Evaluation of Pharmaceutical Wastewater Treatment Effluent at PT. X, Surabaya City

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Abstract

PT. X is a pharmaceutical company that produces wastewater with the potential to harm the environment. Although the company already has a wastewater treatment system in place, this study evaluates its performance through direct field surveys and qualitative analysis based on ideal treatment standards. The treatment system at PT. X uses a series of five stabilization tanks operated in a continuous flow. However, BOD and COD test results from November 2019 to March 2020 show that the treated effluent does not meet the required pharmaceutical wastewater quality standards. This indicates the need to redesign the existing treatment system. One solution is to improve the biological treatment process, as the current BOD/COD ratio of around 0.5 suggests poor biodegradability. In addition, introducing an electrocoagulation process could enhance performance, with COD removal efficiency reaching up to 55.4%.

Keywords: *Pharmaceutical Wastewater, COD, BOD, Quality standards, Wastewater Treatment*

Introduction

The PT. X is a manufacturing company that produces pharmaceutical products which of course also produces waste that needs to be processed first before being discharged into water bodies. The wastewater treatment plant is designed to treat industrial wastewater biologically and chemically before being discharged into water bodies. The pharmaceutical industry produces liquid waste that has toxic and hazardous characteristics. The most toxic contaminants are antibiotics, analgesics, and anti-inflammatory drugs. The presence of this hazardous waste can cause serious damage to the environment, especially surface water (Stackelberg et al. 2004). Pharmaceutical waste has the potential to be generated through various activities in the health care system, pharmaceutical waste is included in the list of wastes containing commercial chemical products and their characterization is arranged according to the hazards they pose, such as flammability, corrosiveness, reactivity and toxicity (Agarwal et al. 2018; Jaseem et al. 2018). To overcome this, it is necessary to develop wastewater treatment technology that is easy to operate, economical and meets environmental standards (Bura 2019; Fadhilah et al. 2020; Pangestu et al. 2021).

By implementing a wastewater treatment plant, it is hoped that the risk of water contamination can be minimized. Good wastewater management can maintain environmental quality and can minimize disaster risk (Sofiyah et al. 2025b, c, a). Along with the function of the application of the wastewater treatment plant, it is necessary to study the wastewater treatment process at PT. X. This study is one of the important efforts made to anticipate water pollution. Further studies are needed regarding the wastewater treatment plant at PT. X because the production process requires and produces a lot of water.

A ubiquitous, low concentration pharmaceutical active compound in water bodies receiving wastewater treatment effluents. In addition, pharmaceutical waters such as paracetamol cause waste information, these compounds occur in water bodies and thus can affect human health (Koagouw et al. 2021). Implementation of standard operating procedures for wastewater treatment and evaluation and improvement is deemed necessary to produce a good wastewater treatment process (Rimantho 2019). The purpose of this study was to analyze the process and treatment of wastewater from pharmaceutical wastewater of PT. X.

The main objective of this study is to evaluate and improve the existing wastewater treatment system at PT. X, a pharmaceutical manufacturing facility, to ensure compliance with environmental standards and to minimize the risk of water pollution. This research aims to assess the performance of the WWTP at PT. X by analyzing its ability to process effluents containing pharmaceutical contaminants such as antibiotics, analgesics, and anti-inflammatory compounds. The study will focus on key wastewater parameters including Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and pH to determine whether the plant meets regulatory standards. In addition, the study seeks to identify inefficiencies or process gaps within the existing system that may cause the treated effluent to exceed quality thresholds set by national environmental regulations. Particular attention will be given to the BOD/COD ratio to understand the biodegradability of the pharmaceutical wastewater and evaluate whether biological treatment alone is adequate. The study also aims to explore the application of advanced treatment methods, such as electrocoagulation or enhanced biological processes, which have the potential to significantly reduce COD levels and improve overall treatment efficiency. Based on empirical data collected through surveys and laboratory analyses, a redesign or technical upgrade of the WWTP may be proposed to better align with best practices in pharmaceutical wastewater management. Furthermore, the study intends to support the development of sustainable wastewater management at PT. X by recommending improved standard operating procedures (SOPs), maintenance practices, and monitoring systems. Lastly, this research will contribute to the broader discourse on environmental compliance in the pharmaceutical industry and serve as a practical reference for similar industrial facilities in Indonesia and other developing countries.

Methodology

Study Timeframe and Location

This research was carried out in August 2020 within the operational area of PT. X, a pharmaceutical manufacturing company located in Surabaya City, Indonesia. The study was designed to evaluate the effectiveness of the company's existing wastewater treatment plant. Fieldwork included direct site visits to observe the treatment system, collect primary data, and validate operational conditions. In addition to field observations, secondary data on wastewater quality collected by PT. X from November 2019 to March 2020 was used to support the analysis.

Sampling Procedure

Wastewater quality was measured using a composite sampling method, which involves collecting multiple samples over a defined period and combining them to form a representative sample. This method was chosen to ensure that variations in pollutant concentration throughout the day could be captured effectively. Sampling was conducted during peak operational hours on randomly selected days to avoid bias and ensure that every day within the observation period had an equal chance of being represented in the sample. The samples were taken at the outlet point of the wastewater treatment plant and analyzed for standard quality parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and pH.

Analytical Approach

The collected data were compared against Indonesia's wastewater discharge standards for pharmaceutical industries, as stipulated in the national regulations. Deviations from the permitted limits were noted and used as a basis for identifying gaps in the treatment system.

Recommendation Development

Recommendations for improving the wastewater treatment process were formulated through an extensive literature review of current best practices in pharmaceutical wastewater management. Scientific articles, journals, and conference proceedings from reputable sources were used to identify advanced and cost-effective treatment technologies suitable for addressing the challenges observed at PT. X. Particular focus was placed on evaluating alternative biological processes, the potential of electrocoagulation, and integrated treatment systems that offer improved removal efficiency for pharmaceutical compounds.

Result and Discussion

Industrial Processes at PT. X

PT. X is a pharmaceutical manufacturing company that operates continuously for 24 hours from Monday to Friday. Its production activities are conducted in a sterile environment to ensure that all products meet high-quality standards. The production process begins with the manual addition of raw ingredients into a main mixer, where they are thoroughly blended. Once the mixing process is complete, the product is transferred to a storage tank. Before moving to the packaging phase, the equipment, including the mixer, storage tanks, and filling machine, is cleaned to prevent contamination between different product variants. The final stage involves packaging the products using a filling machine.

PT. X manufactures a variety of products that include hand body lotion, body wash, mouthwash, hair and body wash, hand sanitizer, and floor cleaner. These products are categorized into two divisions: Hand Body Lotion (HBL) and Household (HH) items. Despite the distinction, both product categories follow the same production flow.

Water plays a crucial role in the operations of PT. X. The facility stores water in a 1,000 cubic meter capacity tank, from which water is distributed for domestic, utility, and production needs. For domestic purposes, the water is used directly without prior treatment for activities such as flushing toilets and watering plants. The resulting domestic wastewater is discharged directly into the area's drainage system, bypassing any form of treatment, which could pose environmental risks.

For utility operations, the water is used in the boiler blowdown process and in the chiller system during softener regeneration. The wastewater generated from these processes is directed to the facility's wastewater treatment plant, where it undergoes treatment before being released into the regional sewer system.

Water intended for use in the production process must undergo two pre-treatment stages: filtration and demineralisation. The filtration stage removes particulate matter, while the demineralisation or demin regeneration process involves the use of hydrochloric acid (HCl) and sodium hydroxide (NaOH) to produce high-purity water with no ionic content. This demineralised water is then used as a raw material in product formulation, as well as for cleaning storage tanks and packaging units. The wastewater generated from these activities is also channeled into the wastewater treatment system for further processing.

Existing Wastewater Treatment System

The wastewater treatment system at PT. X currently relies on a grease trap-based method designed specifically to handle effluents containing high levels of fats and oils. The system is composed of five interconnected tanks that facilitate the treatment process in a continuous flow manner. Initially, wastewater enters Tank 0, which is used to collect and store separated fats and oils. These fats are later processed using a filter press, which compresses the waste into sludge. The sludge is then categorized and disposed of as hazardous waste in accordance with environmental regulations.

Subsequently, the main wastewater stream enters Tank 1, which collects effluent from three primary sources within the facility: the hand body lotion production line, the household product manufacturing process, and the demineralisation regeneration unit. From Tank 1, the wastewater flows into Tanks 2 and 3, where the physical separation of water and remaining oil or fat particles takes place. These tanks allow time for gravity separation, helping to isolate floating fats from the liquid phase. Finally, the treated effluent moves to Tank 4, which serves as the final holding tank before the wastewater is pumped out to the regional sewerage network.

Routine maintenance of the wastewater treatment system is conducted to ensure optimal performance. Wastewater samples are collected twice weekly, on Mondays and Thursdays, and sent to an accredited laboratory for Chemical Oxygen Demand (COD) analysis. Floating oils and fats that accumulate on the surface of the tanks are manually removed and redirected back to Tank 0 for further processing. In addition, any fat deposits that settle in Tanks 1 and 2 are cleaned on a monthly basis. These maintenance activities aim to preserve the system's operational efficiency.

Despite regular maintenance efforts, the facility continues to experience challenges with high COD levels in the treated effluent, indicating insufficient organic matter removal. This issue has been linked to the limited effectiveness of the grease trap system and the underperformance of the filter press unit. The inability of the current system to consistently reduce COD levels to meet environmental discharge standards highlights the need for an upgrade or redesign of the wastewater treatment infrastructure. Enhanced biological treatment methods or advanced processes such as electrocoagulation may be required to achieve compliance and protect the surrounding environment from harmful contaminants.

Wastewater Treatment Results

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Table 1. Results of Measurement of Effluent COD and BOD in Wastewater Treatment at PT. x

Time	Sampling Number	COD (mg/L)	BOD (mg/L)
November 2019	1	1534	767
	2	1176	588
	3	5062	2541
December 2020	1	8000	4000
	2	1380	690
January 2020	1	409	204.5
	2	5370	2.685
	3	563	281.5
	4	511	255.5
February 2020	1	2147	1073.5
	2	972	486
	3	2608	1304
March 2020	1	4091	2045.5
	2	2761	1380.5
	3	2096	1048

Recommendation

Based on the results presented in Table 1, it is observed that the BOD/COD ratio in the effluent is approximately 0.5. This ratio indicates that the wastewater is moderately biodegradable, and therefore potentially suitable for treatment using biological processes (Darwin et al. 2021; Sofiyah and Suryawan 2021; Suryawan et al. 2021). However, studies on pharmaceutical wastewater treatment reveal that conventional biological methods, such as activated sludge systems, are generally ineffective in removing complex pharmaceutical compounds from hospital and industrial effluents (Supriyanto and Issa 2017). For instance, Anaerobic Baffle Reactor (ABR) systems, which are used in some hospital wastewater treatment plants, have demonstrated low efficiency in reducing orthophosphate and free ammonia (NH_3-N) levels, often resulting in effluents that still fail to meet environmental quality standards.

Due to these limitations, post-treatment technologies are essential to ensure compliance with regulatory standards and to achieve higher pollutant removal efficiencies. Advanced treatment methods include adsorption using activated carbon, ultraviolet (UV) photolysis, advanced oxidation processes (AOPs), reverse osmosis, and nanofiltration. Research by Escola Casas et al. (2015) demonstrated that a hybrid treatment system employing various carriers was able to achieve a pharmaceutical compound removal efficiency of up to 71%, indicating the effectiveness of integrating physical and chemical treatment processes (Casas et al. 2015).

An alternative or complementary treatment method that shows promise is electrocoagulation. This technique involves placing two electrode plates into the wastewater and applying a direct current (DC) to induce an electrochemical reaction. At the anode, metal oxidation occurs, releasing metal ions into the wastewater. These ions then undergo hydrolysis, forming metal hydroxides that act as coagulants. These coagulants neutralize the charges of suspended organic pollutants, facilitating their aggregation into flocs. Simultaneously, at the cathode,

hydrogen and oxygen gases are produced, which help lift the flocculated particles to the surface for removal. In addition to DC, alternating current (AC) may also be used to enhance the process. Previous studies have demonstrated the effectiveness of electrocoagulation in treating oily and greasy wastewater, showing COD removal efficiencies of up to 55.4%, oil and grease removal of 98.4%, and total suspended solids (TSS) reduction of up to 96.59%, when operated at 18.2 volts for 23.5 minutes(Butler et al. 2011).
To improve the performance of its current wastewater treatment system, PT. X should upgrade the existing grease trap by integrating biological treatment, such as an activated sludge process. This method is effective in reducing organic pollutants like BOD and COD. For contaminants that are more resistant to biological treatment, electrocoagulation can be introduced as a complementary process. This combined approach can significantly enhance pollutant removal efficiency. Regular monitoring of wastewater quality is essential for assessing system performance and ensuring compliance with environmental standards. Monitoring and flexibility also plays a key role in adaptive environmental management (Imelda et al. 2024; Suhardono et al. 2024; Suryawan et al. 2024b, a, 2025; Sutrisno et al. 2024; Ulhasanah et al. 2025; Yang et al. 2025), enabling timely adjustments based on real-time data. In parallel, staff must be trained to properly operate and maintain both the biological and electrochemical treatment units to ensure consistent performance. By applying this adaptive management strategy, PT. X can progressively improve its wastewater treatment system, meet regulatory requirements, reduce environmental impacts, and avoid financial penalties.

Conclusion

The wastewater generated at PT. X originates from both production and domestic activities. Wastewater from the production process is treated before being discharged, while domestic wastewater is released directly into the regional sewer without treatment. The current wastewater treatment system at PT. X uses a grease trap, which is primarily designed to remove oil and grease. However, the system has not been effective in reducing COD levels to meet environmental quality standards. As a result, the company faces penalties due to high COD concentrations in its discharged wastewater.

To address this issue, an adaptive management approach is recommended. PT. X should consider upgrading its wastewater treatment system by integrating biological processes, such as activated sludge or aerobic treatment, which are more effective for biodegradable waste. In addition, chemical processes like electrocoagulation can be introduced to further reduce COD levels. Regular monitoring, evaluation, and periodic maintenance of the treatment system should also be improved. This adaptive strategy will help PT. X comply with environmental regulations, reduce operational costs related to fines, and support sustainable industrial practices.

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