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Sustainable Campus Wastewater Treatment using Anaerobic Baffled Reactor Systems

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ABSTRACT

Aim: This study aims to investigate the efficiency of the Anaerobic Baffled Reactor (ABR) system in domestic wastewater treatment at the Graha Rectorate of the State University of Malang (UM), part of the UM Green Campus program.

Methodology and results: The study was conducted by installing a laboratory-scale ABR system and investigating its performance in reducing pollutant concentrations. Sampling was carried out at the inlet and outlet ports, and the system was run for Hydraulic Retention Time (HRT) of 24 hours. The samples were analyzed for chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), Total Coliform (TC), pH, dissolved oxygen (DO), and temperature. The results showed that the ABR system with a flowrate of 1.408 m³/day and a reactor volume of 1.901 m³, consisting of 9 compartments, was able to reduce TSS and COD concentrations to meet the quality standards of Permen LHK No. 68/2016. Statistical tests showed significant reductions in COD, BOD, and TSS parameters. The removal efficiency of each parameter is TSS (91.33%), COD (40.44%), BOD (32.14%), and TC (51.18%). **Conclusion, significance, and impact study:** This study demonstrated that ABR is effective in treating campus wastewater, but further design optimisation or hybridisation with another system is still required. A combination of additional treatments is recommended to ensure compliance with regulatory standards and support the achievement of Sustainable Development Goals (SDG 6 and SDG 11), particularly in the areas of clean water and sanitation, as well as sustainable cities.

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- Anaerobic baffled reactor (ABR)
- Reactor design
- Sustainable wastewater management
- Universitas Negeri Malang
- Wastewater treatment

1. INTRODUCTION

Domestic wastewater is the result of various routine activities, such as toilet use, bathing, washing, and other activities that take place in settlements, public facilities, and educational institutions (Pratama *et al.*, 2023). This waste generally contains organic, inorganic substances, as well as pathogenic microorganisms that can pollute the environment if not treated properly. In developing countries, domestic waste accounts for up to 85% of the total pollutants of water bodies, whereas in developed countries, it is approximately 15% (Adhani *et al.*, 2020). This fact indicates that wastewater management in developing countries still faces serious obstacles, both in terms of infrastructure, regulation, and public awareness.

The education sector also contributes a large amount of domestic wastewater, especially from laboratories, canteens, and sanitation facilities. Based on the Regulation of the Republic of Indonesia No. 32/2009, each institution is responsible for the waste management generated from its activities (Hariyadi *et al.*, 2020). Therefore, integrated and sustainable wastewater management is important, not only as an environmental responsibility, but also as a contribution to the achievement of the Sustainable Development Goals, particularly of SDG 6 (Miller *et al.*, 2017).

Universitas Negeri Malang (UM), as an educational institution, is committed to the principle of sustainability, which has implemented the Green Campus program and built a conventional on-site wastewater treatment (extended septic tank) at four locations on the campus (e.g. new lecture building, Graha Rectorate, student dormitory, and Faculty of Sports Science) (UM Green Campus, 2022). However, the existing wastewater treatment still has limitations in terms of the removal efficiency and technical function of wastewater treatment, especially at the Graha Rectorate. This issue encourages the need to develop a more efficient and environmentally friendly wastewater treatment system.

Anaerobic Baffled Reactor (ABR) is a low-cost wastewater treatment technology that can be used as an alternative solution for campus wastewater treatment. It has advantages in terms of cost efficiency, ease of operation, and the ability to significantly reduce pollutant loads such as BOD, COD, and TSS (Suryani, 2020). The implementation of ABR has proven successful in reducing pollutant levels by more than 90% in several countries (Kurniawan *et al.*, 2023). However, up to now, there have not been many studies that specifically test the effectiveness of ABR systems in the context of educational institutions in Indonesia, especially at the laboratory scale as an initial

implementation model. The characteristics of wastewater originating from campus administrative activities tend to be different from domestic household wastewater, in terms of characteristics and flowrate; and therefore, a specific experimental study is needed. In addition, there is no standardised approach that adapts ABR technology to be implemented on the campus through a small-scale approach or laboratory tests as an initial stage of wastewater treatment plant (WWTP) system design.

The application of the ABR system in the UM campus is expected to be a strategic solution in increasing the effectiveness of wastewater treatment, while strengthening the institution's commitment to realising a sustainable campus. The successful implementation of this system can be used as a reference model for other educational institutions that face similar challenges. Thus, UM has the potential to strengthen its position as one of the pioneers in the development and application of waste treatment technology innovations in Indonesia's higher education and contribute significantly to supporting the sustainable development agenda at the national level.

2. RESEARCH METHODOLOGY

2.1 Research Location

Figure 1 shows the Universitas Negeri Malang (UM) map in which the study was conducted. Wastewater sampling was collected from the wastewater tank of the Graha Rectorate Building. The ABR prototype installation was placed at the B9 Building of the Department of Civil Engineering and Planning.

2.2 Anaerobic Baffled Reactor Design

Wastewater discharge is calculated from the clean water consumption used by the staff and visitors of the UM Graha Rectorate Building, that converted into 80% of the total clean water consumption. The total of clean water used by the staff and visitors was 17.6 m³/d, and the wastewater production was 14.08 m³/d. The lab-scale of the ABR design was 1:10 compared to the real design dimension. The concentration of BOD, COD, TSS, and TC of the domestic wastewater collected from the UM Rectorate Building exceeds the quality standards (Ministry of Environment and Forestry Regulation No. 68/2016), indicating high organic and microorganism content that potentially cause the pollution. DO concentration of 2.4 mg/L and temperature of 26 °C were also analysed with reference to Government Regulation No. 22/2021 concerning the

Implementation of Environmental Protection and Management, which consists of the river water quality standards and ensures that treated wastewater remains safe before being discharged into receiving water bodies.

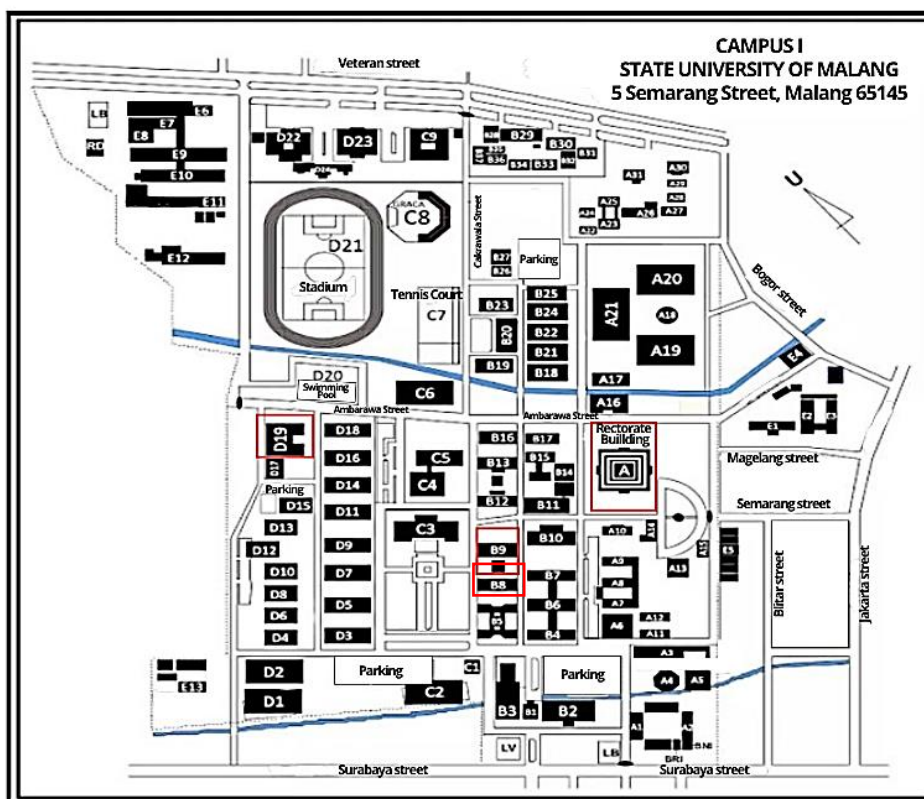


Figure 1 Research location

Table 1 Wastewater characteristics of the graha rectorate

Parameters	Concentration	Unit	Quality Standard
COD	246.9	mg/L	100
BOD	82.97	mg/L	30
TSS	143	mg/L	30
TC	840,000	CFU/100 mL	3,000
pH	7.8	-	6-9
DO	2.4	mg/L	1 (min)
Temperature	26	°C	40 (max)

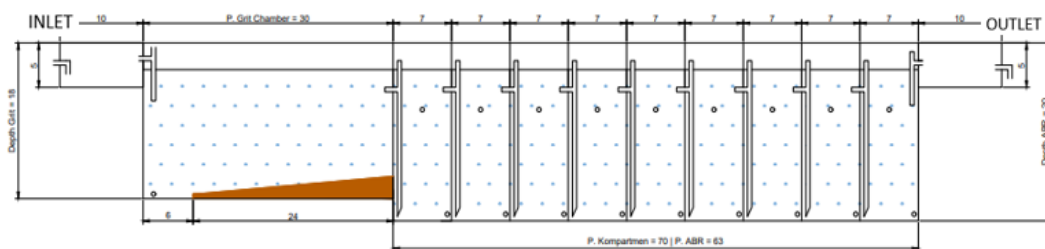


Figure 2 Design of the lab-scale ABR

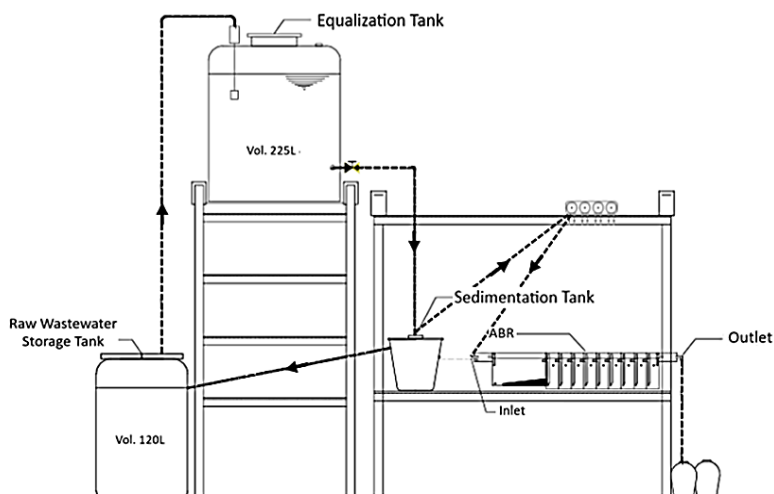


Figure 3 The ABR System

Furthermore, ABR was designed based on the guidelines of the SNI 8455: 2017 (Indonesian National Standard) and domestic wastewater characteristics in Table 1. The ABR dimension was calculated for the sedimentation tank and ABR compartments. By its calculation results, the dimensions of ABR were 113 cm of length, 15 cm of width, 18 cm of depth in the sedimentation tank, and 20 cm of depth in ABR compartments (Figure 2). The ABR system (Figure 3) consists of:

- 1) A 120 L raw wastewater storage tank.
- 2) A 225 L of the equalisation tank, which is inserted by a stirring machine for mixing.
- 3) A 55 L sedimentation tank.
- 4) ABR reactor, using glass material with a total of 9 compartments.

2.3 Wastewater Sampling

Domestic wastewater sampling at Graha Rectorate UM was collected according to the water sampling procedure. Samples from the ABR were taken from the inlet and outlet within the duration of three months, and the sampling was conducted twice per week. To maintain this cleanliness, the sample bottle was washed using 1M H₂SO₄, then rinsed with distilled water. The hydraulic retention time used in this experiment was 24 hours. The analysis of wastewater samples was conducted in the Environmental Laboratory of the Department of Civil Engineering and Planning of UM.

2.3.1 Parameter Analysis of the Sample

The parameters tested in this study refer to Permen LHK No. 68/2016 in the forms of TSS, COD, BOD, TC, pH. In addition, DO, and temperature were also analysed with reference to Government Regulation No. 22/2021. The sample analysis was carried out at the Environmental Laboratory of UM and Perum Jasa Tirta I Malang Laboratory. The TSS, COD, BOD, and TC are used according to the standard of the American Public Health Association (APHA). Analysis of pH, DO, and temperature parameters was conducted on-site using an HQ Series Multimeter LDO101.

2.3.2 Data Analysis

The results of data processing will be presented both descriptively and quantitatively in the form of tables and graphs, processed using Microsoft Excel and SPSS. The concentration of each parameter was determined to evaluate the efficiency of reducing pollutant concentrations using the ABR system (Equation 1). This equation serves to calculate the level of efficiency of wastewater treatment by comparing the concentration of parameters before and after the treatment process. The higher the efficiency value, the more effective the ABR system is in reducing pollutant concentration in wastewater. Afterwards, data analysis will be conducted using the parametric Paired Sample T-Test and non-parametric Wilcoxon Signed Rank Test.

$$Efisiensi = \frac{a-b}{a} \times 100\% \quad (1)$$

E = Concentration reduction efficiency (%)

a = Parameter concentration at the inlet

b = Parameter concentration at the outlet

3. RESULTS AND DISCUSSION

3.1 Inlet and Outlet Concentration Values

Based on the data presented in Table 1, it is known that the concentrations of TSS, COD, BOD, and Total Coliform of the Graha Rectorate wastewater exceeded the domestic wastewater quality standards, while the pH, DO, and temperature are in accordance with the standards (Table 2). Physical and biological processes in the ABR effectively reduce the pollutant concentration. TSS and COD have met the quality standards with an average value of 13.35 ± 5.04 mg/L and 90.11 ± 17.01 mg/L, respectively. Although there was a decrease in BOD and Total Coliform, both still did not reach the quality standards. The pH, DO, and temperature parameters remained within a stable range and in accordance with the quality standards.

Table 2 Inlet and outlet concentration of wastewater treated with ABR

Parameters	Inlet	Outlet	Unit	Quality Standard
COD	150.30 ± 63.20	90.11 ± 17.01	mg/L	100
BOD	75.56 ± 21.63	51.28 ± 9.89	mg/L	30
TSS	154.01 ± 232.92	13.35 ± 5.04	mg/L	30
TC	$190,000 \pm 308,823$	$92,762 \pm 122,761$	CFU/100 mL	3,000
pH	7.24 ± 0.91	6.87 ± 0.21	-	6-9
DO	2.06 ± 1.01	2.02 ± 0.86	mg/L	1 (min)
Temperature	25.47 ± 2.05	25.68 ± 1.91	°C	40 (max)

3.2 Wastewater Treatment Analysis

3.2.1 Chemical Oxygen Demand (COD)

The results of the COD analysis showed an average concentration of 150.30 ± 63.20 mg/L at the inlet and 90.11 ± 17.01 mg/L at the outlet, with a significant decrease based on the Paired Sample T-Test test with a significance *p-value* of 0.009 (Figure 4). The average value obtained has met the domestic wastewater quality standards according to Permen LHK No.68/2016 (max 100 mg/L). In general, the decrease in COD was consistent, except for the fifth sampling which experienced an increase of 8.59 mg/L. The fluctuation is in line with the findings of Rambe, (2015), which states that changes in COD are caused by the decomposition activity of organic matter by

microorganisms. The increase in COD can be caused by additional organic matter that has not had time to decompose optimally. However, the decrease occurred again in the following week as the performance of microorganisms recovered.

The decrease in COD concentration in line with the decrease in BOD indicates that most of the organic matter in wastewater is biodegradable (Mardianto, 2014). This effectiveness is further strengthened by an adequate HRT, which provides enough time for microorganisms to gradually degrade organic matter (Rambe, 2015; Hendrasarie *et al.*, 2023). The activity of microorganisms in the ABR system plays an important role in this process, where these microorganisms utilize organic matter in wastewater as a source of nutrition (Armesta *et al.*, 2023). Overall, these results show that the ABR system can be able to function effectively in reducing organic load and biologically treating domestic wastewater.

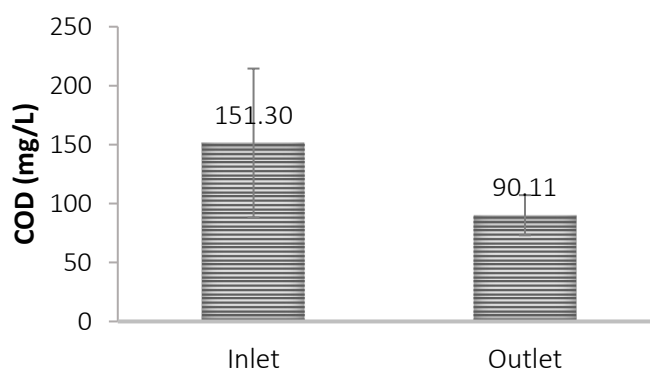


Figure 4 COD concentration at the inlet and outlet of ABR

3.2.2 Biological Oxygen Demand (BOD)

The average BOD concentration showed a decrease from 75.56 ± 21.63 mg/L (inlet) to 51.28 ± 9.89 mg/L (outlet) indicates that the ABR system is capable of reducing some of the organic load in wastewater (Figure 5). This is supported by the results of the Paired Sample T-Test with a *p-value* of 0.007, indicating the significance of the change. However, the effluent BOD value, which remains above the quality standard threshold according to Ministry of Environment and Forestry Regulation No. 68/2016 (≤ 30 mg/L), indicates that the system needs to be improved. This condition is inline with previous research by Kartens *et al.* in Yulistiyorini *et al.*, (2019), which reported that the average BOD of effluent from the ABR system was around 50 mg/L.

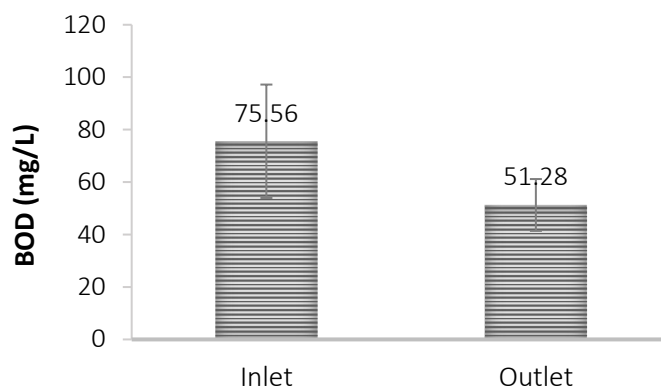


Figure 5 BOD concentration at the inlet and outlet of ABR

The main reason for failing to meet the standard is related to the inherent limitations of the anaerobic process itself, which tends to be slower than aerobic processes in breaking down organic compounds, particularly complex compounds such as proteins and fats (Xu *et al.*, 2014; Khan, A., 2023). Anaerobic microorganisms have low growth rates and are highly sensitive to environmental changes such as temperature, pH, and concentrations of toxic compounds like ammonia and phenolic compounds, all of which can hinder degradation efficiency (Yenji *et al.*, 2021). Additionally, low efficiency can also be caused by HRT. Optimum HRT is important to allow microorganisms to have appropriate time to fully degrade the organic matter (Yulistiyorini *et al.*, 2020).

Organic load imbalance (overloading) is also a significant factor, as an excess of organic material entering the system without being balanced by the microbial population can lead to saturation and a decrease in biological activity. In some cases, inconsistent flow rates can also cause turbulence within the baffle chamber, resulting in short-circuiting and reducing the effectiveness of contact between microorganisms and the substrate (Xu *et al.*, 2014). Furthermore, suboptimal reactor design and construction-such as uneven flow distribution between compartments or sludge accumulation causing blockages-can disrupt organic load distribution and reduce system efficiency (Yulistiyorini *et al.*, 2019; Yulistiyorini *et al.*, 2020).

3.2.3 Total Suspended Solids (TSS)

The results of the TSS analysis showed an average value of 154.01 ± 232.92 mg/L at the inlet and

13,35 ± 5,04 mg/L at the outlet (Figure 6). Based on statistical analysis using the Wilcoxon Signed Rank Test, a significance *p* value of 0.006 was obtained, which indicates a significant decrease between the inlet and outlet points. This finding indicates that the treatment system used is effective in reducing TSS concentrations. The primary mechanisms contributing to this reduction are the sedimentation of suspended particles and biological degradation by anaerobic microorganisms. The compartmentalized design of the ABR can reduce the water velocity and the effluent flow, providing sufficient time for suspended particles to settle effectively (Tilley *et al.*, 2014).

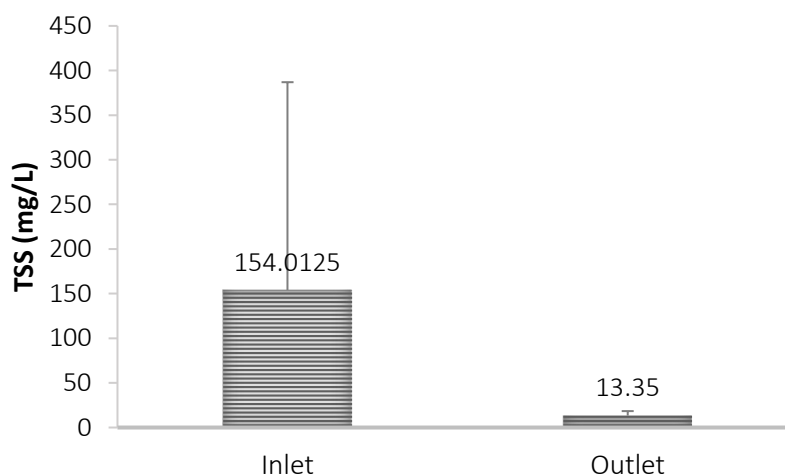


Figure 6 TSS concentration at the inlet and outlet of ABR

Sufficient hydraulic retention time (HRT) also plays a crucial role in this process, enabling optimal activity of anaerobic microorganisms in degrading organic matter. A study by Mahdi *et al.*, (2022) showed that TSS removal efficiency increases with increasing HRT, reaching 91% at an HRT of 36 hours. However, in this study, an HRT of 24 hours was used, and the results still showed a significant reduction in TSS. This indicates that an HRT of 24 hours is sufficient to support the sedimentation process and anaerobic microbial activity within the ABR system. Reductions in TSS often correlate with reductions in COD, as most of the organic matter contributing to COD values is present in the form of suspended particles. This is supported by the results of a study Mardianto, (2014) stating that a decrease in TSS is generally followed by a decrease in COD in wastewater treatment systems. Therefore, the removal of TSS through sedimentation and biological activity indirectly reduces COD concentration (Lau *et al.*, 2024).

3.2.4 Total Coliform

The mean TC concentrations at the inlet and outlet were recorded at $190,000 \pm 30,882$ CFU/100 mL and $92,761.86 \pm 122,761$ CFU/100 mL (Figure 7), respectively, which still far exceeded the domestic wastewater quality standard of 3000 CFU/100 mL. The results of the Wilcoxon Signed Rank Test statistical analysis, obtained a significance *p value* of 0.164 which means that there is no significant decrease for TC in ABR process. The decrease in concentration over the eight weeks was inconsistent, increasing values occurred in the fifth and sixth weeks, indicating operational disruptions. Factors such as HRT and OLR have a major effect on treatment efficiency. An increase in HRT can improve bacterial removal efficiency through sedimentation and microbial activity, while a high OLR can lead to system overloading (Kubaish & Salama, 2024). The lower TC concentration in the seventh and eighth weeks indicates the adaptation of microorganisms to operational conditions, which supports the recovery of treatment efficiency (Nasr, M., 2022; Subroto *et al.*, 2022). Although it does not meet the standards, the ABR system is still able to reduce TC by 97,238.14 CFU/100 mL.

The average concentration of TC at the inlet and outlet was recorded at $190,000 \pm 30,882$ CFU/100 mL and $92,761.86 \pm 122,761$ CFU/100 mL, which is still far above the domestic wastewater quality standard of 3,000 CFU/100 mL. The results of the Wilcoxon Signed Rank Test statistical analysis yielded a significance *p value* of 0.164, indicating that there was no significant decrease in Total Coliform levels in ABR. The decrease in concentration over eight weeks was inconsistent, with an increase in values occurring in the fifth and sixth weeks, indicating operational disruptions. Additionally, this was due to the limitations of the ABR system in removing pathogens, as the anaerobic process tends to be less effective in removing microorganisms such as Total Coliform. Studies show that the efficiency of coliform removal in the ABR system ranges between 12-18% (Aghalari *et al.*, 2020).

Factors such as HRT and OLR significantly influence treatment efficiency. The HRT used in this study was 24 hours, which, although highly effective for TSS parameters, was insufficient to ensure maximum TC removal efficiency. Research by Ebrahimi, A., (2021) showed that increasing HRT from 12 hours to 36 hours can improve Coliform removal efficiency to over 90%. Increasing HRT can enhance bacterial removal efficiency through sedimentation and microbial activity, while high OLR can cause system overload (Ahmed, 2021). The decline observed in the seventh and eighth weeks indicates microbial adaptation to operational conditions, supporting the recovery

of treatment efficiency (Nasr, 2022). Other studies have also noted that the adaptation time of microorganisms in anaerobic systems can vary depending on fluctuations in organic load and environmental parameters such as temperature and pH (Park *et al.*, 2023).

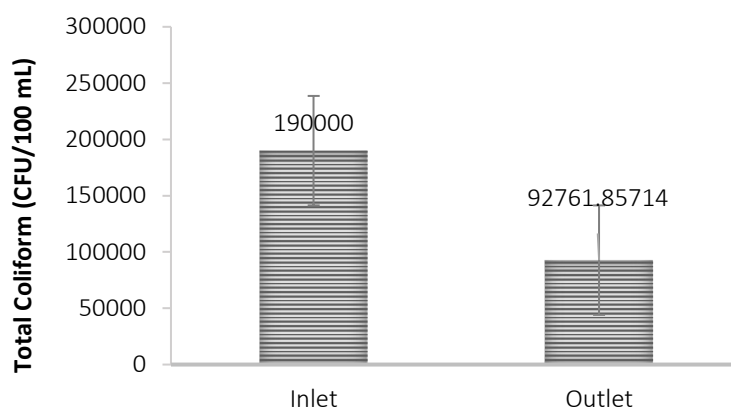


Figure 7 Total coliform concentration at the inlet and outlet of ABR

3.2.5 Potential of Hydrogen (pH)

The pH measurement results show an average value at the inlet and outlet points of 7.24 ± 0.91 and 6.87 ± 0.21 , respectively, which is still within the range of domestic wastewater quality standards (6-9), thus indicating the condition of wastewater supports the activity of microorganisms (Harmawan, 2022; Subroto *et al.*, 2022). However, based on Figure 8 and Wilcoxon Signed Rank Test analysis, there was a significant decrease in pH ($p\text{-value} = 0.064$) from inlet to outlet. This decrease contradicts the findings of Yulistiyorini *et al.* (2019) which noted an increase in pH values after treatment with ABR, and Hermanus *et al.* (2015) which stated that an increase in CO₂ causes an increase in BOD. In this study, the decrease in pH without fluctuation during the measurement period indicates that the activity of anaerobic microorganisms is slower, which may be influenced by external factors such as high rainfall and decreased ambient temperature, thus increasing CO₂ levels and impacting BOD treatment efficiency.

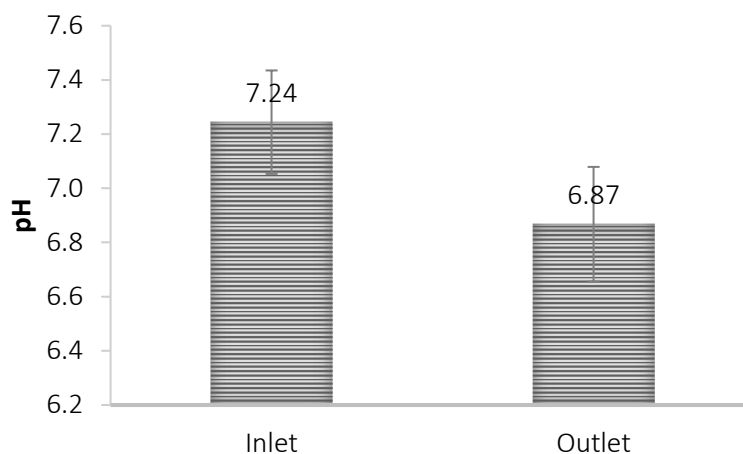


Figure 8 pH concentration in inlet and outlet ABR

3.2.6 Dissolved Oxygen (DO)

The average DO values at the inlet and outlet points were recorded at 2.06 ± 1.01 and 2.02 ± 0.86 mg/L (Figure 9), respectively.

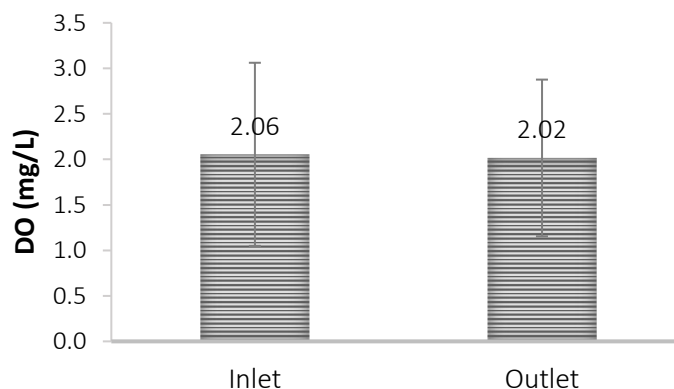


Figure 9 DO concentration in inlet and outlet ABR

Although there was a slight decrease, Paired Sample T-Test results show that the difference is not significant with a significant *p value* of 0.878. The pattern of DO fluctuation was inconsistent, with significant increases on days 4, 8, 10, 12, and 15, which is thought to be due to the influence of rainwater that lowers temperature and increases oxygen solubility (U.S. Geological Survey, 2018). In contrast, the decrease in DO was influenced by the activity of aerobic organisms and the evaporation of oxygen due to weather changes.

3.2.7 Temperature

Temperature measurements were taken at 09:00 am to minimize the influence of weather fluctuations. However, since the study took place during the rainy season, temperature changes still occurred. The results of the Paired Sample T-Test test obtained a significant *p value* of 0.105, which means that there is no significant difference between the inlet and outlet. The average inlet and outlet temperatures were 25.47 ± 2.05 °C and 25.68 ± 1.91 °C (Figure 10) respectively, still within the mesophilic range (20-45 °C) that supports biological activity in ABR systems (Kholif *et al.*, 2020; Subroto *et al.*, 2022). Despite the slight change in temperature, the statistical test results showed insignificant differences, indicating that temperature does not directly affect system performance. A stable temperature still plays an important role in supporting the effectiveness of the organic matter degradation process (Hastuti *et al.*, 2017).

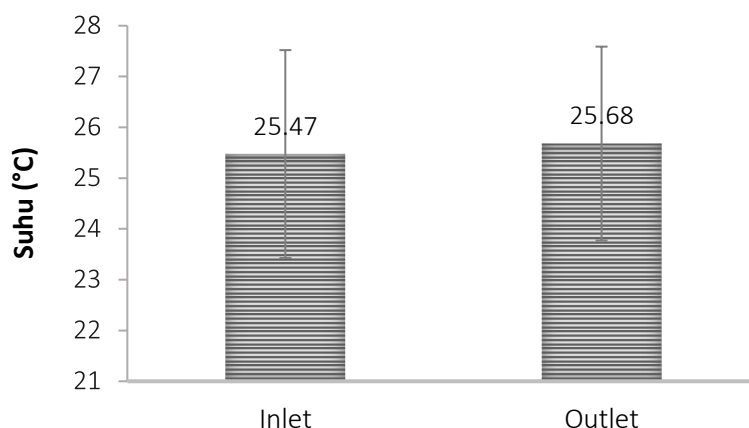


Figure 10 Temperature concentration in inlet and outlet ABR

3.2.8 Removal Efficiency

Based on the calculation of the efficiency of reducing pollutant concentrations using the Equation (3) and the results of significance analysis using the Paired Sample T-Test and Wilcoxon Signed Ranks Test can be seen in Table 3.

Table 3 Summary of efficiency calculation and significance

Parameters	Efficiency
TSS	91.33 %
COD	40.44 %
BOD	32.14%
Total Coliform	51.18%

The results showed a significant decrease in several wastewater quality parameters after treatment in the ABR system. The efficiency of TSS reduction reached 91.33%. This achievement is higher than the results of Yulistiyorini *et al.* (2020). Yulistiyorini *et al.* (2020), who reported a TSS reduction efficiency of 75% and 97% after being combined with an additional filter. Research by Khan (2023) also supports these findings, stating that the efficiency of ABR in removing TSS is highly dependent on baffle design and flow rate, with efficiencies reaching more than 90% under optimal conditions. This shows that the ABR system for the UM Rectorate Graha works optimally in reducing suspended solids.

The COD analysis results showed a significant decrease with an efficiency of 40.44%. Although the efficiency was relatively low, the outlet COD concentration still complied with the domestic wastewater quality standards. The decrease in COD, along with the decrease in BOD, indicates that organic compounds in wastewater are generally biodegradable and can be effectively decomposed by anaerobic microorganisms in the reactor (Mardianto, 2014, Subroto *et al.*, 2022). The efficiency of BOD removal was recorded at 32.14%. Although this has not yet met the quality standards, it indicates that organic matter decomposition occurred, but was still not optimal. Influencing factors include the hydraulic retention time, microbial activity, and environmental stability such as pH and temperature. Longer retention times increase the potential for organic matter degradation (Kholif *et al.*, 2020).

However, the efficiencies of COD and BOD removal in this study still indicate the need for further process optimization. Previous studies have shown that hybrid approaches, such as Hybrid Anaerobic Baffled Reactor (HABR) systems, can improve treatment efficiency, with BOD removal reaching up to 65.12% using activated carbon media (Sugito *et al.*, 2021). Similarly, Handayani *et al.* (2023) reported that combining ABR with filtration reduced COD and BOD by 68% and 79%, respectively. These findings can serve as a reference for improving the Graha Rectorate wastewater treatment system.

Total Coliform analysis also showed a decrease with an efficiency of 51.18%. These results indicate that the ABR system has the ability to reduce the content of pathogenic microorganisms through biological processes and sedimentation. Although it has not reached the quality threshold, this achievement shows the potential of ABR systems in reducing microbiological contaminants, especially when the system operates under stable and optimal conditions (Kubaish & Salama, 2024). In addition, a study by Ghatak and Ghosh (2019) also supports that coliform reduction can occur significantly in a stable operated ABR, with the main contribution coming from extreme anaerobic conditions and adequate residence time.

4. CONCLUSION

The results showed that the ABR system designed with a discharge of 14.08 m³/day and a reactor volume of 19.01 m³ then adjusted to a scale of 1:10, consisting of 9 compartments measuring 7 cm in length, 15 cm in width, and 20 cm in height, was effective in treating UM Rectorate Graha wastewater with a detention time of 16.2 hours. However, in this study a 24-hour detention time was used for sampling. This system is able to reduce the concentration of TSS and COD to meet the quality standards of Permen LHK No. 68/2016. Statistical tests showed significant reductions in COD, BOD, pH, and TSS parameters, while DO, temperature, and Total Coliform did not show significant differences. The reduction efficiency of each parameter, namely TSS (91.33%), COD (40.44%), BOD (32.14%), and Total Coliform (51.18%), proves that ABR is a potential technology for domestic wastewater treatment. Although COD and BOD efficiencies are not yet optimal, ABR shows strong potential as a scalable solution for decentralized urban wastewater treatment. Its integration into urban wastewater infrastructure can help reduce the environmental footprint of institutions. Hybrid approaches, such as combining ABR with filtration or tertiary treatments, are recommended to enhance system performance and ensure compliance with regulations.

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