nations with serious water pollution problems while customizing the technology to meet local requirements.
- Disaster Response: Make use of technology in places affected by natural disasters to assist in clearing oil pollution and debris.

8. Opportunities for Growth.

- Global Market Potential: As more nations prioritize sustainability, there will probably be a greater need for solar-powered waste management systems, which will lead to the opening of new markets abroad.
- Adaptation in Diverse Environments: These systems can be modified to operate in isolated or off-grid locations, offering oil and waste management options when more conventional approaches are impractical.

9. Participation in the Community

- Public knowledge: Solar oil, garbage collectors can be used as teaching aids to increase community knowledge of sustainability and waste management.

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