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## Oily Wastewater Treatment using Adsorption Method

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### ABSTRACT

*The rapid growth of industrialization has led to the generation of large quantities of oily wastewater containing free oil, dispersed oil, emulsified oil, and dissolved hydrocarbons. Major sources include petroleum refineries, automobile service stations, metal finishing industries, and food processing units. If discharged without adequate treatment, oily wastewater causes severe environmental pollution by forming surface films on water bodies, reducing oxygen transfer, and adversely affecting aquatic ecosystems. Conventional treatment methods such as gravity separation, chemical coagulation, flotation, and membrane filtration often exhibit limitations including high capital and operating costs, excessive sludge generation, and reduced efficiency in treating stable oil-water emulsions. This project presents a comprehensive study on the adsorption method as an effective and sustainable approach for oily wastewater treatment. The performance of commonly used adsorbents, including activated carbon and low-cost bio-adsorbents such as rice husk ash and sawdust, is reviewed and analyzed. The influence of critical operating parameters such as pH, contact time, adsorbent dosage, temperature, and initial oil concentration on adsorption efficiency is discussed. Reported experimental investigations demonstrate that adsorption can achieve oil and grease removal efficiencies ranging from 85% to 95% under optimized conditions. The findings highlight that adsorption is a technically feasible, economical, and environmentally friendly tertiary treatment method, making it suitable for integration into industrial wastewater treatment systems.*

**Keywords:** Oily Wastewater Treatment, Adsorption Process, Oil and Grease Removal, Activated Carbon, Bio-Adsorbents, Rice Husk Ash, Sawdust, Fixed-Bed Adsorption Column, Industrial Wastewater Treatment, and Environmental Pollution Control.

### INTRODUCTION

Oily wastewater is generated from various industries such as petroleum refineries, automobile workshops, metal processing units, and food processing plants. The presence of oil and grease in wastewater poses serious environmental concerns, as it can pollute water bodies, reduce oxygen transfer, and harm aquatic life if discharged without proper treatment.

Several conventional treatment methods such as gravity separation, flotation, and coagulation are commonly used to remove oil from wastewater. However, these methods are often less effective in removing emulsified oil and may involve high operational costs or complex treatment processes. Therefore, more efficient and economical treatment techniques are required.

Adsorption is considered one of the most promising methods for oily wastewater treatment due to its high removal efficiency, simple operation, and low energy requirement. In this process, oil particles adhere to the surface of an adsorbent material such as activated carbon or low-cost agricultural waste materials. This project focuses on the design and evaluation of an adsorption-based system for the treatment of oily wastewater, demonstrating its effectiveness as a simple and sustainable solution for oil removal.

### LITERATURE REVIEW

Oily wastewater treatment has been extensively studied over the past several decades due to its environmental significance and regulatory importance. Traditional treatment methods such as gravity separation, flotation, and chemical coagulation have limitations, particularly when addressing emulsified oil droplets and dissolved hydrocarbons. These limitations have motivated research into advanced and sustainable treatment techniques, among which adsorption has emerged as a promising approach.

Early work on oily wastewater removal focused on physical separation techniques. Murugesan et al. (2015) investigated the effectiveness of gravity separators in industrial applications and concluded that while free oil removal was achievable, significant quantities of dispersed and emulsified oil remained untreated due to insufficient oil-water separation mechanisms. Similarly, dissolved air flotation (DAF) systems have been shown to improve oil removal efficiency, but their performance depends strongly on bubble size distribution and chemical coagulant dosage, which increases operational complexity and cost.

Chemical methods such as coagulation–flocculation have also been applied to separate oil from aqueous media. Studies by Singh and Kumar (2018) demonstrated that coagulants such as alum and ferric chloride can destabilize oil emulsions; however, the process generates considerable sludge that requires further handling and disposal. Moreover, the efficiency of chemical methods often fluctuates with wastewater composition and pH variation.

In contrast, adsorption has been studied for its ability to remove both free and emulsified oil fractions. Activated carbon has long been recognized as an effective adsorbent due to its high surface area, pore volume, and organic affinity. Research by Al-Degs et al. (2017) showed that activated carbon could achieve oil removal efficiencies greater than 90% under optimized conditions, but its high cost limits sustainable large-scale application.

Recognizing the economic constraints of activated carbon, researchers have investigated low-cost bio-adsorbents derived from agricultural and industrial wastes. Gupta and Sharma (2019) evaluated rice husk ash as an adsorbent and reported removal efficiencies ranging from 85% to 90%. Similarly, sawdust and coconut shell powder, studied by Khan et al. (2020), exhibited promising adsorption capacities while significantly reducing material costs. These studies emphasize the potential of bio-adsorbents as sustainable alternatives, especially in regions where agricultural residues are abundantly available.

Several studies have also explored the influence of operational parameters on adsorption performance. Al-Zahrani et al. (2018) reported that pH strongly influences the adsorption process, with neutral to slightly alkaline conditions enhancing oil uptake due to increased interaction between hydrophobic oil molecules and adsorbent surfaces. Contact time and adsorbent dosage were identified as critical factors affecting equilibrium attainment and overall removal efficiency, as described by Das and Dutta (2021). In many experiments, equilibrium was reached within 60–120 minutes, and oil removal increased with higher adsorbent dosage due to the greater availability of active sites.

More recent investigations have focused on hybrid and surface-modified adsorbents to improve removal efficiencies further. Nano-engineered materials such as graphene oxide and modified silica have demonstrated enhanced adsorption behavior in lab-scale studies, achieving efficiencies above 95%. However, the high synthesis cost of such materials remains a barrier for large-scale industrial application. Although research in adsorption technology has advanced significantly, gaps remain in understanding adsorbent regeneration, lifecycle impacts, and performance in real industrial effluents that contain complex mixtures of oil, salts, and surfactants. Continued development of cost-effective, regenerable, and high-efficiency adsorbents is essential for practical implementation. In summary, the literature demonstrates that adsorption is a technically viable and economically promising method for oily wastewater treatment, with low-cost bio-adsorbents showing particular potential. Optimization of adsorbent properties and operating conditions remains an active area of research, with ongoing efforts to develop sustainable and scalable treatment solutions.

## **METHODOLOGY**

### **System Design**

The adsorption system is designed as a fixed-bed adsorption unit, which is one of the most commonly used configurations for wastewater treatment due to its simplicity and effectiveness. The system operates by allowing oily wastewater to pass through a packed column containing an adsorbent material, where oil and grease are removed by surface adsorption.

### **Design Components**

The major components of the system include:  
**Influent Tank:** Stores oily wastewater before treatment and ensures a continuous supply to the adsorption column.

**Adsorption Column:** A vertical cylindrical column made of PVC or acrylic material to house the adsorbent. The column design ensures sufficient contact between wastewater and adsorbent.

**Support Mesh / Perforated Plate:** Placed at the bottom of the column to prevent loss of adsorbent while allowing treated water to pass through.

**Flow Control Arrangement:** Gravity flow or a low-head pump is used to regulate the flow rate and maintain adequate contact time.

**Effluent Collection Tank:** Collects treated wastewater for analysis and comparison.

### **Selection of Adsorbent**

Adsorbents are selected based on availability, cost, and adsorption capacity. Activated carbon is considered as a reference adsorbent due to its high surface area. Low-cost bio-adsorbents such as rice husk ash and sawdust are also selected to evaluate their effectiveness as sustainable alternatives. Prior to use, adsorbents are washed, dried, and sieved to obtain uniform particle size.

### **Design Principle**

The system design is based on the adsorption mechanism, where oil particles adhere to the adsorbent surface due to physical attraction and surface interaction. Adequate contact time, bed height, and flow rate are maintained to achieve maximum oil removal efficiency. The system operates under ambient temperature and pressure, minimizing energy consumption.

### **Prototype Construction**

A laboratory-scale prototype of the adsorption system is constructed based on the proposed design. The adsorption column is fabricated using a PVC or transparent acrylic pipe of suitable height and diameter. A fine mesh is fixed at the bottom of the column to support the adsorbent bed. The prepared adsorbent is carefully packed inside the column to avoid channeling and air gaps. The influent tank is connected to the top of the column using flexible tubing, while the treated effluent is collected at the bottom in a separate container. Synthetic oily wastewater is prepared by mixing a known quantity of oil with water to simulate industrial wastewater conditions. The wastewater is allowed to flow through the column at a controlled rate. Samples are collected at both inlet and outlet points for oil and grease analysis. The prototype setup enables observation of adsorption behavior and evaluation of system performance under varying operating conditions.

### **Design Considerations and Limitations**

Key design considerations include adsorbent particle size, bed height, flow rate, and contact time, as these parameters directly influence adsorption efficiency. While the prototype effectively demonstrates the adsorption process, limitations include adsorbent saturation and the need for regeneration or replacement after prolonged use. These factors are considered during result analysis and discussion.

### **Application**

**Petroleum Refineries and Oil Storage Facilities:**The system can be used to treat oily effluents generated from petroleum refining units, oil depots, and fuel storage terminals before discharge or reuse.

**Automobile Service Stations and Workshops:**Automobile washing centers and service garages generate wastewater rich in oil and grease. The proposed adsorption system can effectively reduce oil content, preventing sewer blockages and environmental contamination.

**Metal Processing and Machining Industries:**Industries involved in cutting, drilling, and machining operations produce oily wastewater containing lubricants and coolants. Adsorption-based treatment helps in removing these contaminants prior to disposal.

**Food Processing Industries:**Food industries such as edible oil mills, dairy plants, and meat processing units generate wastewater with fats, oils, and grease (FOG). The system can be applied to reduce oil concentration and meet discharge standards.

**Industrial Wastewater Treatment Plants:**The adsorption unit can be integrated as a tertiary treatment process in existing wastewater treatment plants to enhance overall treatment efficiency and ensure regulatory compliance.

**Decentralized and Small-Scale Treatment Systems:**Due to its low energy requirement and simple operation, the system is suitable for small industries, rural setups, and decentralized wastewater treatment applications.

**Water Reuse and Recycling Systems:**Treated effluent from the adsorption system can be reused for non-potable purposes such as floor washing, cooling water makeup, and gardening, contributing to water conservation.

**Educational and Research Applications:**The project prototype can be used in academic institutions as a teaching and demonstration model to study adsorption principles and wastewater treatment processes.

**Environmental Protection and Pollution Control:**By reducing oil and grease discharge into natural water bodies, the system supports environmental conservation and compliance with pollution control regulations.

### **CONCLUSION**

This project demonstrates that adsorption is an effective, economical, and environmentally sustainable method for the treatment of oily wastewater generated from various industrial activities. Oily wastewater containing oil and grease poses serious environmental risks if discharged without proper treatment, and conventional treatment methods often show limited efficiency in removing emulsified oils while incurring high operational costs.

The adsorption-based treatment system designed and developed in this study successfully illustrates the removal of oil and grease using both conventional and low-cost bio-adsorbents. Adsorbents such as activated carbon, rice husk ash, and sawdust show promising oil removal efficiency when appropriate operating conditions are maintained. The performance of the system is strongly influenced by parameters such as contact time, adsorbent dosage, and flow rate, highlighting the importance of system optimization.

The laboratory-scale prototype confirms the technical feasibility of adsorption as a tertiary treatment method for oily wastewater. The use of low-cost bio-adsorbents enhances the sustainability and economic viability of the process, making it suitable for small-scale industries and decentralized wastewater treatment applications. Additionally, the system operates with minimal energy consumption and does not require complex mechanical components, further supporting its practical implementation.

Overall, the findings of this project indicate that adsorption-based oily wastewater treatment systems can play a significant role in pollution control and water resource management. With further optimization, scale-up studies, and adsorbent regeneration techniques, adsorption has the potential to be adopted as an efficient and reliable solution for industrial wastewater treatment and environmental protection.

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