



Utilization of Slow Sand Filter to Reduce Wastewater Pollution Levels from Restaurant Operations

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Abstract

Restaurant wastewater is categorized as domestic wastewater. It contains high levels of fats, spices, detergents, and cleaning agents, all of which can pose substantial environmental hazards if inadequately treated. This study compared the effectiveness of slow sand filters with various thicknesses of filter material and measured physical and chemical parameters, employing a combination of natural filter media, including gravel, silica sand, zeolite, and coconut fiber. The study assessed several water quality parameters, including pH, ammonia concentration, temperature, turbidity, and dissolved oxygen (DO). The results indicate that the filtration system effectively reduced ammonia concentrations to levels that comply with the regulatory standards. Parameters pH values had minor changes, they remained below the thresholds required by applicable regulations. A substantial reduction in turbidity was observed, while the effluent temperature remained within acceptable environmental limits. However, a decrease in DO levels was noted post-filtration, due to microbial activity and temperature dynamics within the filtration media. Overall, the findings suggest that slow sand filtration systems utilizing natural and locally available materials offer a low-cost, and environmentally sustainable alternative for the treatment of restaurant wastewater.

Keywords: *slow filtration, wastewater, natural material, water quality, and wastewater treatment.*

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INTRODUCTION

According to PERMEN LHK No. 68 of 2016, Concerning domestic Wastewater Quality Standards, restaurant waste is also included in the classification of domestic wastewater. Restaurant wastewater contains fats, spices, and soaps or detergents used in washing dishes and cooking utensils [1]. Wastewater is a significant environmental and social concern, as its improper management can lead to ecosystem degradation and adverse impacts on public health and community well-being [2]. Wastewater is a major contributor to river pollution and can cause significant environmental degradation if not properly managed [3], [4]. Generally, restaurants do not have their waste processing system so, that wastewater with these contents will be directly discharged into the environment, where this will harm the ecosystem and aquatic biota [5].

The concentration of pollutants in wastewater by restaurants is estimated to be two to three times higher than that found in wastewater produced by cafes. This variation is largely due to differences in the types and complexity of food ingredients used, as restaurant operations generally involve more elaborate food preparation and cooking activities, which contribute to a higher pollutant load in the resulting effluent [6]. Chemicals such as antiseptics and disinfectants used for cleaning food equipment and floor cleaners are typically acidic. As a result, the pH of the resulting wastewater can decrease ($\text{pH} < 7$), which is harmful to the environment [7].

Domestic wastewater consists of approximately 99.7% water and 0.3% other substances, such as solids, colloids, and dissolved materials. These substances may be either organic or inorganic in nature [8], [9]. Wastewater has a high organic content can emit an unpleasant odor. In the case of restaurants of catering services, the generated waste, both solid and liquid waste, poses a significant environmental concern [10]. Based on PP RI No. 22 of 2021. concerning the Implementation of Environmental Protection and Management, all domestic wastewater must be treated to meet established quality standards before being discharged into public channels such as water bodies. This aligns with previous findings that emphasize the importance of sustainable sanitation management in small communities to ensure environmental and public health protection [11].

River water pollution can lead to elevated levels of *Escherichia coli* (E. coli) and, when used for agricultural irrigation, may contribute to reduced crop yields [12]. The reuse, recycling, and recovery of wastewater benefits are encouraged. Restaurant waste management activities generally encompass four key aspects such as storage, collection, treatment, and final disposal [13]. However, common methods for treating restaurant wastewater generally require large land areas and are difficult to operate. Therefore, there is a need for a more practical and easily applicable technology for restaurant wastewater treatment.

Slow sand filter technology is one of the alternatives used for wastewater treatment, which can be implemented in managing wastewater. A slow sand filter is a filtration system that utilizes a tank filled with sand as the filter medium, typically composed of fine-grained sand with a high quartz content. The filtration process occurs slowly and by gravity, taking place uniformly across the

entire surface of the filter media. The composition of the materials used in the filter plays a significant role in reducing pollutants in wastewater, both through physical filtration and adsorption processes [14], [15], [16].

In this study, various filter media, namely gravel, silica sand, zeolite stones, and coconut fiber, were utilized. Gravel functions as a filtration medium that removes coarse particulate matter [17], [18]. Gravel-based filtration demonstrates high efficacy in the removal of sediments and heavy metals. A higher mass of silica sand is effective in reducing the concentration of suspended solids in water. However, the color and turbidity of the water do not show a significant change compared to the original condition [19], [20].

Natural zeolite, as an adsorption medium, possesses a porous crystalline structure, a large surface area, high thermal stability, and is both non-toxic and effective [21], [22]. Filtration using coconut fiber and activated charcoal with a contact time variation of 6 minutes resulted in a reduction of iron content [23], [24], [25]. This filter material was chosen because it is commonly used by the public, are easily available, and economical [26].

The purpose of processing restaurant wastewater using slow sand filters is to compare the effectiveness of slow sand filters with various thicknesses of filter material and to measure physical and chemical parameters of wastewater before and after filtration to determine whether the treated wastewater meets the standards for discharge into the river.

METHODS

In this study used Padang restaurant' wastewater located in Bandar Lampung is a restaurant that operates every day from 08.00-22.00 and sells local cuisine that meets the demand of buyers in the local area. This restaurant produces quite a lot of liquid waste in its production process. The liquid waste is then disposed of through a channel without processing which goes directly to the river flow and will end up in a body of water. The method used in this study is the experimental method.

Filter Making

The design for making a slow sand filter as a wastewater treatment for restaurants consists of several components, which functionally consist of a slow sand filtration model made in the form of a 30 x 30 x 50 cm tube, which is the place for the slow sand filter. Two different filtration models were developed in this study, with their compositions presented in the following section in Table 1. The model schematic is illustrated in Figure 1.

Table 1. Slow Sand Filtration Model

No	Material	Size (mm)	Model 1 (cm)	Model 2 (cm)
1	Palm fiber	-	3	3
2	Silica Sand	2-6	10	15

3	Gravel	6	5	5
4	zeolite	3	20	15

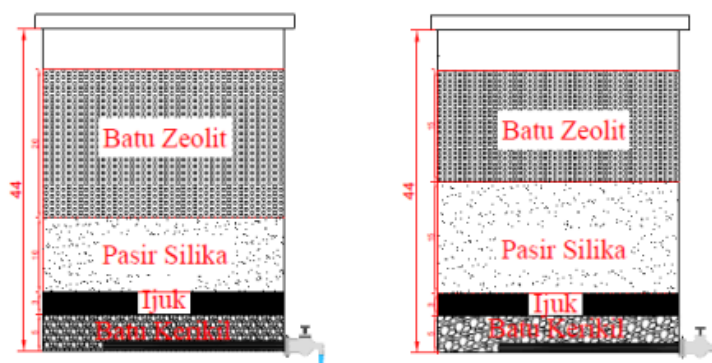


Figure 1. Slow Sand Filtration Model concept

A total of 20 liters of domestic wastewater was initially collected for treatment. The slow sand filter system employed sand and gravel as filtration media. In the first filtration tank, gravel with a particle size of 2–3 mm and coarse silica sand were used, whereas the second tank utilized gravel of the same size but with finer sand. The total thickness of the filtration media in each tank was 1 meter. The media volume in the first tank was 20m³, while the second tank contained 30m³ of filtration media.

The discharge rate is determined based on the time required for the wastewater to pass through and exit the filtration system. The collected restaurant wastewater sample was introduced into the pre-constructed filtration tanks. Each stage of the treatment process was documented. The treated wastewater was then collected in sample bottles for subsequent analysis of the designated water quality parameters.

Parameter Testing

The analyses conducted in this study included both chemical and physical tests. Chemical analysis involved the use of litmus paper to detect the presence of ammonia and to estimate pH. Physical parameters measured included turbidity, temperature, and dissolved oxygen (DO). pH measurement is essential in wastewater treatment, as it reflects the concentration of hydrogen ions in the solution and is a key indicator of its acidity or alkalinity.

Turbidity was measured using a turbidimeter, which was calibrated by the standards outlined in the Minister of Health Regulation Number 32 of 2017, with a provision of 25 NTU, with a reference value of 25 NTU. Temperature was assessed using a thermometer, while dissolved oxygen (DO) levels were measured using a DO meter. All tests were performed in two replicates, and the values presented represent the average of the two repetitions.

RESULTS AND DISCUSSIONS

Slow sand filter parameter measurement results

The wastewater sample from the restaurant was analyzed in the Soil and Water Engineering Laboratory. The filter media quantities differ between Tank 1 and Tank 2, leading to variations in their average discharge rates. Tank 1 exhibits a discharge rate of 1.2 L/s, whereas Tank 2 records a lower rate of 0.98 L/s. This is attributed to the greater amount of filter material in Tank 2, which increases the time required for water to pass through the filtration media.

The primary objective of this analysis was to assess various wastewater quality parameters, including pH, turbidity, temperature, dissolved oxygen (DO), and ammonia. The initial measurement results for the parameters presented in Table 2 for chemical parameters and Table 2 for Physical parameters.

Table 2. The results of chemical analysis of restaurant wastewater before and after the filtration treatment.

Parameter	Unit	Filtering time		
		5 (minute)	10 (minute)	15 (minute)
pH	Before filtration	6	6	6
	Model 1	7.2	6.2	7.8
	Model 2	7.2	6.2	7.8
	Quality standards	8	8	8
Amoniak	Before filtration	7	7	7
	Model 1	1.4	0.5	0.5
	Model 2	0.6	0.7	0.8
	Quality standards	4	4	4

The relatively small variation in pH values across different treatment conditions is likely attributed to the high organic content in the restaurant wastewater. As a result, after treatment, the pH did not increase to a standard value of 8. In a similar study, the pH measurements before and after treatment with zeolite and activated carbon media also showed no significant change in pH levels. This suggests that the treatment process did not significantly influence the pH value of the water. A comparison of the pH measurement results can be observed in Figure 2.

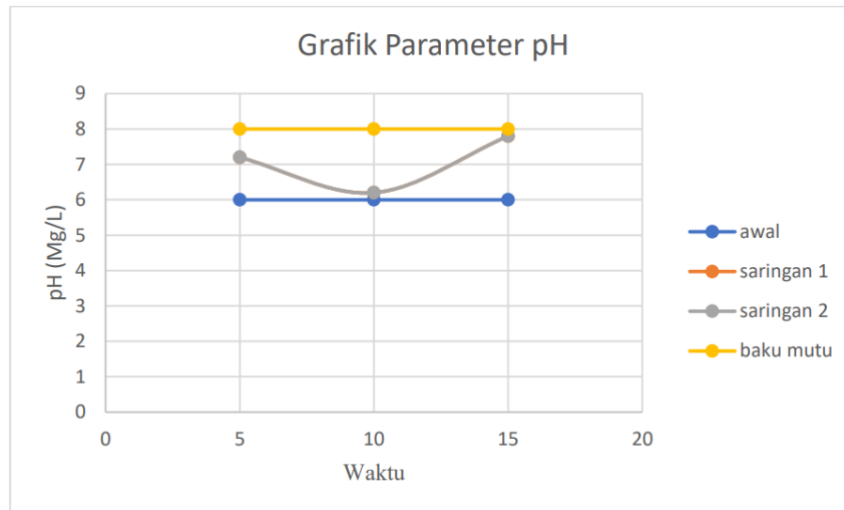


Figure 2. Comparison graph of measurement results of pH parameter.

The ammonia concentration measured before filtration was at a value of 7, indicating non-compliance with the quality standards stipulated in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 68 of 2016. Concerning Domestic Wastewater Quality Standards. However, following the filtration process, the ammonia levels were reduced to meet the acceptable limits defined by the regulation. These findings indicate that the applied treatment method is effective in reducing pollutant levels. Graph comparing the measurement results of ammonia in Figure 3.

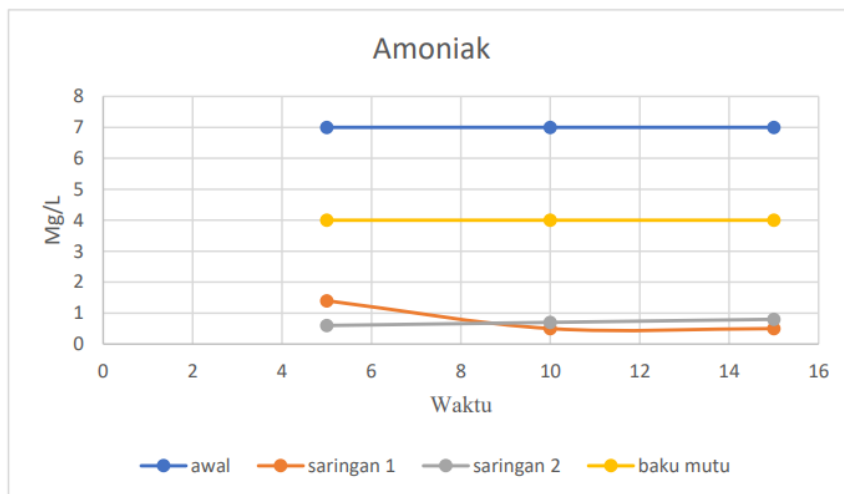


Figure 3. Comparison graph of measurement results of the ammonia parameter.

Physical parameter measurements were initiated by recording the temperature. According to Regulation No. 063/AL/Lablingk DHL/2021, the standard temperature range for domestic wastewater quality is 25–32 °C with standard quality under 40 °C. Based on the results of this study, it can be concluded that the measured temperature values comply with the established water quality standards. A comparison of temperature measurement results can be observed in Table 3 and Figure 4.

Table 3. The results of physical analysis of restaurant wastewater before and after the filtration treatment.

Parameter	Unit	Filtering time		
		5 (minute)	10 (minute)	15 (minute)
Temperature	Before filtration	27.6	27.6	27.6
	Model 1	28.3	27.7	27.5
	Model 2	28.1	27.7	27.6
	Quality standards	40	40	40
Turbidity	Before filtration	25.72	25.72	25.72
	Model 1	11.42	9.98	7.8
	Model 2	9.98	9.96	6.02
	Quality standards	25	25	25
DO	Before filtration	31	31	31
	Model 1	1.4	0.5	0.5
	Model 2	0.6	0.7	0.8
	Quality standards	4	4	4

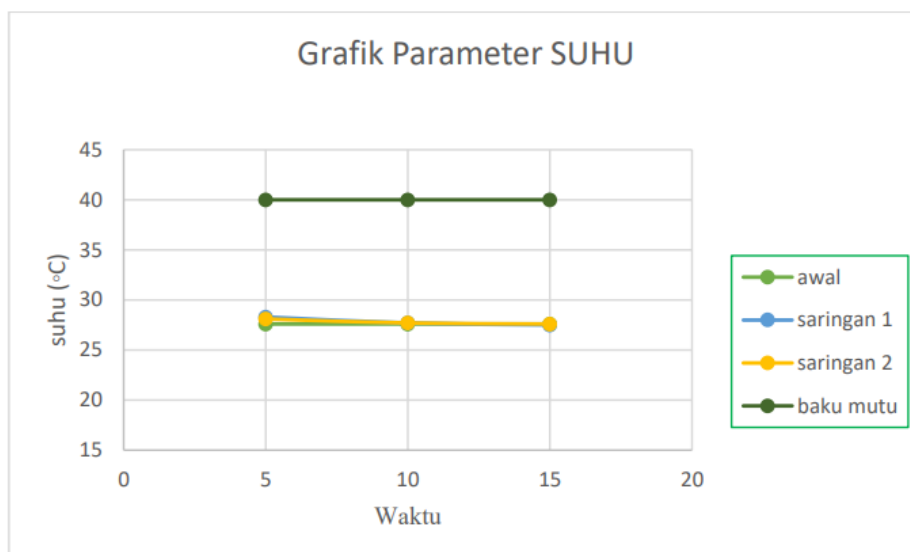


Figure 4. Comparison graph of measurement results of amonia's parameter.

Figure 4 illustrates a reduction in turbidity levels, with the final measurement recorded at 11 NTU, representing a 67% decrease. However, this value still exceeds the turbidity quality standard of 25 NTU as stipulated in the Regulation of the Minister of Health Number 32 of 2017. concerning Environmental Health Quality Standards and Water Requirements for Sanitation Purposes. The observed reduction in turbidity is influenced by the filtration media used. Changes in odor and color were also noted, suggesting further improvements in water quality. These effects are likely

attributable to the presence of silica sand, which plays a significant role in reducing turbidity and odor.

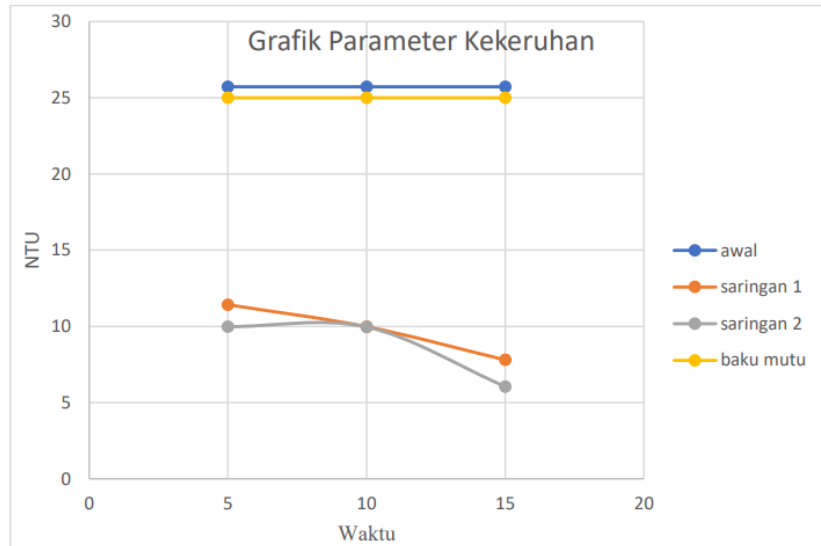


Figure 5. Comparison graph of measurement results of turbidity's parameter.

Dissolved oxygen (DO) refers to the amount of oxygen available in water, which is essential for the respiration and metabolic processes of aquatic organisms. A higher DO value in wastewater generally indicates better water quality. Based on established quality standards, optimal DO levels in wastewater should range from 0 to 6 mg/L. Wastewater temperature significantly influences DO levels; as temperature increases, the solubility of oxygen decreases, resulting in lower concentrations of dissolved oxygen. As illustrated in Figure 6, this research findings confirm that higher wastewater temperatures are associated with reduced DO levels, aligning with the theoretical relationship between temperature and oxygen solubility.

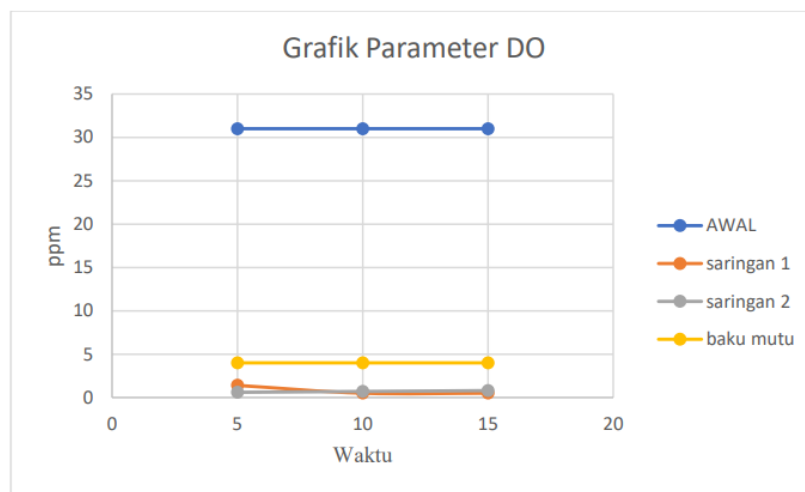


Figure 6. Comparison graph of measurement results of turbidity's parameter.

Based on the analysis of all tested parameters, slow sand filtration has been shown to reduce pollutant levels in restaurant wastewater. These findings highlight the importance of encouraging restaurant operators to implement proper wastewater treatment measures before discharge into natural water bodies. Further research is required to explore and optimize combinations of slow sand filter media to enhance treatment efficiency and improve overall performance. The documentation of the implementation is presented in Figure 7.



Figure 7. Slow Sand Filtration Model

CONCLUSION

The results of the study indicate that slow sand filtration is effective in reducing pollution in domestic wastewater. Generally, the second model demonstrated a greater efficacy in reducing pollution levels, particularly in terms of ammonia and dissolved oxygen (DO) parameters, compared to the first model. This outcome can be attributed to the greater amount of silica sand in Model 2, as silica sand is the most influential filter material in reducing pollution. The study also demonstrates that slow sand filters can effectively treat wastewater by reducing both chemical and physical parameters, making it a viable method for ensuring wastewater meets quality standards prior to being discharged into water bodies.

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AUTHORS CONTRIBUTIONS

All authors are major contributors to this research. SDR, DK, EAP, NAR, and TM collaborated to design the research and write the initial research draft. EAP and NAR: executed the experiment, SDR and TM: wrote the article draft and revised the draft, SDR and DK: contributed suggestions for article improvement.

CONFLICT OF INTEREST

The authors declare no conflict of interest. This research, including the selection of the research project, study design, data collection, analysis, interpretation, manuscript writing, and decision to publish, was conducted independently and without any external influence or funding sponsor involvement.

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