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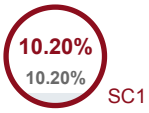

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Tackling Sanitation Gaps: Improving Fecal Sludge Management through Stakeholder Engagement in Indonesia
[Mengatasi Kesenjangan Sanitasi: Meningkatkan Pengelolaan Lumpur Tinja melalui Keterlibatan Pemangku Kepentingan di Indonesia]

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Abstract. The management of sewage sludge is an urgent and crucial component of domestic sanitation systems, directly impacting public health and the environment. In Indonesia, the challenges associated with waste management have become increasingly complex due to population growth and the rising demand for adequate sanitation infrastructure. This study aims to identify the factors influencing the performance of domestic wastewater management operators and to provide recommendations for enhancing service quality. **This research design uses a mixed method, combining**

quantitative and qualitative data. Quantitative data were obtained from a survey of 106 respondents. While qualitative data were collected through semi-structured interviews. Quantitative data analysis was carried out using Exploratory Factor Analysis (EFA), while qualitative data analysis used a thematic approach. The research findings indicate that there are two primary factors influencing the performance of sewage sludge management, namely Financial Management and Human Resources, as well as Service Provision and Operational Efficiency. These two factors are interrelated, demonstrating that there is significant potential for improvement. Improved financial management, along with enhancements in operational capacity and human resources, is essential for increasing the system's efficiency. This study provides significant contributions to the understanding of sewage sludge management in developing countries. The research highlights the need for a comprehensive approach that integrates financial, operational, and human resource factors to achieve more sustainable sanitation management in Indonesia. Further research is eagerly anticipated to explore the role of public-private partnerships and community engagement in enhancing sanitation management.
Keywords - Efficiency; Fecal Sludge; Mixed Method; Sustainability; Wastewater

Abstrak.Pengelolaan lumpur tinja merupakan bagian penting dalam sistem sanitasi domestik yang berpengaruh langsung terhadap kesehatan masyarakat dan lingkungan. Di Indonesia, masalah pengelolaan limbah ini semakin kompleks dengan pertumbuhan penduduk dan meningkatnya kebutuhan terhadap infrastruktur sanitasi yang memadai. Penelitian ini bertujuan untuk mengidentifikasi faktor-faktor yang memengaruhi kinerja operator pengelola air limbah domestik dan memberikan rekomendasi untuk meningkatkan kualitas layanan. Desain penelitian ini menggunakan metode campuran, menggabungkan data kuantitatif dan kualitatif. Data kuantitatif diperoleh dari survei terhadap 106 responden. Sementara data kualitatif dikumpulkan melalui wawancara semi-terstruktur. Analisis data kuantitatif dilakukan dengan Exploratory Factor Analysis (EFA), sedangkan analisis data kualitatif menggunakan pendekatan tematik. Hasil penelitian menunjukkan bahwa terdapat dua faktor utama yang mempengaruhi kinerja pengelolaan lumpur tinja, yaitu Manajemen Keuangan dan Sumber Daya Manusia serta Penyediaan Layanan dan Efisiensi Operasional. Kedua faktor ini saling terkait dan menunjukkan bahwa pengelolaan finansial yang lebih baik dan peningkatan kapasitas operasional serta sumber daya manusia sangat diperlukan untuk meningkatkan efisiensi sistem. Studi ini memberikan kontribusi penting terhadap pemahaman pengelolaan lumpur tinja di negara berkembang. Penelitian ini menggarisbawahi perlunya pendekatan holistik yang mencakup faktor keuangan, operasional, dan sumber daya manusia untuk mencapai pengelolaan sanitasi yang lebih berkelanjutan di Indonesia. Penelitian lebih lanjut diharapkan dapat mengeksplorasi peran kemitraan publik-swasta dan keterlibatan masyarakat dalam memperbaiki pengelolaan sanitasi
Kata Kunci - Efisiensi; Lumpur Tinja; Metode Campuran; Keberlanjutan; Air Limbah

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1. I. Introduction

The management of domestic waste, particularly fecal sludge, is of paramount importance for public health and sanitation . Inadequate systems can lead to environmental pollution and the spread of disease . This issue is commonly encountered in low- and middle-income countries that are densely populated, where rapid urbanization and limited infrastructure hinder the establishment of effective sanitation systems . The challenges in Indonesia are becoming increasingly complex due to outdated technology, high costs, and a low level of public awareness . It is emphasized that despite the existence of technological solutions, their implementation in low-income areas is impeded by various constraints. Although the government is endeavoring to enhance access to sanitation, a significant gap remains in the management of domestic waste . To achieve Sustainable Development Goal (SDG) 6, which aims to ensure access to sanitation by 2030, it is essential to address this inefficiency. Presidential Regulation No. 59 of 2017 provides a framework for improving sanitation services; however, challenges persist, particularly in areas that are inaccessible due to various causes.

The primary issue addressed in this research concerns the management of domestic wastewater, particularly fecal sludge, by inefficient operators. These operators are frequently hindered by high costs, limited technical capacity, and outdated infrastructure, which adversely affect the quality of service provided. The literature suggests the need for a comprehensive approach that encompasses technological advancements, investment, and regulatory enforcement to address these challenges effectively. Several previously proposed solutions include the . However, the solution has not yet fully addressed the specific challenges faced by operators in Indonesia, as there remain limitations in modern technology and significant infrastructure gaps.

Solutions to the challenges of wastewater management have been proposed, as indicated in previous research. One such solution is the utilization of affordable technologies for managing fecal sludge, such as vacuum trucks and small-scale treatment facilities, which can enhance services in areas with limited resources . Furthermore, public-private partnerships (PPP) are regarded as a strategy to enhance services and financing. According to , the Public-Private Partnership (PPP) can provide resources and expertise to address the investment shortfalls of the public sector, as well as support the implementation of innovative technologies and financing mechanisms tailored to local needs. Strengthening regulations for the management of fecal sludge is also crucial to ensure that service providers comply with existing standards. The strengthening of regulations concerning the management of sewage sludge is also crucial to ensure that service providers comply with existing standards. A study by recommends that the government implement stricter regulations and oversight to facilitate effective sewage sludge management and mitigate environmental risks. Other studies indicate that although technology, investment, and regulatory reforms are important, a focus on community engagement and public awareness is also crucial . The involvement of local communities in managing wastewater services can ensure the sustainability of sanitation systems. The community-based sanitation programs can enhance public participation and accessibility to services. Public awareness campaigns are also crucial for educating communities about good sanitation practices and their role in maintaining the environment . However, there remains a gap in the literature regarding the integration of these solutions in Indonesia, particularly concerning the challenges faced by operators in managing fecal sludge. This can be seen in table 1 below.

Table 1. Previous Studies and the Determination of Research Position

Researcher	Model Classification	Parameter	Objective
A. Taweesan, T. Koottatep, and K. Dongo	Evaluative model using Response Surface Methodology (RSM)	Collection efficiency, treatment efficiency, benefit-cost ratio, social satisfaction	Evaluate sludge management services and identify critical factors for improving services
Z. Hadianto, S. Syafrudin, and S. Sunarsih	Descriptive evaluative model reviewing management, social, and regulatory aspects	Management, social, and regulatory aspects	Analyze the fecal waste management system in Surabaya City. Identify challenges and opportunities in fecal waste management. Provide recommendations for improving fecal waste management services
K. Conaway, S. Lebu, K. Heilferty, A. Salzberg, and M. Manga	Systematic review of on-site sanitation emptying practices in low- and middle-income countries	Frequency of emptying, type (manual/mechanical), cost, accessibility, return pathways to environment	Explores the practice of sludge

dewatering, the factors that influence it, and its impact on sanitation and public health
M. M. Hussein, A. O. Odongo, A. Kerochi, and J. Snuggs Cross-sectional mixed-methods study Latrine access/use, emptying methods/cost, perceptions, satisfaction, socio-demographics Assessing fecal sludge management practices and identifying sociodemographic factors influencing access to services, and analyzing community perceptions of sanitation and fecal sludge management
D. Jean-Baptiste and F. Monette, Comparative Life Cycle Assessment (LCA) of on-site sanitation systems using lagoons and drying beds in low-income tropical countries Environmental impact of processing one ton of wet fecal sludge per year, taking into account sludge composition, covering nine combinations of toilet types and processing methods Comparing various sanitation systems that use sludge treatment technology. Identifying the system with the lowest environmental impact.
R. Peletz et al Market evaluation model comparing demand (WTP) vs. supply (service pricing and availability) WTP, market prices, household affordability, required subsidy, service accessibility Analyze the extent of promotion of safe sludge management in low-income neighborhoods. Explore households' willingness to pay for government-provided waste disposal services and compare them with private prices. Identify challenges and opportunities in increasing access to safe and efficient sanitation services.
M. Silumesii, E. Mwanaumo, and L. Mwiinga. Case study based on Theory of Environmentally Responsible Behavior Sludge volume, distance to disposal site, response time, labor costs Identifying factors that influence the cost of sludge removal in unplanned residential areas. Understanding the socio-economic dynamics that influence the accessibility of sludge management services.n lumpur tinja.
C. Murungi and M. P. van Dijk Economic analysis of the FSM service chain Emptying cost, transport cost, disposal fee, accessibility, affordability Mengidentifikasi pelaku utama dalam layanan pengelolaan lumpur tinja. Menganalisis faktor-faktor yang memengaruhi biaya pengurasan lumpur tinja. Mengidentifikasi kendala yang menghambat peningkatan penyediaan layanan.
P. Reymond, R. Chandragiri, and L. Ulrich, Systematic multi-level governance analysis; hybrid governance framework Governance structures, stakeholder roles, small-scale wastewater treatment plants (SSTP) performance, institutional coordination Identify key actors in sludge management services. Analyze factors influencing sludge removal costs. Identify barriers hindering improved service provision.
This Research Position Factor analysis model in the performance of fecal sludge management Service, Finance, Operations, Human Resources and Governance Aspects Analyze factors that influence the performance of domestic wastewater management operators and recommend service improvement strategies.

This study aims **to** analyze the **factors that influence the performance of** domestic wastewater management operators in Indonesia. The research employs a mixed-methods approach to identify the challenges faced by operators and to propose strategies for service improvement. Additionally, the study explores the potential for public-private partnerships and community involvement in wastewater management. The proposed integrated approach, which combines technological, financial, and social solutions, is anticipated to tackle the challenges associated with fecal sludge management. The findings of this research are expected to provide policymakers and other stakeholders in the sanitation sector with valuable insights, as well as to support the development of more efficient and sustainable wastewater management systems in Indonesia.

2. II. Method

This study employs a mixed-methods approach, which integrates both quantitative and qualitative methodologies. This approach facilitates a more comprehensive analysis by integrating numerical data and contextual insights . The design is sequential, with the quantitative phase conducted first, followed by the qualitative phase to elucidate and expand upon the findings derived from the quantitative data . Each stage focuses on specific data from stakeholders involved in wastewater management in Sidoarjo, East Java, Indonesia. The quantitative data collection method is conducted through structured surveys directed at stakeholders in wastewater management, such as the Department of Housing, Settlements, Cipta Karya and Spatial Planning (DP2CKTR), the Regional Development Planning Agency (Bappeda), the Working Group for Housing and Settlement Development (Pokja PKP), the Technical Implementation Unit for Domestic Wastewater Management (UPTD PALD), sanitation consultants, and public health personnel. This survey aims to gather data regarding key variables. The purposive sampling technique was employed to select participants who possess direct experience or knowledge regarding domestic wastewater management . The survey sample consists of 106 respondents, which is deemed sufficient based on the recommendation to have at least five times the number of indicators, specifically 19 items . The 19 indicators in question have been adopted from the technical guidelines for the performance assessment of the Regional Technical Implementation UPTD, as issued by the Ministry of Public Works and Housing (PUPR) . Item details are as follows: Growth in the number of customers increases (X1), Customer complaints can be resolved (X3), Customer requests can be completed within 24 hours (X4), Possession of an operational cost plan (X5), Revenue has reached target (X6), Management of budget planning (X7), Have Standard Operating Procedures (SOP) (X8), The effluent water from the IPLT processing has met the quality standards (X9), Effluent sampling has been carried out (X10), The sludge has been processed at the IPLT (X11), Operation and maintenance are carried out according to SOP (X12), Domestic wastewater treatment at the IPAL has been carried out efficiently (X13), Human Resource needs planning has been carried out according to needs (X14), The organizational structure and work procedures are clear (X15), Innovation to facilitate service (X17), Has conducted a Community Satisfaction Index Survey (X18), The service administration SOP has been implemented well (X19). Qualitative data were obtained through semi-structured interviews with key stakeholders. This method provides the flexibility to explore respondents' perspectives while ensuring that the discussion remains focused on the main topics . The selection of interview participants was conducted using purposive sampling techniques to identify individuals with in-depth knowledge regarding the challenges and solutions associated with wastewater management, comprising the UPTD PALD, Bappeda/Pokja PKP, and sanitation consultants .

Conducted Data analysis in two stages: quantitative data analysis and qualitative data analysis. Quantitative data was analyzed using Exploratory Factor Analysis (EFA), a statistical technique aimed at identifying relationships between variables and reducing data to a few principal factors. This technique was employed to determine the factors influencing the performance of domestic wastewater management. In contrast, qualitative data collected from interviews was analysed using thematic analysis. This analysis involved several stages: Firstly, the interview transcripts were reviewed and coded to identify significant themes related to the research questions. Subsequently, these were organized and grouped to form a coherent narrative aligned with the research objectives.

Figure 1. Research Stages

3. III. Result and disscusion

The Factor of Domestic Wastewater Management Operator

Before conducting the Exploratory Factor Analysis (EFA), an essential preliminary step is to evaluate the suitability of the data to be utilized. In this

process, two metrics are employed: the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett's test of sphericity. The results obtained indicate a KMO value of 0.923, which exceeds the accepted minimum threshold of 0.6. This finding suggests that the sample size used in this analysis is adequate and also indicates a significant relationship among the variables under investigation. Furthermore, the results of Bartlett's test revealed a significant p-value of less than 0.05, as presented in Table 2. These findings further substantiate the argument that the existing data is highly suitable for factor analysis, thereby enabling the researcher to proceed to the subsequent stage.

Table 2. Results of the KMO and Bartlett's Test

KMO and Bartlett's Test Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0,923
Bartlett's **Test of Sphericity Approx.** Chi-Square	1556,558
df	171
Sig.	0,000

The method employed subsequently is the percentage of variance approach, also known as the Eigenvalue method. The number of factors is determined based on variables that possess an Eigenvalue greater than 1 following the factor extraction process. The results of the extraction indicate the formation of 2 optimal factors, each with an Eigenvalue exceeding 1, which serves as the standard threshold for retaining factors. Collectively, these two factors account for 62.99% of the total variance. The first factor has an Eigenvalue of 10.448, which accounts for 54.989% of the variation in all items. Meanwhile, the second factor has an Eigenvalue of 1.522, which accounts for 8.010% of the variation in all items. Further details can be found in Table 3.

Table 3. Factor Extraction Results

Comp-onent	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10,448	54,989	54,989	10,448	54,989	54,989	7,062	37,167	37,167
2	1,522	8,010	62,999	1,522	8,010	62,999	4,908	25,833	62,999
3	0,957	5,035	68,035						
4	0,926	4,876	72,910						
5	0,846	4,454	77,364						
6	0,647	3,404	80,768						
7	0,539	2,836	83,604						
8	0,487	2,562	86,166						
9	0,439	2,313	88,479						
10	0,369	1,940	90,419						
11	0,317	1,668	92,087						
12	0,262	1,377	93,464						
13	0,237	1,246	94,709						
14	0,208	1,097	95,806						
15	0,207	1,091	96,897						
16	0,189	0,995	97,892						
17	0,152	0,802	98,694						
18	0,127	0,666	99,360						
19	0,122	0,640	100,000						

The results of the Rotated Component Matrix analysis in the Exploratory Factor Analysis (EFA) indicate two primary areas of concern regarding the performance of wastewater management operators, as outlined in Table 3. The first factor, "Financial Management and Human Resources," elucidates that the ability to manage operational costs and optimize revenue collection effectively is crucial for the sustainability of wastewater management services. Furthermore, the availability of trained personnel and effective human resource management is essential to ensure that services are delivered efficiently. The second factor, "Service Provision and Operational Efficiency," emphasizes that enhancing the efficiency of service delivery, particularly in terms of sludge collection and disposal, is a key area that requires improvement. The capacity of the Fecal Sludge Treatment Plant (IPLT) to handle an increasing volume of sewage sludge is also a significant consideration.

Table 4: Results of the Rotated Component Matrix in EFA

Component	Description	1	2	Factor: Financial Management and Human Resources	Factor: Service Provision and Operational Efficiency
X7	0,838	Management of budget planning			
X17	0,794	Innovation to facilitate service			
X5	0,792	Possession of an operational cost plan			
X15	0,768	The organizational structure and work procedures are clear			
X8	0,756	Have Standard Operating Procedures (SOP			
X12	0,756	Operation and maintenance are carried out according to SOP			
X3	0,754	Customer complaints can be resolved			
X6	0,708	Revenue has reached target			
X14	0,669	Human Resource needs planning has been carried out according to needs			
X19	0,642	0,578	The service administration SOP has been implemented well		
X1	0,603	0,505	Growth in the number of customers increases		
X2					
X16					
X11		0,841	The sludge has been processed at the IPLT		
X9	0,827		The effluent water from the IPLT processing has met the quality standards		
X10		0,742	Effluent sampling has been carried out		
X13		0,689	Domestic wastewater treatment at the IPAL has been carried out efficiently		
X18		0,622	Has conducted a Community Satisfaction Index Survey		

X4 0,560 Customer requests can be completed within 24 hours

The results of the Exploratory Factor Analysis (EFA) indicate two primary factors that influence the performance of fecal sludge management, namely Financial Management and Human Resources, as well as Service Provision and Operational Efficiency. The first factor highlights the importance of sound financial management and enhancing human resource capacity, while the second factor focuses on operational efficiency and developing a more optimal service system. These two factors are highly interrelated and must be managed concurrently to ensure that wastewater management is efficient and sustainable. The foremost issue that frequently arises is suboptimal financial management. Operators often encounter challenges in terms of funding, relying on government subsidies that are not always sufficient to finance the infrastructure and maintenance of wastewater management facilities . In this context, improved budget planning and the exploration of alternative revenue sources have become increasingly important. One of the primary recommendations arising from the interviews is the need to enhance investment in wastewater management infrastructure, particularly in the development and maintenance of IPLT. Furthermore, it is recommended that operators explore more sustainable financing models, such as adjusting service tariffs to better align with customer affordability and operational requirements . As interviewed with Vicky Mundiahi (IUWASH Tangguh consultant):
"There are three alternatives after we assess financial capacity. If we can't, then these are the three approaches we take. The first is tariff adjustment. The second is cost efficiency, whatever that entails. And the third is increasing revenue." (Interview, February 4, 2025).
The participation of the private sector is also regarded as crucial in creating more flexible and innovative financing, as implemented in Poland, Ireland, Scotland, Bangladesh and China . With efficient financial management, the sustainability of wastewater management services can be better assured.

Not only is financial management crucial, but human resource management also plays a significant role in enhancing the quality of services. One of the issues faced is the shortage of skilled personnel in the processing of sludge and the maintenance of IPLT. This situation arises due to the limited opportunities for training and professional development for staff involved in wastewater management. Consequently, one of the key recommendations that emerges is the need for increased investment in technical skills training, enhanced working conditions, and offering incentives for skilled workers, such as competitive salaries and career development opportunities . As stated in an interview with Indah Nursanthi (UPTD PALD):
"We need to improve the skills and competencies of staff to achieve safe sanitation targets.... We need to increase internal capacity so that all work complies with SOPs (technical standards)... There are performance targets (for personnel) that will be continuously evaluated (and this will impact personnel incentives/income)" (Interview, January 31, 2025).
Training for workers as implemented in Somalia, Nigeria, Kenya, Ghana, India, Philippines, and Bangladesh . Effective management of human resources will enhance operational efficiency and overall service quality.

Furthermore, one of the most significant challenges in wastewater management is operational efficiency, particularly concerning the collection, transportation, and treatment of sludge. Interview results indicate that limitations in operational hours result in the inability to meet the continually increasing demand for fecal sludge management, especially during weekends and public holidays, leading to considerable waiting times of approximately 2 to 3 days. This issue arises from a shortage of personnel and equipment. Consequently, one proposed solution is to extend operational hours to accommodate demand during weekends and public holidays, as well as to augment resources and personnel to enhance service capacity. Additionally, the adoption of modern technology and the digitalization of processes related to automated ordering, collection, transportation, and treatment of fecal sludge are also recommended to improve operational efficiency . As interviewed by Indah Nursanthi (UPTD PALD):
"We need to use drying technology. We can't just rely on nature for drying. Another alternative is to add new processing technology. We can't use SSC (Sludge Separation Chamber). We can add new processing units that can process waste independently of the existing wastewater treatment plant (IPLT) system. We can develop MIS, QRIS payments (digital payment innovations), virtual accounts in collaboration with Bank J, and paperless services." (Interview, January 31, 2025).
The application of effective appropriate technology in the management of fecal sludge has been implemented in Thailand, India, Bangladesh, Philippines, Nigeria, Kenya, Italy, Spain, Austria, France, and Netherlands . Thus, it can enhance the quality of service and reduce operational costs.

One of the significant factors that influence the performance of wastewater management is the growth of the customer base. The increase in the number of customers has a substantial impact on the financial sustainability and efficiency of services; however, it is accompanied by considerable challenges. A primary concern is the mismatch between population growth and the planning of wastewater management infrastructure. As the population increases, particularly in new settlements, many areas remain unconnected to the wastewater management system. This results in limited processing capacity and hinders the expansion of services. Furthermore, the low level of public awareness regarding the importance of adequate sanitation also poses a significant barrier . To address this challenge, it is recommended to strengthen public education campaigns that emphasize the importance of effective wastewater management and its impact on health. As stated in an interview with Ratih Dewi and Arief Riyadi (IUWASH Tangguh consultant):
"The most important strength is community promotion and awareness. We need specific innovations, such as collaborating with village-based organizations (Dasawisma) and others (PKK cadres, neighborhood cadres, and Village-Owned Enterprises). We need to develop a more structured marketing strategy. We also need to promote through social media." (Interview, February 4, 2025).
"More creative marketing (education) efforts include partnering with BDA (private sector). We also collaborate with environmental cadres, such as in B Village. If each village had a cadre like Mrs. Pr, the educational results would be extraordinary." (Interview, February 5, 2025).
The education takes the form of public awareness campaigns, training for communities and sanitation activists, sanitation programs in schools, and community involvement as implemented in Ghana, Somalia, Kenya, Japan, and Bangladesh . Effective education can enhance public awareness and encourage individuals to connect with existing sanitation systems.

Furthermore, to expand the coverage of services, coordination, and collaboration between the government and the private sector are necessary for the development of wastewater management infrastructure. This collaboration may include the provision of selective subsidies to facilitate easier access to sanitation services for households . Another recommendation derived from the interviews highlights the importance of regulatory oversight and the enforcement of standards in wastewater management, ensuring that operators can meet performance expectations while also promoting active community involvement in achieving sanitation infrastructure standards. As reported in an interview with Shanty Wahyu Anggraini (BAPPEDA):
"For sanitation, we hoped to reach at least 2% (of the regional budget). But it turns out we haven't achieved that. We're trying to find alternative financing (Baznas, CSR, third-party investment, or B2B). Every new settlement is recommended to manage domestic waste communally, not individually. In the future, new housing (settlements) will be subject to stricter supervision. There are already regulations recommending communal management. But on-the-ground oversight is still lacking" (Interview, January 31, 2025).
Strengthening the regulatory framework and providing clear guidelines for the management of fecal sludge can enhance the overall performance of wastewater management systems , as also implemented in Thailand, Bangladesh, China, India, Poland, Ireland, Scotland, and African countries (Ghana, Senegal, Uganda, Kenya, Zambia) . This collaboration takes the form of fecal sludge management services, investment and technological innovation. With these measures in place, we can achieve sustainable growth in customer numbers, aligning with the development of adequate infrastructure.

The management of complaints also constitutes a significant issue related to service performance. Although the number of complaints received is relatively low, the handling of these complaints is often impeded by unclear complaint procedures and a lack of responsiveness from the call center. This results in many complaints not being addressed swiftly, thereby impacting the quality of service. Consequently, to enhance service quality, it is crucial to establish an efficient complaint management system with clear procedures and to provide a more diverse range of communication channels for customers. Furthermore, training staff in complaint handling is also essential to ensure that they can resolve complaints promptly and accurately , enhancing this complaint system will assist in maintaining customer satisfaction and improving the reputation of wastewater management services.

In terms of operational aspects, the capacity of the IPLT has emerged as a significant issue. According to interviews conducted, the IPLT is currently operating at 70%-80% of its maximum capacity, indicating a pressing need for capacity enhancement to accommodate the steadily increasing demand. This capacity limitation is also associated with the increasing volume of sludge processing, which hinders drying processes due to unstable weather conditions. To address this issue, the construction of new IPLTs and the enhancement of existing facility capacities are strongly recommended. Furthermore, the development of decentralized wastewater treatment systems or small-scale treatment systems may also serve as viable solutions, particularly in densely populated areas, to alleviate pressure on IPLT facilities, as implemented in India, Tanzania, and Jordan . Additionally, interview findings suggest alternative uses for sludge, such as utilizing it as a planting medium to mitigate environmental impacts and generate economic benefits . As reported in an interview with Shanty Wahyu Anggraini (BAPPEDA):

"The final solids from the accumulated fecal sludge are finally composted to be given to customers (along with plants)... The Head of the UPTD will consult with the central government regarding alternative uses for the final solid residue from the fecal sludge" (Interview, January 31, 2025).

This recommendation aligns with the concept of sustainable economic circulation in the context of sanitation, which has been implemented in several countries, including Ghana, Sweden, Australia, Malaysia, Cambodia, and the United Kingdom. Domestic waste is used as organic fertilizer, fuel, clean water, and bricks .

Overall, the integration of quantitative and qualitative results suggests that to enhance the management of fecal sludge in Indonesia, it is essential to strengthen financial management, as well as improve operational capacity and efficiency. These two factors must mutually support one another through better regulation, enhanced human resource capacity, and the adoption of efficient technologies to improve waste management infrastructure. Furthermore, improved complaint management and public awareness are also vital for the sustainability of the sanitation system in the future (figure 2).

Figure 2. The integration results

4.

5. IV. Conclusion

This study identifies two primary factors influencing the performance of fecal sludge management in Indonesia: Financial Management and Human Resources, as well as Service Provision and Operational Efficiency. The research findings indicate that the success of management is highly dependent on effective financial management and human resources, as well as improvements in infrastructure and operational efficiency. The aspect of financial management, particularly the suboptimal management of budgets and revenue collection, poses significant challenges. Furthermore, in terms of human resources, the lack of training and staff capacity represents a considerable obstacle. This research contributes to the understanding of fecal sludge management in developing countries such as Indonesia, emphasizing the importance of a holistic approach that integrates financial, operational, and human resource factors to enhance the sustainability of domestic waste management systems. The findings also underscore the necessity for policies that support sustainable financing and the strengthening of human resource capacities. The limitations of this research pertain to its restricted geographical scope, which consequently prevents the identification of areas with differing conditions, such as those related to social, economic, cultural, regulatory, and local government fiscal capabilities. Further research could explore the effectiveness of public-private partnerships and the role of communities in enhancing sustainable sanitation management, and explore responses from the public or customers regarding the performance of sludge management operators.

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