POLLUTANT LOAD CAPACITY OF RAWA BESAR LAKE, DEPOK, WEST JAVA

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Abstract

Depok City has dozens of lakes and one of them is Lake Rawa Besar. The Depok government gives priority to Rawa Besar Lake to be development as a tourist destination. At this time the waters of Rawa Besar Lake are in a polluted condition caused by domestic waste, land use change, chicken farming and floating net caramba. The study aims to analyze water quality, determine the carrying capacity of pollutant loads and provide recommendations for pollutant load reduction. The calculation of the Pollution Load Capacity refers to Minister of Environment Regulation No. 28 of 2009. Based on water quality analysis, 5 parameters exceed the quality standard, such as BOD, COD, total phosphate, total nitrogen, and total *coliform*. Using the model and calculation of the pollutant load capacity of lake and/or reservoir. The pollutant load capacity of Lake Rawa Besar for BOD parameters is 50.26 kg/year while the existing load is 262.76 kg/year, COD is 418.81 kg/year existing load is 1150.41 kg/year, phosphate is 0.50 kg/year existing load 26.45 kg/year, nitrogen 12.56 kg/year existing load 85.88 kg/year and total coliform 8.4×10^4 amount/year existing load 9.6×10^6 amount/year. The burden of incoming pollutants exceeds the pollutant load capacity of Lake Rawa Besar. Pollution control efforts are carried out by implementing communal wastewater treatment systems such as an Anaerobic Baffled Reactor (ABR).

Keywords: *pollutant load capacity, pollution control efforts, Rawa Besar Lake, water quality*

Introduction

Depok City has 40 lakes scattered across 11 districts. However, currently, only 23 of these lakes are considered active (Hartono, 2021). According to research conducted by Hendrawan et al., 2020, it was discovered that in 2017, 40% of the lakes in Depok were heavily polluted, and in 2019, this percentage had increased to 60%. The rapid population increase of Depok City has led to a change in land use management, with open space being converted into constructed land. This has had an impact on the current situation. Furthermore, there is currently a lack of comprehensive implementation of wastewater management in communities. The primary contaminants that infiltrate the lakes in Depok originate from residential areas, eateries, and small-scale industry such as tofu production. (Hendrawan dkk., 2020)

Rawa Besar Lake is one of the lakes with poor water quality in the city of Depok and is a top priority for the government in terms of revitalization to develop it as a tourist area. This lake covers an area of 13.5 hectares and is located in the Depok Jaya Village, Pancoran Mas Subdistrict, West Java. Ecologically, Rawa Besar Lake has an important role as a water catchment area as well as a buffer zone in the Depok City and its surroundings and habitat for aquatic organisms (Setiawati, 2019).

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The water source of Rawa Besar Lake comes from springs, rainwater, and drainage channels from the residential areas surrounding Rawa Besar Lake. Pollution of Rawa Besar Lake is caused by community activities along the lake's banks, wastewater drainage channels from the surrounding residential and industrial areas that do not have containment facilities, land use conversion, and floating net cages activities. This results in a decline in water quality, productivity, capacity, and sustainability of water resources, ultimately reducing the richness of natural resources.

Considering the function and utilization of Rawa Besar Lake, which is widely used by the local community and serves as source of livelihood as a fisheries class function, a study has been conducted on the Analysis of Pollutant Load Capacity in Rawa Besar Lake, Depok City. This can certainly serve as a research foundation for pollution control efforts and provide recommendations for reducing pollutant loads in Rawa Besar Lake. This research is expected to provide a strong foundation for the government and the local community to formulate appropriate policies and actions to control pollution and maintain the sustainability of the lake's function.

Research Methodology

Sampling Activity

This research was conducted at Rawa Besar Lake in April-June 2023. In this study, the lake was divided into 6 sampling points for measurements and observations. Point 1 is located at the inlet of Rawa Besar Lake, point 2 represents the area of floating net cages, point 3 is at the inlet of domestic wastewater discharge, point 4 is in the middle and at the inlet of the tofu industry wastewater discharge, point 5 is the inlet of sewage domestic with a significant amount of solid waste, and point 6 is the outlet leading to Pladen Lake. These points were selected based on the sources of pollution entering the lake. The location of sampling points can be seen in Figure 1.

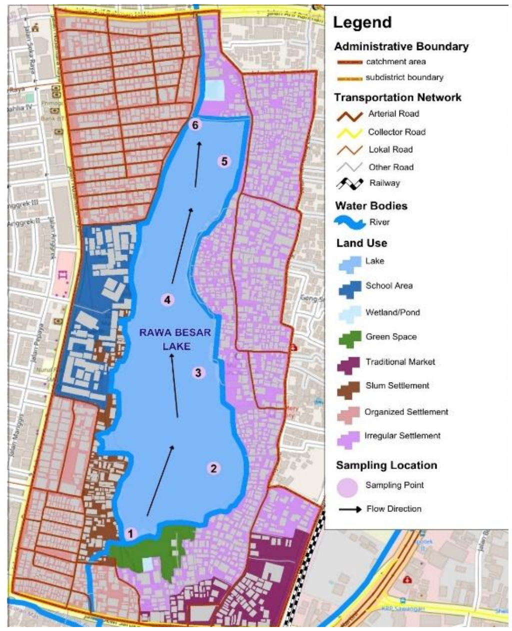

Figure 1. Distribution of sample location

Grab sampling was the approach that was utilized in order to collect water samples. SNI 6989.57:2008 on Water and Wastewater – Section 57: Surface water sampling procedures is the document that is meant to be consulted in order to determine the procedure for taking surface water samples. A device known as a water sampler was utilized in order to collect water samples. Sampling was carried out at each sampling location two times (in duplicate) to mitigate errors during the sample collection process. Afterward, the water obtained from the water sampler was transferred into bottles with a capacity of 1.5 liters each.

Sample bottles were labeled with details specifying the sampling location and the time when the samples were collected. Afterward, the sample bottles were stored in a cooler box to minimize temperature-related chemical reactions and maintain the stability of the measured parameters. The water samples were then transported and stored at the Environmental

Laboratory of Trisakti University for water quality analysis.

Water Quality Analysis

The water quality testing was conducted based on three parameters, which include physical, chemical, and biological. The measurement methods used refer to the Indonesian National Standards (SNI). In this research, water quality analysis was conducted using 10 parameters such as temperature, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), total nitrogen, total phosphate, and total *coliform*.

Table 1. Water Quality Parameters and Measurement Methods

No	Parameters	Unit	Methods	Measurement Type
A.	**Physics**			
1	Temperature	^oC	Thermometer	In Situ
2	TSS	mg/L	Gravimetric Method	Ex Situ
3	TDS	mg/L	Gravimetric Method	Ex Situ
B.	**Chemistry**			
1	pH	-	pH meter	In Situ
2	DO	mg/L	DO meter	In Situ
3	BOD	mg/L	Titrimetric Method	Ex Situ
4	COD	mg/L	Titrimetric Method	Ex Situ
5	Total Nitrogen	mg/L	Kjeldahl Method	Ex Situ
6.	Total Phosphate	mg/L	Spectrophotometric Method	Ex Situ
C	**Biology**			
1	Total *Coliform*	MPN/100 ml	Most Probable Number Method	Ex Situ

The water quality data acquired from laboratory analysis were compared to the water quality standards stipulated in Government Regulation Number 22 of 2021 for the classification of Class 2 water quality.

Pollutant Load Capacity

Regulation Number 28 of 2009 issued by the Minister of Environment, which pertains to the Pollutant Load Capacity of Lake and/or Reservoir Water, serves as the basis for the computation of the Pollutant Load Capacity. As can be seen in Figure 2, the model and calculation of the pollution load capacity of the lake and/or reservoir are presented.

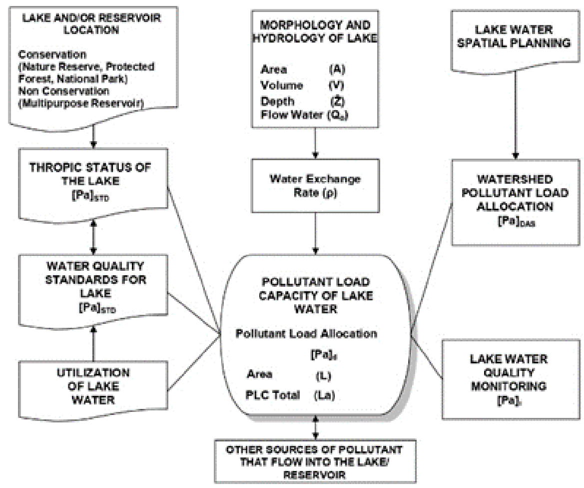

Figure 2. Model and Calculation of Pollutant Load Capacity

Result and Discussion

Water Quality

Water quality testing is conducted to assess whether a body of water is suitable for its intended use. The parameters measured in this research include physical, chemical, and biological parameters. The physical parameters such as temperature, TSS and TDS. The chemical parameters such as pH, DO, BOD, COD, total nitrogen, total phosphate, and the biological parameter is total *coliform*. Water sampling was performed three times, in April, May, and June 2023. According to the Depok City Environmental Agency (2018), Rawa Besar Lake is conserved and used for fish cultivation as well as for rainwater retention to address flood-related issues. A comparison will be made between the findings of the water quality analysis conducted on Rawa Besar Lake and the water quality standards for lakes that are outlined in Government Regulation Number 22 of 2021, specifically for the Class 2 designation. There are a variety of applications that are designated for class 2 water, such as water recreation facilities, the cultivation of freshwater fish, livestock, irrigation, and other uses that require water quality standards that are comparable to those authorized for class 2. Table 3 displays the findings of an investigation of the water quality in Rawa Besar Lake that was conducted during three different sample periods in the months of April, May, and June of 2023.

Table 2. The Average of Water Quality During 3 Sampling Periods

No	Parameters	Unit	Quality Standards	Sampling Point					
				1	2	3	4	5	6
A.	**Physics**								
1	Temperature	^oC	Deviation 3	30.67	30.33	30.50	29.83	30.00	29.33
2	TSS	mg/L	50	18.67	37.50	39.00	33.33	24.00	24.67
3	TDS	mg/L	1000	125.00	93.50	100.83	91.55	98.33	96.83
B	**Chemistry**								
1	pH	-	9	6.65	7.12	7,52	7,72	8.50	8.62
2	DO	mg/L	4	2.97	3.32	3,13	4,87	4.13	4.53
3	BOD_5	mg/L	3	18.29	17.00	17,96	11,84	15.49	13.52
4	COD	mg/L	25	83.30	76.15	81,63	49,19	65.47	56.28
5	Total Phosphate	mg/L	0.75	1.85	1.84	1,40	1,35	1.47	1.73
6	Total Nitrogen	mg/L	0.03	7.96	7.19	6.53	4.81	4.29	4.48
C	**Biology**								
1	Total *Coliform*	MPN/100 ml	5000	2.6×10^6	1.7×10^6	3.4×10^5	6.7×10^5	2.1×10^5	1.1×10^5

Note:

The quality standards of Government Regulation No. 22 of 2021, class 2

Red-typed figures indicate that the consentration exceeds the Quality Standards

Based on the water quality analysis, several parameters exceed the water quality standards, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total phosphate, total nitrogen, and total coliform.

a. Biochemical Oxygen Demand (BOD)

The highest BOD concentration of 18.29 mg/L was detected at point 1, which is the main inlet of Rawa Besar Lake. At this point, the source of pollution originates from domestic wastewater from residential areas and markets. This is primarily due to the absence of a Wastewater Treatment Plant (WWTP) in Situ Rawa Besar. Additionally, there are floating animal carcasses at this point. The decomposition of these deceased animals contributes to the organic matter content in the lake water. High BOD concentrations in the water can lead to a decrease in oxygen levels, which can be harmful to aquatic organisms and biodiversity.

b. Chemical Oxygen Demand (COD)

The highest COD concentration of 83.30 mg/L was detected at point 1. The high COD concentration is due to the input of domestic wastewater from residential areas. The organic materials present in domestic wastewater originate from kitchen activities, bathrooms, laundry rooms, and similar sources. These organic materials are both biodegradable and persistent. Biodegradable organic materials originate from food scraps, fruits, vegetables, meat, and so on. Meanwhile, persistent organic materials come from detergents, bleaching agents, disinfectants, and the like. Both biodegradable and chemical organic materials can enter the receiving water body through drainage channels and have the potential to degrade water quality.

c. Total Phosphate (TP) and Total Nitrogen (TN)

Concentrations of Total Phosphorus (TP) and Total Nitrogen (TN) tend to be high at points 1 and 2. Point 1 has TP concentrations of 1.85 and TN concentration of 7.96, while point 2 has TP concentration of 1.84 and TN concentration of 7.19. Point 1 represents the main inlet of Rawa Besar Lake, which receives domestic wastewater from residential areas and market waste. Point 2 is the location of Floating Net Cages. The high concentrations of TP and TN are caused by the input of domestic waste and the presence of aquaculture activities. High concentration of TP and TN can lead to an explosion of algae growth in water (algal blooms), resulting in a decrease in dissolved oxygen levels in the water and having an impact on fish mortality. Based on visual observations, owners of Floating Net Cages scatter feed without paying attention to the proper dosage. Inaccurate and excessive feed distribution can lead to the accumulation of leftover feed in the water. Fish farming activities contribute to 65.1% (TN) and 62.6% (TP) of dissolved forms, while feed contributes 71.4% phosphorus and 68-86% nitrogen to the aquatic environment, with the remainder consumed by fish (Mazón et al., 2007; Morris and Price, 2013).

d. Total *Coliform*

The highest Total *Coliform* concentration of 26 × 106 MPN/100 ml was detected at point 1. This is caused by the input of domestic and non-domestic waste that directly enters the water body. Additionally, there is a significant amount of organic and non-organic waste polluting the water. Organic waste includes food scraps, leaves, and deceased animals, while non-organic waste consists of plastic and Styrofoam. Moreover, in this area, there are some poultry cages, which can lead to poultry waste from the poultry cage entering the body of water.

The determination of the pollutant load capacity is one of the strategies that can be employed to maintain the sustainability and balance of aquatic ecosystems. By regulating the quantity and types of pollutants entering the water, it is possible to prevent excessive pollution levels and their negative impacts on living organisms, water quality, and other aquatic resources. This also contributes to efforts to rehabilitate polluted aquatic environments and ensures that the water quality remains suitable for use by the community and other purposes. The results of the pollutant load capacity calculation can be seen in Table 3.

Table 2. The Result of the Pollutant Load Capacity Calculation

Description	**Unit**	**Value**
Morphometry		
Lake Area	Ha	13.5
Average Depth (Z)	m	1.60
Volume	m^3	216000
Inlet Flow Rate	m^3/second	6.00
Outlet Flow Rate	m^3/second	3.50
Total Outlet Flow (Qt)	m^3/year	110284326
Water Exchange Rate (ρ)	per year	510.58
Residence Detention Time	year	0.0005

Water Quality	**Unit**	**Parameters**				
		BOD	**COD**	**Total Phosphate**	**Total Nitrogen**	**Total *Coliform***
Measured ([Pa]i)	mg/m^3	15684.62	68671.11	1609.06	5876.67	5.8×10^5 (MPN/100 ml)
Quality Standard ([Pa]Std)	mg/m^3	3000	25000	30	750	5.0×10^3 (MPN/100 ml)
Watershed Allocation	mg/m^3	-12684.62	-43671.11	-1579.06	-5127.67	-5.7×10^5 (MPN/100 ml)

Water Quality	**Unit**	**Parameters**				
		BOD	**COD**	**Total Phosphate**	**Total Nitrogen**	**Total *Coliform***
([Pa]DAS)						
R	-	0.054	0.054	0.054	0.054	0.054
Pollutant Load Capacity						
Pollutant Load Capacity per Area (L)	kg/m^2.year	3722.77	31023.12	37.23	930.69	6.2×10^3 (amount/m^2.year)
Pollutant Load Capacity Total (La)	kg/year	50.26	418.81	0.50	12.56	8.4×10^4 (amount/year)
Pollutant *Existing*						
PL-CA per Area	kg/m^2.yar	19463.44	85215.69	1959.49	6361.81	7.1×10^5 (amount/m^2.year)
PL-CA Total	kg/year	262.76	1150.41	26.45	85.88	9.6×10^6 (amount/year)
Excess Load	Times	5.23%	2.75%	52.64%	6.84%	114.33%

The maximum amount of pollutants that Rawa Besar Lake can handle for the BOD parameter is 50.26 kg/year, but it currently has an excess load that is 5.23 times higher. For the COD parameter, the lake's capacity is 418.81 kg/year, but the excess load is 2.75 times higher. The total phosphorus capacity is 0.50 kg/year, but the excess load is 52.64 times higher. The total nitrogen capacity is 12.56 kg/year, but the excess load is 6.55 times higher. Lastly, the total coliform capacity is 8.4 x 104 kg/year, but the excess load is 114.33 times higher than the lake's capacity. The factors contributing to the increased excess load are as follows**:**

1. Increased Human Activities

The presence of street sellers and other human activity near the lake has the potential to adversely affect the water quality and the aquatic ecology. Street vending activities are often associated with trade and food consumption, which can generate waste such as plastic litter, food scraps, and other organic waste that can pollute the lake.

It is important to manage human activities around the lake through strict regulations and supervision, including educating street vendors about waste management and the use of environmentally friendly materials (Peters & Meybeck, 2000; Liyanage & Yamada, 2017).

2. Land Use Changes

The conversion of water bodies into residential areas can affect the physical characteristics and water quality of a water body and its capacity to handle pollution loads. Changes in land use can alter the flow patterns of water, reduce natural buffer areas, and disrupt the natural functions of the surrounding ecosystem. Additionally, changes in land use can lead to soil erosion and increased sedimentation in the lake. Therefore, wise land use management is essential in preserving the environmental capacity of the lake and maintaining the balance of the aquatic ecosystem. Measures such as preserving natural vegetation around the lake, implementing natural buffer zones, and regulating human activities that can harm the environment can help minimize the negative impacts of land use changes on the capacity and water quality of the water body.

3. Floating Net Cage Activities

Floating net cage activities can impact the pollutant load capacity of the lake. Leftover fish feed and fish waste in the floating net cages contribute to organic material that affects water quality. If floating net cage activities are not controlled, the organic load in the lake can increase, leading to a decrease in water quality. Therefore, there is a need for awareness campaigns and guidelines for fish farmers regarding the proper feeding practices for fish (Syandri et al, 2020).

4. Climate Change

Climate change can have significant impacts on the pollutant load capacity of the lake. Climate

changes such as increased temperatures or unusual rainfall patterns can affect lake water quality by influencing water flow and circulation within the lake. This can increase the movement of pollutants within the lake. Increased water temperatures can impact the ability of oxygen to dissolve in water. Elevated temperatures can diminish the water's capacity to retain dissolved oxygen, thereby limiting the oxygen supply for aquatic species.
Murdoch et al, (2000) said that reduced dissolved oxygen can affect the decomposition of pollutants and reduce the water's capacity.

5. Infrastructure and Waste Management

Ineffective or inadequate wastewater treatment infrastructure can worsen pollution and reduce the pollutant load capacity. Communities without adequate Wastewater Treatment Plants (WWTP) can negatively impact the lake's pollutant load capacity. The pollutant load capacity refers to the lake's capacity or maximum limit to retain or treat waste and pollutants before they contaminate its waters. If communities around the lake do not have adequate WWTP, domestic wastewater pollutants may directly enter the lake or flow through drainage channels without proper treatment.

Recommendations for Management Strategies for Large Swamp Sites in Efforts to Control Pollution

Based on the analysis results, five parameters exceed the government-set standards and also exceed the pollutant load capacity that the water body can accept. Parameters that exceed the water quality standards and pollutant load capacity can harm the aquatic ecosystem, damage fish populations and other aquatic organisms, and disrupt the potential uses of the water for various purposes, such as aquaculture, recreation, or agriculture. Considering the importance of Rawa Besar Lake, efforts should be made to improve its water quality through the following measures:

1. Implement a waste management system for communities around the lake to prevent littering.
2. Place trash traps in drainage channels that flow into Rawa Besar Lake.
3. Dredging the site periodically to reduce the rate of sedimentation.
4. Reduce the influx of domestic wastewater by establishing a communal wastewater treatment plant (WWTP). The wastewater treatment scheme for Rawa Besar Lake can be seen in Figure 3.

The wastewater management system scheme in Figure 3 illustrates that each settlement within the Rawa Besar Lake catchment area is served by two types of drainage: surface runoff drainage for surface water and household wastewater drainage for wastewater originating from the surrounding settlements. Wastewater flows towards the wastewater treatment plant (WWTP), while surface runoff drainage flows into the stormwater channel. The implementation of the stormwater channel is intended to prevent runoff from the surface from directly entering the water body.

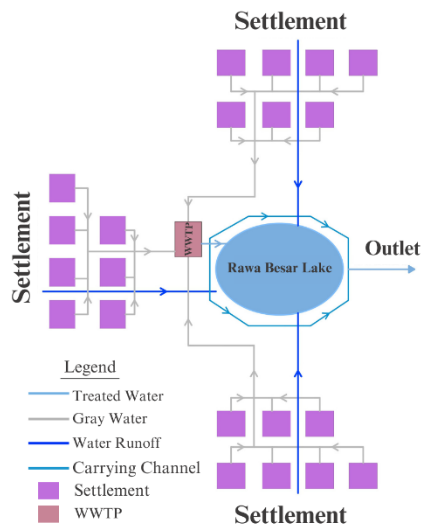

Figure 3. Scheme of a Wastewater Treatment System

Surface runoff typically contains suspended particles, and the presence of the stormwater channel in Rawa Besar Lake is expected to minimize the entry of suspended particles into the water body. All wastewater entering the WWTP is wastewater collected from the drainage of the surrounding residential areas. The installation of a wastewater treatment plant (WWTP) will enhance the water quality of Rawa Besar Lake by preventing the direct entry of organic waste from domestic wastewater into the lake. Consequently, this will improve the level of cleanliness, public health, and general quality of life for the community. The WWTP recommended in this study is an Anaerobic Baffled Reactor (ABR). The selection of an Anaerobic Baffled Reactor (ABR) wastewater treatment facility is influenced by the restricted land availability in the Rawa Besar Lake region. Below is the technical design drawing of the ABR wastewater treatment plant.

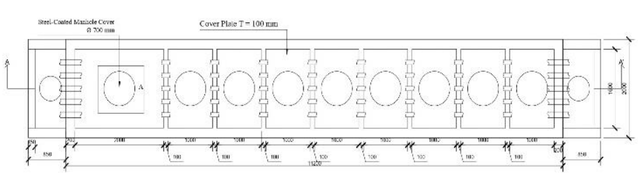

Figure 4. Top View Technical Drawing Design of ABR WWTP

The Anaerobic Baffled Reactor (ABR) is an anaerobic system used for treating wastewater containing suspended solids. It is composed of several compartments divided by vertical baffles. The ABR system is generally utilized for wastewater with low organic content or as an initial treatment step. The vertical baffles guide the wastewater through an alternating upward and downward flow from the inlet to the outlet, promoting efficient interaction between the liquid waste and the active biomass (Hastuti et al, 2012). According to Sasse (1998), the design criteria for an anaerobic baffled reactor (ABR) are as in Table 4.

Table 4. Design Criteria of ABR

No.	Parameters	Value	Unit	Reference
1	Removal COD	65-90	%	Sasse, 1998
2	Removal BOD	70-95	%	
4	Organic load	<3	Kg COD/m^3.day	
5	Hyraulic retention time	>8	hour	Sasse, 1998
6	Upflow velocity	<2	m/hour	

The manhole detail of the ABR wastewater treatment plant is shown in Figure 2 below.

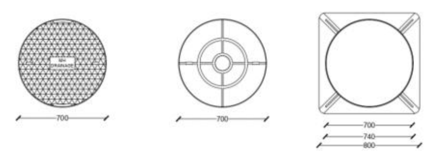

Figure 5. Manhole Detail of ABR WWTP

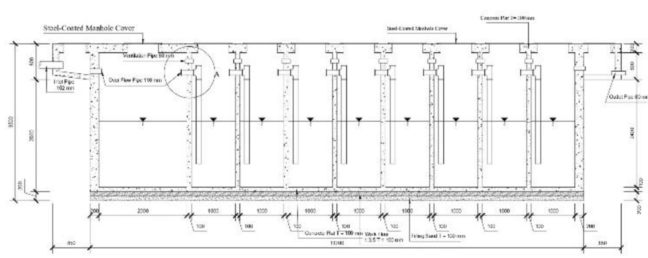

Figure 6. Cross-Section A-A' Technical Drawing Design of ABR WWTP

Conclusions

Based on the water quality analysis, five parameters exceed the standards established by Government Regulation No. 22 of 2021. These parameters include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total phosphate, total nitrogen, and total *coliform*. The deterioration in water quality is caused by human activities along the lake's banks, wastewater discharge from residential and industrial areas without proper containment, land use changes, and activities related to floating net cages. The pollution load of Rawa Besar Lake has beyond its natural capacity. Specifically, for the BOD parameter, it has exceeded 5.23 times, COD 2.75 times, total phosphate 52.64 times, total nitrogen 6.84 times, and total coliform 114.33 times. Therefore, further treatment is needed to reduce pollution and restore the water quality in Rawa Besar Lake. One of the measures that can be taken is the implementation of a communal wastewater treatment plant (WWTP) within the catchment area of Rawa Besar Lake.

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