



Installation Performance Evaluation Domestic Wastewater Treatment Plant in Fulfil Minister of Environment and Forestry Regulation No. 11 of 2025

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Abstract

Wastewater management domestic is aspect crucial in control pollution environment. especially in developing areas like Merauke Regency. Research This aim evaluate performance Installation Domestic Wastewater Treatment Plant (WWTP) in Housing District Ulilin in fulfil standard quality Minister of Environment and Forestry Regulation No. 11 of 2025. Research method use approach quantitative descriptive – evaluative with design studies case. Taking sample carried out at the inlet and outlet of the IPAL during September–October 2025 using grab sampling method. with Analysis of TSS, pH, BOD₅, COD, oil and fat, NH₃-N, and total coliform parameters based on Standard Methods (APHA, 2017). The results show that characteristics influence majority exceed standard quality. especially in the parameters BOD₅ (33.4 mg/L), COD (122.5 mg/L), TSS (35.5 mg/L), oil and fat (6.15 mg/L), NH₃-N (13.1 mg/L), and total coliform (3.59×10^3 MPN/100 mL). After processing. all effluent parameters fulfil standard quality with level 100% compliance Efficiency elimination show very good performance. with decline significant on BOD₅ (83.38%), COD (84.04%), TSS (49.30%), and NH₃-N (93.13%). High safety margin to standard quality show system own capacity adequate and resilient reserves to fluctuations burden polluters. In overall. domestic wastewater treatment plant District Ulilin operate effective. stable. and feasible in support protection quality environment in a way sustainabl.

Introduction

Wastewater domestic is one of the source polluter main water bodies in the area urban and residential areas developing (Mito et al., 2026; Zhou et al., 2026; Sun et al., 2026). Improvement amount population and activities domestic impact direct to improvement burden organic, nutrients, and contaminants microbiological entry to environment waters. Without adequate treatment of wastewater domestic can lower quality of water bodies, triggering eutrophication, as well as increase risk disease waterborne diseases (Chen et al., 2021; Dave et al., 2026; Enerijiofi et al., 2026). Therefore that, existence Installation Domestic Wastewater Treatment Plant (WWTP) become component crucial in system sanitation sustainable (Lubis et al., 2026; Laouane et al., 2026; Sari et al., 2026). Globally, wastewater management become part integral to the development agenda sustainable, especially in achievement of Sustainable Development Goals (SDGs) goal 6 related to clean water and sanitation (Maliga et al., 2025; Lamichhane et al., 2025; Tella et al., 2025). The latest study show that effectiveness system processing biology is very important ability reduction of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which are indicator main pollution organic (Zhang et al., 2022; Rashid, 2025; Nguyen et al., 2025). Optimal performance of the WWTP system does not only determined by design technology, but also by stability operational and capacity

adaptation to fluctuations burden polluters (Hu et al., 2026; Abreham Awono & Adam, 2025; Khasnabis et al., 2025).

In Indonesia, control wastewater pollution domestic arranged through regulations standard mandatory quality every manager system processing ensure effluent fulfil standard before thrown away to environment (Soewondo et al., 2025; Hasan & Mizzouri, 2026; Angi et al., 2025). Evaluation level compliance to standard quality become indicator important in evaluate effectiveness system processing as well as protection quality environment (Poursaeid, 2025; Das et al., 2025; Yang et al., 2025). Research latest emphasize that approach evaluation based efficiency allowance and safety margin to standard quality give description more comprehensive about resilience operational installation processing (Li et al., 2023). Water quality parameters such as Total Suspended Solids (TSS), BOD₅, COD, ammonia (NH₃-N), oil and fat, and total coliform are indicator main in evaluate domestic wastewater treatment plant performance. The high the concentration of these parameters at the inlet reflects burden polluter actual that must be reduced through physical, biological, and chemical processes. Research by Wang et al. (2021) shows that efficiency elimination nutrients and materials organic is greatly influenced by conditions operational reactor biological, including time stay hydraulics and balance microorganisms.

In addition, the relationship between BOD and COD often used For evaluate level Biodegradability of wastewater (Savaliya et al., 2026; Arzhanghi & Partani, 2025; Javaid et al., 2025). Ratio and correlation both parameters can describe proportion compound organic that can decompose in a way biological compared to with resistant compounds on the biodegradation process (Zhou et al., 2020; Aboutayeb et al., 2025; Pan et al., 2024). Analysis linear regression between BOD₅ and COD becomes approach relevant statistics For understand characteristics organic wastewater as well as need optimization of processing units predecessor. In the context area developing and areas settlement with level urbanization moderate, challenging domestic wastewater treatment plant management covering discharge fluctuations, variations burden pollutants, as well as limitations supervision technical (Arastou et al., 2026; Nurdianto et al., 2025; Ma et al., 2025). Recent studies confirm that system processing with capacity adequate reserve (buffer capacity). tend more resilient to surge burden organic (Gao et al., 2022). Therefore that, safety margin analysis between quality effluent and standard quality become important For measure resilience system in term long.

Merauke Regency as a developing region in the region eastern Indonesia faces dynamics growth potential settlements increase wastewater production domestic. Evaluation performance of domestic wastewater treatment plants in this region become important No only For ensure compliance to regulations, but also for support management environment based evidence (evidence-based environmental management). Assessment laboratory data based to inlet and outlet quality provides description empirical about effectiveness of the ongoing processing process. Based on description mentioned, it is necessary study which in a way systematic evaluate domestic wastewater treatment plant performance through analysis characteristics wastewater quality, efficiency pollutant parameter removal, level compliance to standard quality, and connection statistics between organic parameters main. Approach This expected can give contribution scientific in optimization strategy development system wastewater treatment sustainable and adaptive domestic to dynamics burden pollutants at the level local. Purpose from study This is For evaluate performance Installation Domestic Wastewater Treatment (WWTP) in housing District Ulilin, Merauke Regency.

Methods

This research project was conceived in a quantitative paradigm and framed as a descriptive evaluative research based on a case study methodology. This was aimed at more than just describing the nature of wastewater, but to critically evaluate the functionality of the Domestic Wastewater Treatment Plant that serves the Ulilin residential community in the Merauke Regency. Placing the study in the context of a case, the analysis is closely related to the real operational environment of the treatment system and the findings are based on the real field conditions and not the controlled or simulated environment. The study was carried out between September and October 2025, which is two months of time, deemed enough to identify consistent operational patterns and yet sensitive to short term changes in the nature of the wastewater.

To make it possible to capture the transformation process in the treatment system, two points, which were strategically defined, were sampled, i.e. the inlet and the outlet of the installation. The inlet is the raw wastewater that enters the system and is the best indicator of the actual amount of pollutant produced in the residential area by the domestic activities. The outlet on the other hand represents the last treated effluent released to the environment. With the help of the two points, the study can directly monitor the level to which the system minimises the concentration of pollutants. A grab sampling method was used to collect samples based on the instructions in the Standard Methods of the Examination of Water and Wastewater. The technique was chosen due to the fact that it gives a real-time picture of the quality of wastewater at certain points that is suitable in evaluation of performance under normal operational conditions.

The study analytical emphasis was focused on major physicochemical and microbiological indicators that are known to be common signals of domestic wastewater quality. These were Total Suspended Solids, pH, Biological Oxygen Demand, Chemical Oxygen Demand, oil and grease, ammonia nitrogen and total coliform. All the parameters were studied with the help of accepted laboratory methods so that the results could be reliable and comparable. Gravimetric methods were used to measure Total Suspended Solids, whereas Biological Oxygen Demand was obtained by five day incubation process which is an indication of the biodegradable organic load. The method of chemical Oxygen Demand was done through closed reflux method to capture the biodegradable and non biodegradable organic matter. The concentration of ammonia was determined by spectrophotometric analysis and the microbiological quality was evaluated by the use of the Most Probable Number method of total coliform. The protocols of all analytical procedures were based on the procedures described in APHA and were backed up by standard references in the wastewater engineering, which provided methodological rigor during the laboratory phase.

The results of the laboratory analysis were subjected to a systematic descriptive analysis. The initial step was to come up with an average concentration of each parameter in the inlet and outlet to have a considerable background on the conditions of the system input and output. Based on this, the performance of the treatment was evaluated with the help of the calculation of the removal efficiency in the form of a percentage difference between the inlet and outlet concentrations. This measure is an immediate measure of how effective the system is in reducing the loads of pollutants under the various parameters. Meanwhile, the analysis was not confined to the effectiveness but covered adherence to regulatory standards. The quality of the effluent was compared in an organized manner with the limits provided in the Minister of Environment and Forestry Regulation No. 11 of 2025, which made it possible to base the assessment on the relevance of the policy.

Results and Discussion

Characteristics of Wastewater at the Inlet of the Wastewater Treatment Plant System

Analysis results wastewater characteristics domestic at the inlet of the residential wastewater treatment system District Ironwood during period The September-October 2025 research is presented in Table 1 below :

Table 1 Characteristics Wastewater Quality Domestic Inlet of Residential Wastewater Treatment Plant District Ulilin

Parameter	Unit	September 2025	October 2025	Average	Quality standards*	Compliance Status
TSS	mg/L	36	35	35.5	30	EXCEED
pH	-	6.5	5.8	6.15	6 - 9	FULFIL
BOD ₅	mg/L	33.7	33.2	33.4	30	EXCEED
COD	mg/L	122.7	122.4	122.5	100	EXCEED
Oil & Fat	mg/L	5.5	6.8	6.15	5	EXCEED
NH ₃ -N	mg/L	12.8	13.4	13.1	10	EXCEED
Total Coliform	MPN/100mL	3,669	3.52	3.59	3	EXCEED

Source : Analysis results laboratory, 2025

Based on Table 1, the characteristics of wastewater domestic inlet shows worrying conditions with majority of parameters exceed standard quality Minister of Environment and Forestry Regulation No. 11 of 2025. The average TSS parameter of 35.5 mg/L exceeds standard 30 mg/L, indicating height content solids suspended. BOD₅ and COD indicate average values of 33.4 mg/L and 122.5 mg/L, respectively, both exceed standard quality 30 mg/L and 100 mg/L.

Oils and fats exceeded 6.15 mg/L on average standard 5 mg/L, indicating contribution significant waste kitchen. NH₃-N with an average of 13.1 mg/L is very high standard quality 10 mg/L, indicates height organic nitrogen load. The average total coliform was 3.59×10^3 MPN/100 mL exceeding standard 3×10^3 MPN/100 mL, indicating contamination microbiological high. Only the pH parameter with an average of 6.15 meets the requirements. range standard 6-9, although tend acid. The majority of inlet conditions exceed standard quality show the need wastewater treatment system with efficiency tall For reach quality effluent that meets standard.

Characteristics of Wastewater at the Outlet of the Wastewater Treatment Plant System

Evaluation suitability results wastewater treatment with standard quality Minister of Environment and Forestry Regulation No. 11 of 2025 is presented in Table 2:

Table 2. Characteristics Wastewater Quality Domestic Outlet of Residential Wastewater Treatment Plant District Ulilin

Parameter	Unit	Outlet Sept 2025	Outlet Oct 2025	Average	Quality standards	Compliance Status
TSS	mg/L	16	20	18	30	FULFIL
pH	-	7.1	7	7.05	6 to 9	FULFIL
BOD ₅	mg/L	4.7	6.4	5.55	30	FULFIL
COD	mg/L	17.2	21.9	19.55	100	FULFIL
Oil & Fat	mg/L	2.2	2.1	2.15	5	FULFIL
NH ₃ -N	mg/L	0.7	1.1	0.9	10	FULFIL

Parameter	Unit	Outlet Sept 2025	Outlet Oct 2025	Average	Quality standards	Compliance Status
Total Coliform	MPN/100mL	520	526	523	3,000	FULFIL

Source : Analysis results laboratory, 2025

Based on Table 2 monitoring wastewater quality September and October 2025, all parameters have been fulfil standard established quality. Efficiency system processing looks very significant, especially in the elimination burden organic like COD (down) to 19.55 mg/L) and BOD₅ (down to 5.55 mg/L), both of which far below thresholds of 100 mg/L and 30 mg/L respectively. Overall Compliance Rate : 100% (7 out of 7 parameters meet standard quality). In addition, the NH₃-N parameter shows decline drastic up to 0.9 mg/L with level efficiency reached 93.28%, indicating the nitrification process running optimally. Content total coliform bacteria are also under control with the figure is 523 MPN/100 mL from the maximum limit of 3,000 MPN/100 mL. In a way Overall, the performance of the IPAL is in the very good category, so that the processed water safe For released to environment in accordance regulation.

Research result show that waste water domestic at the inlet of the Domestic Wastewater Treatment Plant Housing area District Ironwood Merauke Regency has distinctive characteristics For area tropical with level urbanization moderate. A BOD₅ concentration of 33.7 mg/L classifies the wastewater as This as wastewater currently based on criteria Metcalf and Eddy (2014) Which sets the wastewater limits moderate at 110 mg/L. However, numbers This has exceeding Environmental Quality Standards of 30 mg/L.

Research result show level 100% compliance with standard quality Minister of Environment and Forestry Regulation No. 11 of 2025, which is very good achievement. Analysis per parameter:

Parameters with High Safety Margin

Based on monitoring results, the WWTP unit is currently operating with an extraordinary level of efficiency, as seen from the outlet value which has a very high safety margin against the Environmental Quality Standard (BML). The BOD₅ parameter only reached 5.55 mg/L from the limit of 30 mg/L (margin 81.5%), while COD was at 19.55 mg/L from the threshold of 100 mg/L (margin 80.5%). In fact, the NH₃-N (Ammonia) parameter showed the most impressive performance with a value of 0.9 mg/L below the maximum limit of 10 mg/L, creating a safety margin of 91%.

This very wide margin is not simply a compliance indicator, but rather an indicator that the wastewater treatment plant (WWTP) system has adequate buffer capacity. This provides operational resilience for the facility in the face of fluctuating pollutant loads and the potential for unexpected operational disruptions. In other words, the system is able to maintain environmentally safe effluent quality even when there are sudden spikes in wastewater discharge or concentration from the source.

Parameters with Medium Safety Margin

Different with organic parameters that have very wide margins, the results analysis show that TSS and oil and fat are in the lower margin zone small. TSS parameters are recorded average value of 18 mg/L compared with a maximum limit of 30 mg/L, which means only have a margin of safety by 40%. Meanwhile that, the Oil & Fat parameter is at 2.15 mg/L against threshold of 5 mg/L, with a safety margin by 57%.

Although in a way legality both parameters Still fulfil standard quality, relative margin of safety low This indicates that system own greater vulnerability tall to fluctuations burden. A little just increase solids or spill oil from inlet side can with fast push outlet value approaching or even beyond regulatory limits.

Comparison with International Standards

Quality effluent from this IPAL system No only comply regulations local, but also shows performance superior to meet standard WHO (2018) international for use reuse wastewater domestic. With BOD₅ value of 5.55 mg/L, processed water This has be under threshold of 10 mg/L, so that worthy used For irrigation limited. Likewise with TSS levels of only 18 mg/L (below the limit of 30 mg/L) for disposal to surface water bodies, as well Total Coliform content of 523 MPN/100 mL is satisfactory criteria safe For contact recreation (maximum limit 1,000 MPN/100 mL).

When compared with study previous, results This in line with findings Metcalf and Eddy (2014) Yang stated that system processing optimal biological can reduce burden organic to below 10 mg/L. In addition, the efficiency elimination coliform bacteria in studies This more Good compared to results study Sutanhaji, Suharto and Darmawan (2021) In a similar IPAL unit, where the coliform count is still often fluctuates above 1,000 MPN/ 100 mL. This prove that the disinfection and stabilization units on your system are working with very high efficiency.

Conclusion

Domestic Wastewater Treatment Plant (WWTP) Housing area District Ironwood Merauke Regency shows very effective performance in lower burden pollutants and fulfill standard applicable quality. The characteristics of the wastewater at the inlet show The majority of parameters, including TSS, BOD₅, COD, oil and fat, NH₃-N, and total coliform, exceeded regulatory threshold, which indicates height burden polluter domestic. However Thus, the results monitoring on the outlet shows level 100% compliance with standard quality with efficiency significant removal, especially on organic and nutrient parameters, as well as a high safety margin against regulatory limits. Analysis regression between BOD₅ and COD shows connection positive affirmation that the biodegradation process walk effective, although Still there is indication existence compound non-biodegradable organics that require attention to the processing unit predecessor. In Overall, the IPAL system has capacity stable and resilient operations to variation burden pollutants, so that worthy stated capable protect quality environment recipient in accordance applicable provision.

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