



INFRASTRUCTURE PERFORMANCE ANALYSIS OF THE ON-SITE DOMESTIC WASTEWATER MANAGEMENT SYSTEM IN BANDA ACEH

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ABSTRACT

The On-Site Domestic Wastewater Management System (OWMS) serves as the primary sanitation service in Banda Aceh, playing a critical role in managing household wastewater. This study aims to analyze the existing conditions of OWMS infrastructure, evaluate the performance of its management, and formulate improvement strategies using a SWOT analysis. The research employed a descriptive approach with data collection conducted through field surveys, interviews, direct observations, and secondary data from relevant municipal agencies. Samples were selected purposively from septic tank users, faecal sludge transport operators, Faecal Sludge Treatment Plant (FSTP) personnel, and technical institutions. The findings indicate that the OWMS infrastructure faces several challenges across its subsystems, including household-level treatment, sludge transportation, and sludge processing. These challenges include low frequencies of scheduled desludging, limited vehicle availability, and insufficient public awareness regarding safe sanitation practices. Furthermore, the management evaluation highlights the need for regulatory strengthening, improved inter-agency coordination, and operational enhancements. The SWOT analysis produced several priority strategies, including capacity development, optimization of scheduled desludging services, institutional strengthening, and expanded sanitation education. This study provides foundational insights to improve on-site sanitation systems and support the achievement of safe sanitation services in Banda Aceh.

Keywords: OWMS, Faecal sludge, Sanitation, FSTP, SWOT

ABSTRAK

Sistem Pengelolaan Air Limbah Domestik Setempat (SPALD-S) merupakan layanan sanitasi utama di Kota Banda Aceh untuk pengelolaan air limbah rumah tangga. Penelitian ini bertujuan menganalisis kondisi existing infrastruktur SPALD-S, mengevaluasi kinerja manajemen pengelolaannya, serta merumuskan strategi peningkatan melalui analisis SWOT. Metode penelitian menggunakan pendekatan deskriptif dengan pengumpulan data melalui survei lapangan, wawancara, observasi, serta data sekunder dari instansi terkait. Sampel diperoleh secara purposive dari pengguna septic tank, pengangkut lumpur tinja, operator IPLT, dan dinas teknis. Hasil penelitian menunjukkan bahwa infrastruktur SPALD-S masih menghadapi kendala pada sub-sistem pengolahan setempat, pengangkutan, dan pengolahan lumpur tinja, seperti rendahnya frekuensi penyedotan berkala, keterbatasan armada, dan minimnya pemahaman masyarakat mengenai sanitasi aman. Evaluasi manajemen mengindikasikan perlunya penguatan regulasi, peningkatan koordinasi antar instansi, dan pembenahan aspek operasional layanan. Analisis SWOT menghasilkan beberapa strategi prioritas, yaitu peningkatan kapasitas

pengelolaan dan penyedotan terjadwal, serta penguatan kelembagaan dan perluasan edukasi sanitasi. Penelitian ini diharapkan dapat menjadi dasar perbaikan sistem sanitasi setempat dan mendukung pencapaian layanan sanitasi aman di Kota Banda Aceh.

Kata kunci: SPALD-S, Lumpur tinja, Sanitasi, IPLT, SWOT

Introduction

The increase in population in urban areas has a direct impact on the increasing demand for housing and domestic wastewater production. Domestic wastewater, as defined in PERMEN PUPR No. 4 of 2017, is wastewater from household activities, workplaces, public facilities, and business premises, consisting of faecal and non-faecal waste. If not managed properly, this wastewater has the potential to cause environmental pollution and pose a risk to public health. National regulations, including Government Regulation No. 22 of 2021, have set wastewater quality standards as the maximum concentration limit for pollutants before they are discharged into water bodies or soil (Bakkara, 2022), making domestic wastewater management an important component in the provision of sanitation services.

One of the main elements in local sanitation is faecal sludge management. Faecal sludge is the accumulation of solids from the decomposition of excreta in septic tanks, which must be managed through a series of services, including collection, transportation, and treatment (Fahmi, 2022). This process ideally ends at a Faecal Sludge Treatment Plant (FSTP), which serves to reduce pathogen levels and produce effluent that is safe for the environment (Oktarina & Haki, 2013). To ensure that desludging is carried out regularly, the government has established the Scheduled Sewage Sludge Service (L2T2) as a mandatory mechanism with a desludging frequency of every 3–5 years (PERMEN PUPR No. 4 of 2017), in line with the mandate of the Minimum Service Standards (Government Regulation No. 02 of 2018) and the policy of accelerating sustainable sanitation (Permendagri No. 87 of 2022).

The Banda Aceh City Government has planned the L2T2 program since 2017 through the Environmental, Sanitation, and Green Open Space Office (DLHK3) as an effort to improve on-site sanitation services. However, its implementation faced several technical and institutional constraints, resulting in the program only becoming effective in 2025. The launch of L2T2 in that year also served as a response to the decline in groundwater quality and the growing need to expand access to safe sanitation. These circumstances indicate that the management of the On-Site Domestic Wastewater Management System (OWMS) in Banda Aceh still requires a comprehensive evaluation, covering infrastructure conditions, operational performance, and service management.

Given this urgency, this study aims to analyze the existing conditions of the On-Site Domestic Wastewater Management System (OWMS) in Banda Aceh City, evaluate the performance of its management, and formulate optimization strategies based on a SWOT analysis. In addition to providing theoretical contributions to the development of sanitation infrastructure evaluation methods, this study also offers practical recommendations that can be utilized by local governments and service operators to improve the effectiveness and sustainability of domestic wastewater

management. This research is limited to OWMS systems operating across nine districts in Banda Aceh City, with an analytical scope covering the past ten years, and does not include an in-depth assessment of environmental impacts or centralized wastewater management systems (CWMS).

Methods

The research area covers the entire OWMS service region within Banda Aceh City, while effluent quality sampling was conducted at the Faecal Sludge Treatment Plant (FSTP), which functions as the primary processing unit. The study utilized both primary and secondary data. Primary data were obtained through field observations, infrastructure surveys, in-depth interviews with technical institutions, FSTP operators, faecal sludge truck drivers, and service users, as well as laboratory analysis of collected samples. Secondary data were gathered from official documents including reports from DLHK3 and the Department of Public Works and Spatial Planning (PUPR), administrative maps, scientific literature, and relevant regulations on domestic wastewater management.

Sampling was conducted using a purposive sampling technique, in which respondents and sampling units were selected based on their relevance and direct involvement in the OWMS management system. The on-site treatment subsystem involved household and public facility septic tank users. The transportation subsystem included faecal sludge truck operators, while the treatment subsystem involved FSTP personnel. Management evaluation was carried out through interviews with key stakeholders, including representatives from DLHK3, the Department of Public Works and Spatial Planning (PUPR), Perumdam Tirta Daroy, and community members.

The collected data were analyzed through several stages, including identification, reduction, tabulation, and conclusion drawing. Interview data were processed using a descriptive approach by categorizing information based on thematic clusters, conducting narrative interpretation of relevant findings, and verifying the consistency and validity of the results prior to drawing conclusions. The analysis of existing conditions was carried out by describing field findings across the three main OWMS subsystems: on-site treatment, faecal sludge transportation, and sludge processing at the FSTP. Management evaluation was conducted by comparing these conditions with established standards and regulations for safe sanitation. The final stage of the study employed a SWOT analysis to identify internal factors (strengths and weaknesses) and external factors (opportunities and threats), which were then integrated into a SWOT matrix to formulate strategic recommendations for improving OWMS management in Banda Aceh City.

Results and Discussion

Existing Condition of OWMS Infrastructure in Banda Aceh City

The results indicate that the OWMS infrastructure in Banda Aceh City has not yet operated optimally across its three main subsystems: on-site treatment, faecal sludge transportation, and sludge processing. Within the on-site treatment subsystem, most households are equipped with septic tanks; however, many of these units do not

comply with technical standards. Field observations revealed that a considerable number of septic tanks are non-watertight, lack desludging access points, and are not desludged regularly. These conditions reduce the effectiveness of primary wastewater treatment and increase the risk of groundwater contamination in residential areas.

The transportation subsystem also faces several operational challenges. The number of desludging trucks remains insufficient to adequately serve the entire urban area, resulting in low desludging frequency, which is generally carried out only in response to problems (reactive) rather than on a scheduled basis (preventive) in accordance with the recommended 3–5-year interval. The scheduled desludging program (L2T2), which is intended to enhance on-site sanitation services, has not yet operated effectively due to limitations in fleet capacity, human resources, and an underdeveloped scheduling system.

The sludge treatment subsystem, operated through the Faecal Sludge Treatment Plant (FSTP), functions as the primary processing unit in Banda Aceh. Although the facility remains operational, the volume of sludge received is still below the estimated desludging demand, resulting in underutilization of its installed processing capacity. Several components of the installation also require improved operation and maintenance to ensure that effluent quality meets established standards and that long-term service sustainability is maintained. Laboratory analysis shows that the compost produced from faecal sludge treatment at the FSTP is well decomposed, with a total nitrogen (N-Total) content of 2.52% and P_2O_5 of 0.58%. These values indicate adequate levels of macro-nutrients, making the product suitable for soil improvement. However, wastewater quality tests reveal that the treatment process has not been effective in reducing organic load, as indicated by unchanged COD values at the inlet and outlet (15,000 mg/L). In contrast to COD, the Total Suspended Solids (TSS) concentration experienced a significant reduction from 26.996 mg/L to 10.250 mg/L (a 62.03% decrease), demonstrating that the system is relatively effective in lowering suspended solids.

Results of OWMS Management Evaluation in Banda Aceh City

a. On-Site Treatment Subsystem

The evaluation results indicate that most household septic tanks in Banda Aceh do not comply with the technical requirements of SNI 2398:2017. The primary nonconformities include non-watertight tank construction, insufficient distance between septic tanks and clean water sources, and the absence of scheduled desludging. Many households continue to use conventional septic tanks and practice reactive maintenance, which increases the risk of groundwater contamination and reduces treatment efficiency. In addition, many soakaway units are not constructed according to technical specifications, and in several cases, effluent is discharged directly into the soil without adequate filtration. Limited public knowledge regarding safe sanitation further exacerbates these issues. Overall, the on-site treatment subsystem remains within the basic to unsafe sanitation category, highlighting the need for improvements through physical rehabilitation, implementation of scheduled desludging services, and strengthened community education.

b. Transportation Subsystem

The transfer of management authority from DLHK3 to Perumdam Tirta Daroy in July 2025 represents a strategic step toward strengthening governance and improving the integration of faecal sludge transportation services in Banda Aceh. Although the fleet comprising 21 licensed private operators is considered adequate, coordination between government and private service providers still requires improvement, particularly in standardizing operational procedures, reporting systems, and data integration. The continued use of manual recording by several operators limits monitoring effectiveness, highlighting the need to expand digital applications such as M-Water. Despite the adequate fleet capacity, the utilization of the Gampong Jawa FSTP remains low at approximately 30% of its installed capacity. This condition is primarily attributed to the limited implementation of scheduled desludging (L2T2), the low frequency of septic tank desludging by households, and insufficient public awareness of the importance of regular desludging. Consequently, the volume of faecal sludge transported to the treatment plant remains below its design capacity.

From a service delivery perspective, Perumdam Tirta Daroy has implemented the scheduled desludging system for PDAM (regional water company) customers, while private operators continue to use an unscheduled, on-call scheme for non-PDAM users. This discrepancy results in irregular desludging activities and may reduce the overall effectiveness of the OWMS system. Public satisfaction with desludging services is relatively high; however, a portion of households do not yet utilize the service due to septic tanks not being full or cost considerations, with service fees ranging from IDR 150,000 to IDR 350,000. These conditions indicate the need to increase community awareness regarding the importance of regular desludging, as well as to improve synchronization between government and private service providers. Overall, strengthening institutional coordination, enhancing digital reporting systems, and optimizing FSTP capacity are essential measures to improve the effectiveness and sustainability of the faecal sludge transportation subsystem in Banda Aceh.

c. Faecal Sludge Treatment Subsystem

The evaluation results indicate that the faecal sludge treatment subsystem in Banda Aceh generally complies with most technical and institutional requirements stipulated in SNI 2398:2017 and the Ministry of Public Works and Housing Regulation No. 4 of 2017. Of the 100 septic tanks surveyed, 72% did not comply with SNI 2398:2017, 65% were non-watertight, 58% lacked desludging access points, and 81% had never been desludged according to the recommended schedule. These findings indicate that the primary limitation of the on-site treatment subsystem is not merely the availability of septic tanks, but the poor compliance of their design and maintenance with national technical standards. Non-watertight septic tanks increase the risk of untreated wastewater infiltrating into surrounding soil and groundwater, while the absence of desludging access points discourages regular desludging, thereby reducing the effectiveness and sustainability of the entire OWMS system.

From a technical perspective, the DEWATS (Decentralized Wastewater Treatment System) implemented at the Gampong Jawa FSTP has an installed treatment capacity of 83 m³/day; however, its actual utilization remains limited to approximately 25–30 m³/day, indicating the need to optimize scheduled desludging (L2T2) services and increase desludging frequency. The treatment units, including the Bio-Digester, Sludge Drying Bed, and Horizontal Gravel Filter, were observed to be operating as designed and support a closed treatment system with minimal environmental impact. Laboratory analyses also indicate that the compost produced is of acceptable quality, with total nitrogen (N-total) and P₂O₅ contents of 2.52% and 0.58%, respectively. However, the liquid treatment performance remains unsatisfactory. COD concentrations showed no reduction between the inlet and outlet (15,000 mg/L), indicating that the system has not been effective in removing dissolved organic pollutants. In contrast, TSS concentrations decreased substantially, demonstrating that the treatment process is more effective in removing suspended solids than dissolved organic matter. These findings suggest that, although the sludge treatment units perform satisfactorily, improvements to the liquid treatment process are still required to achieve overall treatment objectives.

d. Strategies for Improving OWMS Management in Banda Aceh City

The SWOT analysis was employed to assess the internal and external factors influencing the management of OWMS in Banda Aceh across the subsystems of on-site treatment, sludge transportation, and faecal sludge processing at the FSTP. This method evaluates four key elements: strengths, weaknesses, opportunities, and threats, which collectively provide an overview of the system's current condition and serve as the foundation for formulating management improvement strategies (Mukhlisin & Pasaribu, 2020). The internal analysis focuses on identifying the system's potential and limitations, while the external analysis examines policies, environmental conditions, and socio-economic factors that may present opportunities or threats (Arda et al., 2020). The simplicity, collaborative nature, flexibility, and integrative capacity of the SWOT framework make it a relevant strategic tool for defining more effective development pathways for OWMS (Mas'adi et al., 2020).

Each factor in the SWOT analysis was assigned a weight and rating to assess its level of influence on the performance of OWMS management. The weight reflects the relative importance of each factor, while the rating indicates the extent to which the factor contributes to strengthening or weakening the implementation of OWMS services, including on-site treatment, sludge transportation, and faecal sludge processing at the FSTP. The results of the weighting and rating process were subsequently used to determine the strategic position on the X and Y axes of the SWOT quadrant diagram, which serves as the basis for formulating strategic directions to enhance OWMS management in Banda Aceh City.

Table 1. Internal Variables of OWMS Infrastructure

No.	Internal Factors	Rating	Weight	Rating x Weight
STRENGTH				
1.	The availability of basic OWMS infrastructure such as sludge trucks and FSTP	2,8	10,29	28,812
2.	The availability of trained technical human resources in the management of domestic wastewater	2,1	7,72	16,212
3.	The sludge suction service system is already recorded through PDAM	1,9	6,98	13,262
TOTAL				58,286
WEAKNESS				
1.	Maintenance of the treatment system is difficult due to the closed design of the processing unit	2,1	6,40	13,44
2.	The volume of incoming faecal sludge is not yet stable and is often below design capacity	2	6,09	12,18
3.	Low public interest means that processed fertilizer products cannot yet be marketed	2	6,09	12,18
4.	The transfer of responsibility from DLHK3 to PDAM in a short time has caused uncertainty in the new system which is still in the adjustment stage	2,1	6,40	13,44
TOTAL				51,24

Tabel 2. External Variables of OWMS Infrastructure

No.	External Factors	Rating	Weight	Rating x Weight
OPPORTUNITY				
1.	Policy support from the city government and related agencies	2,9	8,95	25,955
2.	There is cooperation with third parties (private suction) in supporting the operational of OWMS services	2,2	6,79	14,938
3.	Utilization of cake as a product with economic value to support the sustainability of OWMS	3,0	9,25	27,75
TOTAL				68,643
THREATS				
1.	There is no data collection system for private sludge suction customers	2,8	5,07	14,196
2.	The public complained about the lack of socialization and understanding regarding the L2T2 system	1,5	5,71	8,565

No.	External Factors	Rating	Weight	Rating x Weight
3.	People still don't understand proper septic tank management	2,5	4,52	11,3
4.	There is still the practice of illegally dumping faecal sludge into open land by private suction companies	2,4	4,34	10,416
5.	Many septic tanks do not meet SNI standards	2	3,62	7,24
6.	Groundwater pollution due to leaking septic tank	2,6	4,71	12,246
TOTAL				63,963

The SWOT matrix was utilized to formulate priority strategies by optimizing strengths and opportunities while minimizing weaknesses and threats in the management of OWMS in Banda Aceh City. Strategic scenarios were determined by combining variables with the highest and lowest weights derived from the SWOT analysis. Table 3 presents the preference weights for each variable, whereas Table 4 displays the weighted scores of the prioritized strategic scenarios.

Table 3. Weight Scores of SWOT Factors

No.	Strategy	Weightes Score
1.	Strength (S)	58,286
2.	Weakness (W)	51,24
3.	Opportunity (O)	68,643
4.	Threats (T)	63,963

Table 4 Weight Scores of SWOT Strategic Combinations

No.	Strategi	Weightes Score
1.	<i>Strength (S) + Opportunity (O)</i>	126,929
2.	<i>Strength (S) + Threats (T)</i>	122,249
3.	<i>Weakness (W) + Opportunity (O)</i>	119,883
4.	<i>Weakness (W) + Threats (T)</i>	115,203

Based on the calculation results, the highest preference weight is found in the Strength–Opportunity (S–O) combination, with a value of 126.929. This value serves as the basis for determining the priority strategies for optimizing the implementation of OWMS in Banda Aceh City. The S–O strategy emphasizes leveraging internal strengths and external opportunities to enhance the sustainability and overall performance of OWMS management.

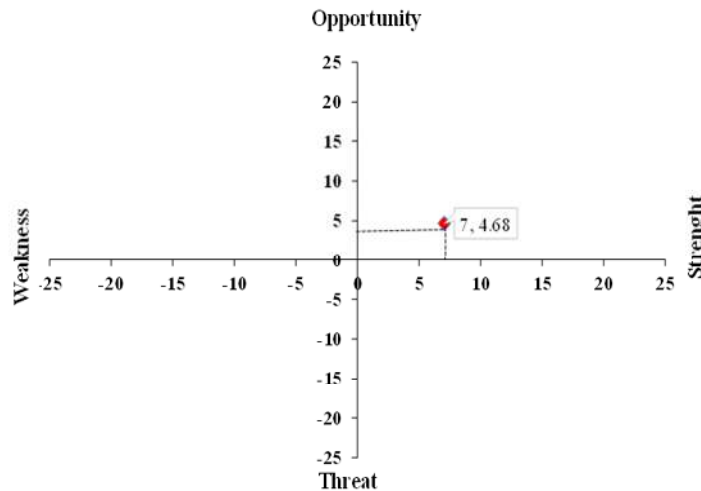


Figure 1. SWOT Analysis Diagram of the OWMS System

X Axis = Weight of Strength – Weight of Weakness
= 58,286 – 51,24
= 7,046

Y Axis = Weight of Opportunity – Weight of Threat
= 68,643 – 63,963
= 4,68

Based on the strategic position mapping in the SWOT diagram, the coordinate point (7; 4.68) indicates that strengths outweigh weaknesses and opportunities exceed threats. This places the OWMS system in Banda Aceh within Quadrant I (S–O strategy). Such a position reflects a favorable strategic condition in which internal strengths and external opportunities can be optimally utilized to enhance system performance. Accordingly, the most appropriate approach is an aggressive or growth-oriented strategy, which focuses on maximizing existing strengths to capitalize on available opportunities.

The implementation of the aggressive strategy is focused on strengthening institutional capacity and operational governance, enhancing human resource capabilities, and promoting innovation in decentralized domestic wastewater treatment technologies. This approach aims to improve operational effectiveness and efficiency, expand service coverage, and strengthen community participation in the implementation of decentralized domestic wastewater management. Furthermore, the strategy emphasizes the importance of fostering synergistic partnerships among local governments, the private sector, and the community to establish a more collaborative, adaptive, and environmentally sustainable decentralized wastewater management system.

The results of the SWOT matrix analysis indicate that the internal factors of the decentralized domestic wastewater management system (OWMS) in Banda Aceh City are relatively strong, with a strength score of 58.286, exceeding the weakness score of 51.240. Similarly, the external factors demonstrate that opportunities

(68.643) outweigh threats (63.963). These findings indicate that the OWMS possesses a solid internal foundation and substantial external opportunities to enhance the effectiveness, resilience, and long-term sustainability of decentralized domestic wastewater management services. The implementation of the aggressive strategy focuses on strengthening institutional capacity and operational governance, enhancing human resource competencies, and promoting innovation in on-site domestic wastewater treatment technologies. This approach aims to improve operational effectiveness and efficiency, expand service coverage, and reinforce community participation in on-site sanitation management. In addition, the strategy emphasizes the importance of developing synergistic partnerships among local government, the private sector, and the community to establish a more collaborative, adaptive, and environmentally sustainable OWMS management system.

In addition to the S–O strategy as the primary approach, the W–O strategy is recommended to address internal weaknesses by leveraging external opportunities, including enhancing the technical capacity of operators and the community, and improving maintenance systems for treatment facilities. The S–T strategy focuses on utilizing existing strengths to mitigate external threats, such as strengthening desludging service performance and optimizing user fees to support operational and maintenance activities. Meanwhile, the W–T strategy prioritizes community education, reinforcement of local regulations, and stricter supervision of non-compliant sludge disposal practices. Collectively, these strategies are expected to reinforce a sustainable and responsive OWMS management system that aligns with the sanitation needs of Banda Aceh City.

Conclusion

The evaluation of the On-Site Domestic Wastewater Management System (OWMS) in Banda Aceh indicates that, while the existing infrastructure and institutional framework provide a reasonable foundation for service delivery, several critical challenges continue to limit overall system performance. These include the widespread use of non-standard and non-watertight septic tanks, low public awareness of proper sanitation practices, unscheduled desludging services, limited integration between government and private sludge transportation, and the underutilization and suboptimal treatment performance of the Gampong Jawa Faecal Sludge Treatment Plant (FSTP). Addressing these technical, operational, and institutional constraints is essential to improving the effectiveness, efficiency, and sustainability of decentralized domestic wastewater management.

The SWOT analysis demonstrates that the OWMS in Banda Aceh is positioned in Quadrant I (Strength–Opportunity), indicating that the system possesses strong internal capacities and favorable external opportunities for development. Accordingly, an aggressive (growth-oriented) strategy is recommended, focusing on strengthening institutional governance, enhancing human resource capacity, promoting innovation in decentralized wastewater treatment technologies, expanding service coverage, and increasing community participation. Furthermore, establishing stronger partnerships among local government, private operators, and communities, supported by integrated data management and the adoption of circular economy

principles, will contribute to a more effective, resilient, and environmentally sustainable domestic wastewater management system.

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