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Analysis of The Effectiveness of the Wastewater Treatment Installation and The Quality of Liquid Waste at XYZ Hospital in Cilegon City

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ABSTRACT

WWTP in Cilegon City demonstrates a strong commitment to controlling environmental pollution through the operation of its Wastewater Treatment Plant (WWTP). This study aims to evaluate the quality of treated effluent and assess the effectiveness of the WWTP in reducing key pollution parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and free ammonia (NH_3-free). Wastewater samples were collected from the WWTP inlet every three months and from the outlet monthly, each consisting of 2 liters, and analyzed in accordance with Indonesian environmental standards (PERMENLH No. 5 of 2014). The analysis showed that the treated effluent met regulatory quality standards, with pollutant removal efficiencies reaching 96.55% for TSS, 87.28% for BOD, 79.86% for COD, and 99.76% for NH_3-free. These findings indicate that the WWTP functions effectively, with high removal efficiency for both organic and inorganic pollutants, thus ensuring compliance with environmental regulations and highlighting its success as a model for Hospital wastewater management.

Keywords: Hospital, Waste Water Treatment, COD, BOD, TSS

1. INTRODUCTION

Hospital as health service institutions produce complex and varied liquid waste, caused by various medical and non-medical activities. This liquid waste generally contains domestic, pharmaceutical, laboratory, and infectious waste components, which if not managed properly can pollute the environment by increasing levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and pathogenic microorganisms. In Indonesia, the management of Hospital liquid waste is regulated in the Decree of the Minister of Environment No. 5 of 2014, which requires every Hospital to treat wastewater to meet environmental quality standards before being discharged. The implementation of effective treatment technologies—both biologically, chemically, and physically—is essential to ensure compliance with regulations and minimize the risk of pollution [1] [2].

XYZ Hospital in Cilegon City is a real example of a health institution that has a high commitment to environmental management through the operation of a wastewater treatment plant (WWTP) that is in accordance with legal provisions. The WWTP system implemented at WWTP utilizes a combination of physical, chemical, and biological processes to reduce pollutant levels such as BOD, COD, TSS, and the burden of pathogenic microorganisms before the wastewater is released into the environment [3]. The application of the precautionary principle in medical waste management at XYZ Hospital also supports sustainable development goals and maintains the health of the aquatic ecosystem around the Hospital. Evidence from various similar studies in Indonesia shows that WWTP that is optimally designed and operated is able to protect public health and environmental quality [1].

In general, Hospital waste is classified into three main groups, namely solid, liquid, and gas waste. Each category of waste has its own characteristics and has the potential to cause serious environmental impacts if not handled with the right processing methods [4]. Hospital liquid waste, especially that classified as hazardous and toxic waste (B3), generally contains toxic, pathogenic, and infectious compounds. If this waste is not treated adequately, its contents can accumulate in the food chain and pollute the surrounding environment, including soil, water, and have an impact on living organisms such as plants, animals, and humans. This not only threatens public health, but can also reduce environmental quality and damage natural resources sustainably.

Therefore, every hospital is required to carry out thorough waste treatment before discharging it into the receiving water body. This treatment must comply with the standard quality of Hospital wastewater as stipulated in national regulations such as the Decree of the Minister of Environment No. 05 of 2014 and the Regulation of the Minister of Environment and Forestry No. 68 of 2016. One of the technologies used is the Wastewater Treatment Plant (WWTP), which aims to significantly reduce pollutant parameters such as BOD, COD, TSS, pH, temperature, and free ammonia [5].

Based on these problems, this study aims to analyze the quality of liquid waste at the WWTP outlet and evaluate the effectiveness of its WWTP system. The evaluation was carried out by assessing the efficiency of reducing the main parameters such as BOD, COD, TSS, temperature, pH, and free ammonia. The results of similar studies show that the effectiveness of wastewater treatment systems in several Hospitals in Indonesia is able to reduce pollutant parameters by more than 90%, although some still face challenges in controlling pH and ammonia.

2. MATERIALS AND METHODS

2.1. Materials

This study used liquid waste as the main material taken from two collection points, namely the inlet and outlet of the Wastewater Treatment Plant (WWTP) at XYZ Hospital in Cilegon City. Each sample of liquid waste was collected as much as 2 liter per point by considering the specified collection frequency. The liquid waste taken reflects the characteristics of water quality before and after the treatment process, which is then analyzed to assess the effectiveness of WWTP performance in reducing pollutant levels.

The tools used in the research process include sterile sampling bottles that function to take and store samples, and a camera used to document sampling activities in the field. Temperature measurements were taken using a digital thermometer directly during sampling. For laboratory analysis purposes, a set of standard test equipment was used to measure wastewater quality parameters, namely Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), pH, temperature, and free ammonia (NH_3). All tools used have met water quality analysis standards to ensure the accuracy and validity of the data obtained.

2.2. Experimental procedure

This study was conducted over a period of six months, located at WWTP of XYZ Hospital in Cilegon City. Sampling of liquid waste was carried out at two strategic points, namely the inlet (entering the wastewater treatment plant) and outlet (exiting the wastewater treatment plant) at Wastewater Treatment Plant. The frequency of sampling was determined differently for each point: samples at the inlet were taken every three months, while samples at the outlet were taken once a month.

Each sample was collected as much as 2 liter using a sterile sampling bottle to maintain authenticity and prevent contamination. All samples that had been coded and packaged with standard procedures were then sent to an accredited laboratory for analysis based on standardized parameters, referring to the provisions of the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Hospital Wastewater Quality Standards. The effectiveness of the wastewater treatment plant was calculated based on the percentage reduction in pollutant levels from the inlet to the outlet. Evaluation of liquid waste quality is also carried out by comparing water quality data with quality standards adjusted based on Decree of the Minister of Environment No. 115 of 2003 concerning Guidelines for Determining Water Quality Status, also known as the STORET method.

3. RESULTS AND DISCUSSION

This study aims to evaluate the effectiveness of the Wastewater Treatment Plant (WWTP) of XYZ Hospital based on the parameters of liquid waste water quality, namely temperature, TSS, BOD, COD, pH, and free ammonia (NH_3). The evaluation was carried out by comparing the measurement results between the inlet and outlet sections of the WWTP and assessing the effectiveness of treatment for each parameter.

3.1. Temperature

The results of wastewater temperature measurements in the wastewater treatment plant showed that the average outlet temperature of 29.5°C remained within the optimal range for the biodegradation process. This temperature condition plays an important role in maintaining the activity of dominant decomposing microorganisms in biological treatment. According to Quraini et al. [6], the optimal temperature for the anaerobic process in the wastewater treatment plant is between 35–55°C, while the aerobic process remains effective at temperatures around 25–35°C, which indicates that the outlet temperature at wastewater treatment plant still supports the biodegradation process efficiently.

Table 1. Temperature data at inlet and outlet

Month	Temperature (^{0}C)		Standard Limit (^{0}C)
	Inlet	Outlet	
1	30	30	
2	30	30	
3	30	30	30
4	30	30	
5	30	28	
6	30	28	
Average	30	29.5	

The insignificant decrease in temperature indicates that the treatment process does not cause drastic thermal changes that could affect the balance of the microbiological ecosystem in the WWTP. Another study by Aniriani et al. [7], also confirmed that controlling temperature within the optimal range can accelerate the pollutant degradation process, so that the efficiency of wastewater treatment increases significantly. In addition, Pasetia & Nurkhasanah [8], showed that a stable temperature in the WWTP helps maintain dissolved oxygen levels which are essential for the activity of aerobic bacteria in the biodegradation process. Therefore, achieving a stable and appropriate temperature in wastewater treatment plant strengthens the statement that the treatment process carried out has been carried out optimally in supporting the balance of the microbiological ecosystem in the treatment system.

3.2. Total Suspended Solid (TSS)

The effectiveness of TSS reduction of 96.55% achieved by the wastewater treatment plant shows excellent performance in controlling physical parameters of wastewater. This level of efficiency far exceeds the results of several previous studies. Rhofita & Russo [9], reported that the treatment of sugar industry wastewater at WWTP in Kediri and Sidoarjo Regencies achieved an average TSS reduction effectiveness of 89%, with the sedimentation process as a key stage in the treatment.

Similarly, Rarasari et al. [10],in a study at the Suwung Denpasar WWTP noted that the effectiveness of TSS reduction was greatly influenced by the efficiency of sedimentation in the sedimentation pond and effluent canal, which could support the overall performance of the WWTP. In addition, Wibowo & Yogisutanti [11], found that the application of an aerobic biological system at the Dr. HA Rotinsulu Lung Hospital was able to reduce TSS to an effectiveness of 94%, which emphasized that the combination of sedimentation and biological processes was very effective in reducing suspended solids content in Hospital wastewater.

Table 2. TSS data on waste input and output

Month	TSS (mg/L)		Standard Limit (mg/L)	Treatment Effectiveness (%)
	Inlet	Outlet		
1	52	4		
2	52	3		
3	52	3		
4	151	2	30	96.55
5	151	7		
6	151	2		
Average	101.5	3.5		

Compared to Arifin's [12] study at the X Hospital, Banjar Regency, which recorded a TSS effectiveness of 86%, the results at the XYZ HOSPITAL showed higher efficiency. This reflects the high effectiveness of the sedimentation and filtration processes in the WWTP system. The final TSS value was much lower than the threshold of 30 mg/L. The achievement of the wastewater treatment plant which is higher than the average literature indicates that the design and operation of the sedimentation and filtration units have been running optimally, so that they are able to meet and exceed the established quality standards.

3.3. Biochemical Oxygen Demand (BOD)

The effectiveness of BOD reduction of 87.28% in the wastewater treatment plant shows excellent treatment system performance, especially in the biofilter unit and aeration process. This reduction rate is higher than the research results of Manurung et al. [13], at Ansari Saleh Hospital which recorded an effectiveness of 81.6%, reflecting that the design and operation of the biological unit in the wastewater treatment plant have been optimal in decomposing organic compounds that require dissolved oxygen.

Table 3. BOD data at inlet and outlet

Month	BOD (mg/L)		Standard Limit (mg/L)	Treatment Effectiveness (%)
	Inlet	Outlet		
1	30	4		
2	30	10		
3	30	5		
4	58	4	50	87,28
5	58	9		
6	58	2		
Average	44	5.6		

Similar research by Samina et al. [14], also showed that the domestic wastewater treatment system in Cirebon City was able to achieve BOD reduction effectiveness in the range of 80-90%, where efficiency was greatly influenced by the quality of aeration and the stability of the microorganism population in the biological process [14]. In addition, Aniriani et al. [7],reported that the application of the Moving Bed Biofilm Reactor (MBBR) significantly increased the effectiveness of BOD reduction in domestic wastewater treatment plants, with reduction results reaching more than 85%.

This decrease is better than the results of Manurung et al. [13] which recorded a BOD effectiveness of 81.6% at Ansari Saleh Hospital. This shows that the wastewater treatment plant has a more optimal biofilter and aeration system in decomposing dissolved organic matter that requires oxygen.

3.4. Chemical Oxygen Demand (COD)

The effectiveness of COD decrease of 79.86% achieved by the WWTP shows very good performance, especially in handling organic and inorganic compounds that are difficult to decompose biologically. This figure is better than the study by Waang et al. [15], at the W.Z. Yohanes Kupang Hospital which recorded a reduction of only 75%, indicating that the combination of electrocoagulation and membrane filtration processes at the WWTP is able to increase the efficiency of removing non-biodegradable compounds.

Table 4. COD data at inlet and outlet

Month	COD (mg/L)		Standard Limit (mg/L)	Treatment Effectiveness (%)
	Inlet	Outlet		
1	100	18		
2	115	52		
3	115	27		
4	176	22	80	79,86
5	176	47		
6	176	10		
Average	145.5	29.3		

Another study by Samina et al. [14], also showed that the effectiveness of COD reduction in domestic wastewater treatment plants in Cirebon City can reach 80-85% if the aeration and biological treatment processes run optimally. In addition, Aniriani et al. [7], reported that the addition of Moving Bed Biofilm Reactor (MBBR) in wastewater treatment plants can increase COD reduction due to the efficiency of biofilm in decomposing complex organic substances. Similar research by Rarasari et al. [10], at Suwung Denpasar Wastewater Treatment Plant showed that optimizing the organic material decomposition process at the biological stage greatly contributed to increasing the effectiveness of COD reduction to nearly 80%, reinforcing that the right combination of technologies is the key to the success of wastewater treatment plants. Thus, the use of combination technology at Wastewater Treatment Plant has proven effective in improving the performance of wastewater treatment systems, so that they can meet environmental quality standard requirements.

3.5. pH

The stability of the wastewater pH in the WWTP, which was recorded at an average of 8.03 after the treatment process, shows that the treatment system is able to maintain an optimal environment for biological processes. The pH value that remains within the standard quality range of 6–9 supports the continuity of microorganism activity, especially in the aeration process. This is in line with research by Rawis et al. [16], which shows that a stable pH in the Hospital wastewater treatment is an indicator of the success of controlling the wastewater treatment process and contributes to the effectiveness of the decomposition of organic compounds.

Table 5. pH data at inlet and outlet

Month	pH		Standard Limit
	Inlet	Outlet	
1	8	8	
2	8	8.2	
3	8	8	
4	8	8	6-9
5	8	8	
6	8	8	
Average	8	8.03	

In addition, Ahmad et al. [17], also reported that pH stability in biological reactors is greatly influenced by the balance of alkalinity and volatile acids produced during wastewater treatment, where pH control is key to maintaining optimal performance of the WWTP unit. These results are also consistent with the findings of Hutabarat et al. [18] , which emphasize that proper pH regulation will increase colloid stability and sedimentation processes, so that the quality of the wastewater produced meets environmental quality standards [18]. Thus, pH stability in the wastewater treatment plant strengthens the role of the treatment system in producing effluent that is safe for the environment.

3.6. Free Amonia (NH_3)

The 99.76% reduction in free ammonia (NH_3) achieved by the wastewater treatment plant demonstrates a very superior performance in the nitrogen treatment process. This finding far exceeds the effectiveness of conventional contact aeration systems—for example, membrane bioreactors (MBRs) demonstrated ammonia removal capabilities of up to 98.3%, as recorded in pilot studies on industrial wastewater Dvorak et. al [19]—confirming the superiority of implementing biofilter and membrane bioreactor technologies in modern wastewater treatment systems.

Table 6. Free NH3 data at inlet and outlet

Month	Free Amonia (NH_3)		Standard Limit (mg/L)	Treatment Effectiveness (%)
	Inlet	Outlet		
1	4	0.2		
2	4	0.9		
3	4	0.01		
4	1.3	0.06	1	99.76
5	1.3	0.01		
6	1.3	0.02		
Average	2.65	0.02		

The nitrification process that occurs in the biofilter plays a key role, where nitrifying bacteria convert ammonia to nitrate, thereby significantly reducing wastewater toxicity. A study by Rarasari et al. [10], at the Suwung Denpasar WWTP also showed that high effectiveness in reducing ammonia is closely related to pH stability, dissolved oxygen availability, and the population of nitrifying bacteria in the biological reactor unit.

In addition, a recent study by Aniriani et al. [7], reported that the integration of MBBR (Moving Bed Biofilm Reactor) can increase the efficiency of nitrogen reduction in domestic wastewater, in line with the high performance achieved at the wastewater treatment plant. With this almost perfect effectiveness, the wastewater treatment plant not only meets, but exceeds environmental quality standards for ammonia parameters, while also contributing to reducing the risk of eutrophication in receiving water bodies.

Table 7. STORET Method measurement results

Parameter	Unit	Standard Limit	Measurement Results						Total Score
			Maximal	Score	Minimal	Score	Mean	Score	
Temperature	C	30	30	0	28	0	29.1	0	0
TSS	mg/L	30	7	0	2	0	3.5	0	0
pH	-	6-9	8.2	0	8	0	8.03	0	0
BOD	mg/L	50	10	0	2	0	5.6	0	0
COD	mg/L	80	52	0	52	0	29.3	0	0
Free-NH_3	mg/L	1	0.9	0	0.01	0	0.2	0	0
Total Score STORET									0

3.7. Analisys of STORET

Evaluation of the wastewater quality of the wastewater treatment plant using the STORET method resulted in a total score of 0, which indicates that the quality of the processed water is in category A (very good). These results indicate that all standard quality parameters have been consistently met, starting from temperature, TSS, pH, BOD, COD, to free ammonia. The STORET method is a comprehensive evaluation reference because it takes into account parameter deviations from the established standards, as also stated in the study of Rawis et al. [16], where the application of the STORET method to the Bhayangkara Manado Hospital WWTP was effective in assessing the performance of Hospital wastewater treatment.

According to Hutabarat et al. [18], the stability of all parameters within the established quality limits indicates that the control of biological, physical, and chemical processes in the wastewater treatment plant is running effectively, which contributes to the achievement of a very good STORET value. Thus, the results of the STORET evaluation at the wastewater treatment plant show that the treatment system not only meets regulatory obligations but also actively contributes to maintaining environmental quality [20].

4. CONCLUSION

The results of the study indicate that the Wastewater Treatment Plant (WWTP) at XYZ Hospital which is managed by PT. Enviro Global Persada with the Decentralized Wastewater Treatment System (DEWATS) and activated sludge, is effective in treating liquid waste. Evaluation of the TSS, BOD, COD, and free-NH_3 parameters resulted in efficiencies of 96.55%, 87.28%, 79.86%, and 99.76%, respectively, with the quality of the wastewater treatment plant outlet meeting the established quality standards. The STORET method assessment showed a Total Score of 0, so that the WWTP of XYZ Hospital was categorized as class A (Meets Quality Standards) according to the Regulation of the Minister of Environment No. 5 of 2014.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Safril Kartika Wardana: Conceptualization, methodology, validation, writing – original draft. Syariful Maliki: writing – review and editing. Fikri Maulana: investigation, methodology, data curation. Dadi Cahyadi: Supervision, validation

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