

Performance Evaluation and Redesign of Hotel Wastewater Treatment Plant to Improve Effluent Compliance and Operational

¹Marsha Febrina Noorsy, ²Muhammad Faza Faidhan, ³*Nurandani Hardyanti, ⁴Wiharyanto Oktiawan

^{1,2,3,4}Department of Environmental Engineering, Faculty of Engineering, Universitas Diponegoro, Jalan Professor Soedarto, S.H., Semarang 50275, Indonesia

*Corresponding Author's E-mail: oktiawanwiharyanto@gmail.com

Abstract - The hospitality sector generates domestic wastewater that can potentially pollute the environment if not properly treated. Grand Candi Hotel Semarang produces wastewater with BOD 80 mg/L, COD 179.3 mg/L, TSS 36 mg/L, oil and grease 52 mg/L, pH 6.12, and fecal coliform 17,900 MPN/100 mL, with an average discharge of 143.3 m³/day. The existing wastewater treatment plant (WWTP) is known to be operating sub-optimally, thus requiring a redesign of the treatment system. This study aims to redesign the WWTP by selecting the most appropriate treatment technology based on the hotel's wastewater characteristics and operational conditions. The selection of treatment alternatives was conducted using the Multi-Criteria Decision Making (MCDM) method. The selected treatment units include a grease trap, bar screen, equalization tank, moving-bed biofilm reactor (MBBR), sedimentation tank, sludge holding tank, disinfection tank, and effluent tank. The results indicate that implementing MBBR technology can improve the removal efficiency of organic matter and suspended solids, producing effluent that meets the wastewater quality standards set by Permen LH No. 11 of 2025.

Keywords: Hotel wastewater treatment plant, redesign, MBBR, domestic wastewater.

I. INTRODUCTION

The hospitality sector is a major source of domestic wastewater generated by various activities, such as guest room use, restaurants, laundry services, swimming pools, and other supporting facilities [10]. Wastewater generally contains organic matter, suspended solids, oils and fats, and pathogenic microorganisms that can pollute the environment if not properly treated [11]. Grand Candi Hotel Semarang generates domestic wastewater with varying pollutant load characteristics. Based on laboratory test results, the wastewater has a BOD concentration of 80 mg/L, COD of 179.3 mg/L, TSS of 36 mg/L, oils and fats of 52 mg/L, pH of

6.12, and fecal coliforms of 17,900 MPN/100 mL, with an average flow rate of 143.3 m³/day. The existing WWTP is known to be operating suboptimally, necessitating a redesign of the treatment system to meet applicable quality standards [8].

One of the biological treatment technologies widely used for domestic wastewater treatment is the Moving Bed Biofilm Reactor (MBBR) [1]. This technology utilizes biofilm media as a growth medium for microorganisms, thereby enhancing the efficiency of organic matter treatment and demonstrating greater resilience to fluctuations in pollutant loads [17]. This study aims to plan the redesign of the WWTP at Grand Candi Hotel Semarang by selecting the most suitable treatment technology alternative using the Multi-Criteria Decision Making (MCDM) method and designing a treatment unit capable of producing effluent that meets applicable quality standards. Effluent that meets quality standards can be utilized for irrigation and flushing [2].

II. METHODOLOGY

This study was conducted at the Wastewater Treatment Plant (WWTP) of the Grand Candi Hotel in Semarang, located at Jl. Sisingamangaraja No. 16, Kaliwiru, Candisari District, Semarang City, Central Java 50232. Wastewater sample testing was performed at the Environmental Engineering Laboratory of Diponegoro University. The calculation, analysis, and report preparation processes were carried out at Diponegoro University, Semarang.

The planning phase began by identifying the existing conditions of domestic wastewater characteristics by collecting wastewater samples at the Grand Candi Hotel Semarang Wastewater Treatment Plant (WWTP) and testing them against government-established quality standards. Next, primary and secondary data were collected. Primary data were obtained through observation, interviews, and direct sampling of domestic wastewater [9]. Secondary data were obtained from relevant agencies, including regulations on domestic

wastewater, literature on wastewater treatment units, and the 2025 Semarang City Unit Price List.

Subsequently, wastewater characteristics were analyzed using laboratory test results from wastewater samples to determine the magnitude of pollutant loads for the specified parameters. Following the analysis of wastewater characteristics, an observation of the existing conditions of the wastewater treatment plant (IPAL) was conducted, covering the dimensions of each unit, the treatment stages within each unit, and the available area to support the redesign. Subsequently, an assessment was conducted of the facilities' physical condition, the operational efficiency of the treatment units, and potential constraints that could affect the planning process.

The next stage involved designing the Wastewater Treatment Plant (WWTP), which included the following steps: determining wastewater treatment alternatives, calculating the design details of the selected unit, calculating the hydraulic profile, calculating mass balance, and drafting the design of the planned Wastewater Treatment Plant (WWTP) [16]. The design process yields an output: a Wastewater Treatment Plant (WWTP) design that is more effective at removing pollutant loads and more efficient in operation.

Following the design phase, this planning process involves determining the utilization of the WWTP effluent. After undergoing treatment at the Wastewater Treatment Plant (WWTP), the resulting effluent meets applicable quality

standards and is therefore safe for reuse. The utilization of this effluent must be carefully selected to provide environmental benefits while supporting the principles of sustainable water management [19]. Among the various utilization options, irrigation of green open spaces (RTH) was selected as the primary option.

The final stage of planning involves analyzing the Cost Estimate (RAB). Based on the results of unit dimension calculations and operational analysis of the WWTP, an estimate of the costs required for the construction and operation of the system is conducted. This cost estimate uses the 2025 Semarang City Basic Unit Price as a reference and serves as an initial estimate. The costs considered include the construction costs of the WWTP building, as well as operational and maintenance costs.

III. RESULTS AND DISCUSSIONS

3.1 Existing Conditions Analysis

An analysis of existing conditions was conducted to determine the wastewater treatment capacity and the characteristics of wastewater generated by the Grand Candi Hotel in Semarang. Based on calculations of clean water usage and the assumption that approximately 80% of it becomes wastewater, the average wastewater flow rate was determined to be 143.30 m³/day, or 0.0016 m³/second. This wastewater flow rate is influenced by the hotel's operational activities, such as guest room occupancy, laundry operations, kitchen activities, and other common facilities.

Table 1: WWTP Existing Dimensions

Units	Length	Width	Height	Numbers of Tank	Volume	Volume total
	m	m	m			
Netralizatin	1,5	1	4	3	6	18
grit chamber	1,5	1	1	1	1,5	1,5
flow control box	0,6	1,05	0,75	1	0,4725	0,4725
Equalization	9,5	2,2	4	2	83,6	167,2
Aeration activated sludge	9,5	2,4	4	3	91,2	273,6
sedimentation	4,8	4,8	4	1	92,16	92,16
defoaming	1	2,3	4	1	9,2	9,2
Chlorination	1	1,05	4	2	4,2	8,4
outlet	3,3	3	4	1	39,6	39,6
sludge storage tank	3,3	1,6	4	1	21,12	21,12

Additionally, wastewater flow fluctuations occur due to variations in the number of hotel guests at different times. Therefore, the designed treatment system must be capable of accommodating these flow fluctuations to ensure the treatment process remains stable. An evaluation of the existing wastewater treatment system indicates that its capacity and performance are not yet optimal for reducing pollutant

concentrations, such as BOD, COD, and TSS. Consequently, a redesign of the wastewater treatment system is necessary to ensure compliance with applicable domestic wastewater quality standards [3].



Figure 1: Existing Manhole

3.2 Selection of Treatment Technology

The selection of treatment technology was conducted by comparing several alternative wastewater treatment systems suitable for the characteristics of hotel wastewater and scum. Some of the alternative technologies considered include aerobic-anaerobic biofilters, the activated sludge system (CAS), and the Moving Bed Biofilm Reactor (MBBR) [5]. Based on the results of technical and operational analyses, the Moving Bed Biofilm Reactor (MBBR) technology was selected as the primary treatment system. This technology offers several advantages, including high treatment efficiency, resilience to fluctuations in organic load, relatively smaller land requirements, and ease of operation [1, 17]

In the MBBR system, microorganisms grow on a biofilm medium that moves within the reactor, allowing the degradation of organic matter to occur more stably. This system also increases the surface area available for microbial growth, thereby enhancing the treatment efficiency of pollutant parameters.

3.3 Wastewater Treatment Plant Design

The wastewater treatment plant was designed for a peak flow rate of 592.61 m³/day, accounting for detention time, treatment efficiency, and available land conditions [11]. The designed treatment system consists of several main treatment units. The first unit is a grease trap that separates oils and fats from wastewater generated by kitchen activities. After that, the wastewater is directed to a screen tank, which filters out large debris to prevent it from interfering with the treatment process in subsequent units.

Next, the wastewater enters an equalization tank, which balances the flow rate and concentration, making the inflow to the biological treatment unit more stable. This tank is designed with dimensions of 2.5 m in length, 1.5 m in width, and 2 m in

depth, enabling it to accommodate fluctuations in wastewater flow. The primary treatment process occurs in the MBBR reactor, where microorganisms attached to the biofilm media reduce the concentration of organic matter. This reactor is designed with dimensions of 9.5 m in length, 4.8 m in width, and 3 m in depth, providing sufficient detention time for the biodegradation of organic matter.

After the biological process, the wastewater is directed to a sedimentation tank to separate the sludge from the treated water. The resulting sludge is then directed to a sludge holding tank for temporary storage prior to further treatment. The final treatment stage is carried out in a disinfection (chlorination) tank, which reduces pathogenic microorganisms before the wastewater is discharged into the environment or reused.

3.4 Headloss Calculation

Energy loss (head loss) calculations were performed to determine the wastewater flow capacity within the piping system and to establish the pump requirements for the wastewater treatment plant (WWTP) system. Calculations were conducted for each piping segment connecting the treatment units. In the segment from the grease trap to the bar screen, a total head loss of 0.071 m was measured with a static head of 0.18 m, leaving a residual pressure of 0.108 m, allowing gravity flow without a pump. In the segment from the bar screen to the equalization tank, a head loss of 0.023 m was measured, with a static head of 0.07 m and a residual pressure of 0.046 m, indicating that gravity-driven flow can still occur.

However, in the segment from the equalization tank to the MBBR reactor, a total head loss of 3.771 m was measured, with a residual pressure of -3.67 m, so gravity flow cannot occur. Therefore, a pump with a minimum head of approximately 3.77 m is required to convey the wastewater to the biological reactor. In the segment from the MBBR to the sedimentation tank, a head loss of 0.006 m was measured, with a residual pressure of 0.093 m, so gravity flow can still occur. In the segment from sedimentation to disinfection, a head loss of 0.0055 m was measured, and in the segment from disinfection to the effluent tank, a head loss of 0.0053 m was measured, so neither segment requires a pump. Meanwhile, in the segment from the effluent tank to the irrigation system, a total head loss of 0.193 m was obtained with a residual pressure of -1.49 m; therefore, a pump with a head of approximately 4.72 m is required to distribute the treated water to the effluent utilization system.

3.5 Mass Balance Analysis

A mass balance analysis was conducted to determine changes in pollutant loads at each wastewater treatment unit.

Based on the calculation results, the wastewater flow entering the treatment system is 143 m³/day with an initial pollutant load of BOD: 11.46 kg/day; COD: 25.69 kg/day; TSS: 5.15 kg/day; NH₄: 3.86 kg/day; Total coliform: 2,664.45 kg/day; Oil and grease: 11 kg/day.

In the grease trap unit, oil and grease separation occurs with an efficiency of 95%, resulting in a significant reduction in oil and grease load before entering the next treatment unit. The wastewater is then directed to the bar screen and equalization tank, which serve as preliminary screening and flow-rate and concentration balancing. No significant reduction in pollutant load occurs in this unit because it serves only as preliminary treatment. The main treatment process takes place in the MBBR reactor, with treatment efficiencies of 95% for BOD, 90% for COD, and 85% for ammonia (NH₄). After undergoing this biological process, pollutant loads decrease to BOD: 0.57 kg/day; COD: 2.5 kg/day; TSS: 5.15 kg/day; NH₄: 0.58 kg/day.

3.6 Resource Recovery

Treated wastewater is collected in an effluent tank before reuse. Based on mass balance calculations, the treated water shows a significant reduction in pollutant load, making it suitable for reuse in non-potable applications. In this plan, the treated water is intended for irrigation of green open spaces (RTH) on the hotel grounds. The reuse of this treated water aims to reduce clean water consumption, improve the efficiency of water resource use, and enhance workplace safety.

3.7 Operation and Maintenance Procedures

The WWTP's operational requirements are designed to ensure stable operation, with a wastewater flow rate of 143 m³/day. Operation of the MBBR unit requires an adequate aeration system to maintain microbial activity in degrading organic matter. Additionally, routine maintenance of the grease trap unit is necessary to prevent oil and grease buildup, and periodic cleaning of the bar screen is required to prevent blockages in the treatment system. Maintenance is also required for the pumps used in the equalization tank segment leading to the MBBR reactor, as well as for the distribution system of treated water to the irrigation area.

3.8 OSH Identification in WWTP Operation

The operation of a wastewater treatment plant poses potential risks to occupational safety and health. These risks include exposure to hazardous gases, such as hydrogen sulfide (H₂S), direct contact with wastewater, and the potential for mechanical equipment failures. Therefore, an occupational safety system must be implemented, including the use of

personal protective equipment (PPE) such as gloves, masks, boots, and safety helmets for WWTP operators. Additionally, operational training for operators is necessary to minimize the risk of workplace accidents.

3.9 Cost Estimation

A cost estimate was prepared to determine construction costs for the wastewater treatment plant. Based on the calculations, the cost for preparatory work is Rp 12,492,917.67, while the construction cost for the WWTP unit is Rp 209,717,127.39. Some of the main components of the construction cost include:

- Grease trap work: Rp 2,595,854.78
- Equalization tank: Rp 11,514,569.89
- MBBR BOD reactor: Rp 34,927,285.15
- MBBR NH₃ reactor: Rp 111,694,262.80
- Sedimentation tank: Rp 15,119,463.67
- Disinfection unit: IDR 14,638,343.23
- Effluent tank: IDR 19,227,347.87

The total construction cost required is Rp 222,210,045.06. After adding 15% VAT, totaling Rp 33,331,506.76, the total cost of the wastewater treatment plant construction is Rp 255,541,551.82, rounded to Rp 256,000.

3.10 Economic Feasibility Analysis

Based on the analysis of the wastewater treatment plant construction cost of Rp 255,541,551.82, the construction of this wastewater treatment system is deemed feasible for implementation at the hotel facility. This investment provides long-term benefits by helping control environmental pollution and supporting sustainable wastewater management. Additionally, the reuse of treated water for irrigating green open spaces can reduce the consumption of clean water, thereby providing long-term operational cost efficiency.

IV. CONCLUSION

Based on the analysis and design of the emission control system at the tofu industrial center, it can be concluded that the wood combustion process at the Ploso Village Tofu Industrial Center generates various gaseous and particulate emissions, where the particulate emissions from the existing 4 meter unequipped square galvanized chimneys disperse into the surrounding ambient air at a level that exceeds the applicable environmental quality standards. To address these findings and achieve the emission reduction objectives, an air pollution control system consisting of an integrated cyclone and a redesigned 10 meter chimney was engineered, which successfully reduces the particulate emission concentration from 515.49 mg.m⁻³ to 7.77 mg.m⁻³ through a 98.49%

cyclone removal efficiency and decreases the ambient particulate concentration from 558 $\mu\text{g.m}^{-3}$ to 213 $\mu\text{g.m}^{-3}$ to comply with regulatory thresholds, thereby significantly improving local air quality. To further develop this system and enhance environmental sustainability, it is recommended that future initiatives focus on field testing and dispersion modeling to advance air pollution control science for small-scale industries, while ensuring that local MSMEs implement the cyclone system and chimney redesign, local governments provide technical and policy support, and the community participates in collaborative awareness efforts to mitigate pollution impacts.

REFERENCES

- [1] Bering, S., Mazur, J., Tarnowski, K., Janus, M., Mozia, S., & Morawski, A. W. (2018). The application of moving bed bio-reactor (MBBR) in commercial laundry wastewater treatment. *Science of the Total Environment*, 627, 1638-1643.
- [2] Database of Indonesian Laws Website. Surat Keputusan Gubernur Sumatera Barat No. 26 Tahun 2001 tentang Penetapan Baku Mutu Limbah Cair Bagi Kegiatan Hotel di Sumatera Barat.
- [3] Departemen Kesehatan Republik Indonesia. (2009). Pedoman teknis instalasi pengolahan air limbah dengan sistem aerobik lumpur aktif pada fasilitas pelayanan kesehatan. *Pusat Sarana, Prasarana dan Peralatan Kesehatan*.
- [4] Encyclopedia Britannica. (2023). Topography. In Encyclopedia Britannica. Retrieved October 15, 2023, from
- [5] EPA (Environmental Protection Agency). (2020). National Pollutant Discharge Elimination System (NPDES).
- [6] Grady, C., Daigger, G., & Love, N. (2011). Biological Wastewater Treatment. *CRC Press*.
- [7] Gerardi, M. (2016). Activated sludge Wastewater Treatment. *Wiley*.
- [8] Hafiza N, Abdillah A, Islami BB, Priadi CR (2019) Analisis awal karakteristik air hitam dan air abu-abu di Kawasan Jakarta Raya. *IOP Conf Ser Earth Environ Sci* 366:012029.
- [9] Hidayat, R., Irianto, E. W., & Rinjani, R. R. (2010). Evaluasi kinerja proses AUF-EKOTEK untuk pengendalian limbah cair pabrik tahu di S. *Cipeles*.
- [10] Hidayat, D., Suprianto, R., & Dewi, P. S. (2016). Penentuan kandungan zat padat (total dissolve solid dan Total Suspended Solid) di perairan Teluk Lampung
- [11] Jusepa, N.R. & Herumurti, W. 2016. Pengolahan Lindi Menggunakan Moving bed biofilm reactor dengan Proses Anaerobik-Aerobik-Anoksik. *Jurnal Teknik ITS*, 5(2): F254-F259.
- [12] Kementerian Lingkungan Hidup. (2025). Peraturan Menteri Lingkungan Hidup Republik Indonesia Nomor 11 Tahun 2025 tentang Baku Mutu Air Limbah dan Standar Teknologi Pengolahan Air Limbah Untuk Air Limbah Domestik.
- [13] Kementerian Pekerjaan Umum dan Perumahan Rakyat. (2017). Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia Nomor 04/PRT/M/2017 tentang Penyelenggaraan Sistem Pengelolaan Air Limbah Domestik.
- [14] Kurnia, S., Syamsinar, & Afdaliah. (2020). Akuntansi manajemen limbah industri perhotelan (Studi kasus: Sebuah hotel bintang empat di Makassar). *AKUNSIKA: Jurnal Akuntansi dan Keuangan*, 1(1), 1–10.
- [15] Kurniawan, M. W., Purwanto, P., & Sudarno, S. (2013). Strategi pengelolaan air limbah sentra UMKM batik yang berkelanjutan di Kabupaten Sukoharjo. *Jurnal Ilmu Lingkungan*, 11(2), 72–82.
- [16] Mahatyanta A, Razif M (2016) Desain alternatif instalasi pengolahan air limbah dengan reaktor anaerobik ber-baffle dan filter anaerobik untuk Rumah Susun Romokalisari, Surabaya. *Int J ChemTech Res* 9:195–200.
- [17] Mara, D. (2003). Domestic wastewater treatment in developing countries. *Earthscan*.
- [18] Metcalf & Eddy, Inc., Tchobanoglous, G., Stensel, H. D., Tsuchihashi, R., & Burton, F. L. (2014). Wastewater engineering: Treatment and resource recovery (5th ed.). *McGraw-Hill Education*.
- [19] Metcalf and Eddy. (1991). Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd Edition. *New York: Mc Graw Hill Company*.
- [20] Metcalf and Eddy. (2003). Wastewater Engineering: Treatment and Reuse, 41 Edition. *New York: Mc Graw Hill Company*.
- [21] Moduto 1998. Drainase Perkotaan Volume I. Jakarta: Gramedia Pustaka Utama.
- [22] Mubin, F., Binilang, A., & Halim, F. (2016). Perencanaan sistem pengolahan air limbah domestik di Kelurahan Istiqlal Kota Manado. *Jurnal Sipil Statik*, 4(3), 211–223.

Citation of this Article:

Marsha Febrina Noorsy, Muhammad Faza Faidhan, Nurandani Hardyanti, & Wiharyanto Oktiawan. (2026). Performance Evaluation and Redesign of Hotel Wastewater Treatment Plant to Improve Effluent Compliance and Operational. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 10(6), 174-179. Article DOI <https://doi.org/10.47001/IRJIET/2026.106021>
