Jurnal Info Kesehatan
Vol. 23, No. 3, September 2025, pp. 594-602
P-ISSN 0216-504X, E-ISSN 2620-536X
DOI: *10.31965/infokes.Vol23.Iss3.1976*
Journal homepage: *https://jurnal.poltekkeskupang.ac.id/index.php/infokes*

RESEARCH **Open Access**

Filtration Tube Model Utilizing Coconut Husk for Domestic Wastewater Treatment: Oil Removal Method

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Received: 3 May 2025 Revised: 20 July 2025 Accepted: 19 September 2025

Abstract

The presence of oil and fat in household wastewater is a significant water pollutant, as it is typically disposed of without prior treatment. Coconut husks are a promising material that can be used as a filter medium. This study aimed to evaluate the effectiveness of coconut fiber filtration in the treatment of domestic wastewater. The study employed a quasi-experimental design with pre- and post-tests but no control group. Wastewater was passed through tubs filled with coconut husk. Three different filtration tub models were tested: Model A single baffle, Model B with three baffles, and Model C with no baffle. Oil content was monitored on the 3rd, 7th, 14th, 21st, and 28th days in milligrams per liter. A Kruskal-Wallis and Mann-Whitney test was conducted to compare the results of oil content reduction between filter models. The results revealed significant differences in the mean oil content reduction among the various tub models. The percentage of oil reduction reaches 95-99%. Furthermore, the Mann-Whitney test showed no significant difference between Models A and C. However, considerable differences were identified between Models A and C, as well as between Models B and C. In conclusion, this study provides evidence of the effectiveness of coconut husk filters in reducing oil levels, with nearly the maximum observed reduction achieved by the 28th day. Additionally, it is recommended to explore the long-term sustainability and potential applications of coconut husk filters in various oil removal scenarios.

Keywords: Filtration, Coconut Husk, Domestic Wastewater.

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1. INTRODUCTION

Global population growth has led to an increase in wastewater production. According to the World Bank, 36% of the population lives in areas facing water scarcity, which results in declining water quality, inadequate water supply, and insufficient treatment infrastructure. A significant amount of wastewater generated by human activities originates from domestic sources (World Bank, 2018).

Indonesia's urban areas are inhabited by 153 million people, while rural areas are home to 117 million people (BPS, 2021). The total estimated volume of wastewater, including domestic, commercial, industrial, and stormwater runoff, in urban regions is 14.3 km3/year. Interestingly, the capacity for municipal wastewater treatment is only 0.3 km3/year (FAO, 2021). Notably, 85% of domestic pollution in water bodies can be attributed to Indonesia (Widyarani et al., 2022). It is worth noting that domestic wastewater has the potential to pollute both groundwater and surface water, thereby deteriorating water quality and harming aquatic life (Sabeen et al., 2018).

One of the intricate environmental challenges currently faced is the contamination of wastewater with oils from household activities. This is because some of the components are hazardous (Medeiros et al., 2022). Oily wastewater has a detrimental effect on drinking water, groundwater, and other resources (Abuhasel et al., 2021). Infiltration of pollutants into underground water sources harms humans and other living organisms. Furthermore, this process leads to air contamination through oil burners and soil, which adversely affects the food supply chain. Additionally, harmful compounds, such as phenols, petroleum hydrocarbons, and polycyclic aromatic hydrocarbons, which hinder the development of both plants and animals, can be found in oily wastewater. Appropriate disposal within acceptable environmental standards remains a significant challenge for environmental agencies (Samuel et al., 2022). Therefore, there is an urgent need to treat such effluents.

The effective separation of suspended oil relies on costly physical and chemical processes (Adetunji & Olaniran, 2021). Therefore, there is a pressing need to enhance traditional separation methods by employing innovative techniques, materials, and sustainable multidisciplinary approaches to eliminate pollutants efficiently. For instance, the use of natural sorbents such as coconut fiber for sorption methods is worth considering. Coconut husk, coco peat, and coconut coir are fibrous materials left after extracting coconut husk fibers from the shell during processing (Salaenoi et al., 2024). This material has various practical applications in water treatment (Taylor et al., 2023) and has been extensively used for purifying water and wastewater streams (Salaenoi et al., 2024). Moreover, it is gaining recognition as an effective adsorbent for heavy metals and nitrogen removal.

Some studies have suggested coconut husk as an anaerobic filter for optimizing the removal of organic matter, nitrogen compounds, and phosphorus concentration in the final effluent wastewater (de Oliveira Cruz et al., 2019; Zahur-Uz-Zaman et al., 2023). Recent experimental research has demonstrated that coconut fiber filters can yield results on par with those of traditional sand-gravel media filters (Setyowati & Indasah, 2021). Generally, coconut husks are used in direct combustion to produce activated carbon for removing pollutants (Kasmuri et al., 2022). However, across different studies been explored, limited studies investigated the grease and oily removal through coconut husk. A similar study was conducted in Nigeria, where coconut husk was used as a material composite with a high surface area and a well-ordered framework of porosity for crude oil removal (Asadu et al., 2021). Previous studies have faced challenges with implementation owing to cost and plant scale. Therefore, this study proposes the use of coconut husks in simple filtration tubs with different partitions to remove oil from domestic wastewater.

2. RESEARCH METHOD

This quasi-experiment was conducted from April to October 2021, involving the collection of coconut husks in Sambas Regency and the creation of filtration tubs in Pontianak City. It is worth noting that the study did not require an ethical permit as it did not involve human subjects, following Decree no LB.02.01/I.1/086/2021.

Extracting coconut husks involves a manual method in Gersik, Singaraya Village, Semparuk District, and Sambas Regency. Approximately 10 bags of coconut coir separated from the husk were soaked in a bucket to facilitate the extraction process. Separation was carried out using a beating tool, such as a hammer or wood, until the coconut husk was crushed and separated into powder and fiber. The husks were then sun-dried until they were completely dry, as illustrated in Figure 1. Figure 1a depicts the vibrant, fresh version of the coconut husk, showing its natural texture and moisture content. In contrast, Figure 1b shows the dried coconut husk, highlighting its desiccated appearance and firmer consistency.

(a) (b)

Figure 1. Fresh coconut husk (a) dried coconut husk (b)

The filter beds were all 50 cm long, with a bed depth of 35 cm and a width of 30 cm. Figure 2 shows the oil removal process for domestic wastes. The domestic wastewater discharge channel through the sink was connected by a pipe to the filtration tube. Domestic wastewater containing oil was filtered through a filtration tube. The outlet channel shows the direction of the domestic wastewater coming out and becomes the test sampling site after filtration.

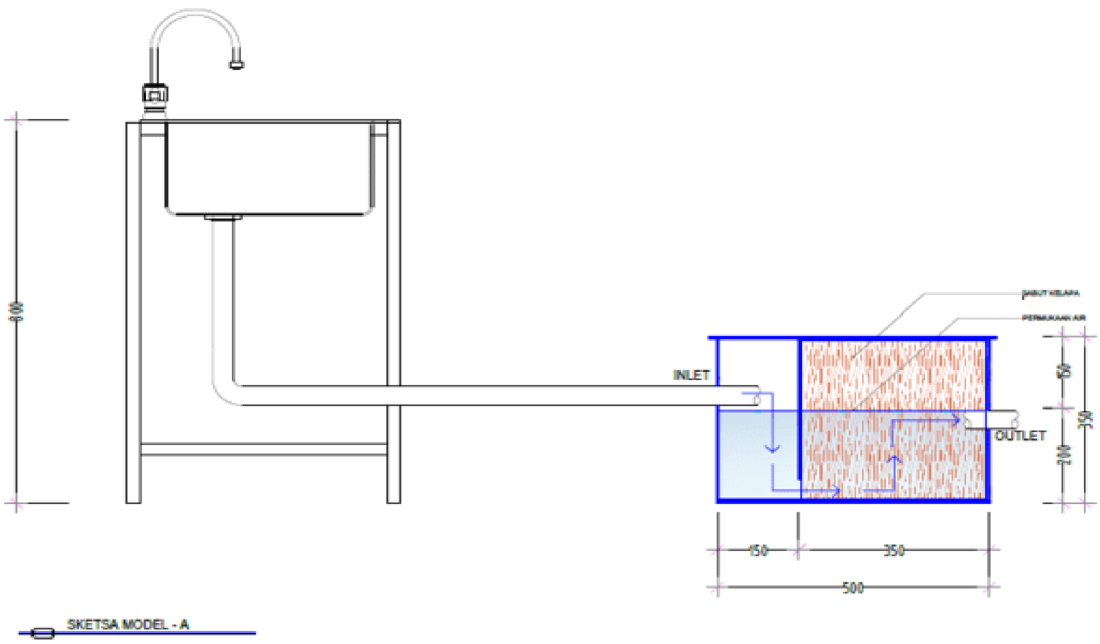

Figure 2. Flowchart of the oil removal through filtration tube model utilizing coconut husk

Figure 3 shows a visual representation of the different models of the filter beds, labeled A, B, and C, which were designed. Model A consisted of a single partition (two blocks) with a working mechanism similar to that of an upstream flow system by draining wastewater through the filter bed, with the flow direction from the bottom of the coconut husk media to the top of the filter media (Figure 3a). Model B had three partitions (four blocks) and wastewater flowed upstream to the filter media, which was divided into two bedrooms. The flow of wastewater from the first to the second bed becomes downflow before finally heading to the outlet (Figure 3b). Model C had no partitions where the wastewater flowed horizontally to the filter medium (Figure 3c). These varying designs aimed to regulate airflow and promote greater contact between the oil (fat) and the filtering medium. The filter beds were assembled by piping connecting the sink to the filtration basin, a faucet stop as an outlet pipe on the filtration bath, and a coconut husk fiber was inserted into the filtration bath according to the bed's height or thickness.

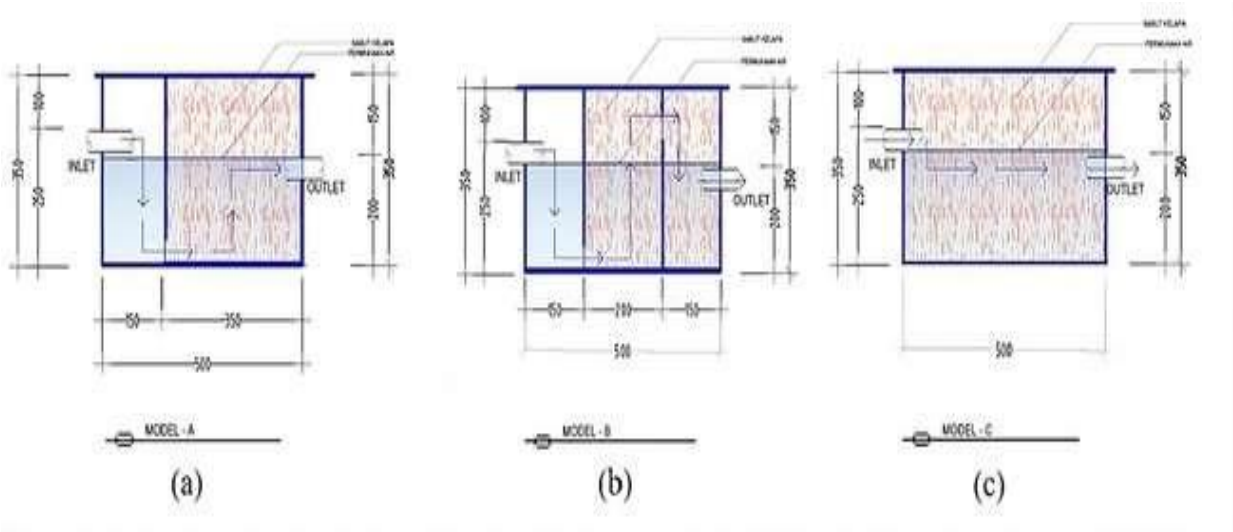

Figure 3. a-c. Filter bed model with different shapes: model A (a), B (b), and C (c)

Figure 4. A detailed top view of the intricate filter bed model

The research process involved simulating laboratory-scale washing scenarios in restaurants. Initially, a solution was prepared by combining 1 liter of used cooking oil with 20 liters of tap water and 400 ml of X-brand dish soap. This mixture was poured into a filtration bath in 50-liter portions and passed through the sink in all filter bed models. Sampling was performed before (pre) and after (post) filtration on days 1, 7, 14, 21, and 28. In a controlled laboratory environment, the oil level was meticulously assessed, using the precise measurement of milligrams per liter (mg/L), ensuring accurate and reliable results in the analysis. We used five samples per filtration bed model (three models) five times over the measurement period, resulting in 75 samples (5 retention times × 3 filter beds × 5 repetitions).

The cooking oil used in the wastewater was examined at the Agricultural Faculty Laboratory of Tanjungpura University, Pontianak. The data were analyzed utilizing One-Way ANOVA to assess the differences in oil level reduction among various models of coconut husk filter beds. However, due to the non-normal distribution of the data, the Kruskal-Wallis test was employed as an alternative methodological approach, with a confidence interval of 95%. Also, the Mann-Whitney test was conducted to compare the results of oil content reduction between filter models.

3. RESULTS AND DISCUSSION

These results suggest that oil levels decrease when in prolonged contact with coconut husk filter beds. Notably, a significant reduction in oil content exceeding 95% was achieved after seven days of contact compared to the initial three days (Table 1). This indicates the potential for effective oil reduction through extended contact with the filter beds. These findings align with those of previous studies demonstrating the effectiveness of coconut husks or coirs in absorbing oil (Parameswaran et al., 2019). This is attributed to the high lignocellulose biomass present in coconut husks, an agricultural and agro-industrial waste (Mujtaba et al., 2023). In addition to removing used cooking oil from wastewater, natural lignocellulosic-based adsorbents can be employed to enhance oil quality (Ahmed et al., 2022; Blasi et al., 2023; Mujtaba et al., 2023).

Table 1. The effectiveness of reducing oil levels varies among different coconut husk filter beds.

Tube	3rd day			7th day			14th day			21st day			28th day		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	6.74	12.53	6.22	0.18	0.17	0.30	0.15	0.18	0.13	0.13	0.10	0.13	0.12	0.10	0.10
2	11.21	7.87	6.01	0.31	0.19	0.16	0.21	0.13	0.16	0.18	0.10	0.12	0.11	0.10	0.13
3	13.47	10.12	10.30	0.30	0.13	0.18	0.22	0.13	0.16	0.19	0.10	0.14	0.12	0.10	0.10
4	6.90	4.87	9.92	0.30	0.13	0.24	0.23	0.14	0.12	0.15	0.10	0.13	0.12	0.10	0.10
5	6.75	4.19	8.98	0.19	0.12	0.13	0.17	0.11	0.11	0.17	0.10	0.11	0.12	0.10	0.10
Mean	9.01	7.91	8.27	0.46	0.15	0.20	0.19	0.14	0.14	0.16	0.10	0.13	0.12	0.10	0.10
% Reduction	-	-	-	95	98	98	98	98	98	98	99	98	99	99	99

The study indicates that statistically, there is a discernible difference in oil content based on the type of coconut husk filter bed used (Table 2). Different designs presented different airflows and contacts between the oil and filtering medium, resulting in different oil reductions. The three filter beds present different space limitations and surface areas for the filter material. The filter beds have different space constraints and filter material surface areas. Baffle filters are known to retain and accumulate oil, which increases the density of the bed (Krasiński et al., 2024). The increased surface contact leads to a higher oil reduction, enhancing the likelihood of capturing the dispersed oil on the fibers by interception (Singh et al., 2022). The interception efficiency is directly related to the square of the mean droplet size of the influent and mean hydraulic pore diameter of the filter bed. Therefore, a filter bed made of finer fibers can effectively coalesce the droplets, thereby improving the oil separation efficiency.

Based on the findings (Table 2), there was a statistically significant variance in oil content depending on the type of coconut husk filter bed used. The diverse designs of the filter beds result in varying airflow patterns and levels of contact between the oil and filtering medium, leading to distinct outcomes in oil reduction (Dziubak, 2022). Each of the three filter beds is associated with specific space limitations and offers different surface areas for the filter material, which significantly influences their oil reduction capabilities. Baffle filters are particularly important because they exhibit the unique ability to retain and accumulate oil, thereby increasing the packing density of the bed (Krasiński et al., 2024; Wei et al., 2017). Consequently, the expanded surface contact area facilitated substantial oil reduction (Mirsalami & Mirsalami, 2024).

Table 2. The difference in oil levels compared to different models of coconut husk filter beds

Filter bed models	Mean Rank	p-value*
Model-A	47.40	
Model-B	29.46	0.014**
Model-C	37.14	

* *Kruskal-Wallis test*
** *Significant difference at p ≤ 0.05.*

The analysis in Table 3 reveals that the variation in the efficiency of the oil level in wastewater among the filtration tank models can be attributed to the specific design of the filters. Model A was equipped with a single baffle, Model B featured three baffles, and Model C had no baffles. This diversity affects the flow speed within the filtration tank, leading to a multitiered filtration process (Ministry of Housing and Urban Affairs, 2017). Consequently, the oil levels from the filter bed with three baffles (Model B) were statistically different compared to Model A, while no statistically significant difference was found between Models A and C.

Table 3. The statistical difference of oil levels compared to each models of coconut husk filter beds

Filter bed models	Mean Rank	p-value*
Model-A	31.10	0.007*
Model-B	19.90	
Model-A	29.30	0.065
Model-C	21.70	
Model B	22.56	0.154
Model C	28.44	

*Mann-Whitney test
* Significant difference at p ≤ 0.05.

The results of this study indicate that as the amount of time a substance is retained increases, the level of oil reduction also increases. This supports previous research, which found that the duration of contact affects how efficiently a substance is removed, regardless of the different sorption tendencies displayed by the sorbent (Mariana et al., 2019). It has been observed that in most cases where coconut husks are utilized to remove heavy metals, the metal removal efficiency is higher with longer detention times. This process is directly influenced by the contact time, surface area, and pore diameter of the filter membrane (Lehtonen et al., 2021). Initially, coconut husks demonstrated a higher ratio of surface area to pore volume compared to pure silica ($SiO2$). However, when converted into activated carbon, the coconut husk displays an even higher ratio of surface area to pore volume, making it more reactive than coconut husk alone.

Nonetheless, the consistent use of the same volume and concentration of oil in the filtration apparatus at each stage of treatment may result in the build-up of oil in the sample. Although precautions are taken to minimize this risk by backwashing and draining the water from each sample filtration, there is potential for a longer retention time to lead to a larger volume of accumulated oil, which could impact the performance and stability of the co-digestion of the grease filter (Zulfikar et al., 2022).

As the filter media became saturated, there was a reduction in the amount of oil (fat) captured by the coconut fiber media as the number of samples increased. This phenomenon aligns with the absorption theory, where particles become trapped within the structure of the medium (Anis et al., 2019; Ritt et al., 2022). Nevertheless, despite this process, it was observed in the present study that oil levels consistently decreased with longer retention times.

This study highlights the potential of using coconut husk filter beds as an effective solution for managing used cooking oil in households and small-scale restaurant wastewater. This approach appears promising, especially compared to the high operational costs associated with existing methods (Ajien et al., 2023). Furthermore, harnessing natural resource-based technology, such as coconut husks, which are readily available and often wasted, presents a practical and sustainable option, particularly in tropical regions such as Indonesia. It is crucial to consider specific process conditions when selecting an appropriate filter type. Notably, utilizing larger pore sizes can lead to higher flow rates and lower pressure drops, resulting in quicker filtration times and reduced membrane maintenance owing to pore saturation (Mo et al., 2021). Moreover, it is essential to highlight the maintenance required after filtering a certain volume in order to reduce the risk of filter performance reduction.

4. CONCLUSION

This study provides compelling evidence of the effectiveness of coconut husk filters in reducing oil levels. The modifications made to these materials resulted in a notable reduction in the oil content. Longer retention times led to even greater reduction. However, similar to other filtration media, it is essential to address the potential saturation of the coconut husk filter and consider periodically replacing the media to maintain optimum performance. Additionally, this study did not cover the optimal retention time for maintenance, including media replacement and backwashing. Further research is crucial to comprehensively analyze the filter model, operational parameters, and maintenance procedures. This in-depth analysis will accelerate the practical implementation of oily wastewater treatment in real-world scenarios.

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