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Research Article

Effectiveness of Coconut Fiber Filter in Grease Trap with Varying Retention Times on the Reduction of Oil and Grease in Canteen Wastewater of a Textile Industry

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ABSTRACT
The canteen in a textile industry currently lacks a domestic wastewater treatment facility, resulting in dishwashing wastewater containing oil and grease concentrations of 132.84 mg/L, which exceeds the quality standards. This study aimed to evaluate the effectiveness of coconut fiber as a filtration medium in a modified grease trap with varying retention times. An experimental pre-test post-test with control design was employed and grab sampling was used to collect wastewater samples inlet and effluent grease trap reactor as treatment. The determination of oil and grease concentrations was performed using the gravimetric method. Statistical analysis was performed using one-way ANOVA. The results demonstrated that oil and grease concentrations were reduced by 87.38% at 5 minutes, 90.75% at 10 minutes, and 92.75% at 15 minutes of retention time. Coconut fiber was found to be effective as a filtration medium for reducing oil and grease in canteen wastewater. It is recommended that industrial canteens apply coconut fiber in grease traps with a retention time of 15 minutes.

Keywords: Coconut Fiber Filter, Grease Trap, Retention Time, Oil and Grease, Canteen Wastewater Treatment

1. INTRODUCTION

Ensuring adequate nutrition for workers during working hours is one of the requirements for occupational safety and health, forming an integral part of efforts to improve workers' health status. The Circular Letter of the Minister of Manpower No. SE-07 of 1990 concerning the Classification of Wage Components and Non-Wage Income, as well as Decree No. SE.01/Men/1979 regarding the Provision of Canteens and Dining Areas, emphasizes that harmonizing workers' nutritional intake according to their job demands is an integrated aspect within the scope of industrial hygiene and occupational health.

The Ministry of Manpower and Transmigration issued a policy recommending that: (1) companies employing 50 to 200 workers provide a designated dining room or eating area; and (2) companies employing more than 200 workers establish a canteen within the workplace.

A textile industry located in the industrial zone of Cimahi City, West Java, provides canteen and dining facilities to meet its workers' nutritional needs. The canteen hosts 12 food vendors. Food and beverage preparation activities generate wastewater from dishwashing processes and leftover food residue. Dishwashing wastewater is discharged directly into drains without prior treatment, allowing oils and grease, detergent residues, and food scraps to contaminate drainage channels and surrounding soil. This results in foul odors, reduced aesthetic quality, and frequent blockages in wastewater drainage systems.

An examination of canteen wastewater in April 2022 showed an oil and grease concentration of 132.84 mg/L. Compared to the domestic wastewater quality standard of 5 mg/L stipulated in Minister of Environment and Forestry Regulation No. 68 of 2016, the canteen wastewater of the textile industry exceeds permissible limits.

Wastewater must undergo treatment prior to discharge. This requirement aligns with Article 3 Paragraph 1 of Minister of Environment and Forestry Regulation No. 68 of 2016, stating that "Every business and/or activity generating domestic wastewater is required to carry out domestic wastewater treatment." The objective of wastewater treatment is to reduce its volume, concentration, or associated hazards so that it meets the required environmental quality standards [1].

Treatment of oils and grease in wastewater can involve physical, biological, or chemical processes [2]. A simple and commonly applied pre-treatment technology is the grease trap, a device designed to retain oils and prevent them from entering wastewater treatment systems. Grease traps operate using multiple baffles to slow wastewater flow, increasing detention time, allowing solids to settle and oils and grease to coagulate and float for easier removal [3] [4].

One commonly used method for removing oils and grease is adsorption, a physical and/or chemical process in which substances accumulate on the surface of an adsorbent. Adding adsorbent media helps optimize the reduction of oils and grease concentrations[5]. Adsorption involves mass transfer onto the porous surfaces of the adsorbent through interfaces between two phases (gas-solid or liquid-solid) [6].

Various materials can serve as adsorbents, including activated carbon, fly ash, grasses or moss, sawdust, zeolite, sugarcane bagasse, corn husks, and other fibrous materials [7]. Several studies have utilized adsorbents to reduce oils and grease concentrations. [8] achieved a 92.59% reduction in oils and grease in produced water from petroleum operations using zeolite. Modified a grease trap with activated carbon, reducing oils and grease levels to undetectable concentrations [9].

Coconut coir is a promising adsorbent because it contains high levels of fiber, particularly hemicellulose. Reported that materials with cellulose and lignin components possess adsorption capacities up to 6000 times greater than activated carbon. Demonstrated that coconut-coir-fiber filtration with varying thicknesses reduced oils and grease concentrations by 95.03% at a 40-cm filter thickness [10], [11].

Building upon these findings, the present study seeks to expand existing research by incorporating variations in hydraulic retention time using coconut-coir-fiber filters in a modified grease trap. This research aims to reduce oils and grease levels in canteen wastewater from the textile industry.

2. EXPERIMENTAL SECTION

The researcher employed a true experimental design (Pretest–Posttest Control Group Design), in which randomization was applied to two groups: the control group and the experimental group. The population and sample in this study consisted of wastewater generated from canteen activities at the Textile Industry. The determination of the required sample size was based on the formula commonly used in experimental research. The number of replications for each treatment followed the formula proposed $t(r–1) \geq 15$ [6] , resulting in the following sample requirements: (3 treatments × 6 replications) + 18 controls = 36 samples Pretest: 6 replications (control) = 6 samples.

This study was conducted using a series-test procedure, requiring 100 L of canteen wastewater for each replication of each treatment. Thus, the total volume of canteen wastewater needed was 4,200 liters. For the laboratory analyses of oils and grease concentrations, the sample volume distribution was as follows:

a. 6 × 500 mL = initial oils and grease analysis (pretest/control)
b. 12 × 500 mL = oils and grease analysis with a 5-minute hydraulic retention time (treatment and control)
c. 12 × 500 mL = oils and grease analysis with a 10-minute hydraulic retention time (treatment and control)
d. 12 × 500 mL = oils and grease analysis with a 15-minute hydraulic retention time (treatment and control.

Total of 42 samples, each contained in a 500-mL bottle, were used for laboratory examination. In each replication, oils and grease concentrations were measured before contact with the reactor, after contact with the reactor (reactor effluent), and under each retention-time variation using a coconut-coir–fiber filter.

2.1. Materials

The grease trap reactor was constructed from fiberglass material. A plastic screen measuring 10 cm^3 with a 3-mm mesh size was installed to filter food residues entering the grease trap. The filtration medium used was coconut-coir fiber, which was placed inside an 8-inch diameter pipe with a thickness of 20 cm. Throughout the duration of the study, the coconut-coir fiber was neither replaced nor washed. This approach was intended to evaluate the adsorption effectiveness of the filter media under continuous use.

2.2. Instrumentation

The grease trap designed in this study was constructed at a laboratory scale. The reactor consisted of two compartments with overall dimensions of 46 cm × 32 cm × 60 cm. The wastewater detention time is a critical parameter as it directly influences the required tank dimensions.

a. For a 5-minute detention time, the required dimension is 46 cm × 32 cm × 25 cm.
b. For a 10-minute detention time, the required dimension is 46 cm × 32 cm × 35 cm.
c. For a 15-minute detention time, the required dimension is 46 cm × 32 cm × 55 cm.

Domestic wastewater samples were stored in the laboratory at 4 °C to prevent alteration of oil and grease content, in accordance with SNI 6989.10-2011. The variations in detention time evaluated were 5, 10, and 15 minutes. The flow regime of the wastewater in this experiment was required to be laminar (without swirling), and the influent conditions were adjusted accordingly to ensure laminar flow. The wastewater discharge rate applied in this study was 0.033 L/s or 2 L/min, representing the peak flow rate occurring during equipment washing activities.

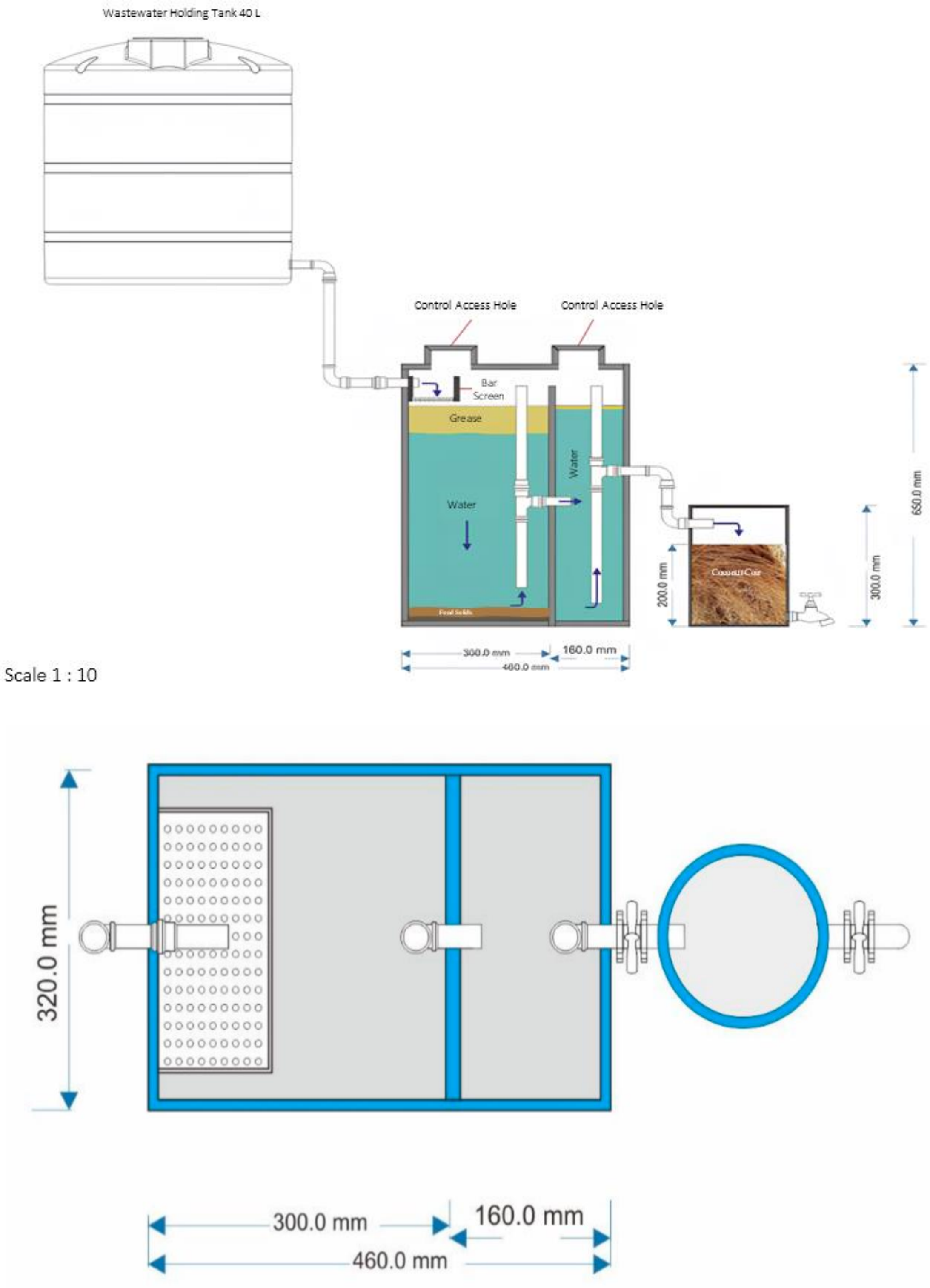

Figure 1. Grease Trap Reactor

2.3. Procedure

The grease trap reactor is divided into two (2) compartments, each connected by a T-shaped interconnecting pipe. The compartments are separated by baffles, which function to retain oils and grease flowing between compartments. Wastewater flows into the grease trap from top to bottom to minimize turbulence. With this design, food particles are allowed to settle by gravity, while oils and grease rise to the surface due to their lower density compared to water.

In Compartment 1, wastewater enters through the inlet, where initial screening of food residues and solids carried from dishwashing activities occurs. Compartment 1 and Compartment 2 are connected by an extended pipe that channels flow from the bottom of Compartment 1. With sufficient detention time, separation between oil and water is expected to occur. Wastewater then flows into Compartment 2 once it reaches the required height to enter the T-shaped connecting pipe. Compartment 2 is intended to capture any remaining oils and grease that escape from Compartment 1, as well as to allow dissolved solids to settle. In this compartment, the accumulation of oils and grease continues and forms a layer at the surface.

The filtration medium employed was grade B coconut coir fiber, characterized by the presence of relatively large cocopet particles. Once wastewater reaches the designated height, it flows through the T-pipe in Compartment 2 into the coconut-coir fiber filter. The coconut-coir filter covers the entire cross-sectional area of the filter chamber and functions to optimize the adsorption of dissolved oils and grease that pass through Compartment 2. Oils and grease are expected to adhere to the pores of the coconut-coir fibers, thereby reducing their concentrations at the outlet tap.

This study utilizes coconut-coir fiber filters with three hydraulic detention time treatments—5 minutes, 10 minutes, and 15 minutes. The filter is expected to function as an additional adsorption medium to reduce oils and grease concentrations in canteen wastewater and to determine the most effective detention time.

2.3.1. Sub-procedure

The Shapiro–Wilk test was used to assess data normality. The Shapiro–Wilk method is an effective and valid normality test, particularly suitable for small sample sizes. A paired t-test was performed to determine whether there were significant differences in oil and grease concentrations before and after the pretreatment using the grease trap reactor. Additionally, a one-way ANOVA was conducted to examine differences in the mean reduction of oil and grease concentrations across two or more groups.

3. RESULTS AND DISCUSSION

Table 1 summarizes the oil and grease concentrations in the control and treatment groups across the three detention times (5, 10, and 15 minutes). Both groups exhibited reductions relative to pre-test values, although the treatment groups consistently demonstrated greater decreases.

In the control group, the highest reduction during the 5-minute detention time occurred in the third repetition (84.50%). For the 10-minute detention time, the greatest reduction (91.98%) appeared in the fourth repetition, whereas the highest reduction in the 15-minute group was recorded in the third repetition (91.40%).

Table 1. The oil and grease concentrations in the control and treatment groups across the three detention times

Repeat	Oil and Grease Concentration (mg/L)	Post Test											
		5 Minute				10 Minute				15 Minute			
		Control		Treatment		Contol		Treatment		Control		Treatment	
	Pre Test	f	%	f	%	f	%	f	%	f	%	f	%
1	120,0	20,8	82,7	12,9	89,3	16,8	86,0	8,6	92,8	13,9	88,5	5,0	95,8
2	126,8	21,8	82,7	13,3	89,4	17,6	86,0	9,5	92,4	14,5	88,5	5,8	95,5
3	87,6	13,6	84,5	7,9	90,9	9,8	88,9	4,2	95,2	7,5	91,4	2,2	97,5
4	90,7	15,0	83,4	9,9	89,0	7,2	92,0	4,4	95,2	7,9	91,3	3,2	96,5
5	95,9	17,1	82,1	15,3	84,6	13,4	86,1	12,1	97,4	9,2	90,4	9,6	89,0
6	127,2	21,9	82,8	20,8	81,1	18,8	85,2	16,4	81,5	12,7	90,0	13,1	82,1
Mean	108,0	18,4	83,0	13,4	87,4	13,9	87,4	9,2	92,4	11,0	90,0	6,5	92,7
Pair t Test		0,000						SD = 8,816					
One Way Anova		0,003						SD = 3,228					

For the treatment groups receiving filtration through coconut-coir fiber, the 5-minute detention time resulted in an additional 4.34% reduction compared with control. The 10-minute and 15-minute detention times produced additional reductions of 3.91% and 2.71%, respectively. The greatest difference between the treatment and control group occurred during the second repetition of the 5-minute detention time (6.72%).

Overall, the highest average reduction of oil and grease concentration was achieved at the 15-minute detention time using the coconut-coir fiber filter (92.72%). However, reductions below the control group were observed in certain repetitions, particularly in the sixth repetition of the 5-minute group and the sixth repetition of the 10- and 15-minute groups. These inconsistencies likely resulted from saturation of the coconut-coir adsorption media.

Table 1 presents the percentage differences between the post-test results of the treatment group compared with the control group. The data indicate that the reduction in oil and grease concentrations in the treatment groups with the addition of coconut-coir fiber filters differed from the control group across varying detention times. For the 5-minute detention time, the average difference was 4.34%, with the highest difference observed in the second repetition (6.72%). For the 10-minute detention time, the difference was 3.39%, with the highest value recorded during the first repetition (6.76%). For the 15-minute detention time, the average difference was 2.71%, with the highest reduction found during the fourth repetition (92.43%).

Overall, the treatment groups achieved a greater reduction in oil and grease concentrations compared with the control group. However, based on Table 4.8, in the sixth repetition of the 5-minute detention time group, although a reduction was observed compared with the pre-test, the percentage reduction was lower than that of the control group by an average of 1.76%. A similar pattern was found in the sixth repetition for the 10-minute and 15-minute detention times, as well as in the fifth repetition of the 15-minute coconut-coir fiber filtration treatment.

The effectiveness of the coconut-coir fiber filter in reducing oil and grease concentrations increased with longer detention times. The highest effectiveness was achieved at the 15-minute detention time, with a reduction percentage of 92.72%. However, after the third repetition, the performance of the treatment groups declined relative to the control group. This decrease may be attributed to the saturation of the adsorption capacity of the coconut-coir fiber filter. This suggests that after the fourth repetition, the filter media should be replaced.

Several factors may explain these results. The coconut-coir fiber used as the filter medium was not replaced or cleaned throughout the study. Variations in oil and grease concentrations during each treatment stage may have led to accumulation and increased concentration within the sample. Initially, the pores of the coconut-coir fiber could effectively trap fine particles, but over time these pores became saturated and were no longer able to function efficiently.

This saturation process resulted in a reduced capacity of the filter media to adsorb oil and grease, causing concentrations in the samples to increase over time. This finding aligns with adsorption theory, which describes adsorption as a process in which particles become trapped within the structure of an adsorbent and effectively become part of the medium. According to contact time influences the amount of adsorbate absorbed, as different adsorbents vary in their adsorption capabilities [12].

Efficient adsorption occurs when the pore size of the adsorbent is sufficiently large to allow adsorbates to enter. Wastewater contains adsorbate particles of varying sizes, which can pose challenges, as larger particles may block smaller ones from entering the pores. However, constant movement of adsorbate particles can minimize blockage. Smaller particles diffuse more rapidly into the pores, enhancing overall adsorption efficiency [13].

During the pre-treatment stage in the grease trap reactor, wastewater entered the filtration chamber containing coconut-coir fiber for the treatment groups. The coconut-coir fiber filter was placed inside a cylindrical tube with a diameter of 8 inches and a thickness of 20 cm. This filter served as an adsorptive medium intended to enhance the performance of the grease trap in reducing oil and grease concentrations in canteen wastewater prior to subsequent treatment processes.

Table 1 shows that the treatment groups demonstrated substantial reductions in oil and grease concentrations compared with the pre-test values. In the first variation (5-minute detention time), the average reduction reached 87.38%. For the second variation (10 minutes), the average reduction was 90.75%, while the highest reduction was observed in the 15-minute group with an average of 92.715%.

Although the use of coconut-coir fiber filters across the three detention time variations effectively reduced oil and grease levels, the mean percentage reduction still did not meet the effluent quality standard stipulated by the Indonesian Ministry of Environment and Forestry Regulation No. 68/2016 on Domestic Wastewater Quality Standards (5 mg/L). However, in the third and fourth repetitions of the 10-minute and 15-minute detention time groups, the treatment achieved reductions that met the regulatory limit. This outcome was strongly influenced by fluctuating pre-test oil and grease concentrations. When initial concentrations were relatively low, the coconut-coir fiber filter was able to optimize adsorption, resulting in post-treatment values below the quality standard [1].

Results presented in Table 1 indicate that longer detention times produced greater reductions in oil and grease concentrations. In a two-compartment grease trap system, flow velocity decreases, allowing oil and grease to rise to the surface. Consequently, the wastewater entering the filter contains lower concentrations of oil and grease, enabling more efficient adsorption by the coconut-coir fiber medium.

According to contact time is a critical factor in the adsorption process, as longer interaction allows more effective diffusion and attachment of adsorbate molecules [9]. Modified a grease trap with a zig-zag filter, achieving the highest reduction (87%) at a 15-minute detention time, who obtained a 97.92% reduction (450 mg/L) using flotation for wastewater treatment at Indonesia Power [4], [14].

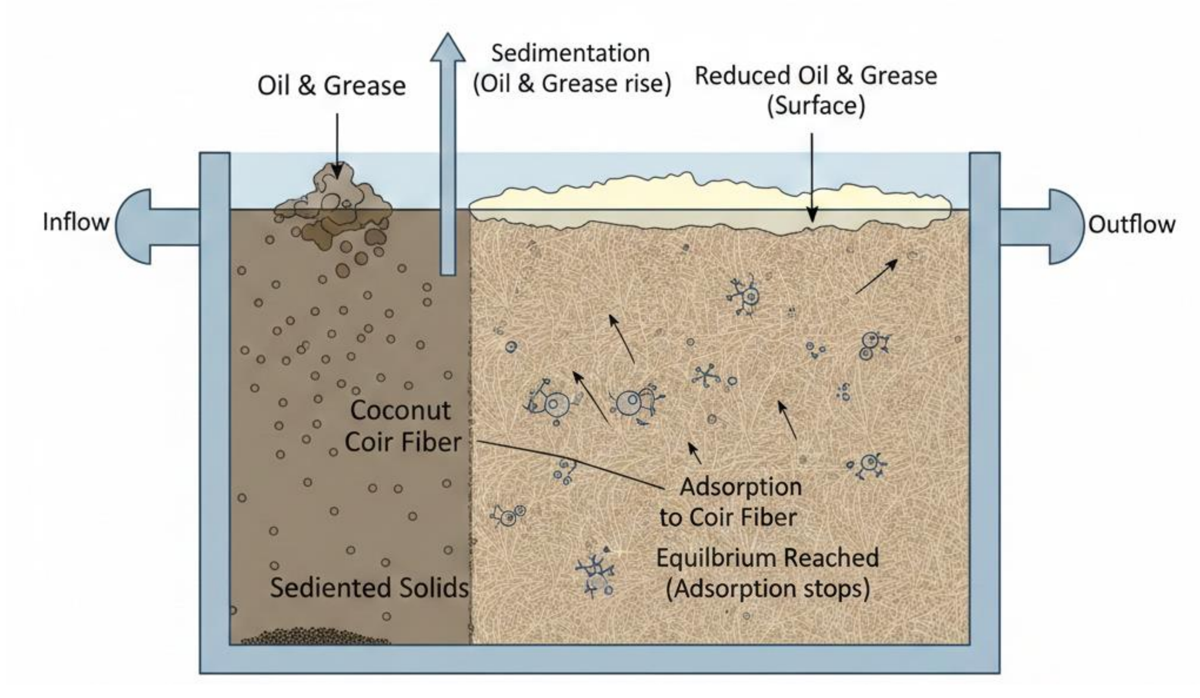

Figure 2. Mechanism of Oil and Grase Trap Reduction by Coconut Coir Filtration

The adsorption efficiency of coconut-coir fiber is influenced by its porous structure. Coconut-coir fiber is suitable as an adsorbent due to its high porosity and semisellulose content. Reported that materials containing cellulose and lignin have an adsorption capacity up to 6000 times greater than activated carbon. Examining coconut fiber and coconut shell as adsorbent media, found a 93.39% reduction in used-cooking-oil color using untreated and undelignified fibers [15], [16].

The reduction in oil and grease following filtration with coconut-coir fiber across the detention time variations is attributable to sedimentation and adsorption processes. Oil and grease particles rise to the surface, while the coconut-coir fiber adsorbs pollutant molecules until equilibrium is reached[17][18].

Adsorption occurs when solid surfaces come into contact with gas or liquid molecules, driven by hydrogen bonding and hydrostatic forces. Van der Waals forces and hydrostatic interactions between the adsorbent and adsorbate contribute to the adsorption process [19]. A larger adsorbent surface area increases adsorption capacity, which is affected by particle size and the amount of adsorbent used [20]. Thicker adsorbent media allow more coconut-coir fibers to capture oil and grease from the wastewater. In this study, the coconut-coir fiber filter was placed in a cylinder with a diameter of 8 inches and a thickness of 20 cm.

4. CONCLUSION

The use of coconut-coir fiber as a filtration medium in a modified grease trap effectively reduced oil and grease concentrations in textile-industry canteen wastewater. The highest removal efficiency (92.72%) was achieved at a 15-minute detention time. Detention time significantly influenced the reduction performance ($p = 0.003$). Although filtration using coconut-coir fiber improved overall removal efficiency, several repetitions did not achieve the regulatory limit of ≤5 mg/L, indicating that the system functions best when initial pollutant levels are moderate and adsorption media are not saturated. Recommendations**:** Industrial canteens should apply coconut-coir fiber as an adsorbent in grease traps, with an optimal detention time of 15 minutes. Coconut-coir fiber should be replaced periodically after 3–4 cycles to avoid adsorption saturation.

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AUTHOR CONTRIBUTIONS

Siti Widianingrum Dina contributed to sample collection, laboratory analysis, and data interpretation. Kahar contributed to data analysis and journal drafting. Nia Yuniarti Hasan contributed to the interpretation and discussion of the findings as well as journal drafting.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest associated with this publication.

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