

Regional Case Study

Domestic Wastewater Treatment to Control River Pollution in Sungai Pinang, Samarinda, East Kalimantan

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Abstract

Filtration is a method for controlling water pollution. This study aimed to engineer a filtration system using a combination of *Melaleuca cajuputi* (galam) wood charcoal and zeolite to process domestic wastewater. The research focused on domestic wastewater from Sungai Pinang Village, Samarinda, East Kalimantan, an area with significant water pollution issues. The samples were divided into three groups, each containing zeolite and galam wood charcoal in different ratios: Group 1 (1:1), Group 2 (1:2), and Group 3 (2:1). Each sample was exposed to contact times of 30, 60, and 90 minutes. Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia (NH₃), and pH were measured for each treatment group at each contact time. Results showed that prolonged contact with the filtration method significantly reduced all parameters except pH ($P < 0.05$). Each treatment combination did not significantly reduce all parameters except pH ($P > 0.05$). Group 2 was found to be the most effective in improving water quality. In conclusion, this study demonstrates that the filtration method can reduce pollutant levels, with the combination of galam wood charcoal and zeolite in a 2:1 ratio being the most effective.

Keywords: Domestic wastewater; filtration; treatment engineering; water pollution

1. Introduction

Environmental pollution is a critical global issue resulting from factors such as industrialization, population growth, urbanization, uncontrolled fuel use, and increased motorized traffic (Awewomom et al., 2024; Manisalidis et al., 2020). This problem has detrimental effects on the environment, including disruptions to ecosystems and harm to living organisms, including humans (Manisalidis et al., 2020). Water pollution is one of a global concern that requires international cooperation and special attention.

Many countries are implementing measures to enhance water waste management to tackle this issue (Warren-Vega et al., 2023).

Liquid waste is categorized into domestic, industrial, and atmospheric liquid waste (Abduraimov, 2021). Domestic wastewater originates from household activities such as bathroom use, washing, and other household chores (Bakkara and Purnomo, 2022; Widyanani et al., 2022). Domestic wastewater can be classified into four types: yellow (urine), brown (feces plus toilet flush water), black (urine, feces, and bacterial activity), and gray (liquid waste from kitchen, laundry, bathroom, and handwashing facilities) (Koul et al., 2022). Domestic wastewater significantly contributes to water pollution in many developing countries with high population densities, like Indonesia. This conclusion is supported by data on water pollution in major rivers across Indonesia. For example, data from Jakarta indicates that domestic liquid waste makes up about 70% of water pollution in the city, while the industrial and manufacturing sectors contribute around 15% and 14%, respectively (Harahap et al., 2020).

Samarinda is one of the cities in Indonesia and serves as the capital of East Kalimantan province. The majority of the city is situated in the flow areas of two major rivers, the Mahakam and Karang Mumus rivers. The Sungai Pinang District in Samarinda City is densely populated and serves as a hub for economic, social, administrative, and environmental services (Mariani et al., 2021). This district is also known for its numerous housing complexes, schools, and home industries, including businesses that produce crackers and engage in hand-painting (Asti and Mayasari, 2023). The activities of the residents in this area contribute to the increase in domestic wastewater resulting from community activities (Mariani et al., 2021). Domestic wastewater typically contains detergents, shampoos, soaps, bleaches with chlorine, nitrogen, and phosphorus compounds (Hayat, 2020; Maliga et al., 2022). Moreover, domestic wastewater includes oil and organic food waste that can decompose, leading to the formation of NH_3 in water bodies. NH_3 levels exceeding 1 ppm can be detrimental to fish, causing their death in water bodies (Satria et al., 2019). Indiscriminate disposal of wastewater can cause water bodies to become murky and unpleasant smelling. This situation can lead to eutrophication due to high levels of Nitrogen (N) and Phosphorus (P), resulting in excessive weed growth that can cover water bodies (Akinawo, 2023). When eutrophication occurs, sunlight is blocked, halting photosynthesis and causing oxygen levels to drop. This lack of oxygen can lead to the death of aquatic organisms and decrease the levels of BOD and COD (Shivsharan and Wani, 2017).

Domestic wastewater derived from organic matter can also be oxidized into weak acids such as oxalic acid, acetic acid, tartaric acid, and others, lowering the pH of the water (Magowo et al., 2020). This change in pH can cause fish and aquatic organisms to perish due to acidic conditions (Darmawan et al., 2021). Moreover, this acidic environment fosters the growth of bacteria and viruses that thrive in such conditions. If this contaminated water is used for bathing, it poses a risk of skin irritation and itching (Yehia and Said, 2021).

To mitigate water pollution, particularly in the Sungai Pinang area, various policies have been put in place. One of the key policies is education and awareness campaigns aimed at increasing public knowledge and changing behaviors related to domestic wastewater disposal. Previous studies have shown that wastewater treatment management is also effective in overcoming and reducing water pollution. For successful implementation of wastewater management methods in society, they must be designed with ease of manufacturing and low production costs at scale (Utari and Herdiansyah, 2020). Wastewater treatment methods have been developed using three primary approaches: physical, chemical, and biological methods. One of the most practical and cost-effective methods is physical filtration (Tarru et al., 2021; Utari and Herdiansyah, 2020).

Filtration uses the principle of separating solid materials from liquids using porous media. Filtration has been shown to effectively remove colloids, suspended matter, and other impurities from water, thereby minimizing contaminant levels (Hamdan et al., 2022). This method is typically carried out using various materials, such as gravel, activated charcoal, zeolite, and sand. Sand has been found to have the lowest effectiveness among these materials. However, the combination of activated charcoal and

zeolite has been shown to be one of the most effective filtration methods for reducing pollutants in domestic wastewater (Utari and Herdiansyah, 2020).

Zeolite is an adsorbent that has been widely researched and is naturally found as crystalline aluminosilicates. Zeolite has been widely used for filtration due to its abundance in nature, making it a low-cost application. In contrast, activated charcoal, which is the oldest and most well-known adsorbent in wastewater treatment, is quite expensive to use and is not as readily available as zeolite (Onyutha et al., 2024). Activated charcoal is an organic material derived from substances with high carbon content, such as coal, coconut shells, or wood dust (Haryati et al., 2017).

Melaleuca cajuputi subsp. cumingiana, also known locally as is a plant that grows in lowland areas, shallow peat forests, and swamp areas. This plant is abundant in several regions of Indonesia, such as South Kalimantan (Ardhana and Alimah, 2018). Galam wood remains a valuable commodity that provides many benefits to people, both personally and economically. However, its utilization is currently limited and not optimal. Galam wood is mainly utilized as a component in building construction. After its use, the wood waste is often discarded and ends up as organic waste (Supriyati et al., 2015; Anggraini and Muzaidi, 2020). Research conducted by Haryati et al. (2017) revealed that galam bark holds potential as a source of active carbon. Additionally, a study by Alpian et al. (2010) indicated that activated charcoal derived from galam wood can enhance the water quality of wells and rivers, leading to improvements in various water quality parameters, with the exception of pH.

The combination of zeolite and activated charcoal from galam wood as a filtration media in domestic wastewater treatment has not been widely studied. Therefore, this present study aims to examine the effect of combining zeolite and activated charcoal from galam wood as a filtration media in domestic wastewater treatment from Sungai Pinang, Samarinda, East Kalimantan. The media is expected to remove colloidal particles and pollutants, resulting in clean and clear water suitable for reuse in irrigation and other purposes. In addition, improvements in water quality parameters such as pH, BOD, COD, and NH₃ levels are expected to be observed, indicating the effectiveness of the filtration media. If the results of this study support further research, then the combination of filtration using zeolite and activated charcoal from galam wood is a new media combination that can be used in the domestic liquid waste treatment.

2. Methods

2.1. Domestic wastewater sampling

This study employed a pre-and post-test design to evaluate the effectiveness of combining zeolite and activated charcoal from galam wood in improving domestic wastewater quality parameters. The study focused on wastewater collected from several drainage areas in the Sungai Pinang District, Samarinda City, East Kalimantan Province, Indonesia (**Figure 1**). Sungai Pinang District is a district resulting from the expansion of Samarinda District, East Kalimantan. The Sungai Pinang area borders North Samarinda District to the north and Samarinda Ilir District to the south, while to the west and east are Samarinda Ulu District and Sambutan District, respectively. The population of Sungai Pinang in 2023 is 861,878 people with an area of 34.16 km².

Daily wastewater samples were collected for 14 days between 7:00-10:00 am, as this period corresponds to the peak hours of community activities such as washing, bathing, and cooking. To prevent contamination, the wastewater samples were taken in clean containers and rinsed with distilled water before measurement. Prior to the initial water quality parameters of pH, BOD, COD, and NH₃ were measured.

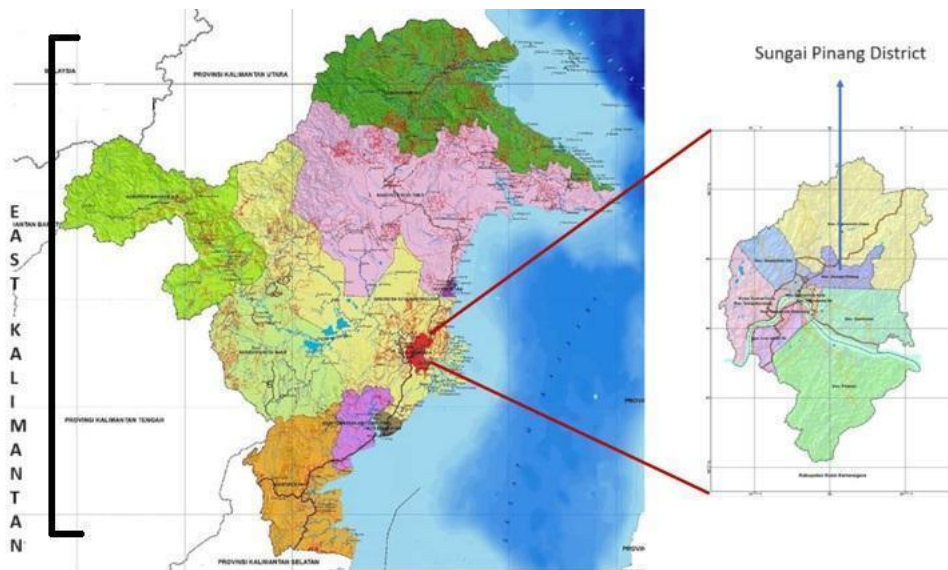


Figure 1. Domestic wastewater sampling location points in Sungai Pinang District

2.2. Wastewater treatment diagram

The wastewater treatment system is set up with three tanks at different heights from the floor (Figure 2) using a downflow operation system. Each tank is made of plastic and has the same dimensions: 31 cm in length, 21 cm in width, and 70 cm in height, with a water volume of 2 L. The design of the water tank in this study is based on the tank created by Amri and Wesen (2015) for domestic wastewater treatment.

Wastewater enters the initial first tank with a pipe at the bottom of the tank. Subsequently, the wastewater flows from the initial tank into the second tank, which is the filtration tank. The filtration tank comprises variations of media combinations: (1) 1500 grams of zeolite + 1500 grams of galam wood activated charcoal (1:1); (2) 1000 grams of zeolite + 2000 grams of galam wood activated charcoal (1:2); and (3) 2000 grams of zeolite + 1000 grams of galam wood activated charcoal (2:1). The filtration treatment process lasted for 90 minutes for each treatment. The water samples were collected at 30, 60, and 90 minutes from the outlet pipe at the bottom of the filtration tank. After each filtration treatment, the water quality parameters were measured, including pH, BOD, COD, and ammonia. Additionally, the galam wood charcoal used has a mesh size range of 50-70, and the design of the wastewater treatment with the filtration system is shown in Figure 2.

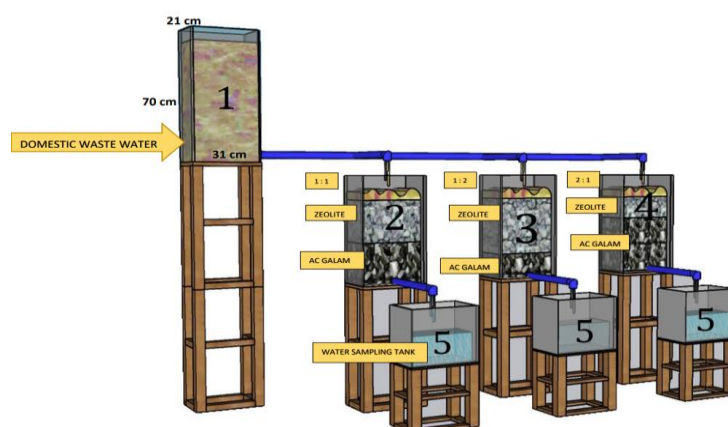


Figure 2. Process diagram illustration for domestic wastewater treatment system. (1) initial tank; (2) treatment 1 group (1:1; zeolite: galam wood activated charcoal); (3) treatment 2 group (2:1; zeolite: galam wood activated charcoal); (4) treatment 3 group (1:2; zeolite: galam wood activated charcoal); and (5) water sample for analysis. AC: Activated Charcoal

2.3. Water quality analysis

Wastewater pH measurements were conducted using an electrometric method with pH meters. Prior to usage, the pH meter was calibrated with three buffer solutions at pH 5, 7, and 9 to ensure precise readings. Following calibration, the electrode was immersed into the wastewater until the pH meter displayed a stable reading (Ramayanti and Amna, 2019).

The BOD level was analyzed using Winkler's titration method. BOD levels were measured by taking a 60-mL wastewater sample. The sample was added to a Winkler bottle and diluted with distilled water until full. Then, one sample was incubated for five days at 20°C as DO₅. A second sample was prepared similarly, without incubation. Next, each sample solution received one milliliter of MnSO₄ solution and one milliliter of alkali iodide azide solution added with the pipette tip directly above each solution. Each mixture was covered, homogenized until a perfect lump formed, and left for five to ten minutes in the dark by wrapping it in aluminum foil. One milliliter of concentrated H₂SO₄ solution was added to each mixture, and the bottle was closed again and left until the precipitate had become homogeneous and completely dissolved. The resulting solution was transferred to a 50-mL Erlenmeyer flask and titrated using Na₂S₂O₃ as an indicator, with starch added as an indicator. Titration continued until the blue color disappeared, and results were recorded (Ramadani et al., 2021).

The COD level is measured using Winkler's or titration method. To begin, 2 ml of wastewater samples and 8 ml of distilled water are combined. Next, 5 ml of the diluted sample is transferred to an Erlenmeyer flask. Then, 5 ml of H₂SO₄ 6N solution and 20 ml of K₂Cr₂O₇ are added. The mixture is shaken and heated in a water bath for 10 minutes. After heating, the mixture is allowed to cool until it reaches a temperature of 25°C and then wrapped in aluminum foil. The resulting mixture is titrated with 0.1 N Na₂S₂O₃ until a yellow color appears. Subsequently, 10 drops of starch are added as an indicator. The titration process continues until the blue color turns light green (Ramadani et al., 2021).

NH₃ levels in water are measured using the spectrophotometric method. This method involves preparing a sample solution by adding 1 ml of 10% phenol solution and sodium nitroprusside to a 25 ml water sample. Standard solutions with concentrations of 0, 0.2, 0.4, 0.6, 0.8, and 1 ppm ammonia were also prepared. Each sample and standard solution was then mixed with 2.5 ml of oxidizing solution, covered with aluminum foil, and left for 1 hour to allow for the reaction. After an hour, the solutions turned blue, and their absorbance was measured using spectrophotometry at a wavelength of 630 nm (Butler et al., 2022).

2.4. Data analysis

This research was conducted by analyzing laboratory data, specifically the results of testing the parameters pH, BOD, COD, and NH₃ in domestic wastewater before and after treatment. Each measurement was repeated three times, and the average was calculated. Laboratory data were compared with the required quality standards set by the Minister of Environment and Forestry Regulation Number 68 of 2016, which regulates the environmental regulations for wastewater treatment. Furthermore, Additionally, test data were analyzed using Two Two-Way ANOVA the IBM SPSS statistics for Windows 11 application to determine the effect of treatment combination and contact time in improving the water quality parameters measured in this study. Statistical significance was set at $P < 0.05$ for all tests, tests identify differences. Data were using tables, figures, etc., with the help of Microsoft Excel 2019 for Windows 11.

3. Result and Discussion

Before undergoing treatment with various combinations of wastewater treatment processes at different times, the quality parameters of domestic wastewater were measured as initial parameters. These initial parameters were measured as follows. The parameters were also compared with the standard water quality regulations set forth in Minister of Environment and Forestry Regulation Number 68 of 2016. The initial water quality parameters and their comparison with the standards are presented in Table 1.

Table 1. Initial characteristics of wastewater

Parameter	Unit	Values in Wastewater	Standard Value
pH		5.3	6.0 – 9.0
BOD	mg/L	75.66	30
COD	mg/L	136.97	100
NH ₃	mg/L	11.108	10

The results in Table 1 show that the wastewater has been polluted with pollutants. This can be seen from the pH value, BOD, COD, and NH₃ levels, which exceed the standard values. High BOD and COD concentrations of wastewater are due to high organic content, resulting in an increased demand for oxygen gas. The higher the BOD and COD concentrations, the fewer microorganisms can survive in them (Nurhayati et al., 2019). On the other hand, the NH₃ in wastewater is also high. NH₃ measured in waters is in the form of total ammonia (NH₃ and NH₄⁺). NH₃ is a byproduct of the decomposition of plant or animal proteins or their feces. Artificial fertilizers also contain ammonia and its compounds, so the runoff from fertilizers carried by water can decompose and potentially increase the NH₃ content in the water (Sulistya and Septisya, 2019). According to Hidayah (2018), the high concentrations of BOD, COD, and NH₃ illustrate that organic materials have polluted the environment; therefore, it is necessary to carry out treatment.

In this study, we propose a filtration method using a combination of zeolite and activated galam wood charcoal to enhance water quality parameters. We employed three different combination treatments: 1:1, 1:2, and 2:1 for zeolite to activated galam wood charcoal comparison, respectively. Additionally, we measured water quality parameters at three different intervals: 30, 60, and 90 minutes. The results of measuring water quality parameters at these time points and combinations of treatments are presented in Table 2.

Table 2. Wastewater quality parameters (pH, BOD, COD, and NH₃) in several treatment groups at different times

Treatment Group	Parameter	Unit	Time Contact (minute)			P Value
			30	60	90	
I	pH		5.4	5.5	5.7	
	BOD	mg/L	38.32	36.95	35.38	0,035
	COD	mg/L	90.70	83.20	66.90	0,021
	NH ₃	mg/L	9.711	9.644	9.543	0,025
II	pH		5.5	5.6	5.7	
	BOD	mg/L	67.81	36.95	21.65	0,042
	COD	mg/L	124.98	108.47	97.48	0,037
	NH ₃	mg/L	9.153	9.118	9.043	0,045
III	pH		5.4	5.6	5.8	
	BOD	mg/L	34.07	31.65	29.47	0,035
	COD	mg/L	98.01	86.40	79.58	0,021
	NH ₃	mg/L	9.128	9.068	9.055	0,025

The results presented in Table 2 show that the contact time and treatment combination affect the pH value, BOD, COD, and NH₃ levels. The increase in pH did not seem to have met the standard quality standards set by the Indonesian government. Conversely, the BOD level was lower than the standard quality standards at the 90th minute in the filtration process using a zeolite to activated charcoal ratio of 1:2 and 2:1. In contrast to pH and BOD, the COD value was consistently lower than the standard quality standards in all treatment groups, except for group 2 at 30 and 60 minutes. All treatments at all time periods exhibited ammonia levels below the standard quality standards.

The results presented in Table 2 show that the contact duration with each treatment combination significantly affects the pH value, BOD, COD, and NH₃ levels ($p < 0.05$). The data indicate a significant increase in pH and a decrease in BOD, COD, and NH₃ levels. The results of this study are consistent with those of Kurniawati and Sanudin (2020), who found that contact time in the filtration method can decrease the level of BOD and COD in batik industry waste. Additionally, Wirosodarmo et al.'s (2020) research study states that contact time can affect BOD and COD levels in domestic wastewater

The improvement in water quality is attributed to the adsorption of activated charcoal derived from galam wood, which can eliminate aromatic compounds and dissolved compounds (Zilfa et al., 2022; Muzarpar et al., 2020). Adsorption occurs when the attractive forces between solute molecules and the adsorbent are stronger than those between the molecules and the solvent. Additionally, adsorption can take place through weak bonds such as hydrogen bonds and van der Waals forces, enabling molecules to adhere to the surface of the adsorbent. The longer contact duration allows for more pollutants to be removed by activated charcoal from galam wood (Dewi et al., 2018), as more pollutants are captured by the adsorbent over time.

The results in Table 2 also show that the treatment combination did not significantly change the water quality parameters measured in this study ($p > 0.05$). However, the BOD, COD, and NH₃ levels showed a decrease, except for pH. The decrease in BOD, COD, and NH₃ levels is presumably due to the increase in pH value. The level of acidity greatly affects changes in the surface charge of the adsorbent during the adsorption process. In this process, H⁺ and OH⁻ will compete to attach to the cavities of the adsorbent. The effectiveness of the composition of zeolite and galam wood activated charcoal in increasing adsorption rates was found to be about 1.89-9.43%. Meanwhile, BOD levels decreased by 10.37-71.39%. On the other hand, COD levels also decreased by 8.75-71.39%, and NH₃ levels decreased by around 12.57-18.59%.

The contact time of treatment group II for 90 minutes is an effective duration. Contact time refers to the period of contact between wastewater and the media. The longer the contact time, the more pollutants will be captured by activated carbon and zeolite. This is believed to occur because the active sites become saturated with pollutants until the adsorption process reaches equilibrium. At this point, the opportunity for active sites on the surface of the adsorbent to capture pollutants diminishes. Once equilibrium is achieved, the adsorption of pollutants stabilizes in terms of the percentage of adsorbate, as the active groups on the surface of the adsorbent have been utilized (Muhammad, 2013).

The results of this present study also show that Group II, consisting of 1000 grams of zeolite and 2000 grams of galam wood charcoal (1:2), was the most effective treatment in reducing BOD, COD, and NH₃ levels. These results suggest that the composition with a higher proportion of galam wood charcoal leads to better improvement in water quality parameters. This is due to the process of diffusion and attachment of solute molecules, which are adsorbed more effectively. On the other hand, zeolite is a coagulant that has the ability to bind to negative and small particles (Khaleque et al., 2020; Nugraheni et al., 2023). Furthermore, zeolite can neutralize these particles by forming small flocs and allowing them to settle. This precipitation results in a decrease in pollutants in the wastewater, which can be seen from the decrease in BOD, COD, and NH₃ levels (Arita et al., 2022; de Magalhaes et al., 2022).

In general, this study aligns with the findings of Pungus et al. (2019), which indicated that the utilization of activated charcoal and zeolite can decrease the levels of COD and BOD in domestic wastewater. The study also elaborated on how media thickness and contact time play a significant role in influencing the treatment process.

This study has proven that the treatment method can effectively reduce pollutants from domestic waste. The findings of this study can be implemented in the community using models and scales tailored to the volume and discharge of wastewater. Nevertheless, further research is needed to explore this further.

In this study, there are several weaknesses, namely that sampling was carried out only in the morning. Therefore, in future studies, sampling needs to be conducted at various times, such as during the day and evening. Additionally, it should be compared with data from the riverbanks.

4. Conclusions

The results of this present study suggested that the combination of contact time and treatment in this wastewater treatment could increase water pH and decrease the BOD, COD, and NH₃ levels in wastewater. The decrease in BOD, COD, and NH₃ levels was seen below the standard quality limits set by the government but not the pH value. Also, the reduction of BOD, COD, and NH₃ and increased pH indicated that this treatment combination for 90 minutes or more can improve wastewater quality. The best combination of wastewater treatment in this study was seen in the combination of Galam wood charcoal and zeolite in a ratio of 2:1. While this finding is promising, further research is needed to optimize the method, such as investigating the effects of different contact times and treatment ratios, and ensure its widespread adoption as an alternative for improving water quality.

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