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Situbondo communal waste management study: Application of the anaerobic baffled reactor method at the Salafiyah Syafi'iyah Islamic boarding school

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ABSTRACT

Background: This study examines the planning of a communal wastewater treatment plant (IPAL) at the Salafiyah Syafi'iyah Islamic Boarding School, Situbondo Regency, using the Anaerobic Baffled Reactor (ABR) method. **Methods:** This study uses the ABR method supported by literature studies as the basis for the preparation of the writing. The study also involved observation and field observation. **Findings:** (1) the domestic wastewater discharge generated by 4.410 people or 74 rooms is 364.408 m^3/day, while the non-domestic wastewater discharge is 0.20 m^3/day, bringing the total wastewater discharge to 364.608 m^3/day. (2) The ABR method was chosen because it has several advantages, such as relatively small land requirements, ease of construction, operation and maintenance, no need for electrical energy, and more efficient costs. (3) The dimensions of each ABR compartment were designed to be 11.4 m long, 2.3 m wide, and 2.6 m high, which ensures even distribution of wastewater and effective treatment. **Conclusion:** The three research results led to the author's understanding that the ABR method is a suitable and efficient solution for wastewater treatment at Salafiyah Syafi'iyah Islamic Boarding School. For further planning, it is recommended to conduct detailed calculations regarding the Wastewater Management System (WMS) and consider the use of alternative methods such as Constructed Wetland or Anaerobic Filter Reactor, especially considering the area of the pesantren which is surrounded by rice fields. **Novelty/Originality of this study:** This study offers an innovative solution for wastewater treatment in Islamic boarding school environments by applying the Anaerobic Baffled Reactor (ABR) method. This study not only designs an efficient and cost-effective system but also considers the specific context of Islamic boarding schools, paving the way for applying environmentally friendly technologies in Islamic educational institutions.

KEYWORDS: anaerobic baffled reactor; boarding school; wastewater; wastewater treatment; WWTP.

1. Introduction

Waste is generally discarded material that can have a negative impact on society if not managed properly (Darmawan et al., 2023). Domestic wastewater consists of gray water and black water, often discharged into the channel or river in front of the house. Gray water comes from washing clothes, bathing, cooking and other kitchen activities, and contains nitrates, phosphates and organic substances. Water pollution based on its source can be categorized as direct and indirect contamination (Rahmawati, 2022). If domestic

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wastewater is not treated in the long term, it will pollute the environment, so a processing unit is needed to reduce the concentration of dangerous pollutants that can cause disease and disrupt the survival of living things. This pollution can cause physical, chemical, biological or radioactive changes to the water.

The Salafiyah Syafi'iyah Islamic Boarding School in Situbondo, East Java, is one of the largest Islamic boarding schools in the region, founded by Kiai Syamsul Arifin in 1914 and occupies an area of 11.9 hectares. This Islamic boarding school integrates formal and traditional Islamic boarding school education, covering various educational institutions such as Kindergarten, Elementary, Middle School, High School and college. With a population of around 18.000 students, not including daily administrators and teaching staff, this Islamic boarding school faces challenges in providing adequate facilities, including proper sanitation to prevent environmental pollution and health problems.

The increase in the number of students causes an increase in the volume of domestic wastewater in the form of black water and gray water from toilets, showers, ablution places, clothes washing places and kitchens. Currently, domestic wastewater from the Salafiyah Syafi'iyah Islamic Boarding School is directly discharged into water bodies without treatment. This problem becomes serious because of the direct discharge of waste water into the environment through drainage channels into rivers. With the high density of students and bathrooms close together, a centralized wastewater treatment plant using Anaerobic Baffled Reactor technology is needed as an alternative solution for treating domestic wastewater generated from the daily activities of students at the Islamic boarding school.

To overcome this problem, planning for a Communal Waste Water Treatment Plant (IPAL) is very necessary. This processing unit will process all domestic waste in one common installation, adapting to the conditions of Islamic boarding schools which have a very large number of students. Communal WWTP functions to reduce the risk of exposure to viruses and bacteria that can be carried in untreated wastewater, as well as protecting the surrounding aquatic ecosystem from damage to the environment, plants and animals.

The technology used is the Anaerobic Baffled Reactor (ABR) system, which is a development of conventional septic tanks. The ABR consists of a settling compartment followed by several baffle reactors, which direct the water flow upward through a series of mud blanket reactors. This configuration extends the contact time between anaerobic biomass and wastewater, increasing treatment efficiency. The ABR system was chosen because it has advantages such as high efficiency, minimal land use because it is built underground, low construction and operational costs, and resistance to hydraulic loads and organic substances. In addition, this system does not require electricity, can treat greywater, and can be built and repaired with local materials.

Exposure to problems at the Situbondo Salafiyah Islamic Boarding School made the author want to know more about the issue of communal waste. The objectives of research at Salafiyah Islamic boarding schools are explained in three ways. (1) Knowing pH, BOD, COD, TSS in domestic wastewater. (2) Knowing how much dirty water is discharged, and the dimensions of the wastewater treatment plant (IPAL) planning design.

1.1 Sanitation

Sanitation is a concept related to efforts to create a healthy environment for humans, especially including the physical environment such as land, water and air. Sanitation includes behavior aimed at getting used to clean living to prevent direct human contact with dirty and dangerous materials. Thus, sanitation plays an important role in maintaining and improving overall human health.

According to Prasasti et al. (2022), sanitation is an action taken to ensure and create conditions that meet health standards. Experts have different definitions of sanitation. Hopkins states that sanitation is a method of monitoring various environmental factors that influence environmental health. Overall, sanitation is an important effort to maintain public health by creating a clean and healthy environment. This involves preventive measures to avoid contact with hazardous materials and improve the quality of the human living environment.

1.2 Domestic waste

Domestic wastewater is defined as wastewater originating from daily human activities that involve water use (Ministry of Environment and Forestry (LHK)/68, 2016). Wastewater monitoring is carried out to ensure compliance with wastewater quality standards. Any body of water whose quality is affected by human activities can be considered wastewater. Domestic wastewater is produced on a household scale and is divided into two types: black water, which consists of fecal waste and urine, and greywater, which comes from bathing water, kitchen wastewater and laundry water (Said, 2017).

Liquid waste is water that can no longer be used and has the potential to cause negative impacts on humans and the environment (Kuntodiaji et al., 2023). Household waste, especially liquid waste, is an unavoidable part of everyday human life and contributes significantly to the volume of domestic liquid waste (Ni'am et al., 2021). The quality of wastewater from various household activities can vary, but generally, the content of suspended solids and organic substances is quite high.

According to Hammer (1986), the average quality of domestic wastewater is MLSS 240 mg/L, total N 35 mg/L, MLVSS 180 mg/L, total P 10 mg/L, and BOD 200 mg/L. Grey water that is discharged without being treated has specific characteristics such as BOD_5 between 110–400 mg/L, COD 150–600 mg/L, and TSS 350–750 mg/L, and does not contain heavy metals or toxic chemicals (Veenstra, 1995). Research at the ITS Sukolilo Surabaya housing complex by Tangahu and Warmadewanthi (2001) showed that the average characteristics of household waste were pH 6.92, temperature 29°C, TSS 480 mg/L, BOD_5 195 mg/L, and COD 290 mg/L. L.

1.3 Types of sanitary processing

According to the Ministry of Public Works, Director General of Human Settlements (2013), waste water treatment is divided into two systems: a local system (on-site) and a centralized system (off-site). First, local system sanitation (on-site), wastewater treatment with a local system means that the processing facilities are within the boundaries of the land owned. These facilities include septic tanks and cisterns for individual use as well as public toilets for communal use. This system is suitable for use in areas with low population density, namely less than 250 people per hectare (PU, 2012).

Second, centralized system sanitation (off-site), wastewater processing with a centralized system means that the processing facilities are located outside the boundaries of the land owned. In this system, waste water is channeled through a network of pipes from homes to a separate waste water treatment plant. This system is more suitable for use in areas with high population density, namely more than 250 people per hectare (PU, 2012).

2. Methods

2.1 Planning for waste water treatment plants in Islamic boarding schools

This project planning was motivated by the real gap between current conditions and the ideal conditions expected by the government. The Salafiyah Syafi'iyah Islamic Boarding School is a densely populated area with the number of students reaching 18,000 people, consisting of hundreds of heads of rooms. Based on observations, the majority of students use well water and PDAM water as a source of clean water.

The research was conducted at the Salafiyah Syafi'iyah Islamic Boarding School which is located in Sukorejo Village, Banyuputih District, Situbondo Regency, with an area of around 11.9 hectares. The coordinates of Situbondo Regency are at 113°30' - 114°42' East Longitude and 7°35' - 7°44' South Latitude. Administratively, this Islamic boarding school borders Sumberejo Village to the east, Banyuputih Village to the west, Melek Village to the south, and Lebuk Village to the north.

Most Islamic boarding school residents still dispose of their wastewater into nearby channels such as rivers and nearby waterways, which has the potential to cause disease and environmental pollution. The cottage area has been equipped with a septic tank for blackwater treatment, but greywater is still discharged directly into a nearby canal without adequate treatment. This untreated waste can cause various environmental problems such as pollution, unpleasant odors and diarrheal diseases.

For this research literature study is very important as a basis and support for planning this final project. The literature used includes books, national and international journals, as well as relevant laws and regulations and government policies. Some of the topics covered include the definition and characteristics of wastewater, domestic wastewater quality standards, wastewater discharge, wastewater treatment technology, and data collection methods. Therefore, efforts are needed to treat domestic wastewater, especially greywater, through IPAL installations. In this planning, Anaerobic Baffled Reactor (ABR) technology is used.

2.2 Data collection, analysis, and discussion

The data needed to support this planning consists of primary and secondary data. Primary data was obtained through field observations and interviews, which included direct observation of existing conditions such as greywater disposal locations and land availability. Secondary data includes literature studies, data from the RKM (Community Work Plan) in each location, demographic data from the Situbondo Regency Central Statistics Agency, regional maps from the Banyuputih District Planning and Development Agency, as well as waste water quality standards from East Java Governor Regulation No. 72 of 2013.

Then, data analysis and discussion in this project is carried out based on data that has been collected, in accordance with the planning scope. The data is processed by considering two main aspects: technical and cost. In the technical aspect, planning the selected Waste Water Treatment Plant (IPAL) unit involves several steps. First, the Anaerobic Baffled Reactor (ABR) design that will be used must be well designed. Furthermore, the planning period is set for 10 years with the assumption that the area is a densely populated area that will not experience significant population growth. Waste water quality standards are determined based on East Java Governor Regulation No. 72 of 2013. In addition, the selection of appropriate treatment alternatives is carried out by considering the characteristics of waste water, ease of operation and maintenance, availability of land, and the community's ability to develop it. Other side, conclusions and suggestions are prepared based on the results of data analysis and planning discussions, taking into account technical and cost aspects. This thesis has the potential to be developed further.

2.3 Selection of treatment technology options

There are various treatment technology options, in general, some basic technologies commonly applied are anaerobic baffled reactor (ABR), anaerobic filter (AF), Upflow Anaerobic Sludge Blanket (UASB), and Aeration Pond (KA). In its application, the technological options of wastewater treatment systems are highly dependent on the need or treatment capacity, environmental conditions, space availability, and the ability of users or managers to operate and maintain it. First, anaerobic Baffled Reactor, a conventional siphonic tank that has been developed.

ABR consists of a settling component followed by several vertical baffled recators. The rows of baffles force the wastewater to flow past directing an up and down flow through a series of sludge blanket reactors. This flow causes the influent wastewater stream to have a longer contact time with the anaerobic biomass, thus increasing treatment efficiency and performance. Each compartment in the ABR will produce gas so it needs to be equipped with an air duct (vent pipe). BOD reduction in ABR is around 70-95%, a higher reduction presentation than septic tanks. ABR has the potential to treat domestic waste in dense residential areas (Nasr et al., 2009). The planning criteria used as a reference in designing the Anaerobic Baffled Reactor type treatment unit (Sasse, 1998) as follows.

Organic Loading Rate (OLR) = < 3 Kg COD/m3.hour
Hydraulics Retention Time (HRT) = 8 - 20 hours
Flow velocity (Vup) = < 2 m/hour
Compartment Length = 50 - 60% depth

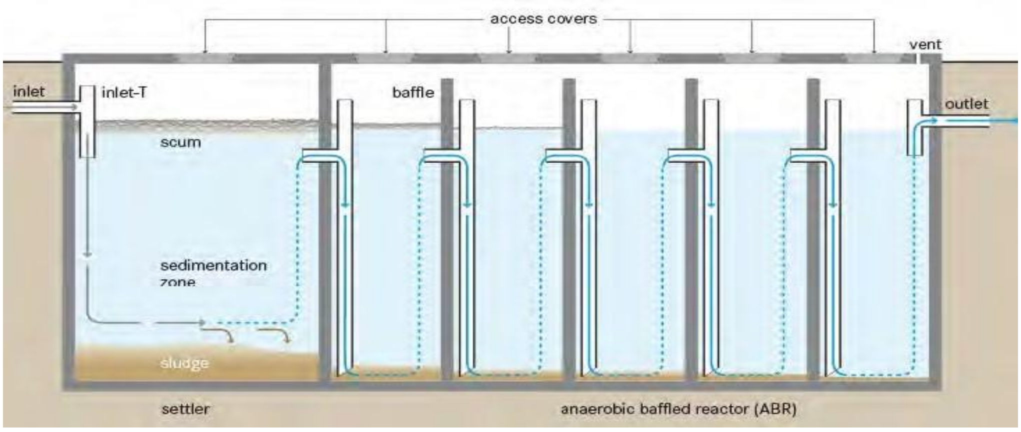

Fig. 1. Anaerobic baffled reactor

Second selection of treatment technology options is anaerobic filter, a septic tank containing one or more compartments (chambers) combined with a filter. The filter is made of natural and simple materials such as gravel, charcoal residue, bamboo, coconut shells or specially molded plastic. The anaerobic process can be triggered by the addition of active bacteria from septic tank sludge. The active bacteria are sprayed on the filter material. The incoming wastewater flow will flow through the filter, then the organic matter will be decomposed by the biomass attached to the filter material. Based on Tilley et al. with a low water table, the planning criteria used as a reference in designing an Anaerobic Filter type treatment unit (Sasse, 1998) as follows.

Organic Loading Rate (OLR) = 4 - 5 Kg COD/m3.hour
OLR BOD = 0.4 - 4.7 kg BOD / m3
Hydraulics Retention Time (HRT) = 24 - 48 hours BOD removal = 70 - 90%
Media specific area = 80 - 180 m2
Flow velocity (Vup) = < 2 m/hour

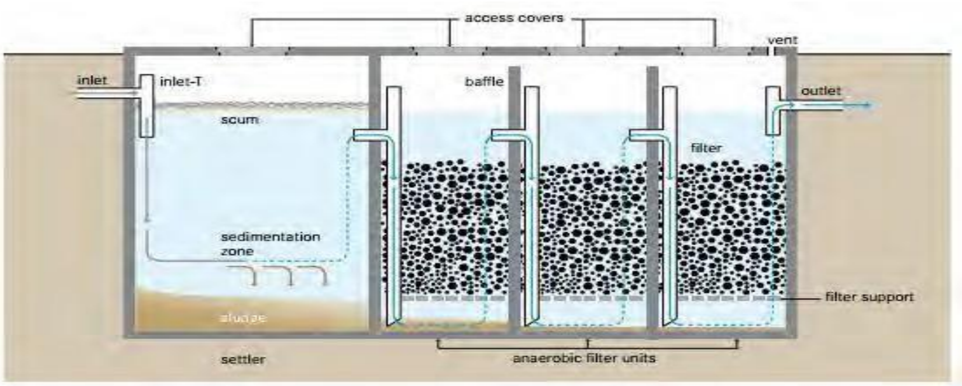

Fig. 2. Anaerobic filter

The third is the UASB Reactor which is a single process tank with an upward flow system. Wastewater enters from the bottom of the reactor and flows upwards through a layer of anaerobically active sludge (sludge blanket) (Tilley et al., 2014). The sludge layer consists of clumps of micro-organisms or referred to as granules with a certain weight so that they are not carried away by the upflow. UASB has a separator to separate sludge, water and biogas. The upflow velocity is maintained at 0.6 - 0.9 m/h so that the sludge layer remains floating and acts as a filter (Soedjono et al., 2010).

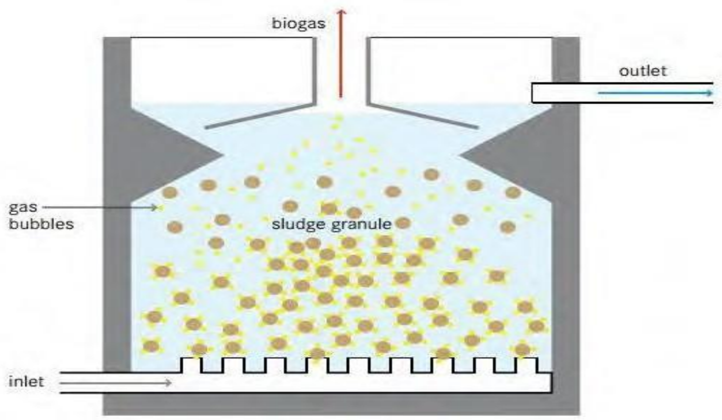

Fig. 3. Upflow anaerobic sludge blanket reactor

Then, Aeration ponds have a similar system to facultative ponds except for the natural presence of oxygen. Aeration ponds require mechanical aerators that serve as oxygen intake to maintain aerobic conditions of suspended microorganisms mixed with wastewater in order to obtain high organic degradation rates. The presence of aerators and the stirring process make aeration ponds more beneficial than stabilization ponds. The higher the level of aeration, provides improved performance on the degradation process as well as removal of pathogenic bacteria (Tilley et al., 2014). The required depth is 2 - 5 m with a HRT of 3 - 20 days. Sludge dewatering of the pond is done every 2 - 5 years. To avoid leakage, a liner should be added to the bottom of the pond. This layer can be made of clay, asphalt, compressed soil or other waterproof materials (Conradin et al., 2010).

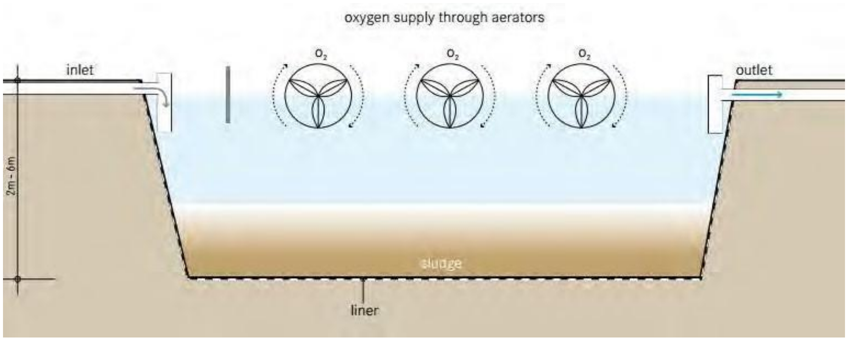

Fig. 4. Aeration ponds

3. Results and Discussion

3.1 Waste processing options in Islamic boarding schools

There are many wastewater treatment technology options that can be applied. The main challenge is to select the most appropriate and efficient technology for specific environmental conditions. This technology must be adapted so that it can be implemented well. Some basic technologies that are often used in Indonesia include Anaerobic Baffled Reactor (ABR), Anaerobic Filter (AF), Upflow Anaerobic Sludge Blanket (UASB), and Aeration Pond (KA). The choice of technology depends on processing needs, environmental conditions, space availability, and the manager's ability to operate and maintain it.

Anaerobic Baffled Reactor (ABR) is a development of conventional septic tanks. ABR consists of several settling components followed by several vertical baffle reactors which direct the wastewater flow through several series of sludge blanket reactors. This design extends the contact time between wastewater and anaerobic biomass, increasing processing efficiency. Each compartment produces gasses that require air passage. The BOD reduction in ABR ranges from 70-95%, higher than in ordinary septic tanks. ABR is suitable for processing domestic waste in dense settlements (Nasr et al., 2009). ABR planning criteria based on Sasse (1998) include: OLR < 3 Kg COD/m3.hour, HRT 8 - 20 hours, flow velocity < 2 m/hour, and compartment length 50 - 60% of depth.

Anaerobic Baffled Reactor (ABR) dimensional calculations include several important parameters. The reactor volume is calculated using the formula $Volume = length \times width \times height$. The organic loading rate (OLR) is determined by the formula $OLR = (Q \times So) : Volume$. Hydraulic residence time (HRT) is calculated by $HRT = volume : (Q \times So)$. The hydraulic load rate (HLR) is $HLR = Q : A\ surface$. The upflow flow velocity (Vup) is $V_{up} = Q : (number\ of\ partitions \times compartment \times reactor\ width)$. Depth (h) is calculated by $H = Volume : A\ surface$.

An anaerobic filter is a septic tank equipped with one or more compartments containing filters made from natural materials such as gravel, charcoal, bamboo, coconut shells, or plastic. The anaerobic process begins by adding active bacteria from the septic tank fecal sludge to the filter. Wastewater flows through a filter, where organic matter is broken down by the biomass attached to the filter. Based on Tilley et al., anaerobic filters are effective in areas with low groundwater levels. Design criteria include an OLR of 4-5 kg COD/m^3. hours, OLR BOD 0.4-4.7 kg BOD/m^3, HRT 24-48 hours, and BOD removal 70-90%.

Calculation of Anaerobic Filter (AF) dimensions according to Said (2008) includes several main parameters. Media volume is calculated using the formula: *V Media = (Q Ave x BOD) / OLD BOD*, where V media is the required media volume, Q ave is the average discharge of liquid waste (L/day), BOD is inlet BOD concentration (mg/L), and OLR BOD is the organic loading rate of BOD. The reactor volume is calculated by the formula: *V reactor = (100 x V Media) / 60* . Residence time (td) is determined by: *td = (V Reactor x 24 hours/day) / Q Ave*.

3.2 Communal waste management system

According to Suriyachan et al. (2012), communal wastewater management systems are very suitable for implementation in urban areas. This system is well received by the community because of its adequate results and the ability to create local jobs. The processing unit efficiency is high and the management technology is relatively simple. Communal wastewater management is a system where management is carried out jointly or handed over to local communities, reducing the involvement of central or regional governments (Massoud, 2008). Several factors were considered to identify communities suitable for using this communal management system, including urban location, processing technology, population, and year of construction. Community leaders, contractors and residents in the communal IPAL management area were interviewed regarding their opinions on the results and management of the system (Suriyachan et al., 2012).

The technology in this management system is designed for small scale with lower construction and maintenance costs compared to centralized systems. The effluent results from wastewater treatment still take into account the quality of the surrounding environment. This system is suitable for difficult areas, such as villages with low population density (Massoud et al., 2008).

Anaerobic Baffled Reactor (ABR) has several advantages according to Barbar and Stuckey (1999). In terms of construction, ABR requires low cost, simple design, does not require mechanical stirring, reduces blockage and sludge bed expansion. In terms of biomass, ABR does not require special settling, has low sludge growth, and high Solid Retention Time (SRT). In terms of operation, the Hydraulic Retention Time (HRT) is low, allows intermittent operation, protects the material from toxic materials in the influent, has long operation and is stable against organic shock. The PPLP Directorate (2011) stated that the advantages of ABR include the need for little land because it is built underground, low construction costs, cheap and easy operation and maintenance costs, and high waste processing efficiency. Disadvantages include the need for skilled personnel for design and supervision as well as skilled craftsmen for high-quality plaster work.

3.3 Projections of population, location and sanitation in Islamic boarding schools

Population projections greatly influence the use of clean water in the future, which in turn will determine the quality and discharge of waste water flowing to treatment plants. In this plan, population projections are carried out using the geometric method for a 10 year period, from 2022 to 2032, based on SNI 03-1733-2004, assuming an average of 60 residents per room. This projection also takes into account the growth of the Islamic boarding school population, which according to the book "Salafiyah Syafi'iyah Islamic Boarding Schools in Figures 2021", experienced growth of 1.24 percent per year from 2010 to 2020. Using the population projection formula($P_t = P_0(1 + r)$), the number of residents in 2032 is estimated to reach 4.191.336 people or 74 rooms.

Locations planned based on guidelines from the Director General of Public Works Cipta Karya in 2014 must meet several technical criteria for the feasibility of wastewater management at the local level. These criteria include: (1) The location is in a densely populated residential area with a minimum density of 100 people per hectare. (2) A minimum of 100 m^2 of land is available for one wastewater treatment plant unit. (3) The region has 50-100 $KK/RT/RW$ that are officially registered. (4) Available water sources (wells, PDAM, or springs). (5) There are drains available that can accept wastewater, such as city drains or rivers.

The clean water source at the Salafiyah Syafi'iyah Islamic Boarding School is used for washing, cooking, bathing and drinking water needs, with 74 rooms, most of which use PDAM water and artesian wells. Based on the results of the field survey, existing sanitation facilities are not yet equipped with a wastewater treatment system. Greywater waste is channeled directly into a concrete channel leading to the river, while blackwater waste is managed using septic tanks and biotanks in each building. This condition shows the need to improve wastewater treatment facilities to prevent environmental pollution.

3.4 Islamic boarding school waste water discharge

In research conducted by Suheri et al. (2019), explained that drinking water needs vary based on regional location. The standard per capita drinking water requirement per day is as follows: 60 liters in rural areas, 90 liters in small cities, 110 liters in medium cities, 130 liters in large cities, and 150 liters in metropolitan cities. Situbondo Regency is categorized as a medium-sized city with a population of between 100,000 and 500,000 people. Based on research by Tardan, MAM, et al. (2014), the need for clean water in a medium city is 110 liters per person per day.

At the Salafiyah Syafi'iyah Islamic Boarding School, domestic clean water needs are calculated by assuming that each student needs 110 liters per day, so the waste water discharge is estimated at 88 liters per person per day or 0.088 m^3 per person per day. With a total number of students of 4,140, the total waste water discharge reaches 364,408 m^3 per day. Apart from that, for non-domestic needs, such as prayer rooms, assuming the number of users is 40 people and the need for clean water is 5 liters per person per day, the clean water flow for prayer rooms is 0.20 m^3 per day.

The total wastewater discharge which includes domestic and non-domestic needs is 364,608 m^3 per day. Of the total wastewater discharge, around 75% is greywater discharge which is calculated to reach 273 m^3 per day. This study is the basis for planning wastewater treatment ponds at the Salafiyah Syafi'iyah Islamic Boarding School with a total average wastewater discharge of 364,608 m^3 per day.

3.5 Comparison of wastewater treatment alternatives

Available wastewater treatment alternatives include Anaerobic Baffled Reactor (ABR), Anaerobic Filter (AF), Aeration Pond, and Upflow Reactor Sludge Blanket (UASB). Based on land requirements, the use of an Aeration Pool is not possible because it requires a large area of land, while the available land is limited. In terms of cost, using UASB and Aeration Pools requires high costs because it requires pump operation or additional electrical energy. Anaerobic Filters have disadvantages in maintenance, namely that they require regular cleaning of the media to avoid clogging and draining.

Each wastewater treatment technology has its own advantages and disadvantages. This time the plan uses ABR technology to process greywater waste in Gayam Village, because of its ease of operation. The IPAL will later be handed over to the community. The wastewater treatment technology comparison matrix is presented in table 1.

Table 1. Comparison of wastewater treatment technologies

Parameter	Processing Type	
	Anaerobic Baffled Reactor	Anaerobic Filter
Maintenance	Mud cleaning is carried out every 2-3 years	The filter is cleaned regularly
Efficiency		
Cost	Low coverage	Low coverage
Land requirements	Moderate	Moderate
Excess	Sludge production is quite small, so it is resistant to fluctuations in hydraulic and organic loads.	There is a decrease in high organic substances. Sludge is also produced in small quantities.
Lack	The start up phase is around 3 months	There is a vulnerability in the start up phase and it is relatively long
Parameter	Aerated Pond	UASB
Maintenance	Mud cleaning is carried out every 2-5 years and there is aerator maintenance.	Pump maintenance and *organic loading control are required*
Efficiency		
Cost	Tall	Tall
Land requirements	Broad enough	Not too big
Excess	Withstands *shock loading* and reduction of bacteria	Low sludge production and high removal of organic material
Lack	A lot of energy and sufficient skill are needed to operate the tool	It requires skill and electricity to operate. Also sensitive to discharge fluctuations

Sources: 1) Sasse, 1998, 2) Morel and Diener, 2006, 3) WSP, 2007, 4) Tilley, 2014 5) Soedjono et al., 2010, 6) Qasim, 1985, 7) Conradin et al., 2010, 8) Nguyen et al., 2007, 9) PU, 2012, 10) US EPA, 2002.

3.6 Waste water treatment installation (IPAL) process

Household or residential wastewater is divided into two types, namely black water and gray water. Black water consists of latrine waste such as feces and urine which is usually disposed of in septic tanks. Meanwhile, gray water includes soapy water, clothes washing water and dish washing water. If this type of waste water is not treated properly it can pollute river water and ground water and affect the availability of clean water.

In areas that already have waste water treatment plants (IPAL), gray water will be discharged into drains such as ditches or sewers, then processed in the IPAL. This process allows treated water to be reused for non-consumable needs or returned to nature without polluting the environment. On the other hand, in areas that do not yet have an IPAL, it is necessary to plan a wastewater treatment building before the water is discharged into the sewer. This is important to ensure that seeping water does not pollute groundwater.

The following is waste water quality data based on previous research, which is used as a reference in planning the dimensions of the Anaerobic Baffled Reactor. Jasa Tirta I laboratory analysis results (2023) show Biochemical Oxygen Demand (BOD) of 11.3 mg/l, Chemical Oxygen Demand (COD) of 46.3 mg/l, Total Suspended Solids (TSS) of 57.8 mg/l l, and a pH of 6.83. This data is critical for understanding wastewater quality and planning effective treatment before wastewater is released into the environment.

3.7 Anaerobic baffled reactor (ABR) calculation process

Anaerobic baffled reactor (ABR) units are designed to treat wastewater with certain quality parameters. The average discharge (Qave) was 364,408 m^3/day with BOD, COD and TSS concentrations of 11.3 mg/l, 46.4 mg/l and 57.8 mg/l respectively. This unit is operated at a temperature of 26ºC and has a sludge drain interval every 24 months. The freeboard height is set at 0.3 meters, and the SS/COD ratio is 0.42. The residence time in the settling tank (Td) is 3 hours, and the velocity upflow is 1.5 hours. In addition, this unit has 6 compartments with a depth of 2 meters.

Next, the hourly debit entering the ABR unit is calculated by dividing Qave by the 24 hour processing time. This calculation produces an answer of 15.2 m^3/hour. The anaerobic baffled reactor calculation process can be described as follows.

$$\begin{aligned} Q\ per\ hour &= \frac{Q\ average}{irrigation\ time} \\ &= \frac{364{,}408\ m^3/day}{24\ hours/day} \\ &= 15{,}2\ m^3/hour \end{aligned} \quad \text{(Eq. 1)}$$

3.8 Calculation of settling tank efficiency in anaerobic baffled reactors

The efficiency of the settling tank in removing COD was calculated using a COD removal factor of 0.40, resulting in a COD removal percentage of 28%. Thus, the effluent COD is 33,408 mg/l. The BOD/COD efficiency factor is 1.06, which results in a BOD removal percentage of 29.7% and effluent BOD of 8 mg/l. The TSS removal percentage in the settling tank was 60%, resulting in effluent TSS of 23.1 mg/l.

Next, the volume of sludge formed was calculated based on the BOD removed and the draining period, resulting in a sludge volume of 16.7 m^3/day. The volume of water in the settling tank is 45.6 m^3. On the other hand, the length of the ABR compartment is calculated as 60% of the compartment depth, and the compartment area is calculated based on the hourly discharge and upflow velocity. Thus, the ABR volume is calculated based on the dimensions and number of compartments, and the Organic Loading Rate (OLR) is calculated to ensure that the ABR can handle the incoming organic load. The process of calculating the efficiency of an anaerobic baffled reactor settling tank can be described in the following details:

(a) Calculation of COD and COD *effluent removal percentages*

$$\begin{aligned} Percentage &= \frac{rasio\ SS/COD}{0{,}6} \times faltor\ removal \\ removal\ COD &= \frac{0{,}42}{0{,}6} \times 0{,}40 \\ &= 28\% \\ COD\ effluent &= COD\ in \\ &\quad \times (1 - COD\ removal\ rate) \\ &= 46{,}4\ mg/\text{l} \times (1 - 28\%) \\ &= 33{,}408\ mg/l \end{aligned} \quad \text{(Eq. 2)}$$

(b) Calculate the percentage of BOD removal, this percentage is calculated based on the intersection of the COD removal percentage and the BOD removal factor (COD removal percentage x BOD *removal factor*), which produces 29.7%; (c) Effluent BOD calculation, this process is calculated through BOD in x (1 – BOD removal rate), which produces an answer of 8 mg/l; (d) TSS removal calculation, this process is calculated by multiplying the two TTS categories (percentage TSS removal x TSS in), which produces a multiplication of 60% x 57.8 mg/l with an answer of 34.7 mg/l; (e) Effluent TSS calculation, this process involves reducing the TSS results by removing TSS (57.8 mg/l – 34.7 mg/l), which shows an answer of 23.1 mg/l.

3.9 The process of knowing the dimensions and number of compartments

The Anaerobic Baffled Reactor (ABR) design process requires a basic understanding of the parameters and interactions of each element required. This calculation process will show the various sizes and capacities of the ABR that have been determined. This calculation step involves calculating the length, width and depth of the compartment, checking the vertical flow velocity and hydraulic residence time, as well as calculating the organic load.

It was determined that the compartment length was based on the criteria outlined by Sasse (1998), namely between 50% and 60% of the compartment depth. The compartments planned in this test are around six with a depth of 2 meters each. In this context, the length of the compartment should not exceed 60% of its depth. The aim is to ensure that incoming wastewater can be distributed evenly throughout all compartments by shortening the distance between these compartments. The following is a calculation of compartment length based on these criteria: The rocess of knowing the length of the compartment. This length is calculated based on the percentage of depth through the formula (compartment length = 60% × compartment depth), which produces the following answer.

Compartment length = 60% × 2m =1.2m

Calculate the compartment area. The compartment area is calculated based on the process of dividing the hourly flow rate by the vertical flow velocity [(Vup): Compartment area = $Q_{\text{per hour}} / V_{\text{Up}}$], which produces the following answer.

$$Area\ Compartment = \frac{Q\ per\ hour}{V\ up} = \frac{15{,}2\ m^3/hour}{1{,}5\ m/hour} = 10{,}1\ m^2 \quad \text{(Eq. 3)}$$

Calculate the compartment width. Compartment width is calculated by dividing the compartment area by the compartment length, which produces the following answer.

$$Compartment\ Width = \frac{Area\ Compartment}{Compartment\ Length} = \frac{10{,}1\ m^2}{1{,}2\ m} = 8{,}4\ m \rightarrow 2\ m \quad \text{(Eq. 4)}$$

Calculate vertical flow velocity. The vertical flow velocity is checked using the following formula.

$$V\ up\ Check = \frac{Wastewater\ Discharge}{Compartment\ Length \times Compartment\ Width} = \frac{15{,}2\ m^3/hour}{1{,}2\ m \times 2\ m} = 6{,}3\ n \quad \text{(Eq. 5)}$$

Calculate ABR volume. The ABR volume is calculated using the following formula.

ABR Volume = Length × Width × Height=
= 12m × 6compartments × 2m × 2m
= $48m^3$

Calculate the length of the ABR

Total length ABR = pbk + (pk × jk) + (td × (jk + 2))
= 2m + (1.2m × 6) + (0.15m × (6+2))
= 20.4m

Calculate the ABR width
Width of ABR = width of settling tank + (wall thickness×2)
= 2m + (0.15m × 2) = 2.3m

Calculate ABR depth
ABR depth = water depth + freeboard + (wall thickness × 2)
= 2m + 0.3m + (0.15m × 2) = 2.6m

Calculate the total area of the ABR
Total land area = total length × total width
= 20.4m × 2.3m = 46.92m ^{2}

Information:
(1) Length of settling tank (pbk),
(2) Compartment length (pk),
(3) Number of compartments (jk))
(4) Wall thickness (td)
(5) Number of compartments (jk)

With this, the results of the calculation detailing the design parameters for the Anaerobic Baffled Reactor (ABR) are presented as follows. The compartment length was determined to be 1.2 meters, with the compartment area calculated to be 10.1 m^2 and the compartment width adjusted to 2 meters. The vertical flow velocity was calculated to be 6.3 n, and the total volume of the ABR was determined to be 48 m^3, based on its dimensions. The total length, width, and depth of the ABR were calculated to be 20.4 meters, 2.3 meters, and 2.6 meters respectively, resulting in a total land area of 46.92 m^2 for installation. In other terms these dimensions ensure the system is designed to efficiently handle the expected wastewater flow.

4. Conclusions

Based on the results and discussion of research regarding the Communal Waste Water Treatment Plant (IPAL) Planning Study at the Salafiyah Syafi'iyah Islamic Boarding School, Situbondo Regency which uses the Anaerobic Baffled Reactor (ABR) method, it can be concluded as follows. First, the Salafiyah Syafi'iyah Islamic Boarding School in Situbondo Regency has a population of 4,410 people spread across 74 rooms. Assuming that each room is occupied by 60 people, the domestic wastewater discharge produced is 364,408 m^3/day. This domestic wastewater includes water that comes from daily activities such as bathing, washing and cooking. Apart from that, there is a non-domestic wastewater discharge of 0.20 m^3/day which comes from other activities outside household needs, such as Islamic boarding school operational activities. The total discharge of waste water produced is 364,608 m^3/day. This figure reflects the large volume of waste water that must be managed every day to maintain the cleanliness and health of the Islamic boarding school environment.

Second, wastewater treatment installations using the Anaerobic Baffled Reactor (ABR) method offer several significant advantages. First, ABR requires a relatively small land area, so it is suitable for locations with limited space. Second, the construction, operation and maintenance process is relatively easy and simple, making it more practical than other processing systems. Third, ABR does not require electrical energy for its operation, so it is more cost-effective and environmentally friendly. Fourth, the overall costs for installing and maintaining an ABR system are more efficient, making it an economical solution. Therefore, ABR is considered suitable to be implemented at the Salafiyah Syafi'iyah Islamic Boarding School, considering these various advantages.

Third, the results of design calculations for the ABR wastewater treatment plant show that each compartment has dimensions of 11.4 meters long, 2.3 meters wide and 2.6 meters high. These dimensions are designed to ensure wastewater treatment efficiency by considering the volume of incoming wastewater and the flow velocity within the compartment. With these dimensions, ABR can treat wastewater effectively, minimize the risk of blockages, and ensure even distribution of wastewater throughout all compartments. This good design also helps in maximizing the anaerobic process in each compartment, so that the waste water treatment results can meet the specified quality standards.

Furthermore, this research provides suggestions regarding Waste Water Management Installations (SPAL) and related further planning. It is necessary to carry out detailed calculations regarding the Waste Water Management System (SPAL) to determine the depth of water in the channel, channel capacity, and flow discharge that allows sedimentation and erosion to occur. This is important to ensure that the wastewater system can function properly without causing blockages or damage to the channels. Apart from that, planning for domestic wastewater treatment plants needs to be done in more detail and comprehensively. Consideration of using other methods such as Constructed Wetland or Anaerobic Filter Reactor also needs to be done, especially considering that the Islamic boarding school area is surrounded by rice fields. This alternative method can provide a sustainable and environmentally friendly solution, where treated water can be reused by the community for non-consumption needs or returned to nature safely.

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