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Analysis of Wastewater Treatment Performance in Animal Slaughtering Industry: Evaluation of Efficiency and Wastewater Quality

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Abstract: The slaughterhouse industry generates liquid waste with high organic loads and complex composition, which can pose environmental and public health risks. This study aims to evaluate the performance of a liquid waste treatment plant in a slaughterhouse. Quantitative methods were used for objective measurements, with sampling conducted at five key points in the wastewater treatment system. Parameters analyzed included pH, DO, COD, TSS, NH3, and fat, oil, and grease. The results showed that The Collecting Tank exhibited high COD reduction efficiencies between 87.52% and 93.89%, alongside TSS reductions ranging from 83.15% to 92.95%. Conversely, the Sequencing Batch Reactor demonstrated inefficiency in COD reduction, with outlet measurements exceeding inlet values; however, it achieved a 50.44% reduction in NH3 in one instance. The Anaerobic Tank showed significant COD reduction efficiencies from 72.66% to 98.27%, but NH3 reduction was negligible. Lastly, the Secondary Clarifier was inefficient in COD performance, with all tests indicating higher outlet results, while TSS efficiency was noted in only one test at 71.96%. The conclusion was although the Collecting Tank and Anaerobic Tank showed high efficiency in COD reduction, the Sequencing Batch Reactor and Secondary Clarifier units showed the NH3 reduction efficiency varied among the units tested.

Keywords: Liquid waste; Pollutants; Slaughterhouse; Water quality; Waste treatment.

Introduction

Because of its complex composition and high organic load, wastewater from the animal slaughtering sector presents serious environmental and public health risks. Because of its high amounts of total suspended solids (TSS), nitrogen, phosphorus, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and other pathogens, this effluent must be treated before being released into the environment (Cruz et al., 2019; Husam & Nassar, 2019; Ziara et al., 2018). Despite the recognized need for effective treatment solutions, there exists a notable research gap in understanding the specific treatment efficiencies and the quality of the treated effluent across different types of slaughterhouses, particularly in relation to the varying operational processes and animal types involved (Bustillo-Lecompte et al., 2016).

The existing literature predominantly focuses on specific treatment methodologies, such as chemical coagulation, electrocoagulation, and biological processes, yet comprehensive evaluations of their performance in real-world slaughterhouse settings remain limited. For example, while studies have demonstrated the efficacy of combined treatment approaches in achieving high removal efficiencies of contaminants (Jensen et al., 2015; Meiramkulova et al., 2020), there is insufficient data on the long-term operational performance and the quality of the effluent produced under varying conditions. Furthermore, the

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integration of advanced oxidation processes with biological treatments has been suggested as a promising avenue for enhancing treatment efficiency, but empirical studies validating these approaches in slaughterhouse contexts are sparse (Bustillo-Lecompte et al., 2016; Zamani et al., 2019).

Moreover, the variability in wastewater characteristics based on the type of animal processed and the specific operational practices employed in different slaughterhouses complicates the development of standardized treatment protocols. Research indicates that wastewater from poultry slaughterhouses, for example, exhibits distinct microbial contamination patterns compared to that from cattle slaughterhouses, necessitating tailored treatment solutions (Aksu et al., 2021; Meiramkulova et al., 2020). The regulatory frameworks governing wastewater discharge often lack specificity regarding the treatment standards required for slaughterhouse effluents, leading to inconsistent practices and potential non-compliance with environmental protection mandates (Ahmad et al., 2023; Bustillo-Lecompte & Mehrvar, 2017). This regulatory gap underscores the necessity for research that not only evaluates treatment efficiencies but also informs policy development aimed at safeguarding public health and the environment.

The novelty of this research lies in its comprehensive evaluation of a liquid waste treatment plant specifically within the context of the slaughterhouse industry, which has been underexplored in existing literature. By employing a rigorous quantitative methodology, this study not only assesses the performance of various treatment units—namely the Collecting Tank, Sequencing Batch Reactor, Anaerobic Tank, and Secondary Clarifier—but also provides a detailed analysis of their efficiencies in reducing critical pollutants such as Chemical Oxygen Demand (COD) and ammonia (NH_3). This research contributes valuable insights into the operational challenges and potential improvements for wastewater treatment processes in slaughterhouses, thereby addressing both environmental and public health concerns associated with liquid waste management in this sector.

The aim was to analyze Wastewater Treatment Performance in Animal Slaughtering Industry. The analysis of wastewater treatment performance in the animal slaughtering industry reveals significant gaps in the current body of knowledge. There is a pressing need for comprehensive studies that evaluate the efficiency of various treatment methods, the quality of the resulting effluent, and the implications of these findings for environmental management and public health. Addressing these gaps will contribute to the development of more effective and sustainable wastewater management practices in the meat processing industry.

Method

Research Design

This study uses a quantitative research design that aims to evaluate the performance of liquid waste treatment installations in slaughterhouses by referring to the Regulation of the Governor of East Java No. 72 of 2013 concerning Liquid Waste Quality Standards in Slaughterhouses. The quantitative design was chosen because it allows objective measurement and statistical analysis of the data collected, so that it can provide a clear picture of the effectiveness of liquid waste treatment in the slaughterhouses studied.

Location and Time of Research

This research was conducted in several liquid waste processing installation units inWWTP Slaughterhouselocated in East Java. Sampling was conducted during the dry season to ensure consistency in environmental conditions that can affect the quality of liquid waste. Sampling was conducted for three consecutive days, namely at 07.00 to 09.00, to minimize variations that may occur due to fluctuations in time and operational activities of theSlaughterhouse. The selection of the dry season for sampling in liquid waste processing installations at the WWTP Slaughterhouse in East Java is grounded in the need for environmental consistency. During the dry season, precipitation is minimal, thereby reducing the dilution of liquid waste and allowing for a more accurate assessment of its quality

Sampling Techniques

In this study, the sampling technique followed the SNI 8990:2021 guidelines which regulate the method of sampling liquid waste for physical and chemical testing. Samples were taken from five key points in the wastewater treatment system, namely: Collection Tank, Sequencing Batch Reactor (SBR), Anaerobic Tank, Secondary Clarifier, and Final Storage Tank. Sampling was carried out using sterile equipment to prevent contamination, and the sample volume was adjusted to the needs of laboratory analysis. Each sample was clearly labeled for easy identification and tracking, ensuring the integrity of the data obtained. This procedure is important to ensure the accuracy of the analysis results that will be used in evaluating the quality of liquid waste. By following the established standards, this study aims to produce valid and accountable data.

In adherence to the SNI 8990:2021 guidelines for sampling liquid waste, several critical components were meticulously followed to ensure the integrity and reliability of the data obtained. Specifically, the standard outlines the necessity for appropriate sample preservation techniques, which were implemented to maintain the chemical and physical properties of the samples during transport and storage. The use of sterile, pre-cleaned containers was mandated to prevent contamination, aligning with the standard's specifications regarding container type. Additionally, the volume of each sample was adjusted according to the analytical requirements, ensuring compliance with the guidelines for sufficient sample size. Each sample was labeled systematically to facilitate easy identification and tracking, a practice emphasized in the standard to uphold data integrity. Collectively, these procedural elements are vital for producing valid and accountable data, thereby supporting the overall objective of evaluating liquid waste quality effectively.

Parameters Studied

The parameters studied in this study include pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Ammonia (NH3), and Fats, Oils, and Grease (FOG). Each parameter has a specific testing method, which is explained as follows: pH: pH measurements are carried out using a previously calibrated pH meter. Measurements are carried out directly at the sampling location to obtain accurate and representative results; Dissolved Oxygen (DO): DO measurements are carried out using a DO meter. This tool is also calibrated before use to ensure the accuracy of the measurement results; Chemical Oxygen Demand (COD): COD testing is done using the closed reflux method, where the sample is refluxed in an acidic environment and then measured using a Proof 600 Spectrophotometer. This method was chosen because of its ability to provide fast and accurate results in determining the levels of organic matter in waste; Total Suspended Solids (TSS): TSS testing is carried out using the gravimetric method, where the liquid waste sample is filtered using filter paper, then the weight of the residue left behind is measured to determine the amount of suspended solids; Ammonia (NH3): Ammonia level testing is done using the Hach reagent method with the Hach DR900 tool. This method involves adding certain reagents to the sample which produces a color that can be measured with a spectrophotometer to determine the concentration of ammonia; and Fats, Oils, and Grease (FOG): FOG testing is carried out in accordance with SNI 6989.10-2011, which involves the extraction and measurement of fat, oil, and grease levels in liquid waste samples.

Laboratory Analysis Procedures

After sampling, all samples were taken to the laboratory for analysis. The samples were stored under appropriate conditions to prevent changes in physical and chemical properties before analysis. Each parameter was tested according to a predetermined method, and the test results were carefully recorded for further analysis.

Data analysis

The data obtained from laboratory testing will be analyzed to determine the performance of the WWTP in meeting the standards set by the Regulation of the Governor of East Java No. 72 of 2013. This study used statistical methods such as descriptive statistics, to measure how often WWTPs met or exceeded regulatory thresholds for pH, DO, COD, TSS, NH3, and FOG. This approach will provide a comprehensive assessment of WWTP effectiveness and compliance, thereby increasing the rigor and relevance of the study.

Result and Discussion

Slaughterhouses in Indonesia are an industry engaged in slaughtering animals from live animals into ready-to-process materials. The liquid waste produced in a day reaches 150-165 m3/day depending on how many cows are slaughtered in one day. In this slaughterhouse, he can slaughter about 50 cows per day. The wastewater produced from these several rooms is then flowed into the waterways to the wastewater treatment plant (WWTP).

In the initial stage, the liquid waste flows after the Pre-treatment, ie to the Primary Treatment, then flows to the Secondary Treatment before being discharged into the water body. Waste is discharged into water bodies in conditions that must comply with quality standards.

Table 1 provides an overview of the existing conditions and residence times of the various units in the wastewater treatment system (WWTP). The first unit, the Collecting Tank, has dimensions of 4m x 6m x 6m and a volume of 144 m^3, with a concrete construction. The designed residence time is 4-8 hours, but the existing residence time is recorded much higher, at 20.9 hours. Next, the Sequencing Batch Reactor measures 2m x 6m x 7m and has a volume of 84 m^3, also made of concrete. Its design criteria are 18-30 hours, but the existing residence time reaches 73.3 hours, indicating a significant discrepancy. The Anaerobic Tank has dimensions of 4m x 12m x 2m and a volume of 96 m^3, with a designed residence time of 12-48 hours, but the existing one is only 13.9 hours. Finally, the Secondary Clarifier and Final Holding Tank have the same dimensions (3m x 3m x 2.5m) and a volume of 22.5 m^3, with a designed residence time of 2-6 hours, but the existing recorded 3.2 hours for both.

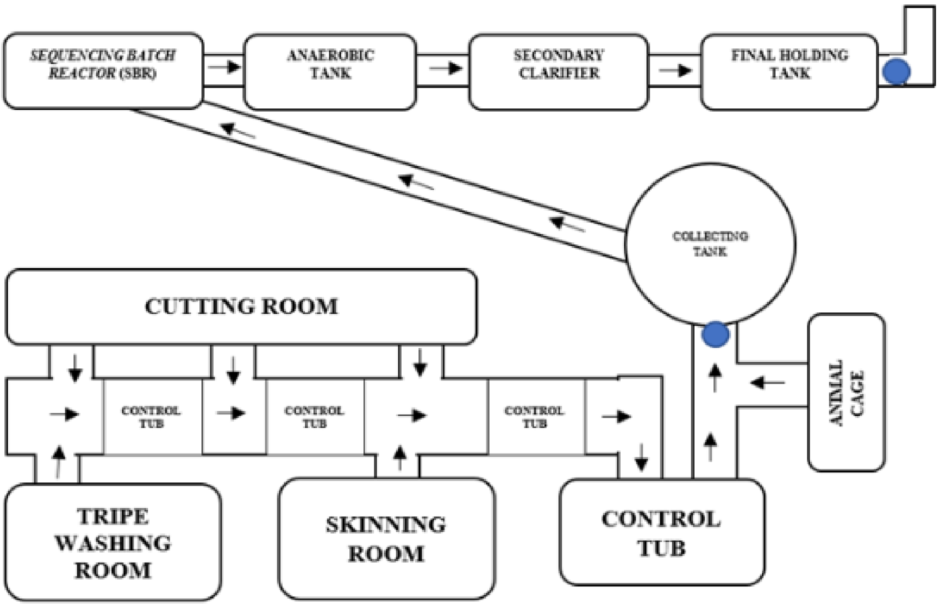

Figure 1. Wastewater Treatment Flow

Table 1. Existing Conditions of WWTP Slaughterhouse

WWTP Units	Building Dimension (meters)			Volume	Building	Time of Detention (hour)	
	Length	Width	Height	(m^3)	Construction	Design Criteria	Existing
Collecting Tank	4	6	6	144	Concrete	4-8	20.9
Sequencing Batch Reactor	2	6	7	84	Concrete	18-30	73.3
Anaerobic Tank	4	12	2	96	Concrete	12-48	13.9
Secondary Clarifier	3	3	2.5	22.5	Concrete	2-6	3.2
Final Holding Tank	3	3	2.5	22.5	Concrete	-	3.2

Table 2 presents the characteristics of the slaughterhouse wastewater, measured at various stages of treatment. The parameters analyzed include pH, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Ammonia (NH3), and Fat, Oil, and Grease (FOG). At the Collecting Tank stage, the pH was stable at 7.0, indicating a neutral condition, while COD, TSS, NH3, and FOG showed high values, reflecting significant levels of pollution. The results from the Sequencing Batch Reactor showed a decrease in COD and NH3, indicating the effectiveness of the wastewater treatment. In the Anaerobic Tank, COD and NH3 again showed high values, indicating the need for further attention in anaerobic treatment. At the Secondary Clarifier stage, there was a significant decrease in COD and TSS, indicating the success of the clarification process. Finally, in the Final Holding Tank, although the pH remained stable, the COD, TSS, NH3, and FOG values showed significant variations, indicating that the wastewater still requires further treatment before being discharged.

Table 2. Characteristics WWTP Slaughterhouse

Part	Parameters	Test Result			Average
		Testing 1	Testing 2	Testing 3	
Collecting Tank	pH	7.0	7.0	7.0	7.0
	COD (mg/L)	15910	9813	17893	14538
	TSS (mg/L)	3870	5230	2524	3874
	NH3 (mg/L)	2976	6672	8786	6145
	FOG (mg/L)	2256	2132	5780	3389
Sequencing Batch Reactor	SV30 (mg/L)	<100	<100	<100	<100
	DO (mg/L)	2.48	1.87	1.88	2.08
	COD (mg/L)	1334	600	2233	1389
	NH3 (mg/L)	4484	6964	9226	6891
Anaerobic Tank	COD (mg/L)	18237	1745	6096	8692
	NH3 (mg/L)	2222	10570	9773	7552
Secondary Clarifier	COD (mg/L)	316	477	441	411.33

Part	Parameters	Test Result			Average
		Testing 1	Testing 2	Testing 3	
	TSS (mg/L)	328	881	178	462.33
Final Holding Tank	pH	7.0	7.0	7.0	7.0
	COD (mg/L)	1685	464	338	829
	TSS (mg/L)	281	247	212	246.67
	NH3 (mg/L)	4068	12658	12658	9795
	FOG (mg/L)	1452	187	140	593

Table 3 presents the performance of wastewater treatment from a slaughterhouse wastewater treatment plant (WWTP) with a focus on water quality parameters, including Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS), as well as ammonia (NH_3). This table is divided into several sections, namely the collecting tank, Sequencing Batch Reactor (SBR), Anaerobic Tank, and Secondary Clarifier. In the collecting tank, the COD and TSS removal efficiencies showed good results, with COD removal efficiencies reaching up to 93.89% and TSS up to 92.95%, indicating efficient performance. However, in the SBR, despite COD measurements, no removal was recorded, indicating that the system is inefficient in treating COD. In the Anaerobic Tank, the COD removal efficiency was also very high, reaching 98.27%, but NH3 removal was unsuccessful. Finally, in the Secondary Clarifier, the results showed that although there was efficiency in TSS removal in one test, most tests showed inefficient performance in treating COD and TSS. Overall, this table illustrates the variation in wastewater treatment efficiency at different stages of the process, with some stages showing good performance, while others are inefficient.

Table 3. Performance of WWTP Slaughterhouse

Part	Parameters	Measurement	Test Result		Efficiency Standards %	Efficiency Removal %	Performance
			Inlet	Outlet			
Collecting tank	COD (mg/L)	Testing 1	15910	1334	40-60	91.66	Efficient
		Testing 2	9813	600		93.89	Efficient
		Testing 3	17893	2233		87.52	Efficient
	TSS (mg/L)	Testing 1	3870	328	50-65	91.52	Efficient
		Testing 2	5230	881		83.15	Efficient
		Testing 3	2524	178		92.95	Efficient
Sequencing Batch Reactor	COD (mg/L)	Testing 1	1334	18237	60-80	Not Removed	Not Efficient
		Testing 2	600	1745		Not Removed	Not Efficient
		Testing 3	2233	6096		Not Removed	Not Efficient
	NH3 (mg/L)	Testing 1	4484	2222	50-65	50.44	Efficient
		Testing 2	66964	10570		Not Removed	Not Efficient
		Testing 3	9226	9773		Not Removed	Not Efficient
Anaerobic Tank	COD (mg/L)	Testing 1	18237	316	40-60	98.27	Efficient
		Testing 2	1745	477		72.66	Efficient
		Testing 3	6096	441		92.77	Efficient
	NH3 (mg/L)	Testing 1	2222	4068	10-30	Not Removed	Not Efficient
		Testing 2	10570	12658		Not Removed	Not Efficient
		Testing 3	9773	12658		Not Removed	Not Efficient
Secondary Clarifier	COD (mg/L)	Testing 1	316	1685	30-60	Not Removed	Not Efficient
		Testing 2	477	464		2.73	Not Efficient
		Testing 3	441	338		23.36	Not Efficient
	TSS (mg/L)	Testing 1	328	281	50-65	14.33	Not Efficient
		Testing 2	881	247		71.96	Efficient
		Testing 3	178	212		Not Removed	Not Efficient

Substantial differences between intended and actual residence durations are identified when the current circumstances and residence times of different units in the wastewater treatment plant (WWTP) are analysed. These differences can have a substantial impact on the efficacy and efficiency of the treatment operations. For instance, the collecting tank currently runs at an average of 20.9 hours even though it is intended for a residence duration of 4–8 hours. The total treatment effectiveness and the quality of the effluent generated may be impacted by problems like solids sedimentation and possible anaerobic conditions brought on by this prolonged residence time (Bugajski et al., 2016; Hegazy & Gawad, 2016; Kurek et al., 2020). The implications of such discrepancies are critical, as they can result in the accumulation of pollutants and reduced treatment performance, necessitating a thorough evaluation of operational parameters and design specifications (Hegazy & Gawad, 2016; Janna, 2016).

With a planned residence duration of 18–30 hours and an actual recorded time of 73.3 hours, the Sequencing Batch Reactor (SBR) exhibits an even more noticeable discrepancy. This considerable over-residence period may be a symptom of operational inefficiencies, such as the retention of wastewater at excessive levels, which could result in higher amounts of byproducts and increased biological activity, which could make downstream processing more difficult (Brantley et al., 2021; Hegazy & Gawad, 2016; Winck et al., 2023). The SBR's function relies heavily on the balance between aeration and settling phases, and prolonged residence times could disrupt this balance, leading to suboptimal treatment outcomes (Hegazy & Gawad, 2016; Pangaribuan et al., 2024). Furthermore, the extended residence time may also contribute to the degradation of certain pollutants (Waangsir et al., 2023; Waangsir et al., 2023), but it could also result in the formation of undesirable by-products, highlighting the need for careful monitoring and management of residence times in such systems (Kurek et al., 2020; Westgate & Park, 2010).

The Anaerobic Tank, on the other hand, exhibits a somewhat closer alignment with its intended residence period, with an existing time of 13.9 hours and a designed range of 12-48 hours. This shows that the tank is functioning as planned, which is essential for preserving the anaerobic conditions required for the biological treatment of organic materials (Handriyono & Rukmi, 2022; Hegazy & Gawad, 2016; Nasr & Mikhaeil, 2015). However, the lower end of the designed range suggests that there may be opportunities to optimize the process further, potentially increasing the efficiency of organic matter degradation and biogas production (Handriyono & Rukmi, 2022; Hegazy & Gawad, 2016). The performance of anaerobic systems is highly dependent on the hydraulic retention time, and maintaining this within optimal ranges is essential for maximizing treatment efficiency (Bugajski et al., 2016; Hegazy & Gawad, 2016).

The performance of secondary clarifiers is crucial in wastewater treatment, as they facilitate the separation of suspended solids from treated effluent, thereby influencing effluent quality and compliance with discharge standards. The designed residence time of 2-6 hours, with an actual time of 3.2 hours, is concerning as it approaches the lower limit of the design range, potentially compromising settling efficiency and sludge separation (Hadi Ghawi & Naji Abudi, 2012). Studies indicate that even minor deviations from optimal residence times can significantly affect the settling behavior of activated sludge, leading to increased suspended solids in the effluent (Ospanov et al., 2018). Furthermore, the hydrodynamics within the clarifier play a vital role in achieving effective solids removal, and non-ideal conditions can exacerbate settling issues. Therefore, continuous monitoring and optimization of residence time and operational parameters are essential to ensure the clarifier operates within its design specifications and maintains high effluent quality (Daigger et al., 2018).

The discrepancies in residence times across various units of wastewater treatment plants (WWTPs) highlight the necessity for continuous monitoring and evaluation of operational parameters. While some units function within acceptable limits, others may require strategic adjustments to align with design specifications, which is essential for enhancing treatment efficiency and ensuring compliance with environmental regulations (Drewnowski et al., 2019; Zaky et al., 2022). The optimization of residence times is critical, as it directly impacts the overall performance of WWTPs, particularly in terms of nutrient removal and energy consumption (Lu et al., 2024; Szeląg et al., 2022). These advancements can lead to more effective management of influent parameters, ultimately enhancing effluent quality and reducing operational costs (Al-Khuzaie & Abdul Maulud, 2023; Nair et al., 2022).

An examination of the treatment of wastewater from slaughterhouses provides important information on how well different phases of treatment reduce pollutants. Ammonia (NH_3), Total Suspended Solids (TSS), pH, Chemical Oxygen Demand (COD), and Fat, Oil, and Grease (FOG) are among the characteristics that are measured. The pH was continuously recorded at 7.0 during the Collecting Tank stage, indicating a neutral state that is necessary for the best possible microbial activity during the following treatment procedures. Nonetheless, the elevated levels of COD, TSS, NH3, and FOG at this point indicate substantial organic pollution levels in the environment, requiring efficient treatment methods to lessen the effects (Dlamini et al., 2021; Meyo et al., 2021).

The Sequencing Batch Reactor (SBR) stage showed a significant drop in COD and NH_3 levels, indicating that organic matter and nitrogenous chemicals are efficiently reduced by this biological treatment technique. In order to achieve reduced COD levels, the SBR's fill-and-draw mechanism enables improved microbial breakdown of pollutants during the aeration phase (Mohammad et al., 2021). The reduction in these parameters indicates that the SBR is a vital component in the overall treatment process, as it utilizes microbial metabolism to convert organic pollutants into less harmful substances (Del Nery et al., 2016). Since the SBR uses microbial metabolism to transform organic pollutants into less hazardous chemicals, the decrease in these parameters suggests that it is an essential part of the entire treatment process (Sadeghi & Jackson, 2024). The high COD and NH_3 levels suggest that further optimization of the anaerobic process is necessary, potentially through the integration of additional treatment technologies or modifications to operational parameters (Mohammad et al., 2021).

The Secondary Clarifier stage showed a significant reduction in both COD and TSS, highlighting the effectiveness of this process in separating solids from the treated wastewater. The clarification process is essential for removing suspended solids, which can hinder the performance of downstream treatment processes and negatively impact effluent quality (Bakiri & Nacef, 2013; Piani et al., 2014). The reduction in TSS is particularly important as it correlates with improved water clarity and reduced turbidity, which are critical for meeting discharge standards (Yue et al., 2020). This stage is often enhanced by optimizing hydraulic retention times and ensuring proper floc formation to maximize solid-liquid separation (Bakiri & Nacef, 2013).

Finally, the Final Holding Tank stage maintained a stable pH of 7.0; However, the significant variations in COD, TSS, NH3, and FOG values indicate that the wastewater still requires further treatment before discharge. This stage serves as a buffer to allow for additional settling and potential biological treatment, but the persistence of high pollutant levels suggests that the treatment process may not be fully optimized (Meyo et al., 2021). The variability in these parameters could be attributed to fluctuations in influent quality or operational inconsistencies, underscoring the need for continuous monitoring and adjustment of treatment processes to ensure compliance with environmental regulations (Zhao et al., 2014). In summary, the treatment of slaughterhouse wastewater involves multiple stages, each contributing to the overall reduction of pollutants. While the SBR and Secondary Clarifier stages demonstrate effective pollutant removal, challenges remain in the Anaerobic Tank and Final Holding Tank stages. Continuous optimization and integration of advanced treatment technologies are essential for enhancing the efficiency of wastewater treatment processes and ensuring the protection of water resources (Mohammad et al., 2021; Sadeghi & Jackson, 2024; Zhao et al., 2014).

The performance of wastewater treatment in a slaughterhouse wastewater treatment plant (WWTP) reveals significant variability across different treatment stages, particularly concerning Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and ammonia (NH3) removal efficiencies. The data presented indicates that the collecting tank demonstrates strong performance, achieving COD removal efficiencies of up to 93.89% and TSS removal efficiencies reaching 92.95% across multiple tests. This high efficiency can be attributed to effective sedimentation processes that facilitate the removal of suspended solids, as supported by findings from Mahvi et al. and Patel et al., who reported similar high removal efficiencies in SBR-based treatment systems (Showkat & Najar, 2019).

In contrast, the Sequencing Batch Reactor (SBR) stage exhibited poor performance in COD removal, with no significant reductions recorded. This inefficiency may be linked to the operational conditions of the SBR, which, while capable of removing ammonia under certain conditions, failed to effectively treat COD in this instance. Previous studies have indicated that SBR systems can achieve varying degrees of organic material removal, with reported efficiencies between 73.49% and 75% for COD in different contexts. The lack of COD removal in the SBR stage of the slaughterhouse WWTP suggests that specific operational parameters or influent characteristics may hinder effective treatment, a phenomenon that has been documented in other studies focusing on SBR performance (Showkat & Najar, 2019).

The Anaerobic Tank stage showed remarkable COD removal efficiency, reaching 98.27%, indicating that anaerobic processes can be highly effective for organic matter degradation. However, ammonia removal was unsuccessful in this stage, which aligns with findings from Ezechi et al. (2014) and other studies that highlight the challenges of ammonia removal in anaerobic conditions (Rabah & Darwish, 2012). The inability to remove ammonia in the Anaerobic Tank may be attributed to the absence of nitrifying bacteria, which is essential for converting ammonia to less harmful forms under aerobic conditions (Ezechi et al., 2014).

Finally, the Secondary Clarifier stage presented mixed results. While one test showed efficient TSS removal (71.96%), the overall performance in treating both COD and TSS was suboptimal, with most tests indicating inefficiency. The overall findings from the WWTP underscore the complexity of wastewater treatment processes, where certain stages excel while others struggle, necessitating a comprehensive approach to optimize performance across the entire treatment train. In summary, the performance of the slaughterhouse WWTP illustrates significant variations in treatment efficiency different stages, with the collecting tank and Anaerobic Tank showing strong COD removal capabilities, while the SBR and Secondary Clarifier stages reveal inefficiencies across treating COD and NH3. This highlights the need for targeted interventions to enhance the overall efficacy of wastewater treatment processes in such facilities.

Conclusion

Based on the results of the research that has been conducted, it can be concluded that the efficiency of reducing Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) varies among the wastewater treatment units tested. Collecting Tank: This unit shows very high COD reduction efficiency, ranging from 87.52% to 93.89%. In addition, TSS reduction is also significant, with values varying from 83.15% to 92.95%. These results indicate that the Collecting Tank functions well in reducing the load of organic pollutants and suspended solids in the incoming waste. Sequencing Batch Reactor (SBR): Unlike the Collecting Tank, the SBR shows inefficiency in COD reduction, where the outlet measurement exceeds the inlet value. This indicates that the treatment process in the SBR may not be running optimally, so it is unable to reduce the COD load. However, this unit managed to achieve a reduction of NH_3 of 50.44% in one test, indicating that although the COD efficiency is low, there is potential to reduce ammonia under certain conditions. Anaerobic Tank: This unit showed significant COD removal efficiency, ranging from 72.66% to 98.27%. However, the NH_3 removal in this unit was very low or insignificant. This indicates that although the Anaerobic Tank is effective in removing COD, it does not contribute significantly to ammonia removal. Secondary Clarifier: This unit showed inefficiency in COD removal, with all tests showing higher outlet results compared to inlet. However, there was one test that showed TSS efficiency of 71.96%, indicating that although ineffective in removing COD, the Secondary Clarifier can still function in removing suspended solids. Overall, it can be concluded that the Collecting Tank and Anaerobic Tank showed high COD removal efficiency, while the Sequencing Batch Reactor and Secondary Clarifier showed variability in NH_3 removal efficiency. These findings emphasize the importance of selecting the right treatment unit based on the parameters to be improved, as well as the need for further evaluation to improve the performance of less efficient units. Further research is needed to understand the underlying mechanisms of the inefficiency of SBR and Secondary Clarifier in COD reduction, as well as to explore the potential for improving the efficiency of NH_3 reduction in Anaerobic Tank.

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The authors declare no conflict of interest.

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