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Science and Environmental Journals for Postgraduate
Vol. 7 No. 2 (pp. 83-101) December 2025
p_ISSN 2655-5085
e_ISSN 2655-5239

EVALUATION OF THE WASTEWATER TREATMENT PLANT (WWTP) MANAGEMENT SYSTEM AT THE IBNU SINA ISLAMIC HOSPITAL PADANG

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ABSTRACT

Managing hospital liquid waste is very important to prevent environmental pollution. Ibnu Sina Islamic Hospital in Padang, as a referral hospital, generates liquid waste that must be treated according to quality standards. This study aims to evaluate the management of liquid waste at Ibnu Sina Padang Islamic Hospital in 2025, considering input, process, and output. The research method uses a descriptive qualitative approach or in-depth interviews thru interviews, observation, and document review with triangulation analysis. The number of informants to be studied is 6 people. The research results show that the inputs, including policies, human resources, budget, and infrastructure, are generally adequate. The planning process is carried out thru annual evaluations, implementation is based on SOPs, and routine monitoring is done with external laboratory tests. The output shows that most of the liquid waste parameters (BOD, COD, TSS, ammonia, oil and grease, pH) meet the quality standards, although fluctuations sometimes occur in pH and coliform. The main constraints are damage to the wastewater treatment plant equipment and delays in repairs due to funding/budget. It can be concluded that the management of liquid waste at Ibnu Sina Islamic Hospital Padang has been quite effective, but continuous monitoring, the provision of backup equipment, and improved cross-sectoral coordination are still needed to optimally control environmental pollution.

Keywords: *Quality Standards, Wastewater, Evaluation, WWTP, Hospital*

INTRODUCTION

Hospitals, as healthcare facilities, are one of the contributors to waste because they generate waste during their operations. Hospital waste is all waste generated from hospital activities in solid, liquid, and gaseous forms that contain pathogenic microorganisms, are infectious, hazardous chemicals, and slightly radioactive. Hospital solid waste is divided into medical and non-medical solid waste. Medical solid waste is further categorized into infectious waste, pathological waste, sharps waste, pharmaceutical waste, cytotoxic waste, chemical waste, radioactive waste, pressurized container waste, and waste with high heavy metal content (Prayitno, 2019).

Beside providing healthcare services, hospital activities also have positive impacts on the community and the environment, including improving public health. However, negative impacts include the waste generated by the hospital. Wastewater from hospital waste is a highly potential source of water pollution. This is because hospital wastewater contains other chemical compounds as well as pathogenic microorganisms that can cause disease to the surrounding community. Hospital wastewater is all liquid waste generated from the entire hospital activity process, including clinical liquid waste, which is wastewater from hospital

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Science and Environmental Journals for Postgraduate
Vol. 7 No. 2 (pp. 83-101) December 2025
p_ISSN 2655-5085
e_ISSN 2655-5239

clinical activities such as used wound wash water, blood wash water, and other sources; and domestic liquid waste, which is waste from bathrooms, kitchens, laundry water, and other sources (Cuñat et al., 2022).

Based on the Decree of the Minister of Environment and Forestry Number 68 of 2016 concerning the quality standard for domestic wastewater for healthcare facilities, which requires every healthcare facility to manage liquid waste before it is discharged into the environment so that the quality of the discharged liquid waste does not exceed the established liquid waste quality standard. In wastewater management, there are several parameters that can determine the quality and characteristics of the wastewater itself (Kementrian Lingkungan Hidup dan Kehutanan RI, 2019).

In the United States, at the Mayo Clinic and Cleveland Clinic healthcare facilities, wastewater treatment has adopted advanced technologies such as activated sludge and membrane bioreactors (MBRs). Activated sludge technology has proven effective in reducing organic and pathogen content in wastewater, while MBRs improve treatment efficiency by combining biological processes and membrane filtration(Smith, 2020a). This approach not only ensures compliance with the strict regulations set by the Environmental Protection Agency (EPA) but also supports environmental sustainability.

Ibnu Sina Padang Islamic Hospital is one of the private hospitals that is quite a popular choice for the people of Padang City and surrounding areas to receive healthcare services because Ibnu Sina Padang Islamic Hospital is one of the leading healthcare facilities in Padang City and has a great responsibility in ensuring that the liquid waste generated does not have a negative impact on the surrounding environment. One of the main negative impacts of hospital liquid waste is water pollution. Liquid waste containing pathogens can contaminate drinking water sources, potentially causing infectious diseases such as diarrhea, hepatitis, and respiratory infections(Liu et al., 2021). Additionally, hazardous chemicals in liquid waste can damage water quality and disrupt aquatic life, potentially leading to a decline in biodiversity (Rahmawati, 2018). In addition, hazardous chemicals in liquid waste can damage water quality and disrupt aquatic life, which can lead to a decline in biodiversity. The impact on public health cannot be ignored either. Exposure to contaminated liquid waste can cause various health problems, especially for workers in healthcare facilities and communities living near hospitals. Research shows that exposure to medical waste can increase the risk of infection and chronic diseases (Pharmawati & Salman, 2024).

Ibnu Sina Padang Islamic Hospital already has a wastewater treatment system (WWTS) using the Sinergi Bio Box system with Bio Media (Saff) and concrete tanks. The WWTS with the Bio Saff system using concrete tanks has been operational since August 2021. Previously, the existing WWTS used the Bio Box Fiber system, which was operational from April 2015 to July 2021. In July 2021, the Bio Box Fiber was damaged and replaced with the Bio Box Saff Beton. Ibnu Sina Padang Islamic Hospital has transitioned from the previous wastewater treatment system (WWTS) using Bio Box Fiber to a more modern system, namely Bio Saff Beton. This decision was made after considering several important factors related to the effectiveness and efficiency of liquid waste management.

The Bio Box Fiber system, which operated from April 2015 to July 2021, experienced several constraints, including significant damage to its structure and functionality. This

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Science and Environmental Journals for Postgraduate
Vol. 7 No. 2 (pp. 83-101) December 2025
p_ISSN 2655-5085
e_ISSN 2655-5239

damage not only disrupts the wastewater treatment process but also potentially poses risks to public health and the surrounding environment. With this damage, Ibnu Sina Hospital realized that the existing system was no longer able to meet the required waste management standards, especially in terms of efficiency and compliance with environmental regulations. Additionally, the Bio Box Fiber system has limitations in terms of durability and its ability to handle the increasing volume of waste as the number of patients and services provided by the hospital grows. In an effort to improve waste management quality, the hospital decided to invest in more advanced and durable technology, namely the Bio box Saff Beton system.

Research conducted at the Haji Regional General Hospital in East Java Province shows that the hospital's wastewater treatment system is equipped with biological, physical, and chemical treatment units capable of reducing pollutant parameters such as TSS by up to 92.9%, BOD by 77.2%, COD by 36.1%, and ammonia and phosphate by 25% and 44% respectively. Although these results indicate that the wastewater treatment system has the ability to treat waste, there are still some parameters that have not reached optimal efficiency, so further evaluation is needed (Kasih et al., 2023).

In an effort to evaluate the effectiveness of the Wastewater Treatment Plant (WWTP) management system at Ibnu Sina Hospital in Padang, a series of laboratory tests were conducted on the wastewater outlet in 2024. The results of this test cover various relevant parameters and are compared to the established quality standards. The Total Suspended Solids (TSS) parameter showed the highest value in January at 18.2 mg/L, which is still below the quality standard of 30 mg/L. The TSS value decreased drastically in February to 0.7 mg/L and remained stable until December, indicating good management. Fluctuations were also observed in Biochemical Oxygen Demand (BOD), with the highest value of 7.73 mg/L in January and the lowest of 1.84 mg/L in October, all below the quality standard of 30 mg/L. Meanwhile, Chemical Oxygen Demand (COD) showed the highest value of 27.2 mg/L.

Oil and fat parameters remained consistent below the quality standard of 5 mg/L, indicating good management. However, pH testing showed the lowest value of 4.01 in August and the highest of 9.96 in September, which is outside the quality standard range of 6.0-9.0, indicating a problem with management. Finally, the Total Coliform parameter showed a drastic surge in June with a value of 39,600, far exceeding the quality standard of 3,000 (Regulation of the Minister of Environment and Forestry Number. P.68/Menlhk-Setjen/2016), posing a serious health risk (Kurniawati & Purwanti, 2024).

Overall, although some parameters are within quality standards, the concerning results for Ammonia-NH3 and Total Coliform indicate the need for evaluation and improvement in the wastewater treatment plant (WWTP) management system. The WWTP at Ibnu Sina Padang Islamic Hospital is relatively new, using a bio-saff system with concrete tanks, so no research has been conducted on its performance. Therefore, a study is needed to assess the WWTP's performance and determine whether it is operating optimally and whether the treated water quality meets standards. Additionally, evaluating the WWTP's performance can help identify any issues in treating wastewater, providing recommendations for the hospital to improve the quality of its wastewater effluent.

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RESEARCH METHODS

The main objective of this research is to analyze the effectiveness of wastewater treatment plant (WWTP) management in meeting liquid waste quality standards according to applicable regulations. In this study, the aspects to be evaluated include the Input, Process, and Output components of the wastewater treatment system. The number of informants surveyed was 6 people, involving various parties, namely wastewater treatment plant operators, hospital management, and other relevant parties, to obtain comprehensive information. This research was conducted at Ibnu Sina Padang Islamic Hospital , which has been using a Bio Saff technology-based wastewater treatment system with concrete tanks since 2021. Data collection will be conducted from July to September 2025, using a descriptive qualitative method in the form of in-depth interviews, including detailed interviews, direct observation of WWTP operations, and analysis of relevant documents such as operational reports and laboratory test results, as well as data documentation and triangulation. The data processing techniques used are data presentation and drawing conclusions. This research has been approved by the ethics committee with the number. 241/UFDK.KEPK/VI/2025.

RESULT AND DISCUSSION

Bio Box technology with the Bio Saff system adopts the principles of sustainable wastewater treatment by utilizing microorganisms to break down organic matter. This system combines anaerobic and aerobic processes, allowing for two-stage wastewater treatment. The anaerobic process occurs without oxygen, where microorganisms break down organic matter into biogas and sludge. Subsequently, the aerobic process uses oxygen to enhance the degradation of remaining organic matter, producing cleaner water that is safe for discharge into the environment. According to Dr. John Smith, a waste treatment expert, "Innovations in wastewater treatment technology, such as Bio Box with the Bio Saff system, not only improve efficiency but also reduce the environmental impact of medical waste".

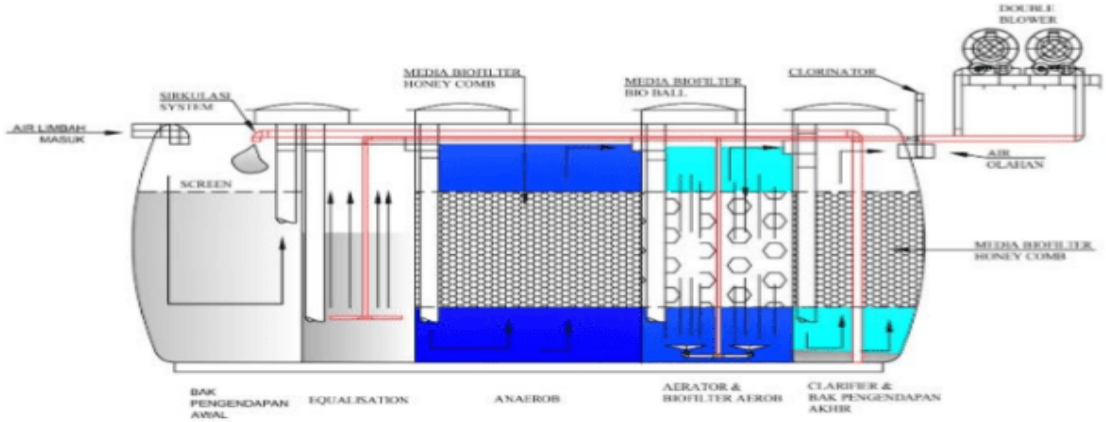

Figure 1. Wastewater Treatment Process Diagram with BioBox Synergy Process With Bio Saff System (Visual)

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Vol. 7 No. 2 (pp. 83-101) December 2025
p_ISSN 2655-5085
e_ISSN 2655-5239

Figure 2. Wastewater Treatment Plant (WWTP) of Ibnu Sina Islamic Hospital in Padang with Bio Saff System

3.1 Input Components

3.1.1 Policy

The research results indicate that Ibnu Sina Islamic Hospital in Padang has internal policies regarding liquid waste management that refer to national regulations, namely Permenkes RI No. 18 of 2020 concerning Waste Management of Healthcare Facilities and Permen LHK No. P.68 of 2016 concerning Domestic Wastewater Quality Standards. This policy was then detailed in the SOP for wastewater treatment plant management, which includes daily operations, maintenance, and the mechanism for reporting effluent quality to the relevant authorities. Nevertheless, based on the results of interviews and observations, it was found that the socialization of this policy is still limited. The majority of understanding regarding SOPs is held only by wastewater treatment plant technicians and general unit staff, while medical personnel, paramedics, and other support units do not fully understand their roles in supporting the liquid waste management system. This creates an implementation gap between formal policy levels and field practice.

This phenomenon aligns with Notoatmodjo, who emphasized that the success of policy implementation is determined by the extent of communication and socialization, not merely by the presence or absence of written rules (Notoatmodjo, 2019). This view is reinforced by Grindle in her theory of policy implementation, which emphasizes that the effectiveness of implementation is highly dependent on the interaction between policy content and the context of implementation (Manalu, 2021). In other words, even tho the Ibnu Sina Padang Islamic Hospital policy is compliant with regulations, its effectiveness remains low if the context of implementation, in this case staff socialization, understanding, and participation, is not supportive. When linked to the conditions of the Ibnu Sina Padang Islamic Hospital , it can be assumed that the policy substance is already appropriate, but the main challenges lie in the context of implementation, namely weak cross-unit socialization, limited understanding of non-technical staff, and the absence of a sustainable internal policy audit mechanism.

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Science and Environmental Journals for Postgraduate
Vol. 7 No. 2 (pp. 83-101) December 2025
p_ISSN 2655-5085
e_ISSN 2655-5239

Base on the findings, the wastewater treatment plant (WWTP) management policy at Ibnu Sina Padang Islamic Hospital is essentially aligned with environmental management regulations and principles, but its implementation is not yet optimal due to weaknesses in the context of implementation, such as socialization, staff participation, and internal monitoring. To improve the effectiveness of the wastewater treatment plant (WWTP) management policy implementation, hospital management needs to conduct regular cross-unit socialization thru training, so that understanding of the SOP is not limited to technicians, but is also understood by all staff. In addition, the wastewater treatment plant policy should be integrated into the new employe orientation program so that from the beginning, employes are aware of the importance of liquid waste management. Hospitals also need to form an internal audit team that periodically assesses compliance with policy implementation so that weaknesses can be promptly addressed. On the other hand, SOPs must be adaptable and reviewed periodically to adjust to the dynamics of liquid waste loads as the number of patients increases. Finally, the success of implementation is highly dependent on leadership support, where the commitment of hospital leaders is a key factor in driving staff compliance and making wastewater treatment plant management an organizational priority.

Table 1. Policy Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
Liquid waste management in hospitals refers to regulations (Minister of Health Regulation No. 18/2020, Government Regulation No. 101/2014, Environmental Impact Analysis (UKL-UPL), Technical Guidelines for Waste). However, the SLO for the wastewater treatment plant has not yet been processed because it is awaiting the results of three consecutive months of testing. The hospital already has an SOP for liquid waste management, including input-output flow, chemical usage, quality monitoring, and damage handling, although not all equipment has an official SOP. Wastewater Treatment Plant operators work a 24-hour shift system, perform routine maintenance, clean channels, and maintain the condition of the WWTP.	Based on document review, an Environmental Impact Assessment (EIA) and Waste Technical Regulations were found as the legal basis for liquid waste management, but the Wastewater Treatment Plant (WWTP) SLO document was not available. The hospital already has some SOP documents, but they are still incomplete and not fully signed by the director. There is also an operational logbook from the WWTP vendor, a maintenance schedule, and technician reports as proof of operational activities.	The observation results show that the wastewater treatment plant is functioning well, but the effluent quality still shows fluctuations in some parameters. Officers appear to be using a logbook in their daily operations, although the SOPs they are using have not been fully formalized. The activities of the technicians, including monitoring, routine maintenance, and cleaning the wastewater treatment plant (WWTP) channels, can be observed directly.	Based on data triangulation, it can be concluded that the liquid waste management policy in hospitals has adhered to regulations and is supported by technical documents, although there are still limitations in terms of legality, particularly regarding the wastewater treatment plant (IPAL) SLO which has not yet been obtained. The hospital already has basic SOPs and an operational logbook, and the technical implementation by the WWTP operators has been running smoothly thru a 24-hour shift system. Nevertheless, the completeness and legality of the SOPs still need to be strengthened and formalized to have legitimate legal force and support compliance with regulations..

Figure 3. Documentation

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p_ISSN 2655-5085
e_ISSN 2655-5239

3.1.2 Human Resources

Based on the research findings, the wastewater treatment plant (WWTP) at Ibnu Sina Padang Islamic Hospital is managed by experienced technicians, but not all of them have PPPA certification. Environmental health personnel are already certified, while technicians only receive internal training, resulting in a capacity gap. This has the potential to reduce management effectiveness, as human resource competency is an important factor in the success of wastewater treatment plants, in addition to technology.

According to the Indonesian Ministry of Health, continuous training and education for human resources are very important to ensure they can perform their duties well. Human resources must also have the ability to monitor and measure liquid waste quality parameters, such as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) (Kemenkes RI, 2023).

Recent studies also reinforce the importance of human resource capacity in wastewater treatment plant management. Kasih et al. (2023) found that the performance of the wastewater treatment plant at Haji General Hospital in East Java is highly dependent on the capacity of the technicians; hospitals with certified technicians are more consistent in meeting effluent quality standards. This supports the findings at Ibnu Sina Padang Islamic Hospital, where only some personnel have certifications, potentially leading to unstable wastewater treatment plant performance (Kasih et al., 2023).

This study indicates that the lack of certification for wastewater treatment plant (WWTP) technicians is a risk factor for the decline in WWTP management quality. Although in-house training provides basic knowledge, it is not sufficient to replace the importance of official national certification. To improve human resource capacity in WWTP management, hospitals need to ensure that technicians obtain PPPA certification so that their competence is formally recognized and can improve the quality of liquid waste management.

Table 2. Human Resource Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
The report states that training on liquid waste management has been conducted thru certified institutions (PPPA and POPAL), but has only been attended by environmental health personnel. The personnel consists of four people (one operator, two technicians, and one environmental health worker) working in three shifts, ensuring the wastewater treatment plant operates 24 hours a day. The environmental health officer has a background in environmental health D3 education, while the technicians are mostly high school graduates who have received training. There are staff members with over ten years of experience, but some technicians had no prior experience before working at the hospital.	The review results show the presence of invitation letters and training certificates for environmental health workers, organizational structure documents, shift schedules, and attendance lists for wastewater treatment plant (WWTP) operators. Additionally, internal training documents (in-house training) were found, although formal external training evidence for technicians was not available.	Field observations showed that the environmental health personnel were actively assisting the technicians. The wastewater treatment plant (WWTP) operates 24 hours a day with technicians rotating according to a shift schedule. High school graduate technicians appear to have a good grasp of basic operational procedures, working under the direction of the Environmental Health Department and following standard operating procedures (SOPs). Experienced staff seem capable of handling technical issues independently.	Based on data triangulation, it can be concluded that the human resources at the wastewater treatment plant management unit are sufficient in number and continuity thru a three-shift work system. The competence of environmental health workers is relatively better because they have undergone certified training, while technicians still rely heavily on field experience and internal mentoring. Therefore, capacity building thru formal training and certification is needed to ensure that the competence of technicians is equal to professional standards.

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3.1.3 Funding

Funding for liquid waste management at Ibnu Sina Padang Islamic Hospital has been allocated routinely thru the annual RKA, ensuring basic operations can continue. Management responds quickly to both routine and urgent needs, but budget flexibility is limited for large expenses, requiring prior approval from the foundation or owner representatives.

Operational costs include the energy, chemical, and labor expenses required to operate the treatment system. In many cases, more efficient processing technology can significantly reduce operational costs. This condition aligns with the Resource-Based View theory, which states that program sustainability is highly dependent on the availability and utilization of resources, including funds. Insufficient allocation of funds, particularly for major maintenance, can reduce the effectiveness and sustainability of the wastewater treatment system. Without adequate financial support, even the presence of competent technology and human resources cannot function optimally (Parida et al., 2022).

Budget limitations are a major obstacle for many hospitals in Indonesia in maintaining the performance of their wastewater treatment plants. Delayed maintenance due to limited funds leads to a decline in effluent quality, potentially exceeding quality standards (Afriliani et al., 2020). Conversely, the study by Makarung (2022) indicates that hospitals with good financial management remain capable of maintaining wastewater treatment plant performance even with limited funds, thru cost-efficiency strategies such as long-term contracts with vendors, collective procurement, and a more structured preventive maintenance schedule (Makaraung et al., 2022).

Base on the findings, limited funding, particularly for major maintenance aspects, is a factor hindering the operational sustainability of the wastewater treatment plant at Ibnu Sina Padang Islamic Hospital. Although operational funds are available and special funds for wastewater treatment plants have been allocated, additional approval procedures from the foundation or hospital owner representatives are causing delays in the execution of repairs to vital components. Therefore, it can be suggested that hospital management needs to allocate funds for wastewater treatment plant maintenance as a mandatory priority separate from general operational funds, so that major repairs are not delayed. The approval mechanism with the YARSI Foundation of West Sumatra can be arranged more flexibly, for example, by setting a certain value limit that can be decided directly by hospital management. Additionally, cost efficiency strategies, preventive procurement, and long-term cooperation with vendors need to be implemented to optimize the use of available funds. With this approach, the operational sustainability of the WWTP can be better ensured and the risk of environmental pollution due to delayed maintenance can be minimized.

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Table 3. Funding Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
The report explains that funding for liquid waste management comes from the annual budget, and is used to support the operation of the wastewater treatment plant, the procurement of chemicals, laboratory testing, and routine maintenance. The budget is considered adequate for basic needs, but in the event of major damage or the procurement of new equipment, additional requests must be submitted thru a tiered mechanism (Foundation → Hospital → Environmental Health Unit). Additionally, special funds are available for cooperation with third parties, while routine and urgent needs generally receive a quick response because they are considered a priority.	The annual RKA document shows a specific budget allocation for liquid waste management, including collaboration with third parties. The technical proposal from the Environmental Health Unit is used as the basis for submitting additional needs, such as wastewater treatment plant renovation. The disposition notes indicate that proposals with low costs can be approved immediately, while proposals with high costs require a priority study. There is no specific contingency budget for major damage.	Observation results indicate the routine use of chemicals, monthly laboratory testing, and evidence of wastewater treatment plant operation, although some equipment is old. Minor repairs can be addressed immediately, while major repairs require time due to awaiting approval. Evidence of cooperation with third parties, such as the transportation of B3 waste, also appears to be on schedule.	Based on data triangulation, it can be concluded that funding for liquid waste management has been allocated routinely thru the annual RKA, thus ensuring the sustainability of basic operations. Management demonstrates a relatively quick response to both routine and urgent needs, but budget flexibility is still limited to large-scale needs requiring foundation approval. The technical study-based mechanism from the Environmental Health Unit shows a system of control and priorities, while the allocation of funds to third parties ensures the continuity of waste transportation and disposal.

3.1.4 Facilities and Infrastructure

The research results indicate that the Bio Saff Concrete WWTP used by Ibnu Sina Padang Islamic Hospital basically functions quite well in treating hospital liquid waste. However, there are limitations in the daily quality monitoring aspect because the available monitoring tools are still limited. Based on interviews, it was found that the hospital already has a pH meter that is used daily to monitor effluent conditions. However, other important monitoring tools such as DO meters and coliform test kits are not yet available in the hospital. The measurement of these parameters still relies on an external party, namely the Health Laboratory (Labkes), with samples sent by environmental health officers. This prevents the early detection process for potential problems in the WWTP from being carried out quickly and in real-time.

Theoretically, this condition aligns with the explanation by Metcalf & Eddy (2014), which states that the effectiveness of wastewater treatment is highly influenced by the completeness of monitoring facilities. Without measuring tools that can provide immediate results, hospitals can only identify problems after external laboratory test results are available, which often takes several days. This situation can certainly lead to delays in taking corrective action when the quality of the effluent does not meet the quality standards. Previous research supports the importance of complete monitoring facilities.

Lumunon et al. (2021) emphasize that daily monitoring is a crucial aspect of maintaining the stability of hospital wastewater treatment plant performance. Routine monitoring with simple tools allows technicians to make immediate operational adjustments before wastewater quality parameters exceed the threshold. (Lumunon et al., 2021). Conversely, research by Azuma et al. (2025) in Japan showed significant differences, where hospitals were already equipped with advanced technologies such as ozonation and UV systems with automatic sensors, thus substantially reducing reliance on external laboratory testing. This indicates that the more complete the monitoring facilities, the higher the WWTP's ability to maintain the consistency of effluent quality (Azuma et al., 2025).

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e_ISSN 2655-5239

Base on the findings, the limitations of monitoring tools at Ibnu Sina Padang Islamic Hospital, particularly the absence of a DO meter and a coliform test kit, reduce the hospital's ability to perform early detection independently. As a result, operational improvements or adjustments can only be made after external laboratory test results are received, potentially delaying the response to technical issues. Therefore, it is recommended that hospitals equip their wastewater treatment plants with simple monitoring tools such as DO meters and coliform test kits, in addition to the pH meters that are already available and used daily. With these additional tools, technicians can perform routine checks independently, allowing potential problems to be detected earlier. Additionally, the evaluation of monitoring equipment needs should be conducted periodically to align with technological advancements and the latest regulations. This improvement in monitoring facilities will strengthen the effectiveness of the WWTP while minimizing the risk of effluent results not meeting environmental quality standards.

Table 4. Facilities and Infrastructure Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
Reports state that the wastewater treatment plant's facilities and infrastructure are quite complete, including blowers, pumps, flow meters, universal pH meters, suction machines, drilling machines, pipes, hoses, and manual tools. This facility is used according to operational needs, with routine monthly control systems by technicians. If damage is found, the equipment is immediately repaired or replaced. Additionally, there are periodic maintenance schedules such as tank draining, pH checking, pump and blower maintenance, grease trap cleaning, fat removal in the nutrition room, and blower oil changes.	Hospital inventory documents show a complete list of wastewater treatment plant (WWTP) facilities and infrastructure, including primary and auxiliary equipment. Additionally, well-documented maintenance schedules, monthly technician reports, and records of WWTP equipment repairs and replacements were found.	Field observation results show that the wastewater treatment plant (WWTP) is functioning with complete basic and supporting infrastructure. It appears there is routine inspection activity, tank draining, pH checking, pump and blower maintenance, and old equipment that has been repaired or replaced with new ones.	The triangulation results from in-depth interviews, document review, and observations indicate that the facilities and infrastructure of the Wastewater Treatment Plant (WWTP) at Ibnu Sina Islamic Hospital in Padang are adequately available, including both main and auxiliary equipment such as blowers, pumps, flow meters, pH meters, suction machines, and other manual tools. All these facilities are managed thru a scheduled routine maintenance mechanism, including tank draining, water quality parameter checks, pump and blower maintenance, and repair and replacement activities for damaged components. Hospital documentation shows an inventory list, maintenance records, and repair reports.

3.2 Process Components

3.2.1 Planning

The research results indicate that the planning for wastewater treatment at Ibnu Sina Padang Islamic Hospital is available and incorporated into the hospital's annual Work Plan and Budget. This planning includes operational, maintenance, and technical evaluation aspects, as well as budget allocation tailored to the needs of liquid waste management. From a capacity perspective, the Bio Saff Concrete Wastewater Treatment Plant owned by the hospital has also been designed according to the number of beds, and considers the potential peak load of liquid waste generated.

This indicates that planning at Ibnu Sina Padang Islamic Hospital is not only administrative but has also anticipated the dynamics of waste load in line with the number of patients. Theoretically, these findings can be analyzed by referring to planning theories that emphasize that good planning must be able to anticipate field dynamics and not just

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Science and Environmental Journals for Postgraduate
Vol. 7 No. 2 (pp. 83-101) December 2025
p_ISSN 2655-5085
e_ISSN 2655-5239

contain normative targets. In the context of wastewater treatment plant management, planning that does not account for fluctuations in patient numbers and liquid waste volume has the potential to cause disruptions in achieving quality standards.

Previous research provides relevant insights. Ramli (2023) found that many hospitals in Indonesia fail to meet quality standards because the design of their wastewater treatment plants does not consider peak load conditions, making the systems easily disrupted when waste volume increases significantly (Ramli, 2023). Conversely, Smith (2020) in his research in the United States showed that hospitals using Membrane Bioreactor (MBR) technology were able to handle fluctuations in waste load more stably, ensuring that the effluent still met quality standards even with a surge in patient numbers. This comparison confirms that the success of wastewater treatment plant planning is not solely determined by capacity appropriate for the number of beds, but also by preparedness to handle operational dynamics in the field (Smith, 2020).

This study indicates that the planning for wastewater treatment plant management at Ibnu Sina Padang Islamic Hospital is already considered good because it is outlined in the annual RKA and has taken into account capacity based on the number of beds and peak liquid waste load. However, its effectiveness still needs to be continuously tested to ensure that existing plans are truly responsive to the dynamics of patient numbers and technological developments. Therefore, it is recommended that hospitals periodically re-plan the capacity of their wastewater treatment plants, taking into account the year-on-year increase in patient numbers and the potential for changes in environmental regulatory standards. Additionally, a feasibility study should be conducted to consider options for developing advanced treatment units or adopting new technologies such as MBR if the volume of liquid waste increases significantly. Thus, the WWTP not only meets current needs but is also prepared to face future operational challenges.

Table 5. Planning Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
Liquid waste management planning is carried out thru prior needs assessment and is outlined in an annual work plan with cross-unit coordination. All waste from medical and non-medical units is discharged to the wastewater treatment plant, some of it after pretreatment. Routine monitoring includes pH, flow rate, laboratory tests, and periodic evaluations. The daily waste volume is quite large (inlet >70 m^3, outlet ±60 m^3), and all of it is treated at the wastewater treatment plant without direct discharge into the environment.	The documents show the existence of a work plan, evaluation reports, SOPs, maintenance records, and external laboratory test results. The wastewater source flow and pretreatment techniques are clearly documented, including daily wastewater flow data.	Field observation results show monitoring, routine evaluation, pretreatment activities, and wastewater flow from all units to the WWTP. High wastewater flow rates and functional WWTP facilities were also observed.	Liquid waste management is carried out systematically, documented, and monitored. Waste from all units is treated at the wastewater treatment plant with the support of pretreatment, periodic evaluation, and laboratory testing. There is no direct discharge into the environment, although there are technical constraints in recording the flow rate.

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e_ISSN 2655-5239

3.2.2 Implementation

This research shows that the operational implementation of the wastewater treatment plant at Ibnu Sina Padang Islamic Hospital is in accordance with the applicable SOPs, including the treatment process, routine maintenance, and recording of monitoring results. Environmental health officers and wastewater treatment plant technicians follow operational procedures ranging from daily pH measurement and flow monitoring to sending samples to external laboratories. This proves that the implementation of the liquid waste management system is aligned with the hospital's internal policies.

However, the implementation of wastewater treatment plants sometimes faces obstacles from external factors, particularly power outages. As revealed in the interview results, power outages have the potential to disrupt the continuity of wastewater treatment because the aeration system and pumps require a stable power supply. Nevertheless, Ibnu Sina Padang Islamic Hospital already has a generator that covers the entire hospital area, including the wastewater treatment plant. With this backup power facility, the risk of wastewater treatment plant operations being disrupted due to power outages can be minimized, although good energy management is still needed to ensure optimal generator performance.

Theoretically, these findings align with Van Meter & Van Horn's policy implementation theory, which explains that successful policy implementation is not only influenced by the clarity of SOPs, but also heavily depends on external environmental support. If external factors, such as energy supply or infrastructure conditions, are not supportive, then policy implementation could potentially be hindered even if technical instructions are available. Srimongkol's research shows that by implementing a dedicated backup power system for wastewater treatment plants, the risk of operational disruptions can be minimized, even during prolonged power outages. This finding indicates that a hospital's preparedness in anticipating external factors significantly influences the successful implementation of wastewater treatment plants (Srimongkol et al., 2022).

This study indicates that the implementation of the wastewater treatment plant (WWTP) management at Ibnu Sina Padang Islamic Hospital is already running well according to the standard operating procedures (SOP). However, its operation remains vulnerable to external factors such as electricity supply. Although the generator is available and covers the entire area, including the wastewater treatment plant, operational sustainability is highly dependent on the generator's readiness and condition. Therefore, hospitals need to ensure the generator is always in optimal condition thru routine maintenance and periodic load testing. Additionally, it's advisable to consider power priority settings so that the wastewater treatment plant remains one of the main units with a guarantyd power supply during outages. Thus, the continuity of wastewater treatment can be maintained without being affected by external factors.

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e_ISSN 2655-5239

Table 6. Implementation Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
The report states that liquid waste management adheres to clear SOPs/SPOs and utilizes the Biosafe system (physical, biological, chemical). The chemicals used are alum and chlorine, although the dosing pump is currently damaged, so addition is done manually. The sludge from the wastewater treatment plant is managed thru a sludge drying bed before being handed over to a third party. Radiological waste is also managed by PPLI, and its volume is decreasing because they have adopted a digital system.	Documents show the existence of written SOPs, technical designs for wastewater treatment plants with physical, biological, and chemical stages, as well as records of chemical usage. Official cooperation with PPLI for the management of wastewater treatment plant sludge and radiological waste was also found.	Observation results show that the wastewater treatment process follows SOPs with the Biosafe system, the wastewater treatment unit is complete, there is a sludge drying bed, and radiological waste is only temporarily stored before being handed over to a third party. A dosing pump was also seen in a damaged condition, so chemicals were added manually	Hospital liquid waste management is already structured, documented, and monitored thru SOPs and the Biosafe system. There is official cooperation with a third party for the management of B3 and radiological waste. Technical constraints (damaged dosing pump) were overcome by manually adding chemicals. Overall, the management of liquid waste is in accordance with standards and regulations

3.2.3 Supervision

The research results indicate that monitoring of the wastewater treatment plant (WWTP) management at Ibnu Sina Padang Islamic Hospital has been implemented, both thru internal and external monitoring. From an internal perspective, supervision is carried out by environmental health officers along with the Infection Prevention and Control team, who regularly monitor daily operations, record pH measurement results, and visually inspect the condition of the wastewater treatment plant. Additionally, reports on liquid waste management results are submitted to hospital management as part of the accountability mechanism. From an external perspective, supervision is carried out by the Padang City Environmental Agency (DLH) thru periodic laboratory testing of effluent quality parameters. This is in accordance with the provisions of applicable environmental regulations, namely Ministry of Environment and Forestry Regulation No. P.68 of 2016 and Ministry of Health Regulation No. 18 of 2020 (Kemenkes.RI, 2020).

Although the monitoring mechanism is in place, this study found that internal monitoring has not been fully integrated into the hospital's quality audit system, which means that the wastewater treatment plant (IPAL) aspect is sometimes not prioritized in the quality monitoring agenda. Additionally, limited monitoring facilities mean that daily supervision is not yet fully optimized, as some parameters still rely on external laboratory test results that take time to come back. Theoretically, these findings can be analyzed using the concept of supervision in management theory according to Fayol, which states that the function of supervision (controlling) aims to ensure that activities are carried out in accordance with the established plans and standards. In the context of wastewater treatment plants, strong monitoring is crucial to ensure that all operational stages run according to SOPs and that effluent quality consistently meets standards.

Recent studies reinforce the importance of monitoring in wastewater treatment plant management. Lumunon et al. (2021) found that the effectiveness of hospital wastewater treatment plants is highly influenced by the consistency of daily monitoring, and that weak internal supervision is often the cause of fluctuations in effluent quality (Lumunon et al., 2021). International research by Chen et al. also emphasizes that integrating wastewater

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treatment plant monitoring into hospital quality management systems can improve regulatory compliance while strengthening the institution's reputation in the public eye (Zhu et al., 2019).

Base on the findings, the wastewater treatment plant (WWTP) monitoring at Ibnu Sina Padang Islamic Hospital has been carried out thru internal and external mechanisms, but it is not yet fully optimal. Reliance on external laboratory results and the lack of integrated monitoring in the hospital's quality audit system have the potential to reduce the effectiveness of effluent quality monitoring. Therefore, it is recommended that hospitals strengthen their internal monitoring systems by integrating WWTP indicators into the hospital's quality audits. Additionally, the procurement of additional monitoring equipment (such as DO meters and coliform test kits) will support independent early detection. From an external perspective, more intensive coordination with the Environmental Agency is needed to ensure the frequency of laboratory testing aligns with operational needs. Thus, monitoring of WWTPs can be more comprehensive and sustainable, thereby minimizing the risk of effluent results not meeting standards.

Table 7. Supervision Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
The report states that wastewater monitoring is conducted externally by the Padang City Environmental Agency (DLH) thru routine inspections and laboratory testing, and internally every day by wastewater treatment plant operators who record flow rate, pH, inlet-outlet conditions, pumps, aeration, and blowers. Evaluations are conducted monthly, quarterly, and annually, with follow-up actions taken if the results are not satisfactory. Additionally, stricter supervision is implemented when waste load increases due to a surge in patients.	The documents show external laboratory test results from the West Sumatra Health Laboratory (Labkesda Sumbar), inspection reports from the Environmental Protection Agency, daily checklists, monthly technician reports, laboratory test result reports, and follow-up plans. The notes also show an increase in discharge when the occupancy rate is high.	On the field, there were notice boards displaying laboratory test results, DLH inspection reports, and officers recording water flow and pH. Technicians were also conducting routine checks of pumps, blowers, and aeration systems. Wastewater Treatment Facilities debit increases during full hospitalization, and the lab test results report binder and follow up plan notes are visible if there are follow-up actions.	Wastewater treatment plant (WWTP) monitoring in hospitals is conducted comprehensively thru external (Environmental Agency) and internal (WWTP staff) monitoring that is routine, documented, and includes periodic evaluations with a corrective action plan (CAP) mechanism if non-compliance occurs. Technical and administrative tasks are clearly divided, and supervision is able to adapt to the increased waste load, ensuring that management quality remains under control.

3.2.4 Parameter Results

The research results indicate that the Bio Saff wastewater treatment plant made of concrete used at Ibnu Sina Padang Islamic Hospital has essentially functioned quite well in treating hospital liquid waste. Most important parameters such as BOD, COD, and TSS have consistently met environmental quality standards. However, data from 2024 shows fluctuations in several other parameters, namely pH, ammonia, and coliform, where at certain periods their values exceed the limits set in the Regulation of the Minister of Environment and Forestry No. P.68 of 2016 concerning Domestic Wastewater Quality Standards. Nevertheless, the results of the latest test in 2025 show that all tested parameters, including pH, ammonia, and coliform, have fully met the quality standards. This indicates a significant improvement in the operational and monitoring systems of the Bio Saff Beton WWTP compared to the previous year.

According to the Metcalf & Eddy theory of wastewater treatment, instability in effluent quality parameters is typically caused by technical factors, such as surges in wastewater load, imbalances in biological processes, or limitations in the capacity of certain treatment units.

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In the context of Ibnu Sina Padang Islamic Hospital, the fluctuation of parameters in 2024 can be interpreted as a form of instability in the Bio Saff Beton system when facing certain conditions, such as when waste volume increases or when there is a delay in the maintenance of wastewater treatment plant components (Metcalf, 2024).

The findings of this study are consistent with Lumunon et al., who reported that fluctuating liquid waste loads significantly affect the stability of hospital wastewater treatment plant effluent. Conventional systems like Bio Saff, made of concrete, while effective for medium-scale applications, still have the potential to face limitations in reducing biological parameters such as coliforms if not equipped with additional units (Lumunon et al., 2021). Conversely, Smith's research in the United States showed that using Membrane Bioreactor (MBR) technology was able to maintain effluent quality stability even with high waste loads, because the membrane system is more effective at filtering pollutants and suppressing microbial growth. This comparison confirms that using additional technology or advanced treatment units could be a solution to address effluent quality fluctuations in conventional concrete-based systems (Smith, 2020b).

This study indicates that the fluctuation of effluent quality parameters in 2024 indicates that the Bio Saff Beton WWTP at Ibnu Sina Padang Islamic Hospital has not yet operated optimally under certain conditions, particularly regarding pH, ammonia, and coliform control. However, the achievement in 2025, which successfully met all quality standard parameters, indicates a significant improvement in the system, although the sustainability of the results' stability still needs to be consistently monitored. Therefore, the hospital needs to maintain the success in achieving quality standards obtained in 2025 by strengthening the daily monitoring system and conducting periodic technical evaluations of the Bio Saff Beton Wastewater Treatment Plant. As a preventive measure, hospitals can consider adding advanced disinfection units such as UV sterilizers or ozonation, which have been proven effective in reducing coliform levels and consistently improving effluent quality. Additionally, the pH control system needs to be strengthened by providing buffers or neutralizing chemicals regularly to keep the biological processes in the Bio Saff Concrete WWTP stable. With this step, the effluent quality not only meets the instantaneous quality standards but is also maintained sustainably.

Table 8. Parameter Results Triangulation

Indepth Interview	Dokument Review	Observastion	Conclusion
Reports indicate that wastewater quality testing is conducted routinely every month in collaboration with the West Sumatra Regional Health Laboratory (Labkesda). The parameters tested include pH, BOD, COD, TSS, ammonia, oil & grease, and E. coli. The results generally meet quality standards, although they are sometimes fluctuating (e.g., high coliform or low pH), but are immediately followed up	There are cooperation documents or letters requesting testing with the Labkesda, proof of sample delivery, and test result reports. Data from 2024 shows that some parameters (coliform and pH) temporarily exceeded the threshold, but by 2025, all parameters at the wastewater treatment plant outlet met the requirements of PermenLHK No. 68/2016.	It was observed that environmental health officers were taking samples from the wastewater treatment plant (WWTP) outlet and submitting them to the Regional Health Laboratory (Labkesda). There was daily monitoring of pH and flow rate (even tho the flow meter was broken), and technicians were assisting with sample collection at the inlet and outlet tanks. The wastewater treatment plant (WWTP) appears well-maintained, and the effluent water is clear.	Testing is conducted routinely on a monthly basis using official procedures. Laboratory results show that most parameters meet quality standards, and small fluctuations are immediately corrected. By 2025, all parameters of the wastewater treatment plant outlet will meet standards, proving that the wastewater treatment system is effective in reducing pollutant levels, even tho the receiving water body still shows pollution from other sources.

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3.2.5 Output

The research results show that, in general, the wastewater treatment plant at Ibnu Sina Padang Islamic Hospital is functioning quite well, although fluctuations were still found in several parameters during the previous period, such as BOD, COD, TSS, ammonia, and E. coli. However, based on the results of laboratory tests in 2025, all tested liquid waste parameters have met environmental quality standards in accordance with the provisions of Ministry of Environment and Forestry Regulation No. P.68 of 2016 concerning Domestic Wastewater Quality Standards. This indicates a significant improvement in the performance of the wastewater treatment plant compared to previous years.

Theoretically, these findings can be analyzed using Stufflebeam's program evaluation systems theory, where an output is considered successful if the established goals are fully achieved. In this context, the success of the wastewater treatment plant is measured by its ability to produce effluent that consistently meets quality standards. Although the wastewater treatment plant at Ibnu Sina Padang Islamic Hospital was previously only categorized as "fairly good" due to inconsistency, the 2025 results show that the treatment system is moving toward optimal performance.

This finding aligns with the research by Kasih et al., who reported that most hospital wastewater treatment plants in Indonesia are able to meet quality standard parameters, although some indicators still fluctuate. This confirms that technical and operational constraints are often the main cause of variations in test results (Kasih et al., 2023). Conversely, Santoso (2023) found that wastewater treatment plants that had undergone redesign or the addition of advanced treatment units were able to maintain the stability of all parameters, making them more consistent in meeting quality standards (Santoso, 2023). Thus, the success of Ibnu Sina Padang Islamic Hospital in achieving quality standards for all parameters in 2025 indicates an increase in effectiveness, although it is not yet certain whether these results will remain stable in the long term.

Base on the findings, the output of the Ibnu Sina Padang Islamic Hospital wastewater treatment plant can be categorized as "good" because all test parameters for 2025 have met environmental quality standards. However, considering the history of fluctuations in previous years, this success still carries potential risks if not supported by continuous technical evaluation. Therefore, it is recommended that hospitals conduct periodic technical evaluations of their wastewater treatment plant (WWTP) performance to ensure consistent test results over time. Additionally, adding advanced treatment units should be considered as an anticipatory step to address the potential increase in liquid waste load in the future. Finally, hospitals need to strengthen their daily monitoring systems thru the use of simple equipment and automatic sensors so that early detection can be done without waiting for external laboratory results. With these steps, achieving standard quality in 2025 will not only be a fleeting success, but can be sustained continuously.

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Table 9. Output Triangulation of Wastewater Treatment Plant Management

Indepth Interview	Dokument Review	Observastion	Conclusion
The interview results indicate that the management of hospital liquid waste generally meets the applicable standards. The hospital has SOPs and uses the Biosafe system as a processing method. Quality tests are conducted regularly, although occasional deviations are observed in pH and coliform parameters. The obstacles faced are related to equipment damage and the lack of effluent utilization permits, but the hospital always follows up thru action plans.	The documentation for liquid waste management is quite complete, including SOPs, technical documents, permits, laboratory test results reports, operational feasibility letters (SLO), and equipment damage records and RTL. However, no permit documents for effluent utilization were found. Some test result reports also show fluctuations in certain parameters.	Field observations showed that SOPs and test result records were displayed in the Environmental Health room, sampling activities were carried out routinely, and a daily pH monitoring logbook was available. The Biosafe installation is operating normally, but technical issues were found, such as pump and dosing pump damage without any backup. Additionally, the treated effluent is discharged directly into the city's drainage system without being reused.	Generally, the management of liqui waste in hospitals has been i accordance with standards and wel documented. The results of th wastewater quality test show tha most parameters meet the qualit standards, although there ar fluctuations in pH and coliform level during certain periods. Effluent reus has not yet been possible due t permit limitations, while technica constraints related to equipment ar still being encountered. Neverthele every issue is immediately followe up with an RTL, ensuring th operational sustainability of th WWTP is maintained and support compliance with regulator obligations, including in PROPE assessments.

CONCLUSION

Based on the interview results, the management of liquid waste at Ibnu Sina Islamic Hospital in Padang has generally been implemented according to the plan and applicable standards, as evidenced by the completeness of technical documents, consistent implementation of SOPs, routine liquid waste quality testing that mostly meets quality standards, the acquisition of an Operational Feasibility Certificate (SLO), and the absence of community complaints. However, the aspect that has not yet been implemented is the utilization or recycling of effluent due to permit limitations, and technical obstacles are still encountered in some parameters such as pH and bacteriological levels. Therefore, continuous monitoring and evaluation are still needed to ensure the consistency of liquid waste treatment results according to established standards.

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