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EFFECTIVENESS AND OPTIMIZATION OF HOSPITAL WASTEWATER TREATMENT PLANTS (WWTPS): A LITERATURE REVIEW

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Abstract
The hospital's wastewater recycling system is not functioning properly, and errors in the water mass balance calculation have been identified, which affect efforts to minimize environmental pollution. Therefore, an evaluation of the Wastewater Treatment Plant (WWTP/IPAL) was conducted. The purpose of this study is to assess the hospital's WWTP and propose recommendations to optimize its performance in treating wastewater. The evaluation was carried out with reference to design criteria and quality standards, supported by a literature review using PICO analysis, as well as an assessment of existing conditions based on primary and secondary data. The evaluation results show that the hospital's wastewater discharge reached 166.3 m^3/day, with treatment efficiency categorized as very efficient and efficient for several pollutant parameters, indicating that the treatment process generally functioned well. However, some components including equalization tanks, the first and second settling tanks, activated sludge, trickling filter, filtration, disinfection, and recycling did not meet design standards, requiring recalculations. To address these shortcomings, the study suggests stricter monitoring and testing of effluent quality by improving sampling methods, re-measuring influent wastewater characteristics, and ensuring the WWTP operates in accordance with Standard Operating Procedures (SOP). Overall, based on water quality tests and performance analysis, the WWTP demonstrated high degradation efficiency of wastewater parameters (ranging from very effective to moderately effective), with all tested parameters meeting the applicable quality standards.
Keywords: evaluation, hospital WWTP, effectiveness, design criteria, influent, effluent.

INTRODUCTION

The growing number of health facilities and hospitals has led to an increase in wastewater generation, which in turn raises the risk of environmental pollution due to declining wastewater quality. The government mandates that all healthcare facilities have wastewater treatment units that meet technical and quality criteria in order to lessen the harmful effects of hospital wastewater and provide a comfortable and healthy atmosphere (Kemenkes RI, 2020). Before being sent to final disposal locations, hospital wastewater, especially medical waste, must undergo special treatment in order to be managed properly. Reducing the risk of disease transmission requires effective management.

Wastewater itself refers to liquid residues from production activities that are no longer useful and must be treated before being discharged into the environment to prevent pollution and degradation of environmental quality (Naeemah & Wong, 2023). Hospital wastewater encompasses all liquid waste generated from hospital operations, including domestic wastewater, which contains pathogenic microorganisms, toxic and radioactive chemicals, and blood. These substances pose significant risks to human health and the environment, thus requiring treatment through wastewater treatment plants (WWTP) (Amin et al., 2023). The specific composition and characteristics of hospital wastewater make it particularly impactful, requiring specialized handling (Ajala et al., 2022).

Accordingly, wastewater management strategies must be based on its composition and characteristics to reduce contamination risks. Evaluating hospital WWTP is therefore essential to determine treatment effectiveness and identify areas for improvement. The state of hospital wastewater management in Indonesia is still worrisome: just 36% of hospitals have W

WTP facilities, and 64% of hospitals release untreated wastewater straight into infiltration wells or receiving water bodies (Pariente et al., 2022). Since the hospital's founding, there have been issues with tub recycling that prevent it from operating smoothly and with the water mass balance calculation problems. Therefore, to determine how optimal and effective the WWTP's performance is in treating wastewater, an evaluation pertaining to good and acceptable WWTP performance is required.

A well-operated and efficient WWTP is essential to ensure that the effluent discharged complies with established quality standards, making it safe for release into the environment or nearby rivers without endangering ecosystems or reducing environmental quality. In this study, the evaluation process involved comparing the volume of influent entering the WWTP with its treatment capacity, alongside assessing the performance of individual treatment units against design criteria obtained from relevant literature (Ali et al., 2023). The evaluation is expected to enhance both the efficiency and effectiveness of WWTP. The objective of this study is to assess the hospital's WWTP system and provide recommendations for optimizing wastewater treatment technology. Specifically, the research seeks to identify and analyze the characteristics of influent and effluent wastewater produced by the hospital's WWTP, thereby supporting efforts in resource recovery within the treatment process.

RESEARCH METHOD

Research Design, Setting, and Sample

This study was carried out at WWTP of the Hospital. The evaluation focused on assessing the WWTP's performance by referring to design criteria from various literature sources, calculating wastewater treatment efficiency, and analyzing resource use and recovery under existing conditions, applying the PICO Analysis framework.

Measurement and Data Collection

The research process began with a field survey, literature review, formulation of hypotheses, and data collection for evaluation purposes. Both primary and secondary data were used, including records of wastewater quality at the inlet and outlet of the hospital IPAL, photos of all treatment units, and operational data of the WWTP. These were followed by data compilation, evaluation of each operational and process unit, and calculations of the effectiveness and performance of the system.

Data Analytics

The evaluation was conducted by comparing hospital wastewater quality test results with applicable quality standards, and by analyzing dimensional calculations of the existing treatment units against design criteria from relevant literature. Additionally, the study examined resource use and recovery in current conditions, with consideration of the potential for processing wastewater into clean water suitable for uses such as irrigation. The findings of the evaluation of the hospital's IPAL are presented in the following section.

RESULTS AND DISCUSSIONS

1. Performance of IPAL

Based on one month of analysis data, the efficiency (%) of the biological treatment unit specifically the activated sludge system, which includes the aeration tank and settling tank in reducing organic matter can be calculated.

Table 1. Efficiency (%) TSS parameters(Preisi Goni, Isri R. Mangangka, 2021)

Date and month	influent aeration tank (mg/L)	tank effluent precipitator (mg/L)	Efficiency (%)	(*)Standard Efficiency
22 June	333	48	86	50-60%
3 July	220	164	25	50-65%
9 July	300	64	79	50-65%
22 July	58	56	3	50-65%
Average	227,83	83	64	50-65%

Based on Table 1, the average efficiency of the TSS parameter in the settling tank over one month was 64%. This value falls within the acceptable efficiency range when compared to standard criteria. However, the monthly average cannot be fully relied upon as a reference, since on April 2 and April 16 the TSS efficiency was recorded below the required standard.

Table 2. Efficiency (%) BOD parameters(Basoeki et al., 2018) (Preisi Goni, Isri R. Mangangka, 2021)

Date and month	Tub influent	tank effluent	Efficiency	(*)Standard

	Aeration (mg/L)	precipitator (mg/L)	(%)	Efficiency
22 June	197.31	136	31	85-90%
3 July	80.78	64.68	14	85-90%
9 July	109.47	100.60	8.1	85-90%
22 July	237.97	115.19	51.6	85-90%
Average	156.38	105.37	26.13	85-90%

Based on Table 2, the average one-month efficiency of the BOD parameter in the activated sludge unit was 26.13%. When compared with the efficiency standard of 85–90% set by Metcalf and Eddy (2004), it indicates that the WWTP unit is not performing optimally in reducing organic matter.

2. Performance Wastewater Treatment Unit Dimensions

a. **Barscreen**

Table 3 shows the barscreen unit operating parameters.(Custodio et al., 2022)

Number	Parameter	Design criteria	Mark	Unit	Information
1	Flow velocity as it passes through the bar screen	0.3-0.6	0.5	m/s	In accordance
2	Press loss through the stem (HL)	<150	5.5	m^3	In accordance
3	Hydraulic radius (R)	-	35.58	m	-

Based on the above calculations, all screening unit parameters at the hospital WWTP comply with the design criteria. Therefore, the dimensions of the bar screen are considered appropriate and do not require modification.

b. **Disinfection Tub**

Table 4. Disinfection bath unit operating parameters (Khan et al., 2022)

Number	Parameter	Design criteria	Unit	Condition Existing	Results Evaluation
1	Debit	-	m3/day	166.3	166.3
2	Depth	-	m	0.4	0.3
3	Long	-	m	0.7	1.9
4	Wide	-	m	0.6	0.2
5	Horizontal Speed	2-4.5	m/min	1,408	2
6	Contact Time	15-45	minute	34.48	15

Table 4 displays the initial dimensions of the hospital WWTP filtration tank were 0.7 m × 0.6 m × 0.4 m. However, after recalculation, the revised dimensions of the filtration tank unit were 2.05 m × 0.205 m × 0.208 m.

3. Unit Planning Resources and Recovery

The anaerobic digester of the fixed-dome type is constructed by excavating the ground and building an airtight chamber using bricks, sand, and cement in the shape of a dome or half-sphere. This design, originally developed in China, is also known as the dome type (Isnaeni, 2022). In this system, biogas accumulates in the upper dome section, while the lower part functions as the digester for wastewater treatment. The results of resource and recovery planning for this unit are presented in Table 5.

Table 5 anaerobic digester planning parameters (renfrew et al., 2022)(bijekar et al., 2022)

parameter	unit	mark
tss	kg/ m^3	166.3
q waste water	m^3/day	0.022
v dome tota	m^3	0.275
v biofilter media	m^3	27.5

overall volume (dome + biofilter media)	m^3	27.125
detention time (td)	o'cloc	3.914
long	m	3
wide	m	1.5
depth	m	6

based on the design of the anaerobic digester unit, the dimensions are 3 m × 1.5 m × 6 m. the inclusion of this unit serves to recover methane gas (ch_4), generated through the conversion of approximately 40–60% of organic solids into methane (ch_4) and carbon dioxide (co_2). the treated effluent produced can then be reused for purposes such as plant irrigation, washing, and flushing.

CONCLUSION

The average treatment efficiencies obtained were 26.13% for BOD, 29% for COD, 13% for PO_4, 26% for NH_3, and 64% for TSS. These values remain below the standard efficiency range of 85–90%, except for TSS, which falls within the 50–65% range; however, TSS efficiency alone cannot be used as a reliable reference. The BOD/COD ratio across all IPAL units was within the ideal range of 0.5–1, indicating that the wastewater is biodegradable.

From the evaluation of the wastewater treatment units, several conclusions can be drawn. Based on water quality test results and treatment performance, the degradation efficiency of wastewater parameters was found to be very effective, effective, and moderately effective, with all tested parameters meeting the applicable quality standards. However, according to Regulation No. 69 of 2013 on wastewater quality standards for business and/or processing activities, several IPAL units—namely the equalization tank (TAR), primary settling tank (PST), activated sludge, trickling filter, filtration unit, disinfection unit, and recycling tank—did not comply with the prescribed design criteria. Therefore, readjustment of unit dimensions is necessary to meet the required design standards, along with the addition of resource and recovery units, such as an anaerobic digester, to enhance overall treatment performance.

Compliance with ethical standards

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Statement of informed consent: As authors, we affirm that all actions undertaken in this study were carried out with mutual agreement and consent.

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