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PERFORMANCE OVERVIEW OF THE WASTEWATER TREATMENT PLANT (WWTP) AT PERUMDA TIRTANADI CEMARA, PERCUT SEI TUAN DISTRICT, MEDAN

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Abstract

Population growth and increased domestic activities in urban areas have led to an increase in the volume of wastewater produced annually. If domestic wastewater is not treated properly, it can cause environmental pollution such as decreased water and soil quality, the emergence of unpleasant odors, and the risk of spreading disease. To overcome these problems, an effective wastewater treatment system is needed through a Wastewater Treatment Plant (WWTP). Objective: This study aims to determine the process and stages of domestic wastewater treatment and assess the effectiveness of the performance of the Perumda Tirtanadi Cemara Branch WWTP in reducing the levels of major pollutants such as BOD, COD, TSS, oil and fat, and ammonia to comply with domestic wastewater quality standards based on the Minister of Environment and Forestry Regulation No. 68 of 2016, Method: The research method used is descriptive qualitative, with data collection techniques through interviews, direct observation, and laboratory document reviews of the results of wastewater quality testing at the inlet and outlet of the WWTP, Results: The results of the study showed that the wastewater treatment process at the PDAM Tirtanadi Cemara Branch WWTP was carried out through several stages, namely coarse screening, fine screening, grit chamber, anaerobic reactor (UASB), aeration pond, facultative pond, and sludge drying bed. Based on the analysis results, there was a significant decrease in pollutant levels: BOD from 30.20 mg/L to 7.85 mg/L (74% efficiency), COD from 50 mg/L to 13 mg/L (74% efficiency), TSS from 42 mg/L to 11 mg/L (73.80% efficiency), oil and fat from 0.07 mg/L to 0.02 mg/L (71.24% efficiency), and ammonia from 7.5 mg/L to 5.6 mg/L (25.33% efficiency). The pH remained stable at 7.19, within the quality standard range of 6–9. Therefore, it can be concluded that the wastewater treatment plant (WWTP) of the Tirtanadi Water Company (PDAM) in the Cemara Branch performs well and is effective in reducing domestic wastewater pollutant levels. Therefore, the treated water meets quality standards and is safe for discharge into aquatic environments.

Keywords: Waste Water Treatment Plant, Domestic Wastewater, Tirtanadi Water Company, Treatment Efficiency, Quality Standards

Introduction

Population growth and the development of domestic activities in urban areas are among the main factors causing an increase in wastewater volume each year. As the need for clean water increases, the amount of wastewater generated from household activities automatically increases as well. If this wastewater is not managed properly, it will cause various environmental problems such as water pollution, soil degradation, unpleasant odors, and the risk of disease spread. Water pollution from

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domestic waste accelerates ecosystem damage, such as changes in water quality that are essential for daily life. Public awareness is essential to maintain water cleanliness and prevent further pollution [1].

Domestic liquid waste is the waste product of daily human activities that is continuously produced over time. This waste consists of used water from household activities, such as bathrooms, toilets, laundry areas, and cooking areas. If this liquid waste contains hazardous substances or materials and is discharged directly into the environment without treatment, it can lead to a decline in environmental quality [2].

Domestic wastewater contains various pollutants, such as organic matter, oil and grease, suspended solids (TSS), nitrogen compounds (ammonia), and other chemical compounds that can reduce oxygen levels in water. Therefore, wastewater management is crucial so that liquid waste generated from human activities can be processed to meet quality standards before being discharged into the environment. In this context, the existence of a Wastewater Treatment Plant (WWTP) plays a vital role in reducing the negative impact of wastewater on the environment. The main functions of WWTP include filtering solid waste at the inlet, separating fat and water with a grease trap, a homogenization process in an equalization tank, a biological process with an aeration tank that relies on bacteria to decompose organic matter, thereby reducing BOD and COD by up to 90%, a sedimentation process to precipitate particles and bacteria, and a final process using a chlorinator for disinfection to keep the discharged water free of pathogenic bacteria [3]

Even if the treatment system has been well designed, performance degradation may occur due to technical, operational, or environmental factors. Therefore, the effectiveness of the wastewater treatment plant (WWTP) needs to be evaluated periodically. Although most parameters meet quality standards, operational and maintenance aspects require improvement to maintain WWTP performance and prevent environmental pollution ([4]Evaluation is carried out by comparing wastewater quality at the inlet (before treatment) and outlet (after treatment), and analyzing whether the final results meet domestic wastewater quality standards as stipulated in Regulation of the Minister of Environment and Forestry Number 68 of 2016. Furthermore, monitoring WWTP performance is also part of efforts to ensure sustainable wastewater management. The results of this evaluation can be used as a basis for system improvements, increasing processing efficiency, and developing better waste management policies in the future. Therefore, regular evaluation and updating of the processing process are necessary to improve WWTP efficiency so that the resulting effluent meets environmental standards [5]

In North Sumatra Province, PDAM Tirtanadi is an institution that plays a major role in providing clean water and managing wastewater. One of the processing units managed is the Perumda Tirtanadi Cemara Wastewater Treatment Plant (WWTP), located in Percut Sei Tuan District, Medan City. This WWTP functions to treat domestic wastewater from residential areas and the surrounding environment before being discharged into receiving water bodies. The processing process at the Cemara WWTP is carried out through several stages, including coarse screening, fine screening, sand separation (grit chamber), anaerobic reactor (UASB), aeration pond, facultative pond, and sludge drying bed as a place to dry the processed sludge. Each stage plays an important role in reducing the levels of pollutants such as BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solids), oil and grease, and ammonia.

Based on the description, the problems raised in this study are regarding how the wastewater treatment process is carried out at the Perumda Tirtanadi Cemara Wastewater Treatment Plant (WWTP), the quality of wastewater at the inlet and outlet after going through the processing stages, and the extent to which the WWTP is efficient in reducing the levels of main pollutants such as BOD, COD, TSS, oil and fat, and ammonia to comply with the applicable quality standards.

Method

This research used a descriptive qualitative method, aiming to provide an in-depth description of the actual field conditions of the wastewater treatment process at the Perumda Tirtanadi Cemara Wastewater Treatment Plant (WWTP). This approach was chosen because it provides a comprehensive overview of the wastewater treatment process, the water quality at the inlet and outlet, and the compliance of the treatment results with applicable quality standards.

Data collection was conducted through three main techniques:

1. Interviews, conducted with the management of the Perumda Tirtanadi Cemara Wastewater Treatment Plant (WWTP), to obtain information regarding the wastewater treatment process, challenges encountered, and wastewater quality control efforts.
2. Observations, conducted directly at the WWTP site, to observe the physical condition of the installation, wastewater treatment stages, and wastewater characteristics before and after treatment.
3. Document review, conducted by examining supporting documents such as wastewater quality laboratory test results, WWTP operational activity reports, and references related to domestic wastewater quality standards based on Ministerial Regulation No. 68 of 2016.

To assess the effectiveness of the wastewater treatment system, an efficiency analysis of pollutant reduction levels was conducted using the following formula:

$$E = \frac{(Nilai\ Inlet - Nilai\ Outlet)}{Nilai\ Inlet} \times 100\%$$

This formula is used to determine the efficiency of the wastewater treatment plant (WWTP) system in reducing the concentration of pollutant parameters, such as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The results of this efficiency calculation are then compared with domestic wastewater quality standards as stipulated in Ministerial Regulation of the Environment and Forestry No. 68 of 2016, to determine whether the resulting effluent quality meets applicable environmental regulations.

Results and Discussion

3.1. Processing Process of the Perumda Tirtanadi Wastewater Treatment Plant, Cemara Branch

3.1.1. Inlet

The inlet is the main reservoir that collects wastewater by gravity. Wastewater is channeled to this section via transport trucks or 1,300 mm diameter Reinforced Concrete Pipe (RCP) from the Pump Station on Jalan HM. Yamin and the Cemara Asri Housing Complex. This section can handle a maximum capacity of 20,137 m^3 per day, or approximately 2,945 m^3 per hour. The inlet serves as the starting point before wastewater enters the next treatment process.

3.1.2. Screw Pump

The screw pump functions to channel wastewater from the inlet tank to a specific elevation so it can be transferred to the next processing unit. The pump used is an Archimedean screw, a screw pump designed to lift wastewater containing large particles or hard solids. In the initial operation phase, two pump units were used, each with a capacity of 1,310 m^3 per hour. One unit operates under normal conditions, while the other is prepared as a backup to handle maximum capacity.

3.1.3. Coarse Screen

The coarse screen is used to separate large objects carried along with the wastewater flow, such as pieces of wood, plastic, and other solid waste. This device has a 50 mm grid spacing and is manually operated. Its primary purpose is to protect subsequent processing units from potential damage caused by large materials. Dirt or waste retained by the coarse screen is then collected in a container before being disposed of in a final disposal site.

3.1.4. Fine Screen

The fine filter serves as the next step in the filtration process, capturing small particles that are not retained by the coarse filter. This device has a 6 mm grid spacing and operates automatically. This process ensures that wastewater flowing to the next stage is free of small solids that could potentially interfere with equipment performance or the processing process. The resulting fine debris is collected and then disposed of in a landfill.

3.1.5. Grit Chamber

The Grit Chamber separates materials such as sand and gravel carried along with the wastewater flow. Separation is achieved by slowing the flow rate, allowing heavy particles like sand and gravel to settle to the bottom of the tank. The resulting sediment is then removed from the system, while the water, freed from solid particles, flows to the next processing unit. This process is crucial to prevent clogging and damage to subsequent processing equipment.

3.1.6. Splitter Box

The Splitter Box is a flow-splitting tank that channels wastewater to several main processing units, namely the UASB Reactor. This tank is equipped with six outlets, each with a capacity of 450 m^3 per hour. The Splitter Box allows for even distribution of wastewater flow to each reactor, ensuring optimal and balanced processing.

3.1.7. Reactor UASB

The UASB reactor is a wastewater treatment system that operates anaerobically, meaning it does not require oxygen. In the process, wastewater flows from the bottom to the top through a layer of activated sludge containing microorganisms. These micro organisms function to decompose organic compounds found in the wastewater. Currently, there is one UASB reactor unit with a volume of 3,040 m^3 (measuring 19.2 × 39.2 × 4.06 m). With an average retention time of seven hours, this reactor is capable of achieving a BOD reduction efficiency of around 79%. In addition, this anaerobic process also produces methane gas that can be used as a source of electrical energy.

3.1.8. Sludge Drying Bed

Sludge Drying Bed functions to dry the sludge resulting from waste processing by utilizing solar heat and a natural filtering process so that the sludge becomes denser and easier to manage.

3.1.9. Skimming Tank

The skimming tank separates scum, a layer of foam and oil carried along with the effluent from the UASB reactor. This unit is equipped with a spray nozzle that breaks up and breaks down the foam layer so it doesn't accumulate on the water surface. At the tank outlet, a screen board is installed to trap scum and other floating materials, preventing them from being carried to the next processing stage.

3.1.10. Aerated and Facultative Pond

The Aerated Pond and Facultative Pond are the next stages in the wastewater treatment process after passing through the UASB Reactor. The aerated pond is equipped with two aerator units that function to inject oxygen into the water, allowing microorganisms to grow and help decompose residual organic matter. The pond depth reaches approximately 2.5 meters, which aims to prevent erosion due to turbulence from the aerator. Meanwhile, the facultative pond plays a role in separating suspended solids remaining from the aeration process, resulting in cleaner and clearer treated water. Overall, these two ponds have an area of approximately 3.1 hectares.

3.1.11. Outlet

The final result of wastewater processing is discharged into the river with the condition that the quality of the processed water must first be checked in the laboratory and must comply with the domestic wastewater quality standards of the Ministry of Environment and Forestry Regulation No. 68 of 2016.

3.2. Analysis of Inlet and Outlet of PDAM Tirtanadi Cemara Branch Wastewater Treatment Plant

3.2.1. Analysis of the Inlet of the Tirtanadi PDAM Wastewater Treatment Plant, Cemara Branch

Table 1 Results of Wastewater Parameter Examination at the Inlet of the PDAM Tirtanadi IPAL, CabangCemara

No	Parameters	Units	Inspection Results
1	PH	-	7,80
2	BOD	Mg/L	30,20
3	COD	Mg/L	50
4	TSS	Mg/L	42
5	Oils and Fats	Mg/L	0,07
6	Ammonia	Mg/L	7,5

Wastewater entering the Perumda Tirtanadi Cemara Wastewater Treatment Plant (WWTP) is first checked to determine its initial quality before undergoing treatment. This inspection aims to assess the level of pollution contained in the raw wastewater and determine the effectiveness of the treatment process. The results of the wastewater quality parameter inspection at the WWTP inlet are shown in Table 1 below.

3.2.1.1. PH

The pH value at the inlet of the Perumda Tirtanadi Cemara Wastewater Treatment Plant (WWTP) was 7.80. This result indicates that the wastewater entering the plant is neutral, meaning it is neither too acidic nor too basic. This pH value is relatively stable, so it does not disrupt the biological processes within the wastewater treatment system.

3.2.1.2. BOD

The BOD level at the inlet was 30.20 mg/L. This figure indicates a relatively high amount of oxygen required by microorganisms to decompose organic matter in the wastewater. This BOD value indicates a significant amount of organic matter in the incoming wastewater, requiring biological processing to reduce the organic content before the water is discharged into the environment.

3.2.1.3. COD

The COD value at the inlet was recorded at 50 mg/L. This parameter reflects the amount of oxygen required to chemically oxidize organic and inorganic compounds. This relatively high COD value indicates that the incoming wastewater still contains a significant amount of chemical and organic matter that needs to be decomposed, requiring the treatment process to effectively reduce these.

3.2.1.4. TSS

The TSS level at the inlet reached 42 mg/L. TSS is suspended solids such as silt particles, fine sand, or small organic matter. This value indicates that the incoming wastewater is still quite turbid and contains a significant amount of solids, which could interfere with the treatment process if not filtered first in the initial units such as coarse filters and sedimentation.

3.2.1.5. Oils and Fats

At the inlet, the oil and grease content was 0.07 mg/L. This value indicates that there is a small amount of oil and grease in the incoming wastewater. Although small, oil and grease must still be treated, as they can inhibit biological processes and form a film on the water surface if allowed to accumulate.

3.2.1.6. Ammonia

The ammonia level at the inlet was recorded at 7.5 mg/L. This value indicates the presence of nitrogen compounds resulting from organic waste or the decomposition of food. High ammonia levels can potentially pollute the environment if not properly treated, requiring biological processes to reduce the ammonia content in wastewater treatment plants.

3.2.2. Analysis of the Wastewater Treatment Plant Outlet of PDAM Tirtanadi, Cemara Branch

After undergoing a processing process in the installation, the wastewater that exits the WWTP system is referred to as outlet wastewater. Inspection at the WWTP outlet is carried out to determine the final quality of the treated water and to ensure that the content of pollutant parameters has decreased and meets the quality standards stipulated in the Regulation of the Minister of Environment and Forestry Number 68 of 2016. The results of the wastewater parameter inspection at the WWTP outlet of Perumda Tirtanadi Cemara can be seen in Table 2 below.

Table 2 Results of Wastewater Parameter Inspection at the Outlet of the Perumda Tirtanadi IPAL, Cemara Branch

No	Parameters	Units	Quality Standards	Inspection Results
1	PH	-	6-9	7,19
2	BOD	Mg/L	30	7,85
3	COD	Mg/L	100	13
4	TSS	Mg/L	30	11
5	Oils and Fats	Mg/L	5	0,02
6	Ammonia	Mg/L	10	5,6

From the results of wastewater examination in the Perumda IPAL Cemara laboratory based on the Minister of Environment and Forestry Regulation No. 68 of 2016 concerning wastewater quality standards, the quality of wastewater produced at the Perumda Tirtanadi Cemara outlet was obtained based on the following parameters:

3.2.2.1. PH

The pH value at the WWTP outlet was 7.19, still within the quality standard range of 6–9. This result indicates that the wastewater treatment process did not significantly change the acidity, and the treated water remained neutral, making it safe for discharge into the environment.

3.2.2.2. BOD

The BOD level at the outlet was 7.85 mg/L. This value is significantly lower than the inlet value of 30.20 mg/L. This decrease indicates that the biological processes in the WWTP are working effectively to reduce organic matter levels, and the final result meets the quality standard of below 30 mg/L.

3.2.2.3. COD

The COD value at the outlet was recorded at 13 mg/L, a significant decrease from the inlet value of 50 mg/L. This indicates that the chemical and biological treatment processes in the WWTP are effective in decomposing organic and inorganic compounds, and the results are well below the quality standard threshold of 100 mg/L

3.2.2.4. TSS

The TSS level at the outlet reached 11 mg/L, down from 42 mg/L at the inlet. This decrease indicates that the sedimentation and filtration units in the WWTP are functioning properly, reducing suspended particles in the water, resulting in clearer treated water that meets the 30 mg/L quality standard.

3.2.2.5. Oils and Fats

At the outlet, oil and grease levels decreased to 0.02 mg/L from 0.07 mg/L. This value is well below the 5 mg/L quality standard, indicating that the oil and grease separation process in the skimming tank is very effective, and the treated water is safe for discharge into water bodies.

3.2.2.6. Ammonia

The ammonia level at the outlet was 5.6 mg/L, lower than the inlet level of 7.5 mg/L. This decrease indicates that the WWTP's biological treatment unit is capable of reducing ammonia nitrogen levels, and the final product remains below the 10 mg/L quality standard, making it safe for the environment.

3.3. Efficiency of the PDAM Tirtanadi Wastewater Treatment Plant, Cemara Branch

Table 3 Results of comparison of inlet and outlet quality at the PDAM Tirtanadi IPAL, Cemara Branch

Parameters	Inspection Results		Quality Standards	Efficiency	Description
	Inlet	***Oulet***			
PH	7,80	7,19	6-9 Mg/L	7,82%	Comply with the quality standards
BOD	30,20	7,85	30 Mg/L	74%	Comply with the quality standards
COD	50	13	100 Mg/L	74%	Comply with the quality standards
TSS	42	11	30 Mg/L	73,80%	Comply with the quality standards
Oils and Fats	0,07	0,02	5 Mg/L	71,24%	Comply with the quality standards
Ammonia	7,5	5,6	10 Mg/L	25,33%	Comply with the quality standards

Based on the results of the comparison of wastewater quality between the inlet and outlet of the Perumda Tirtanadi Cemara Wastewater Treatment Plant (IPAL), the treatment efficiency value for each water quality parameter was obtained. This analysis aims to determine the extent to which the wastewater treatment system is effective in reducing pollutant levels to comply with domestic wastewater quality standards based on the Minister of Environment and Forestry Regulation No. 68 of 2016. The explanation of the efficiency of each parameter is described as follows.

3.3.1. PH

The pH at the inlet was 7.80 and the outlet was 7.19, with a pH reduction efficiency of 7.82%. Although the pH decreased slightly, the final result remained within the standard range of 6–9, ensuring that the treated water from the WWTP meets environmental quality standards. This decrease indicates a slight change in acidity due to the biological and chemical processes involved in the treatment, but remains within safe limits. This aligns with research conducted by [6] which showed that higher inlet pH than outlet pH is often due to treatment processes such as chlorination, which lowers the pH slightly through acid formation.

3.3.2. BOD

The BOD reduction efficiency reached 74%, from 30.20 mg/L at the inlet to 7.85 mg/L at the outlet. This value indicates that the biological treatment process at the WWTP is working very effectively in reducing the content of organic matter that requires oxygen to decompose. Because the outlet result is below the 30 mg/L limit, the wastewater meets quality standards and does not pollute the aquatic environment. This aligns with research conducted by [7] which showed that bacterial culture methods in aerobic and anaerobic treatment can reduce BOD to a maximum efficiency of approximately 84.51%.

3.3.3. COD

COD levels decreased from 50 mg/L to 13 mg/L, resulting in an efficiency of 74%. This value indicates that the oxidation process of organic and inorganic materials in the WWTP is highly effective, both through chemical reactions and microbial activity. The final result is well below the threshold of 100 mg/L, so the treated water meets quality standards and is safe for discharge. Similarly, research conducted by [8] recorded a COD reduction efficiency of 92.1% using a physico-biological process involving microbial activity at various stages of treatment.

3.3.4. TSS

The reduction in TSS from 42 mg/L to 11 mg/L represents an efficiency of 73.80%. This indicates that the sedimentation and filtration units in the wastewater treatment plant (WWTP) are working optimally to settle and filter suspended solid particles. With the final results well below the 30 mg/L quality standard, the treated water is clearer and contains fewer solids. This aligns with research conducted at the PT Indorama Polychem Indonesia WWTP by [9] which showed a TSS reduction efficiency of 81.05%. Optimal sedimentation, filtration, and filter media processes significantly reduced the suspended solids content in the wastewater.

3.3.5. Oils and Fats

The oil and fat parameters decreased from 0.07 mg/L to 0.02 mg/L, an efficiency of 71.24%. This value indicates that the oil and fat separation process in the skimming tank unit is effective, resulting in very low oil and fat content in the treated water. This final result is well below the maximum limit of 5 mg/L, thus meeting the quality standard. Another study conducted by [10] used an aeration and sedimentation method that reduced oil/fat content by up to 96%, BOD by up to 73.2%, and TSS by up to 88%. This study demonstrated that the simple aeration and sedimentation method is effective for treating wastewater containing oil and fat.

3.3.6. Ammonia

Ammonia levels decreased from 7.5 mg/L to 5.6 mg/L, with an efficiency of 25.33%. This reduction was not as significant as other parameters, but it was still quite good, as the final result was below the 10 mg/L threshold. This indicates that the biological processes of nitrification and denitrification in the WWTP are functioning, although improvements are needed to maximize ammonia nitrogen reduction efficiency. This aligns with research conducted by [11] which confirmed that successful nitrification, converting ammonia to nitrate and subsequent denitrification to nitrogen gas, requires stable operating conditions and strict control of microbial environmental parameters.

Conclusion

Based on the research results, the wastewater treatment process at the Perumda Tirtanadi IPAL, Cemara Branch has been running effectively through the stages of coarse and fine filtration, grit chamber, anaerobic reactor (UASB), aeration pond, facultative pond, and sludge drying bed. The analysis results showed a significant decrease in pollutant levels, namely BOD from 30.20 mg/L to 7.85 mg/L, COD from 50 mg/L to 13 mg/L, TSS from 42 mg/L to 11 mg/L, oil and fat from 0.07 mg/L to 0.02 mg/L, and ammonia from 7.5 mg/L to 5.6 mg/L. The pH value remains within the quality standard range of 6–9. Overall, the PDAM Tirtanadi IPAL, Cemara Branch has good performance and meets the domestic wastewater quality standards according to the Minister of Environment and Forestry Regulation No. 68 of 2016, although the efficiency of ammonia processing still needs to be improved.

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