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Effectiveness of Hotel Wastewater Treatment and Economic Benefits of Clean Water from STP-Based Wastewater Treatment Plants

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Abstract: Wastewater treatment is an important aspect in the hospitality industry, especially to maintain environmental sustainability and meet water quality regulations. This study aims to analyze the effectiveness of the Wastewater Treatment Plant (WWTP) installation at The Zuri Baturaja Hotel using the Sewage Treatment Plant (STP) method. The analysis was carried out by monitoring the chemical parameters of wastewater quality, such as pH, COD, TSS, BOD, Ammonia, Oil and Fat, Total Coliform parameters. Wastewater sampling was carried out in accordance with the SNI 6989.57: 2008 standard to ensure that the treatment results meet the Environmental Quality Standards. This economic assessment of waste management is carried out to evaluate the cost and benefit aspects of waste management with the aim of increasing efficiency, reducing environmental impacts, and utilizing the economic potential of waste. This assessment includes various approaches, depending on the type of waste being managed. Economic assessment of waste is essential to ensure that waste management not only protects the environment but also provides financial benefits to companies and communities.

Keywords: Economic assessment; Effectiveness; Sewage treatment plants

Introduction

Water is a fundamental natural resource that supports life, economic development, and environmental balance. Increased human activity has led to the production of wastewater containing hazardous chemical, biological, and physical substances that can harm human health and ecosystems if disposed of without proper treatment. Wastewater originates from various domestic and commercial activities, including households, offices, and hospitality facilities (Askari, 2015; Elvania, 2022). Domestic wastewater, in particular, contributes significantly to urban environmental pollution if not managed properly (Supriyatno, 2000). Therefore, effective wastewater management is an important component of sustainable development and environmental protection.

Sewage Treatment Plan (STP) is a Wastewater Treatment Plant (STP) designed to treat wastewater so that it can be safely discharged into the environment or reused (Belladona et al., 2020). STPs are widely used in domestic wastewater management to remove contaminants from liquid waste before it is discharged or reused (Anggoro, 2018). The treatment process generally involves biological mechanisms, including the addition of specific bacterial strains capable of degrading suspended solids, organic matter, and hazardous chemicals (Rahmaniya, 2021). In the hospitality sector, such as at the Zuri Baturaja Hotel, the implementation of the STP system aims to ensure that wastewater quality complies with the Environmental Quality Standards set by the government. From an environmental economics perspective, wastewater management systems can also be evaluated through an economic assessment approach, specifically a cost-

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benefit analysis, to measure the direct and indirect economic value generated by environmental services.

Although STP is widely implemented, its effectiveness is still often assessed mainly from a technical and environmental perspective, while the economic dimension is not comprehensively evaluated. For hotel management, it is important to understand whether investing in wastewater treatment technology provides measurable economic returns, such as savings in operating costs, efficiency in water reuse, and avoidance of environmental sanctions. Without systematic economic evaluation, decision-making regarding environmental investments may lack quantitative justification. Therefore, it is necessary to analyze not only the environmental compliance of the wastewater treatment system at Hotel Zuri Baturaja but also its economic feasibility and overall value contribution.

Recent studies in environmental economics have emphasized the importance of valuing water services and environmental resources using monetary approaches, including willingness-to-pay methods and comprehensive cost-benefit analysis (Benito et al., 2023; Hutabarat et al., 2025). However, this research is specifically limited to examining the economic assessment and implementation of wastewater treatment in the hospitality sector on a local scale. This study offers novelty by integrating a technical evaluation of wastewater management with a detailed economic assessment framework in the context of hotel-based STP operations. The objective of this research is to evaluate the cost and benefit aspects of the wastewater management system implemented at Hotel Zuri Baturaja, including investment costs, operational and maintenance costs, as well as direct and indirect economic benefits. The urgency of this research lies in providing an evidence-based foundation for sustainable environmental investment decisions, ensuring that wastewater management not only meets regulatory and environmental obligations but also generates measurable economic value and social benefits for stakeholders and the surrounding community.

Method

This research was conducted at The Zuri Baturaja Hotel, established in 2020 and beginning operations in 2021. The location map is shown in Figure 1. This research used a quantitative approach, collecting data directly from the Engineering Department at the Wastewater Treatment Plant (IPAL) using the Sewage Treatment Plan method. The samples in this study were taken from the IPAL inlet and outlet tanks. The data results will be compared with the Quality Standards of the Minister of Environment and Forestry Regulation No. 68 of 2016 concerning domestic waste. To determine the effectiveness of using IPAL, the percentage of effectiveness formula is used.

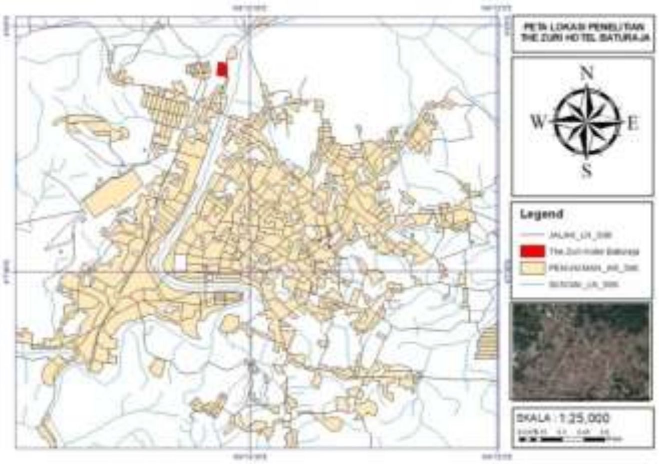

Figure 1. Research location map

The equation for the effective percentage of performance allocation using the efficiency formula (Apip, 2021) is as follows.

$$A = \frac{B - C}{B} x100\% \quad (1)$$

Explanation
A = Effectiveness of parameter value allocation
B = Parameter value before
C = Parameter value after

The economic assessment of treated water from the IPAL is conducted using the Replacement Cost Method and direct economic benefits. This approach is used to evaluate the economic value of treated water from the IPAL by calculating the cost savings in clean water the hotel could achieve if it did not purchase water from the Regional Water Supply Company (PDAM).

Replacement Cost Method

The replacement cost method calculates the economic value of water from IPAL by referring to the costs the hotel would incur to obtain clean water from PDAM if IPAL water were not used.

Clean Water Economic Value Formula

$$NE = Q_{water} \times H_{water} \quad (2)$$

Explanation:
NE = Economic value of clean water from IPAL (Rp/year)
Qair = Volume of water produced by the IPAL that is utilized (m^3/year)
Hair = PDAM water tariff (Rp/m^3)

Analysis of IPAL Operational Costs

The analysis of IPAL operational costs is conducted to determine the actual costs incurred in treating wastewater to produce clean water that can be reused.

$$BO = Electricity + Material + Power \quad (3)$$

Description:
BO= IPAL operational costs (Rp/year)
Electricity = IPAL electricity costs (Rp)
Materials = Chemical and support material costs (Rp)
Labor = Operational labor costs for wastewater treatment plant (Rp)
Maintenance = IPAL maintenance and repair costs (Rp)

Net Economic Benefit (MEB) Analysis

Net economic benefits are calculated to determine the net profit obtained from the use of water produced by the IPAL after deducting operational costs.

$$MEB = NE - BO \quad (4)$$

Explanation:
MEB = Net economic benefit (Rp/year)
NE = Economic value of clean water produced by IPAL (Rp)
BO = Operational costs of wastewater treatment plants (Rp)

Result and Discussion

Characteristics of the Wastewater Treatment Plant at The Zury Baturaja Hotel

Wastewater treatment at The Zury Baturaja Hotel is carried out through filtration before discharge into the river. The following is the workflow of the Sewage Treatment Plant at The Zuri Baturaja Hotel. The process stages are shown in Figure 2.

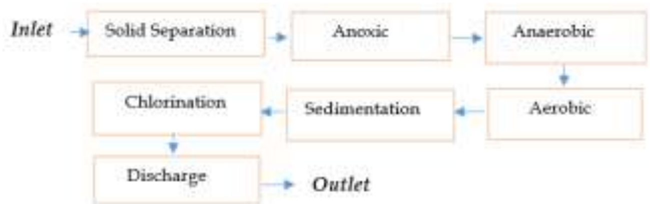

Figure 2. Sewage treatment plant method at the Zury Baturaja Hotel

Initial discharge from Various Departments

Wastewater from toilets, showers, and sinks can be directly channeled into the Sewage Treatment Plant (STP) tank. Kitchen wastewater will be filtered first in a grease trap before being channeled to the Sewage Treatment Plant (STP). All wastewater will be processed in a single wastewater treatment unit to reduce the content of pollutants in the wastewater before it is discharged into the drainage system/river.

Solid Separation Chamber

This tank filters solid or non-organic waste, such as condoms, plastic, sanitary napkins, and cloth. This tank also functions as the primary filter for sand and mud.

Anoxic Chamber

This tank serves to reduce the ammonia content in the water, where amoxicillin itself is a bacterium that grows without oxygen. However, its growth will accelerate if oxygen is present in the tank. Therefore, this tank undergoes denitrification, which reduces the ammonia content in the wastewater.

Anaerobic Chamber

This tank is equipped with Haney Comb plastic media that does not contain oxygen. After the tank has been filled with water for several days, the surface of the Haney Comb will be covered with a layer of biofilm. The biofilm itself serves as a habitat for anaerobic bacteria, where they attach to the plastic media and suspended sludge. These bacteria will break down organic substances that were not broken down in the previous tank.

Aerobic Chamber

This tank requires oxygen, which is typically supplied by aeration. This tank is also designed to decompose microorganisms in the water using a type of bacteria called biowist aqua or bioactivator, which assists the organic degradation process in liquid waste. This bacterium accelerates the bioremediation process.

Sedimentation Chamber

This tank is designed to separate solid particles from water through sedimentation. In this tank, denser solid particles will settle to the bottom, while cleaner water will flow to the next tank.

Chlorination Chamber

This tank is designed for water disinfection using chlorine. Chlorine kills viruses and bacteria remaining in wastewater, thereby improving water quality.

Discharge Chamber

This tank is the final tank in the wastewater treatment process, serving either as the final settling tank for wastewater or as a temporary storage tank to ensure that the wastewater meets quality standards before discharge.

Analysis of Inlet and Outlet IPAL and Percentage Effectiveness of Parameter Reduction

The parameters that indicate wastewater pollution at The Zuri Baturaja Hotel IPAL are pH, COD, TSS, BOD, ammonia, oil and grease, and total coliform. The greater the deviation from wastewater quality standards, the greater the pollution. This causes a decline in environmental quality due to inadequately treated parameters. The average values of the wastewater parameters are shown in Table 1.

Table 1. Average Wastewater Parameter Values at The Zuri Baturaja Hotel

Average Values of The Zuri Baturaja Hotel Parameters				
arameter	Unit	Quality Standard	Inlet	Outlet
H	Unit	6-9	6.6	7.3
OD	mg/l	100	43.18	40.80
SS	mg/l	30	48.3	24.3
OD	mg/l	30	11.1	8.40
mmonia	mg/l	10	0.382	0.342
il and Fat	mg/l	5	121	28.1
otal Coliform	ml	3000	9400	4900

Based on Table 1, the wastewater treatment plant at The Zuri Baturaja Hotel is highly effective in reducing physical and chemical pollutant loads, including pH, COD, TSS, BOD, and ammonia, with most of these parameters meeting quality standards at the outlet.

pH

One measure used to determine how acidic or basic the air is is pH. A pH that is too high (basic) or too low (acidic) can disrupt chemical interactions in the air and endanger living organisms (Sumardjo, 2009). The basic quality of the filter media causes an increase in pH or a tendency toward basic characteristics—the abundance of hydroxide ions (OH-) in the filter media (Lusela, 2015). According to the average table above and the Minister of Environment and Forestry Regulation No. 68 of 2016, the pH at the inlet and outlet channels is within the environmental quality range. The pH value at the inlet is 6.6 and increases to 7.3 at the outlet. This range is still within the quality standard limits (6–9). The increase in pH indicates that the treatment process can neutralize wastewater, making the effluent conditions more stable and safer for the aquatic environment. This indicates that the biological and physical processes in the IPAL are running well.

Chemical Oxygen Demand (COD)

The COD value decreased from 43.18 mg/l at the inlet to 40.80 mg/l at the outlet, well below the quality standard of 100 mg/l. This decrease indicates a reduction in the dissolved organic matter load during the treatment process. Although the decrease was not very significant, normatively, the IPAL has met the established quality standards. COD is the amount of oxygen required to oxidize organic matter in wastewater when potassium dichromate is used as the oxygen source oxygen (Andika et al., 2020). Based on COD values, organic matter is a source of wastewater pollution because it can be oxidized naturally through biological processes and reduce the amount of dissolved oxygen in water (Ningrum, 2018). The decrease in COD levels is caused by the activity of microorganisms in the biofilm, such as oxidation, which breaks down the organic content in wastewater (Islamawati et al., 2018). The low COD value at Outlite indicates that the COD removal process at the IPAL is working well.

Total Suspended Solids (TSS)

The TSS parameter shows a significant improvement, from 48.3 mg/l at the inlet to 24.3 mg/l at the outlet. The outlet value has met the quality standard of 30 mg/l. This indicates that the sedimentation or filtration unit in the IPAL works effectively in reducing suspended solid particles. The concentration of wastewater and the amount of filter media used in the filtration process affect the reduction of TSS levels in wastewater, resulting in more efficient filtration (Ilmannafian et al., 2020). Based on the TSS (Total Suspended Solids) measurements of The Zuri Hotel's wastewater during the observation period, the concentration was less than 30mg/l. This indicates that the water quality after filtration has improved.

Biological Oxygen Demand (BOD)

The BOD value decreased from 11.1 mg/l to 8.40 mg/l, and both were well below the quality standard of 30 mg/l. This condition indicates that the load of readily biodegradable organic matter is relatively low, and the biological processes in the IPAL can reduce the potential for dissolved oxygen pollution in the receiving water body. With the help of the aeration process, which reduces pollutant concentrations, organic matter in the biofilter layer attached to the surface of the filter media decomposes, resulting in a decrease in BOD values (Megasari et al., 2012). The treatment results show that BOD values are below the quality standard, indicating that the wastewater is safe when discharged.

Ammonia

Ammonia concentration decreased from 0.382 mg/l to 0.342 mg/l and is still well below the quality standard of 10 mg/l. This indicates that the nitrification process in the wastewater treatment plant is working quite well, and the potential toxicity to aquatic organisms is relatively low. Ammonia is a byproduct of organic filtration or domestic waste, and high concentrations are hazardous to fish and other aquatic organisms (Pratiwi, 2018). As shown in the table, the ammonia level is well below the established quality standard, making it suitable for disposal.

Oil and Fat

The oil and fat parameters show a very significant decrease, from 121 mg/l at the inlet to 28.1 mg/l at the outlet. However, the outlet value still exceeds the quality standard of 5 mg/l. This condition indicates that although the IPAL can substantially reduce oil and fat levels, the grease trap or preliminary treatment system is not yet operating optimally and requires improvement. Oil and fat usually originate from various kitchen activities, and excessive amounts can interfere with wastewater treatment processes by forming a layer on the water surface, thereby inhibiting oxidation and polluting the environment (Irianto, 2015). In physical processes, oil and fat can block sunlight from penetrating the water. To prevent plants that reproduce in water from performing photosynthesis and causing instability in the aquatic environment (Akbar & Silmi, 2021). When oil is present, a thin layer of oil forms during the process of oxygen absorption into the water, which reduces the concentration of dissolved oxygen in the water (Suseno & Kristiyana, 2021). Based on the table above, the oil and fat content decreased after filtration. However, it is still very high compared to the limit set by the Minister of Environment and Forestry, as stipulated in Regulation No. 68 of 2016.

Total Coliform

The total coliform count decreased from 9,400 to 4,900 counts/100 ml. Despite this decrease, the outlet value is still above the quality standard of 3,000 counts/100 ml. This indicates that the disinfection process at the WWTP is not yet effective in reducing microbiological contamination, thereby posing a potential risk to environmental health. Oils and fats typically originate from various kitchen activities. When their content is excessive, they can disrupt wastewater treatment by forming a surface layer, thereby inhibiting oxidation and polluting the environment (Budiyanti et al., 2020). In the physical process, oils and fats block sunlight from penetrating the water. To prevent plants that grow in water from photosynthesizing and causing instability in the aquatic environment (Windraswara, 2021). When oil is present, a thin layer of oil forms during the process of oxygen absorption into the water, which reduces the concentration of dissolved oxygen in the water. Based on the table above, the oil and fat content decreased after filtration. However, it is still very high compared to the limit set by Regulation of the Minister of Environment and Forestry No. 68 of 2016. Based on the values in Table 1, the parameter efficiencies are shown in Table 2 and Figure 1.

Table 2. Average Efficiency Values of the Parameters

Average Efficiency Value of Parameters	
Parameter	Effectiveness (%)
pH	10.60
COD	5.51%
TSS	49.68%
BOD	24.32%
Ammonia	10.47%
Oils and Fats	76.77%
Total Coliform	47.87

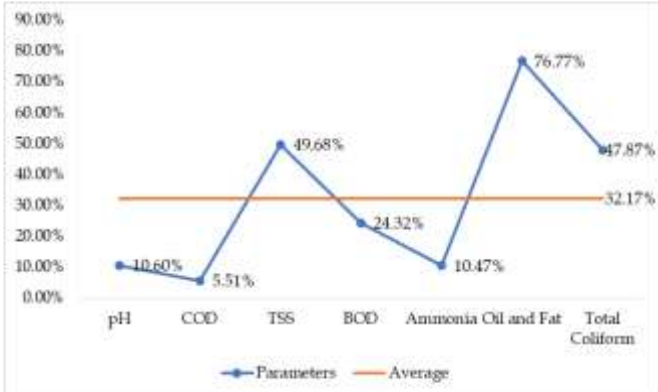

Figure 2. Average effectiveness percentage

Based on Table 3, the average wastewater quality efficiency shows variation in treatment performance across the analyzed parameters. The parameter with the highest efficiency level is oil and grease, with an effectiveness value of 76.77%. This high efficiency indicates that the IPAL treatment unit works optimally in separating hydrophobic compounds, which are generally effectively handled through physical separation processes such as grease traps and initial sedimentation. This condition is important because oil and grease can interfere with biological processes if they are not significantly reduced.

Other parameters that show relatively good performance are Total Coliform and Total Suspended Solids (TSS), with efficiencies of 47.87% and 49.68%, respectively. The TSS efficiency of nearly 50% indicates that the sedimentation and filtration processes are effective in reducing suspended solids content. Meanwhile, the reduction in Total Coliforms to almost half the initial concentration indicates that the treatment system can reduce the microbiological load. However, further treatment stages, such as disinfection, are still needed to achieve a higher level of safety.

The BOD parameter shows moderate efficiency of 24.32%, indicating that the biological degradation of organic matter is not yet optimal. Relatively low efficiencies are also observed in the COD (5.51%), pH (10.60%), and Ammonia (10.47%) parameters. The low COD and ammonia efficiencies indicate the system's limitations in oxidizing non-biodegradable organic compounds and converting reduced nitrogen, which may be due to insufficient hydraulic retention time or unstable biological process conditions.

The calculation of costs and economic benefits at the Zuri Baturaja Hotel Wastewater Treatment Plant (WWTP) was carried out by considering the Volume of water produced by the WWTP, the price of water from the regional water company (PDAM), the operational costs of the WWTP, and economic feasibility indicators in the form of Net Economic Benefit. The results of the calculation are shown in Table 3.

Table 3. Replacement Cost, Operational Costs, and Economic Benefits of Clean Water

Analysis Component	Uni	Monthly Value (IDR)	Value per year (Rp
Water volume from wastewater treatment plant (Q_water)	m^3	900	10,800
Water price from the public water utility (H_water)	IDR/m^3	6,000	6,000
Economic Value of Water (NE)	IDR	5,400,000	64,800,000
Water Cost Savings (PB)	IDR	5,400,000	64,800,000
IPAL electricity costs	IDR	1,200,000	14,400,000
Chemical costs	IDR	800,000	9,600,000
Labor costs	IDR	1,500,000	18,000,000
IPAL maintenance costs	IDR	500,000	6,000,000
Total IPAL Operational Costs (BO)	IDR	4,000,000	48,000,000
Net Economic Benefit (MEB)	IDR	1,400,000	16,800,000

Based on the calculations in Table 3, the Wastewater Treatment Plant (IPAL) at The Zuri Baturaja Hotel is capable of producing 900 m^3 of treated water per month, equivalent to 10,800 m^3 per year. The Volume of water produced by the IPAL, when assessed using the Replacement Cost Method with a PDAM water price of IDR 6,000/m^3, generates an economic value of IDR 5,400,000 per month or IDR 64,800,000 per year. This value represents significant potential savings in clean water costs for hotel operations if water needs are met from PDAM sources.

In terms of costs, the IPAL's total operational costs, including electricity, chemicals, labor, and routine maintenance, amount to IDR 4,000,000 per month or IDR 48,000,000 per year. Although the operation of the IPAL requires relatively stable monthly costs, these costs are still lower than the economic value of the water produced. This condition shows that IPAL not only functions as a means of waste treatment, but also as an alternative clean water production unit that provides real economic benefits.

The difference between the economic value of water and the total operational costs of the wastewater treatment plant results in a net economic benefit (NEB) of IDR 1,400,000 per month or IDR 16,800,000 per year. This positive net economic benefit indicates that the IPAL management at The Zuri Baturaja Hotel is economically feasible. In fact, the hospitality sector is one of the users of clean water with relatively high consumption for rooms, laundry, kitchens, and landscaping. Therefore, a strategy of reusing treated wastewater is a rational alternative to reduce the cost of purchasing clean water while reducing the environmental burden. Empirically, these findings are consistent with the results of previous research conducted by Putri et al. (2022), which found that the implementation of a wastewater recycling system in hotels can reduce water operating costs by 20–30% per year. Similarly, Widodo et al. (2021) concluded that optimal IPAL management in the hospitality sector contributes to cost efficiency while enhancing the hotel's image as an environmentally friendly entity.

Conclusion

Based on the evaluation results, the wastewater treatment plant at The Zuri Baturaja Hotel is generally capable of improving wastewater quality, as indicated by decreases in the concentrations of most pollutant parameters and pH stability within the quality standards specified in Minister of Environment and Forestry Regulation No. 68 of 2016. The highest efficiency was found in the parameters of oil and grease (76.77%), followed by TSS (49.68%) and Total Coliform (47.87%), which indicates the effectiveness of the physical treatment process. However, the parameters of COD, BOD, ammonia, oil and grease, and Total Coliform still require further optimization, particularly in the biological and disinfection units. From an economic perspective, the use of treated wastewater is financially viable, with an water value of IDR 64,800,000 per year and operational costs of IDR 48,000,000 per year, resulting in a net economic benefit of IDR 16,800,000 per year. These results confirm that the IPAL serves not only as a pollution control measure but also as an alternative source of clean water, supporting the efficiency and sustainability of hotel operations.

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E.K.S.: Developing ideas, data collection, analyzing, writing, reviewing, responding to reviewers' comments; E.N., S.T.:

supervising data collection, analyzing data, reviewing data and writing.

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Conflicts of Interest
The authors declare no conflict of interest.

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