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Assessment of Activated Carbon Adsorption for Dairy Wastewater Pollutant Removal

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Abstract: *This study evaluates the efficiency of activated carbon in removing pollutants from dairy wastewater. Batch experiments were conducted to analyze the effects of contact time, adsorbent dose, and pH on COD, BOD, and TDS removal. The adsorption process was assessed using isotherm and kinetic models. Results indicate that activated carbon is effective and feasible for treating dairy effluents*

Keywords: Dairy wastewater, Activated carbon, Adsorption, COD removal, BOD reduction, Isotherm models, Wastewater treatment, Environmental engineering

I. INTRODUCTION

The dairy industry generates large volumes of wastewater rich in organic matter, fats, and suspended solids, which can severely impact the environment if discharged untreated. Conventional treatment methods often struggle to meet discharge standards effectively. Adsorption using activated carbon has gained attention due to its high surface area, strong affinity for pollutants, and ease of application. This study investigates the use of activated carbon for removing key pollutants such as COD, BOD, and TDS from dairy wastewater. Batch experiments were conducted to optimize parameters like contact time, pH, and adsorbent dosage. The results aim to support the development of efficient and economical treatment methods for dairy effluents.

II. METHODOLOGY

Method Dairy wastewater was collected from a local dairy processing unit and characterized for parameters such as COD, BOD, TDS, pH, and turbidity. Activated carbon was used as the adsorbent in batch adsorption experiments. The study varied key parameters including contact time (30–180 minutes), adsorbent dosage (0.5–3.0 g/100 mL), pH (4–9), and initial pollutant concentration. Samples were agitated on a magnetic stirrer, and pollutant concentrations before and after treatment were measured using standard methods. Adsorption isotherms (Langmuir and Freundlich) and kinetics (pseudo-first and pseudo-second order) were applied to analyze the adsorption behavior and efficiency.

III. MODELING AND ANALYSIS

To understand the adsorption behavior of pollutants onto activated carbon, adsorption isotherm models and kinetic models were applied. The **Langmuir isotherm** was used to assume monolayer adsorption onto a homogeneous surface, while the **Freundlich isotherm** described multilayer adsorption on a heterogeneous surface. Experimental data were fitted to both models to evaluate adsorption capacity and affinity.

For kinetic modeling, **pseudo-first-order** and **pseudo-second-order** equations were applied to determine the rate and mechanism of adsorption. The best-fit model was selected based on correlation coefficients (R^2) and comparison between calculated and experimental values. The results helped in identifying the adsorption process as either physisorption or chemisorption and in optimizing parameters for maximum pollutant removal

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IV. EXPERIMENTAL SETUP

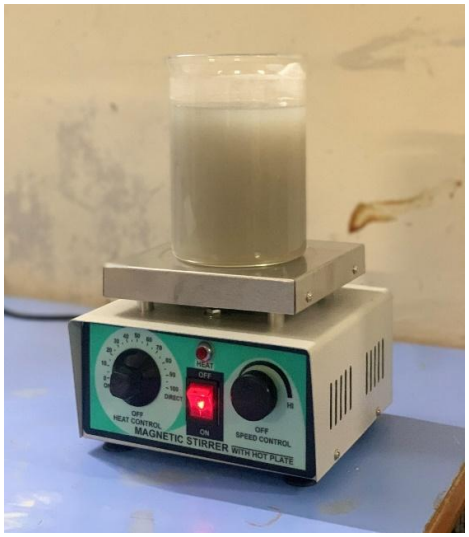

Figure1: 3D Experimental Setup

V. RESULTS AND DISCUSSION

The batch adsorption experiments demonstrated that activated carbon effectively removed pollutants from dairy wastewater. The maximum removal efficiencies achieved were 78% for COD, 74% for BOD, and 69% for TDS under optimal conditions of adsorbent dose (2.5 g/100 mL), contact time (120 minutes), and pH 6.5–7. Pollutant removal increased with higher adsorbent dosage and contact time, while extremely acidic or alkaline conditions led to reduced efficiency.

Adsorption isotherm analysis showed that the data fit well with the Freundlich model ($R^2 > 0.95$), indicating multilayer adsorption on a heterogeneous surface. Kinetic studies revealed that the pseudo-second-order model best described the adsorption process, suggesting that chemisorption was the rate-limiting step. These findings confirm the strong potential of activated carbon as a low-cost and efficient adsorbent for treating dairy wastewater.

The results align with previous studies and support the feasibility of using activated carbon in decentralized or small-scale treatment units. Future work could explore regeneration of used carbon and application to other industrial effluents.

Table 1. Pollutant Removal Efficiency Table

Parameter	Initial Concentration (mg/L)	Final Concentration (mg/L)	% Removal
COD	1200	264	78%
BOD	600	156	74%
TDS	1100	341	69%

Table 2. Pollutant Removal Efficiency Table

Adsorbent Dose (g/100 mL)	COD Removal (%)
0.5	42
1.0	55
2.0	72
2.5	78
3.0	77

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Table 3. Kinetic Model Fitting Results

Model	R^2 Value	Comments
Pseudo-first-order	0.87	Less accurate fit
Pseudo-second-order	0.96	Best fit – chemisorption

Table 4. Isothermal Model Constant

Model	Constant (K)	R^2 Value	Interpretation
Langmuir	0.032 L/mg	0.89	Monolayer adsorption (moderate)
Freundlich	1.98 mg/g	0.95	Heterogeneous surface adsorption

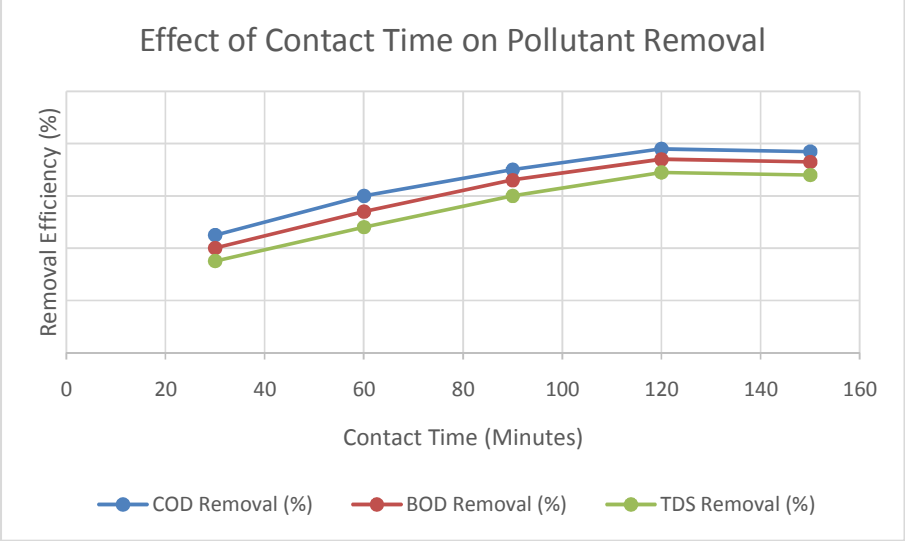

Figure2: Effect of Contact Time on Pollutant Removal

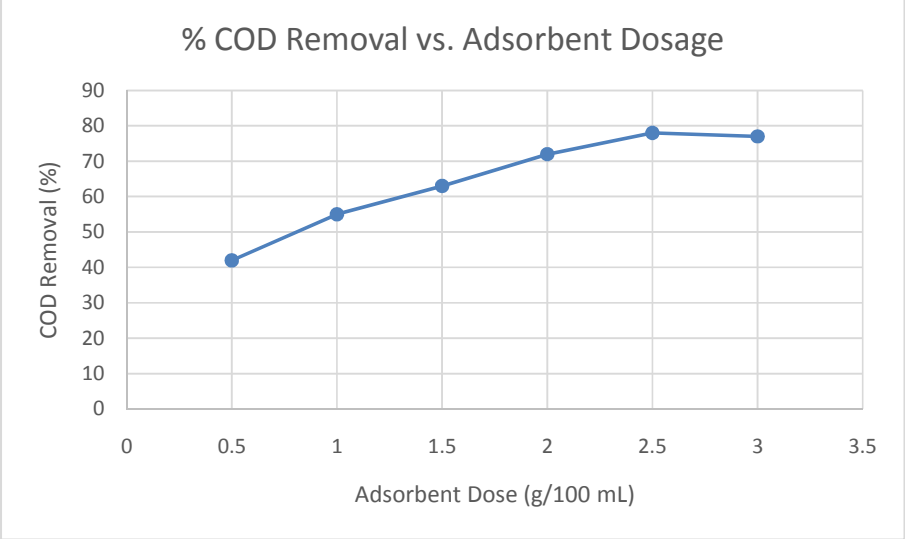

Figure 2:% COD Removal vs. Adsorbent Dosage

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VI. CONCLUSION

The study demonstrates that activated carbon is an effective adsorbent for removing organic and inorganic pollutants from dairy wastewater. Under optimized conditions, significant reductions in COD, BOD, and TDS were achieved, with maximum removal efficiencies of 78%, 74%, and 69% respectively. Adsorption behavior was best described by the Freundlich isotherm and pseudo-second-order kinetic model, indicating multilayer chemisorption on a heterogeneous surface. The results validate activated carbon as a cost-effective and efficient treatment option for dairy effluents. This approach can contribute to sustainable wastewater management, especially for small- and medium-scale dairy industries.

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