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INTEGRATED SYSTEM OF SEDIMENTATION, GREASE TRAP AND ADSORPTION FOR OIL AND GREASE REDUCTION IN WORKSHOP WASTEWATER

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ABSTRACT

Integrated System of Sedimentation, Grease Trap and Adsorption For Oil And Grease Reduction In Workshop Wastewater. *Workshops are significant sources of hazardous wastewater, classified as B3 waste due to the presence of toxic compounds that can endanger the environment and human health. This study aimed to design and evaluate a treatment system for workshop wastewater using sedimentation, grease trap, and adsorption processes. An experimental pretest–posttest with control group design was employed, involving 24 samples and six repetitions. Data were analyzed using the Kruskal–Wallis test to determine differences in oil and grease reduction across various contact times with activated carbon. Statistical analysis showed a p-value of 0.413 (>0.05), indicating no significant difference among contact time variations. The most effective treatment, combining sedimentation, grease trap, and adsorption, achieved an oil and grease concentration of 3.7 mg/L with a 15-minute contact time and 1000 mL activated carbon, corresponding to a 99.96% removal efficiency. This contact time was considered optimal when factoring in both performance and manufacturing cost. The findings demonstrate that while contact time variation did not significantly affect removal efficiency, the integrated process effectively reduced oil and grease to levels compliant with environmental standards. The developed system can serve as a low-cost alternative for small-scale workshops to manage liquid waste, minimizing environmental and health risks. Future studies are recommended to evaluate additional parameters such as total suspended solids (TSS), chemical oxygen demand (COD), and biological oxygen demand (BOD) for a more comprehensive assessment of treatment performance.*

INTRODUCTION

The automotive sector in developing countries has experienced rapid growth in line with the increasing mobility needs of the population. Alongside these advancements, however, significant environmental challenges have emerged, one of which is pollution caused by wastewater from vehicle repair workshops[1]. Such wastewater is generated from activities including oil changes, engine component cleaning, and vehicle repairs, all of which produce oily effluents containing hazardous chemical substances. A major component of this waste is used oil, which contains complex carbon compounds, including polyaromatic hydrocarbons (PAHs) that are both toxic and carcinogenic[2]. When discharged without treatment, this waste has the potential to contaminate surface water and soil, as well as pose risks to human health and other living organisms.

Wastewater from vehicle repair activities is classified as hazardous and toxic waste (B3) due to its high concentrations of toxic compounds and its harmful environmental characteristics [3]. B3 waste includes used oil, residual chemicals, packaging waste, and accidental spills generated during vehicle servicing. A preliminary survey conducted in Sei Besar Village found that each workshop produces an average of six liters of B3 waste per day. Alarmingly, this waste is commonly discharged directly into drainage systems without prior treatment[2], thereby increasing the risk of environmental contamination, especially since waste oil is highly resistant to natural degradation.

One critical parameter that must be controlled in workshop wastewater is oil and grease concentration. According to the Indonesian Ministry of Environment Regulation No. 5 of 2014, the maximum permissible concentration of oil and grease in wastewater is 10 mg/L[4]. Therefore, a simple yet effective treatment system is necessary to reduce these levels before discharge into the environment.

Physical methods such as sedimentation and grease traps are commonly used as preliminary treatment steps. Sedimentation facilitates the settling of coarse particles and a portion of the oil, while grease traps separate oil based on density differences[5][6]. However, these methods alone are insufficient to reduce oil and grease concentrations to below regulatory limits. Consequently, additional treatment such as adsorption is required. Activated carbon adsorption is widely applied due to the material's large surface area and strong affinity for organic compounds such as oil and grease[7].

This study aims to evaluate the effectiveness of an integrated wastewater treatment system combining sedimentation, grease traps, and adsorption using coconut shell-based activated carbon. The focus is on examining the effect of varying adsorption contact times on oil and grease removal efficiency. The findings are expected to provide a practical and cost-effective solution for small- to medium-scale workshops to manage their wastewater independently and in compliance with environmental quality standards.

MATERIALS AND RESEARCH METHODS

This study employed an experimental design to evaluate the performance of an integrated treatment process consisting of sedimentation, grease trapping, and adsorption, with variations in contact time using granular activated carbon derived from coconut shells. The experimental samples consisted of synthetic wastewater containing 5% used oil.

The research design was a pretest–posttest with control group design. The treatment system comprised one feed tank (capacity: 15 L) to regulate flow, one sedimentation tank (capacity: 10 L) with a retention time of 2 hours, one grease trap tank (capacity: 3 L) with a retention time of 30 minutes, and one adsorption tank with capacities of 1000 mL, 2000 mL, and 3000 mL. The adsorption tanks were filled with activated carbon and operated at contact times of 15, 30, and 45 minutes. The system was operated in continuous flow mode at a rate of 1.1 mL/s.

The experiment consisted of four treatments, each repeated six times, resulting in a total of 24 samples. The study was conducted at the Workshop of the Department of Environmental Health, while sample analyses were performed at the BTKLPP Banjarbaru Laboratory.

Data analysis began with a normality test. If the data were normally distributed, statistical analysis was conducted using a one-way ANOVA test. If the data were not normally distributed, the Kruskal–Wallis test was applied.

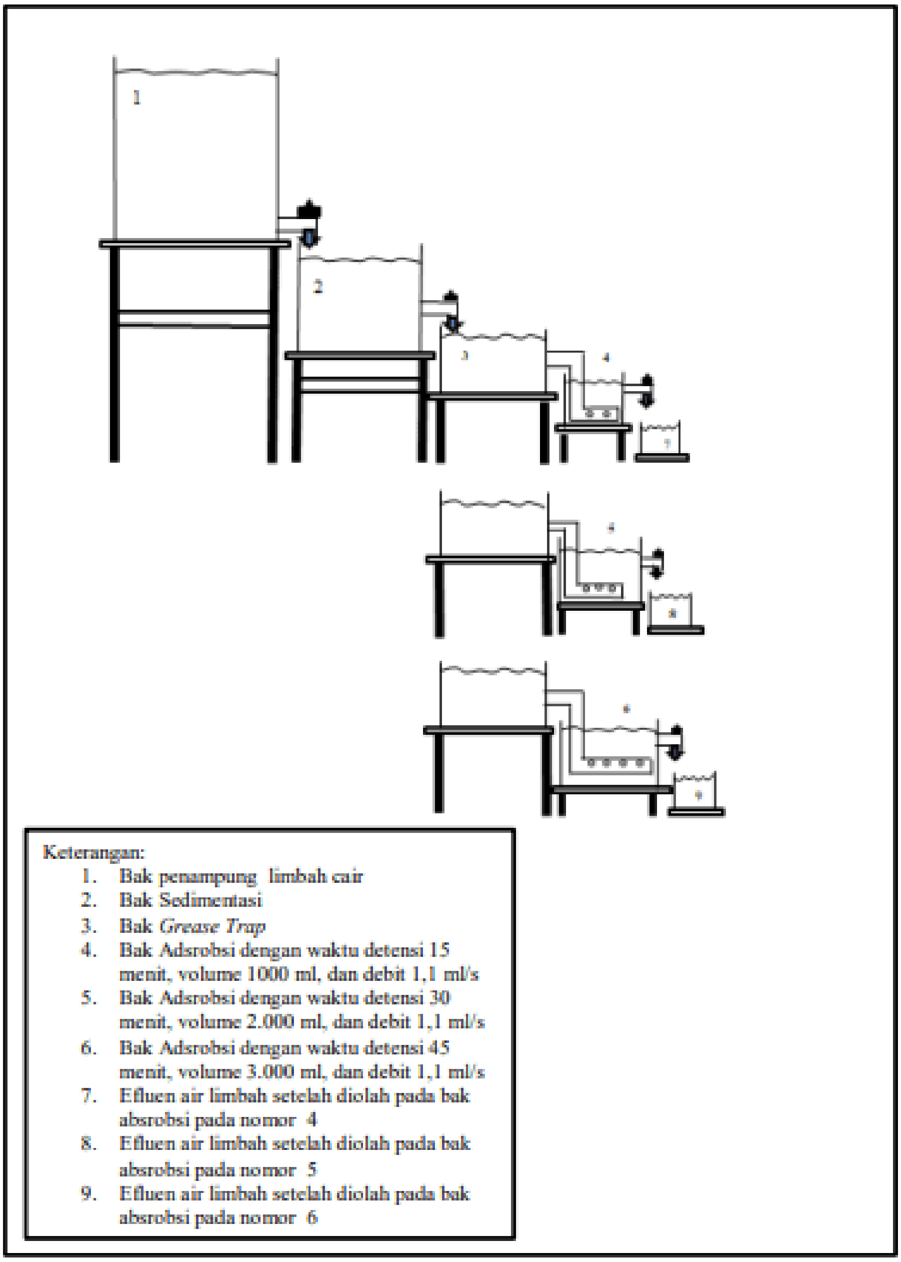

Figure 1. Schematic diagram of the workshop wastewater treatment system used in this study

RESEARCH RESULTS AND DISCUSSION

The wastewater used in this study was synthetic wastewater containing 5% used oil, sourced from a vehicle repair workshop on H.M. Cokrokusumo Street. Laboratory analysis revealed that the initial oil and grease concentration was 14,095.2 mg/L, with a temperature of 26.7 °C. This value far exceeded the permissible limit of 10 mg/L as stipulated in the Indonesian Ministry of Environment Regulation No. 5 of 2014 [4].

Table 1. Oil and Grease Content in Workshop Wastewater Before Treatment

No.	Parameter	Unit	Test Result	Quality Standard
1	Oil and Grease	mg/L	14,095.2	10 mg/L
2	Temperature	°C	26,07	–

Following treatment using the sedimentation and grease trap system, the oil and grease concentration decreased significantly to 6.0 mg/L, with a recorded temperature of 26.6 °C. These results indicate that the initial physical treatment stage was highly effective in reducing oil and grease levels in the wastewater.

Table 2. Oil and Grease Content in Workshop Wastewater After Sedimentation and Grease Trap Treatment

No.	Parameter	Unit	Test Result	Quality Standard
1	Oil and Grease	mg/L	6,0	10 mg/L
2	Temperature	°C	26,6	–

Following sedimentation and grease trap treatment, the process continued with an adsorption stage using activated carbon at three different contact times: 15, 30, and 45 minutes. The average oil and grease concentrations after adsorption varied across treatments. The 30-minute contact time achieved the best performance, with an average concentration of 3.7 mg/L, whereas the 45-minute contact time resulted in an increase to 20 mg/L, likely due to saturation of the adsorbent media.

Table 3. Oil and Grease Concentrations in Workshop Wastewater After Sedimentation, Grease Trap, and Adsorption with Activated Carbon at Different Contact Times

Contact Time	Parameter	Repetitiom						Mean	Quality Standard
		1	2	3	4	5	6		
Control	Oil & Grease	13300,4	11508,0	18680,4	16106,4	16524,0	2122,0	13040,2	10 mg/L
	Temperature	27,5	27,3	27,7	27,6	27,6	27,7	27,5	-
15 min	Oil & Grease	6,8	3,2	4,8	5,6	5,4	<0,5	4,3	10 mg/L
	Temperature	26,9	26,5	26,7	26,5	26,4	26,1	26,5	-
30 min	Oil & Grease	<0,5	13,2	4,0	4,0	<0,5	<0,5	3,7	10 mg/L
	Temperature	26,3	26,5	26,7	26,6	26,1	26,2	26,4	-
45 min	Oil & Grease	Outlier	66,0	13,2	20,0	<0,5	<0,5	20	10 mg/L
	Temperature	26,7	26,6	26,3	26,4	26,2	26,2	26,4	-

The removal efficiency was calculated based on the difference between initial and final concentrations for each treatment. The 30-minute contact time showed the highest efficiency at 99.97%, while the 45-minute contact time had the lowest at 99.85%.

Table 4. Removal Efficiency of Oil and Grease at Different Activated Carbon Contact Times

Contact Time	Removal Efficiency (%)
15 minutes	99,96
30 minutes	99,97
45 minutes	99,85

Normality testing indicated that the data were not normally distributed. Therefore, the Kruskal–Wallis test was applied, yielding a significance value of 0.413 ($p > 0.05$). This result indicates no statistically significant difference in oil and grease reduction among the different adsorption contact times.

In this study, workshop wastewater was fed from a 15 L holding tank and continuously channeled at a flow rate of 1.1 mL/s into a sedimentation tank for two hours, resulting in a treated volume of 7.92 L. Once the sedimentation tank was full, the effluent was directed into a grease trap for 30 minutes, yielding 1.98 L of wastewater. From the grease trap, the effluent was transferred into adsorption units containing activated carbon, with volumes of 1000 mL (15-minute contact time), 2000 mL (30-minute contact time), and 3000 mL (45-minute contact time).

As shown in Table 3, adsorption at a 15-minute contact time achieved an oil and grease removal efficiency of 99.96%, with a mean concentration of 4.3 mg/L, which meets the Indonesian discharge standard of 10 mg/L. Adsorption at a 30-minute contact time achieved the highest removal efficiency of 99.97%, with a mean concentration of 3.7 mg/L. This adsorption process occurs due to the attractive forces on the adsorbent surface, which bind adsorbate molecules. These forces are influenced by slight charge differences and van der Waals interactions, leading pollutant molecules to adhere to the activated carbon surface. A thin particle layer forms on the surface as a result of electrostatic attraction between the positively charged carbon surface and the negatively charged carboxyl groups of the pollutants [7].

In contrast, the 45-minute contact time resulted in an increase in concentration to an average of 20 mg/L (99.85% removal efficiency), likely due to saturation of the activated carbon surface [8–9]. Once the surface becomes saturated or nearly saturated with adsorbate, additional adsorption layers may form over the adsorbed layer, a process known as multilayer adsorption. Unadsorbed molecules may then diffuse out of the pores and return to the fluid stream. Studies investigating multilayer adsorption formation on surfaces that are saturated or nearly saturated with adsorbates have demonstrated various adsorption behaviors influenced by numerous factors and models. One significant threshold in this domain is the relative humidity (RH) point of approximately 0.2, beyond which multilayer adsorption, commonly associated with capillary condensation, can commence within micropores. Research indicates that multilayer adsorption can occur even at lower RH levels, particularly in confined spaces where surface phenomena are accentuated.

Experimental evidence supporting the diffusion of unadsorbed adsorbates out of confined pores and subsequently returning to the fluid stream has also been documented. For instance, in studies of gas-phase adsorption, factors such as pressure have been shown to influence adsorption dynamics, where unadsorbed molecules are capable of diffusing back into the gas phase, especially under conditions that promote their mobility. Additionally, investigations have reported that altering the conditions within porous media can facilitate the diffusion of adsorbates, demonstrating the impact of environmental conditions on adsorption kinetics. Various models accurately describe the transition from monolayer to multilayer adsorption on solid surfaces. The Langmuir and Freundlich models are widely recognized for their roles in characterizing adsorption phenomena—Langmuir typically applying to monolayer adsorption on uniform surfaces, and Freundlich being more suited for multilayer adsorption on heterogeneous surfaces. Moreover, the generalized Brunauer-Emmett-Teller (BET) model provides a robust framework for multilayer adsorption across a range of scenarios, effectively bridging monolayer formation to multilayer complex structures 5. Specific models like the two-layer model by Zhu and Gu elucidate the kinetics and distributions during the multilayer formation period 6, thereby refining our understanding of how adsorption proceeds from simple to more complex structures. [10–15].

Contact time plays a critical role in the adsorption capacity of activated carbon for oil and grease removal. Greater contact time generally increases adsorption until the optimal period is reached, beyond which no significant additional removal occurs. Numerous studies have investigated the effect of contact time on the adsorption capacity of activated carbon for oil and grease removal, revealing that contact time plays a crucial role in optimizing adsorption efficiency. Generally, the adsorption capacity increases with contact time due to the progressive occupation of available adsorption sites on the activated carbon surface. For instance, Fekry et al. demonstrated that oil adsorption capacity improved with increased contact time; however, it eventually plateaued as the pores of the activated carbon began to fill and become blocked, leading to diminished adsorption rates,. This suggests that while increasing contact time may enhance removal efficiency initially, there exists a point of diminishing returns where the rate of adsorption significantly declines as active sites become saturated. Moreover, the literature identifies an optimal contact time for maximizing oil and grease adsorption. Studies such as those conducted by Toamah and Fadhil indicate that an optimal contact time of approximately 20 minutes achieved the highest adsorption capacity for crude oil removal using activated carbon made from papyrus. Similarly, various other studies demonstrate optimal contact times ranging from 30 minutes to 2 hours in different experimental setups, which aligns with reported trends across various types and sources of activated carbon. Regarding how prolonged contact time influences adsorption kinetics, it is observed that longer contact times enable a more thorough occupancy of the available adsorption sites, ultimately affecting kinetic parameters. Fekry et al. noted that initially rapid adsorption kinetics slowed down as time progressed, indicating a transition from the fast initial phase (often described by pseudo-first-order kinetics) to a slower phase characterized by pseudo-second-order kinetics as the surface became increasingly saturated 7,10. Prolonged contact time allows for greater diffusion of the adsorbate into the porous structure of the activated carbon, which can lead to increased removal efficiencies, but also indicates that the adsorption may eventually reach equilibrium, where no significant changes are observed in the concentration of oil or grease adsorbed[16–20].

This is consistent with the findings of Irwandi et al. (2015), who demonstrated that increasing contact time from 30 to 90 minutes enhanced Pb removal efficiency using 1 g, 2 g, and 3 g of activated carbon. However, adsorption capacity declined after 120 minutes due to surface saturation, where the available active sites became insufficient relative to the number of ions in the solution. Several studies have explored the relationship between contact time and activated carbon's adsorption capacity for lead (Pb) removal. Research by Kra et al. indicated that the adsorption capacity of lead ions on activated carbon significantly increases with contact time, with optimal adsorptive performance often achieved within a defined window before plateauing as adsorption sites become saturated. The study reported that higher adsorption efficiencies correlate with increased contact times and other variables such as temperature and initial Pb concentration.

There is also evidence suggesting that adsorption capacity can decline after prolonged contact times, often due to the saturation of the activated carbon surface. When the majority of available adsorption sites are filled, further uptake of lead ions may be limited. For instance, investigations by Igbemi et al. revealed that beyond an optimal time, competitive adsorption processes or desorption can occur, leading to a decrease in lead removal efficiency. The desorption phenomenon may also be influenced by the initial concentration of lead and the specific characteristics of the activated carbon used.

Variations in activated carbon mass significantly impact lead (Pb) adsorption efficiency over contact time. Studies by Aliyu et al. highlighted that as the dosage of activated carbon increases, the removal percentage of lead ions also escalates, which is associated with an improved surface area and additional adsorption sites available for lead ions. While higher doses generally lead to increased adsorption, there exists an ideal range for carbon dosage; beyond this optimum, diminishing returns in adsorption yield occur as the mass increases.

The underlying mechanisms explaining the decline in Pb adsorption efficiency after optimal contact times are multifaceted. Common mechanisms include the filling of active sites, saturation, and potential competitive adsorption. Once the activated carbon is fully saturated with lead ions, no additional binding sites are available, which can halt further adsorption. Additionally, as saturation occurs, lead ions may desorb back into solution, which can be influenced by fluctuations in solution equilibrium or ionic strength.

Several kinetic models address the adsorption of Pb ions onto activated carbon and account for saturation effects during the adsorption process. Kinetic models such as the pseudo-first-order and pseudo-second-order models are frequently utilized to describe initial adsorption behavior. Pseudo-second-order kinetics, in particular, is often favored for its ability to fit experimental data reflecting saturation and rapid early uptake of Pb ions, followed by a slower limiting phase as equilibrium is approached. The Elovich model, which describes adsorption on heterogeneous surfaces, may also be applicable, especially as saturation modifies active site availability and effective treatment dynamics[21–25]. They reported an optimal contact time of 90 minutes with 3 g of activated carbon, achieving a removal efficiency of 94.15% [26].
Statistical analysis in the present study, using normality testing followed by the Kruskal–Wallis test, yielded a significance value of 0.413 ($p > 0.05$), indicating that there was no statistically significant difference among the three contact time variations in terms of oil and grease removal efficiency.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings, the initial concentration of oil and grease in workshop wastewater prior to treatment was 14,095.2 mg/L. Following sedimentation and grease trap installation, the concentration decreased to 6.0 mg/L. Subsequent treatment using a combination of sedimentation, grease trap, and adsorption with varying activated carbon contact times yielded the following results: a 15-minute contact time reduced oil and grease concentrations to an average of 4.3 mg/L, achieving a 99.96% removal efficiency; a 30-minute contact time reduced concentrations to 3.7 mg/L with a 99.97% efficiency; and a 45-minute contact time resulted in 20 mg/L with a 99.85% efficiency. These results indicate that the most effective contact time for reducing oil and grease was 15 minutes using an adsorption tank containing 1000 mL of activated carbon, achieving a removal efficiency of 99.96%.
The findings of this study demonstrate that integrating sedimentation, grease trap, and activated carbon adsorption can effectively reduce oil and grease concentrations in workshop wastewater to below regulatory limits. This integrated approach offers a technically feasible and potentially cost-effective solution for small- and medium-scale workshops seeking to comply with environmental discharge standards.
This study can serve as a reference for future research. It is recommended that subsequent studies include additional parameters such as total suspended solids (TSS), chemical oxygen demand (COD), and biological oxygen demand (BOD) to provide a more comprehensive assessment of workshop wastewater quality. Furthermore, future investigations should consider evaluating the long-term operational stability, maintenance requirements, and economic feasibility of the integrated treatment system. Assessing the scalability of this approach for broader industrial applications will also be crucial for promoting its adoption as a sustainable wastewater management solution.

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