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Design of a Simple Wastewater Treatment Plant at Darul Falah Islamic Boarding School, Banyuwangi

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ABSTRACT

Domestic wastewater discharged directly into rivers can affect the environment that will accommodate the water. The more waste water produced, the greater the capacity used to accommodate the wastewater. This study aims to plan the design of the wastewater Treatment Plant (WWTP) and the WWTP treatment system in accordance with the domestic waste generated by the male dormitory of the Darul Farah Islamic Boarding School. This research method is using descriptive research type. Data were collected through field observations, namely by observing and measuring the discharge and domestic wastewater disposal system in the male dormitory of the Darul Falah Islamic Boarding School, then the collected data were analyzed descriptively. Based on the results of the research, the clean water debit used for activities in the male dormitory of the Darul Falah Islamic Boarding School is 22.2 m3/day, so that the resulting wastewater discharge is 17.76 m3/day. The planned WWTP design uses the *Anaerobic Baffled Reactor* (ABR) method with a width of 2.6 m, a length of 9.6 m, and a height of 2 m. The WWTP design used for the male dormitory of the Darul Falah Islamic Boarding School is the *Anaerobic Baffled Reactor* (ABR). It is recommended for Islamic boarding schools to realize the construction of WWTPs for wastewater treatment in male dormitories so as not to pollute the environment.

Kata kunci: Wastwater Treatment Design, Domestic, Simple

INTRODUCTION

An Islamic boarding school (Pondok Pesantren) is a dormitory for male and female students to study religious teachings and other subjects. Darul Falah Islamic Boarding School is an Islamic-based educational facility in Purwoharjo District, Banyuwangi Regency. Darul Falah is under the management of the Salafiyah Syafi'iyah Islamic Boarding School Foundation, which provides dormitories for the students. The foundation also comprises several institutions, including TPQ Darul Falah, Madin Darul Falah, SMP Darul Falah, and SMK Darul Falah.

Domestic wastewater generated from activities in the boarding school dormitories is generally similar to household domestic wastewater, consisting of greywater and blackwater. The treatment of blackwater originating from toilet activities is managed using septic tanks. Meanwhile, greywater from the male dormitory is directly channeled into a drainage that flows into a river body. According to the 2021 profile of Darul Falah Islamic Boarding School, the total number of residents in the male dormitory is 185, with an estimated wastewater output of approximately 120 L/person/day. As an Islamic educational institution, Darul Falah Islamic Boarding School in Banyuwangi faces similar challenges in managing its wastewater. With many students, the school produces a significant volume of wastewater daily. Wastewater from daily activities such as bathing, washing, and other domestic activities, if not adequately treated, can pollute the surrounding environment and pose health risks to the community (Suoth & Nazir, 2016).

Considering the male dormitory's activities and the hundreds of residents it houses, the domestic greywater must be treated before being discharged into the river body. According to the Indonesian Ministry of Environment and Forestry Regulation of 2016, Article 3, paragraph (1), on Domestic Wastewater Quality Standards, every business and/or activity that generates domestic wastewater must treat the wastewater it produces. The greywater produced by activities in the male dormitory of Darul Falah Islamic Boarding School is currently directly discharged into channels connected to the river. At the same time, blackwater is already contained in septic tanks. Wastewater is disposed of directly into drainage systems or nearby water bodies without proper treatment. This treatment can lead to environmental pollution, significantly affecting groundwater and surface water around the boarding school (Marliani, 2015).

Wastewater contains contaminants such as organic materials, nutrients, and pathogens that can pollute groundwater and surface water sources if not properly managed (Sikosana et al., 2019). Direct discharge of wastewater into rivers can cause environmental pollution. The higher the level of river pollution, the lower the river's capacity to accommodate wastewater. If the domestic wastewater discharge exceeds the environmental capacity, it damages the environment. Without adequate treatment systems, wastewater can cause severe environmental pollution, potentially leading to various diseases. Research by Loh et al. (2022) shows that biofiltration systems can effectively remove organic materials and nutrients from wastewater, but their application requires adequate knowledge and resources.

Applying wastewater treatment technology in Islamic boarding schools requires a simple yet effective approach. Yadav et al. (2023) note that many educational institutions in developing countries face challenges in implementing effective wastewater treatment systems due to limited resources and technical knowledge. Therefore, Islamic boarding schools should have wastewater treatment plants (IPAL) to process their wastewater. The design of the wastewater treatment plant should be carefully considered to ensure the sustainability of wastewater treatment. Before determining the design, it is necessary to calculate the wastewater discharge to determine the design volume and the size of the IPAL. This will then allow for selecting a treatment system suitable for the domestic wastewater generated in the male dormitory of Darul Falah Islamic Boarding School.

RESEARCH METHODS

The type of research used is descriptive research. This study aims to determine the appropriate design of a wastewater treatment plant (IPAL) for the wastewater discharge generated by the male dormitory of Darul Falah Islamic Boarding School.

This research was conducted from February to July 2022. The study was carried out in the male dormitory of the Salafiyah Syafi'iyah Islamic Boarding School Foundation "Darul Falah," located in Dusun Ngadirejo, Bulurejo Village, Purwoharjo District, Banyuwangi Regency, East Java. The variables in this study are wastewater discharge, simple IPAL design, and IPAL treatment system. The tools used in this research are writing instruments and documentation tools.

RESULTS AND DISCUSSION

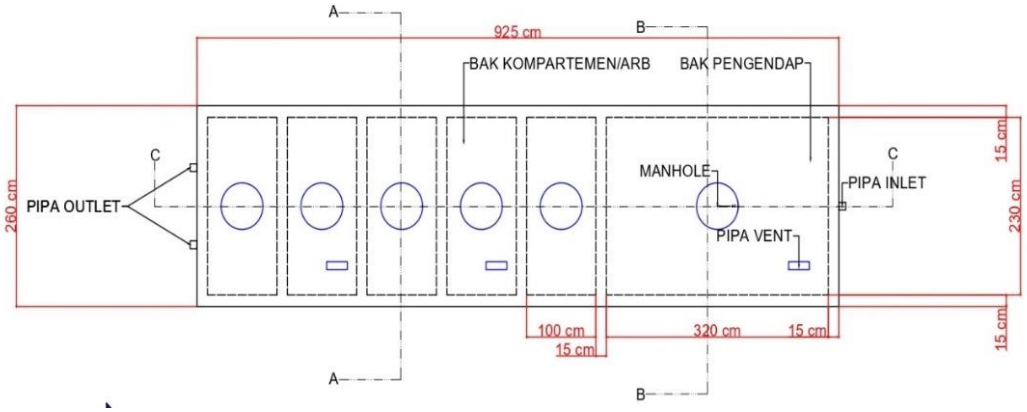

Figure 1
Top View of The Wastewater Treatment Plant Design

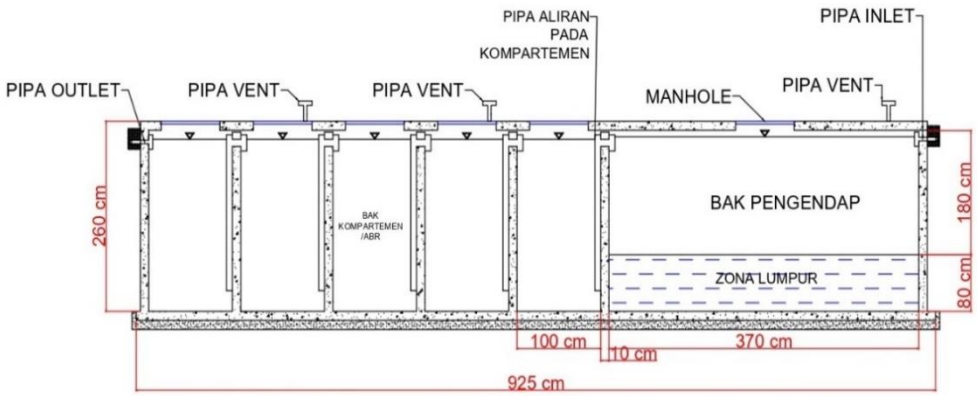

Figure 2
Side View of The Wastewater Treatment Plant Design

The design chosen for this planning uses the Anaerobic Baffled Reactor (ABR) method. This ABR is intended to handle wastewater from bathing, washing, and non-toilet ablution (greywater). The Anaerobic Baffled Reactor (ABR) design works by separating the reactor into several compartments filled with anaerobic bacteria. Each compartment acts as an anaerobic reactor that breaks down organic matter into biogas, such as methane, through fermentation. This design enhances treatment efficiency by optimizing the contact between microorganisms and organic matter in the wastewater. Research by Bodkhe (2009) shows that ABR can achieve organic matter removal efficiency of up to 85-90%. Additionally, the design is simple, and the treatment process is easy and cost-effective. The planned Anaerobic Baffled Reactor (ABR) unit will have 5 compartments and 1 settling tank.

Wastewater Flow Rate Calculation

The planned design for the wastewater treatment plant (IPAL) has a volume of 49.96 m³, with dimensions of 9.25 m in width, 2.6 m in length, and 2 m in height. The determination of the IPAL design size is based on the calculation of the wastewater flow rate. Each compartment is 1 m long, 2.6 m in width, and 2 m in height. The settling tank is designed to provide sludge settling space with a height of 0.8 m, giving the settling tank a total height of 2 m.

In calculating the wastewater flow rate, it is necessary to calculate the demand for clean water first. According to an interview with one of the boarding school administrators, the demand for clean water at Darul Falah Islamic Boarding School is met entirely by bore wells. Therefore, the clean water usage in this study follows the SNI 03-7065-2005 standard. Based on the data obtained, the number of residents in the male dormitory at Darul Falah Islamic Boarding School is 185 people, consisting of 160 students and 25 administrators. The demand for clean water for activities in the male dormitory is approximately 120 liters/person/day. The clean water demand calculation for the male dormitory is as follows:

$Q_{clean\ water}$ = clean water demand (liters/person/day) × number of residents (people)

$Q_{clean\ water}$ = 120 liters/person/day × 185 person

$Q_{clean\ water}$ = 22.200 liters/day

$Q_{clean\ water}$ = 22,2 m^3/day

Thus, the clean water demand calculation is 22,200 L/day or 22.2 m³/day.

The wastewater flow rate is derived from the amount of clean water used multiplied by a coefficient of 80%. The 80% coefficient is based on the assumption that most clean water will become wastewater while the rest is absorbed or lost through other processes, such as evaporation. According to Eddy et al. (2014), this coefficient is widely applied in communal environments where daily activities cause most of the used water to become wastewater. Additionally, Abdi (2019), in an international study, showed that using this wastewater flow rate calculation method can also improve the efficiency of wastewater treatment systems in other educational settings. The clean water demand or flow rate in the male dormitory at Darul Falah Islamic Boarding School is 22,200 liters/day or 22.2 m³/day. Therefore, the domestic wastewater flow rate for the male dormitory can be calculated as follows:

$Q_{wastewater}$ (m^3/day) = 80% × $Q_{clean\ water}$ (m^3/day)

$Q_{wastewater}$ (m^3/day) = 80% × 22,2 m^3/day

$Q_{wastewater}$ (m^3/day) = 17,76 m^3/day

From the calculation above, the wastewater flow rate for the male dormitory at Darul Falah Islamic Boarding School is 17.76 m³/day from 185 residents.

Selection of IPAL Design

In this planning, the chosen treatment design is the Anaerobic Baffled Reactor (ABR) with a centralized treatment system (off-site). The Anaerobic Baffled Reactor (ABR) is an anaerobic suspended system in a bioreactor with baffles. A series of vertical baffles installed in the ABR cause the wastewater to flow under and over the baffles from the inlet to the outlet, thereby promoting contact between the wastewater and active biomass. ABR has been proven effective in treating various types of wastewater, including domestic and industrial waste.

Research by Bodkhe (2009) indicates that ABR can remove 70-90% of Chemical Oxygen Demand (COD) in domestic wastewater treatment. This high treatment efficiency is attributed to the compartment design, which allows for longer hydraulic retention time and enhances contact between biomass and substrate (Hassan et al., 2013). Additionally, ABR offers advantages such as low operational costs, minimal sludge production, and the ability to withstand shock loading (Barber & Stuckey, 1999). Recent studies by Singh et al. (2009) also confirm that ABR can be a sustainable solution for wastewater treatment in developing countries due to its operational simplicity and ability to produce biogas that can be utilized as an energy source.

The Anaerobic Baffled Reactor (ABR) unit selection for the male dormitory at Darul Falah Islamic Boarding School considers various advantages and disadvantages. ABR is highly suitable for Darul Falah Islamic Boarding School because it is efficient, cost-effective, easy to maintain, requires minimal land use, features a simple design, and is appropriate for treating wastewater with a relatively low flow rate.

The ABR design was selected based on the wastewater flow rate and the characteristics of the wastewater, which primarily contains organic materials such as carbon, oxygen, nitrogen, and hydrogen. Studies by Abou-Elela et al. (2015) demonstrate that ABR is effective in treating domestic wastewater with high COD concentrations, achieving COD removal efficiencies of up to 95%.

The design includes several components, namely the compartments and the settling tank. The ABR is a high-rate anaerobic reactor with several compartments with equal volumes. The number of compartments is

determined to minimize the total volume of sludge that must be treated in subsequent processing stages. In this design, there are 5 compartments. Each compartment is separated by alternating standing baffles, which force the wastewater to flow up and down within each compartment, thereby increasing contact between the wastewater and microorganisms in the sludge blanket at the bottom of each compartment. Wastewater flows through compartments 1 to 5 in a zig-zag pattern. The zig-zag flow aims to ensure that the wastewater is well-mixed and homogeneous. Following this, the wastewater moves to the settling tank, where dissolved particles and sludge are settled out after passing through the compartments, resulting in sludge formation. Recent research by Feng et al. (2008) highlights the importance of baffle design and compartment maintenance to enhance the efficiency of ABR. Additionally, advancements in reactor media modification technologies have been made to improve degradation capacity and process stability (Feng et al., 2008).

CONCLUSION

Based on the research, it can be concluded that the existing wastewater treatment conditions in the male dormitory at Darul Falah Islamic Boarding School are inadequate, as domestic wastewater is currently discharged directly into drainage channels leading to the river. To address this issue, it is necessary to plan a wastewater treatment design to treat the wastewater before it is released into the environment. To determine the appropriate design, the calculation of the domestic wastewater flow rate is essential; this study has determined a flow rate of 17.76 m^3/day. Additionally, the design and treatment system should be carefully considered. In this study, the Anaerobic Baffled Reactor (ABR) with a volume of 49.96 m^3, consisting of 5 compartments and 1 settling tank, has been selected. The number of compartments is chosen to minimize the total volume of sludge that needs to be treated in subsequent processes. The IPAL design also considers several factors, including efficiency, low cost, ease of treatment, land availability, and the suitability of the wastewater flow rate for the Anaerobic Baffled Reactor (ABR) design. The planned treatment system for this IPAL design is a centralized (off-site) system.

RECOMMENDATIONS

Based on the research findings, the following recommendations are proposed to the relevant authorities such as conduct outreach to the students at the Islamic Boarding School about the importance of environmental conservation around the boarding school, enhance the sanitation facilities, mainly focusing on domestic wastewater treatment by developing a proper Wastewater Treatment Plant (IPAL), implement regular monitoring and maintenance of the IPAL to ensure its optimal performance, ensure that the IPAL operates effectively by preventing the entry of plastic, wood, and similar waste into the system, especially from the bathrooms, Future studies could investigate other Islamic Boarding Schools with similar conditions, but with a more extensive wastewater treatment system, to provide a broader understanding of effective treatment solutions.

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