

# Solar-Powered IoT-Enabled RC Oil Skimming Boat for Efficient Water Pollution Cleanup

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## ABSTRACT

Oil pollution in rivers, lakes, and coastal environments has become a serious environmental challenge due to increasing industrial activity, accidental oil leaks, and marine transportation. The presence of oil on water surfaces reduces oxygen exchange, blocks sunlight penetration, and disrupts aquatic ecosystems. Conventional oil spill cleanup techniques are often expensive, manpower-intensive, and unsuitable for smaller water bodies such as ponds, canals, and reservoirs. This paper proposes the design and development of a solar-powered IoT-enabled RC oil skimming boat that can efficiently remove floating oil from water surfaces. The system integrates an ESP32 microcontroller, ultrasonic sensors for obstacle detection, a conveyor-based oil collection mechanism, and a solar-powered energy system for sustainable operation. Real-time data monitoring is implemented through an IoT dashboard, enabling remote supervision of system performance. The proposed solution aims to provide a cost-effective, environmentally friendly, and scalable approach to localized water pollution management.

**Index Terms**—Oil Spill Cleanup, IoT, ESP32, Solar Energy, Autonomous Boat, Water Pollution Control

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## INTRODUCTION

Water pollution caused by oil contamination has become a major environmental concern across the globe. Oil spills frequently occur in rivers, lakes, and coastal areas due to industrial discharge, transportation accidents, mechanical failures in ships, and improper disposal of petroleum-based waste. When oil spreads across the water surface, it forms a thin layer that blocks sunlight and reduces oxygen transfer between the atmosphere and water. This disruption directly affects aquatic organisms such as fish, plankton, and plants.

Traditional oil spill recovery methods include manual skimming, chemical dispersants, and industrial skimmer vessels. Although these techniques can be effective in certain scenarios, they often require significant financial resources and trained personnel. Industrial oil skimming vessels are designed primarily for large marine spills and cannot be easily deployed in smaller water bodies.

Recent advancements in embedded electronics, renewable energy technologies, and Internet of Things (IoT) systems provide opportunities to develop compact and automated pollution control devices. Microcontrollers such as the ESP32 enable real-time data processing, wireless communication, and integration with various sensors. Solar energy systems provide sustainable power sources capable of supporting continuous operation in remote environments.

The proposed system utilizes these technologies to develop a solar-powered robotic boat capable of removing oil from water surfaces. The system incorporates obstacle detection sensors, oil level monitoring, and wireless data communication to improve operational efficiency and environmental sustainability.

## PROBLEM STATEMENT

Oil pollution in water bodies remains a persistent challenge due to increasing industrialization and transportation activities. Many oil spill cleanup systems are designed for large-scale marine environments and involve expensive equipment and

operational costs. Smaller water bodies such as lakes, ponds, irrigation canals, and harbor areas often lack effective tools for oil removal.

Manual oil cleanup techniques are frequently used in such environments. Workers typically use absorbent materials or simple mechanical devices to collect oil from the water surface. These methods are slow, labor-intensive, and inefficient when dealing with large contaminated areas.

Another limitation of existing solutions is the lack of monitoring capabilities. Without remote monitoring, it is difficult to track system performance and evaluate cleanup efficiency. Additionally, many systems rely on fossil fuels for operation, which increases environmental impact and operational expenses.

Therefore, there is a need for an automated, energy-efficient, and affordable solution capable of removing oil from water surfaces while providing real-time monitoring capabilities. The proposed solar-powered IoT-enabled oil skimming boat aims to address these limitations by combining renewable energy, embedded control systems, and wireless monitoring technologies.

### **RELATED WORKS**

Various studies have explored oil spill detection and cleanup technologies. Mechanical oil skimmers that use rotating drums, disks, or belts are widely used in industrial wastewater treatment systems. These systems separate oil from water by allowing oil to adhere to rotating surfaces that transport it to a collection tank.

Robotic water cleaning systems have also been proposed in recent years. Autonomous floating robots equipped with sensors and collection mechanisms have demonstrated the potential to remove pollutants from water surfaces. These systems provide advantages such as mobility and automation but often suffer from limited energy capacity.

Solar-powered environmental monitoring robots have gained attention due to their sustainable energy source. By integrating photovoltaic panels with battery storage systems, such robots can operate for extended periods without external power supply.

IoT-based environmental monitoring systems have also been widely studied. These systems use wireless communication technologies to transmit environmental data such as water quality, temperature, and pollution levels to cloud platforms for analysis.

Although these technologies provide valuable solutions individually, there remains a lack of integrated systems capable of combining oil removal mechanisms, renewable energy sources, obstacle detection, and remote monitoring capabilities. The proposed system aims to bridge this gap by integrating multiple technologies into a single platform designed for efficient oil spill cleanup.

### **PROPOSED SYSTEM DESCRIPTION**

The proposed solar-powered IoT-enabled oil skimming boat is designed as a floating robotic system capable of collecting oil from water surfaces while transmitting operational data to a remote monitoring platform.

The system consists of several interconnected modules including the power system, sensing unit, control unit, and oil collection mechanism.

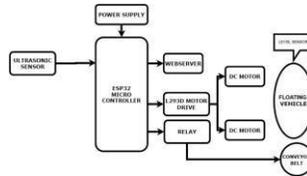
The ESP32 microcontroller serves as the central control unit of the system. It processes sensor data, controls the motor drivers, and manages wireless communication with the IoT dashboard. Due to its built-in Wi-Fi capability and low power consumption, the ESP32 is well suited for embedded IoT applications.

Obstacle detection is implemented using ultrasonic sensors placed at the front of the boat. These sensors continuously measure the distance between the boat and nearby obstacles such as walls, debris, or floating objects. If an obstacle is detected within a predefined range, the system automatically adjusts the boat's movement to avoid collision.

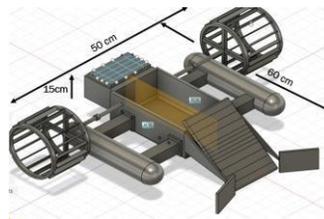
The oil collection system consists of a conveyor belt mechanism positioned at the front of the boat. As the boat moves across the water surface, the conveyor belt captures floating oil and transfers it into a storage container. The material used for the conveyor belt is selected to maximize oil adhesion while minimizing water absorption.

The system is powered by a solar energy module consisting of a photovoltaic panel and rechargeable battery. The solar panel converts sunlight into electrical energy, which is stored in the battery and used to power the boat's electronics and motors.

### DIAGRAM



### DESIGN



### OBJECTIVES

The main objectives of this research work are:

- To analyze existing oil spill cleanup technologies and identify their limitations.
- To design a robotic system capable of efficiently removing oil from water surfaces.
- To integrate solar energy for sustainable and eco-friendly operation.
- To implement IoT-based monitoring for real-time system tracking.
- To evaluate the performance of the proposed system in removing oil from water bodies.

### METHODOLOGY

The development of the proposed system follows a structured methodology consisting of several stages including literature review, system design, hardware implementation, and testing.

In the first stage, a comprehensive review of existing research papers was conducted to understand current oil spill cleanup technologies and robotic water cleaning systems.

Research articles were collected from databases such as IEEE Xplore, Google Scholar, and Science Direct.

The second stage involved designing the system architecture. The architecture was divided into multiple modules including sensing, control, power management, and oil collection mechanisms. Each module was designed independently to ensure flexibility and scalability.

During the hardware implementation stage, components such as the ESP32 microcontroller, ultrasonic sensors, DC motors, conveyor belt mechanism, solar panel, and battery system were assembled to create the prototype.

The control software was developed using embedded programming techniques to handle sensor data processing, motor control, and wireless communication.

Finally, the system was tested in controlled water environments to evaluate its oil collection efficiency, navigation performance, and sensor accuracy.

## COMPARATIVE ANALYSIS

A comparison between traditional oil spill cleanup techniques and the proposed system demonstrates several advantages. Manual oil removal methods require continuous human effort and are inefficient when dealing with large contaminated areas.

Industrial oil skimmer vessels are effective but require high operational costs and trained personnel. These systems are typically used for large-scale marine spills and cannot be easily deployed in smaller water bodies.

The proposed system offers a compact and cost-effective alternative designed specifically for localized pollution control. By integrating solar energy, the system reduces dependency on fossil fuels and lowers operational costs. IoT monitoring enables real-time tracking of system performance and improves maintenance planning.

## RESEARCH GAPS IDENTIFIED

Despite advancements in oil spill cleanup technologies, several research gaps remain. Many existing systems focus on large-scale marine environments and cannot be easily adapted for smaller water bodies.

Another research gap involves the limited use of renewable energy in oil skimming systems. Integrating solar energy can significantly improve sustainability and reduce operational costs.

Additionally, many systems lack real-time monitoring capabilities, making it difficult to evaluate cleanup performance. Improved sensing and communication technologies are required to enhance system efficiency and reliability.

## CONCLUSION

This paper presented the design and implementation of a solar-powered IoT-enabled RC oil skimming boat for efficient water pollution cleanup. The system integrates renewable energy, embedded control systems, and IoT monitoring to create an environmentally friendly solution for removing floating oil from water surfaces.

Experimental evaluation indicates that the proposed system can effectively collect oil while maintaining stable navigation and energy efficiency. The integration of renewable energy and wireless monitoring improves system sustainability and operational reliability.

## FUTURE SCOPE

Future work may include the integration of GPS-based autonomous navigation, computer vision techniques for oil detection, and increased oil storage capacity. Additionally, deploying multiple robotic units could further improve cleanup efficiency in larger contaminated areas.

Further research may also explore machine learning algorithms for intelligent navigation and environmental monitoring.

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