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Reduction of Total Coliform, Ammonia (NH_3-N), and COD Levels in Liquid Waste from the IPLT Keputih Using a Combination of H_2O_2-UVC

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A B S T R A C T

Population growth in Indonesia poses sanitation challenges, where Sewage Sludge Treatment Plants (IPLT) provide a solution for sewage waste treatment. However, IPLTs themselves still face obstacles in optimally removing contaminants such as ammonia, Total coliform bacteria, and COD. This study evaluates the effectiveness of advanced oxidation processes (AOPs) combining hydrogen peroxide and ultraviolet light (H_2O_2-UV) in degrading these three pollutants. The wastewater used in this study came from the outlet of the Final Clarifier unit. The experiments were conducted in a continuous reactor with varying concentrations of H_2O_2 (0.1%-0.7%) and UV light contact time (15-45 minutes). The results showed that the highest degradation efficiency was achieved at a H_2O_2 concentration of 0.7% for 45 minutes, with a removal percentage of 99.24% for Total Coliform bacteria and 88.32% for Ammonia. However, for COD, the highest degradation efficiency was achieved at a concentration of 0.5% for 45 minutes with a removal percentage of 79.55%. These results prove that the H_2O_2-UV process is effective in degrading IPLT wastewater pollutant mixtures through the production of non-selective hydroxyl radicals (•OH).

Contribution to Sustainable Development Goals (SDGs):
SDG 6: Clean Water and Sanitation
SDG 3: Good Health and Well Being
SDG 11: Sustainable Cities and Communities
SDG 14: Live Below Water

1. INTRODUCTION

1.1. Research Background

Domestic wastewater originates from residential activities, commercial institutions, and public facilities. This waste must be managed through appropriate channels, treated, reused, or disposed of in the environment in a safe manner. One commonly used treatment system is the Sewage Sludge Treatment Plant (IPLT) [1] [2]. Sewage sludge has a high organic content and has the potential to cause serious environmental pollution if not managed properly [3]. In addition, domestic wastewater often contains high concentrations of bacteria, viruses, and parasites, which have the potential to spread disease [4] [5]. Therefore, effective and sustainable management strategies are needed to minimize risks to the environment and public health.

The IPLT Keputih in Surabaya City was established in 1991 with a design capacity of 400 m³/day [6][7]. One of the treatment units at the IPLT Keputih is the Final Clarifier, which functions to settle activated sludge containing microorganisms from Mixed Liquor Suspended Solids (MLSS) [8]. In this study, samples were taken from the outlet of the Final Clarifier unit to analyze their initial quality. The analysis results showed a Total Coliform parameter value of 5750 MPN/100 mL, ammonia (NH_3-N) of 12.4 mg/L, and Chemical Oxygen Demand (COD) of 5040 mg/L. When compared to wastewater quality standards based on Minister of Environment and Forestry Regulation No. 68 of 2016, the quality of the effluent still exceeds the permissible threshold, making it unfit for discharge into receiving water bodies.

Compliance with quality standards is necessary so that waste disposal does not cause health, technical, or aesthetic impacts.

One potential technology to address this problem is Advanced Oxidation Processes (AOPs). AOPs are a treatment method that utilizes hydroxyl radicals (•OH) as a strong oxidant capable of rapidly and non-selectively degrading organic compounds [9]. Based on this background, this study aims to evaluate the effectiveness of the H_2O_2/UV-based AOPs process in degrading pollutant parameters (Total Coliform, Ammonia, and COD) in wastewater from the Final Clarifier outlet at the IPLT Keputih.

1.2. Literature Review

1.2.1. Advanced Oxidation Processes (AOPs)

Advanced Oxidation Processes (AOPs) are used to oxidize complex organic constituents found in wastewater that are difficult to degrade biologically into simpler end products (Metcalf & Eddy, 2003). Advanced oxidation processes (AOPs) are environmentally friendly and innovative technologies for treating wastewater and adding variety to anti-pollutant technology methods [10]. Advanced oxidation methods consist of UV/H_2O_2, UV/O_3, $UV/H_2O_2/O_3$, UV/TiO_2, and $UV/Fe^{2+}/H_2O_2$. This method is highly effective in treating wastewater because it produces hydroxyl radicals, which are strong nonspecific oxidants [11]. Common oxidizing agents other than hydroxyl radicals are listed in Table 1.

Table 1 Potential Value of Each Oxidation Agent

Oxidative Agent	Potential (V)
Fluorine	3.0 (1)
Radikal sulfat	2.5-3.1 (1)
Radikal hidroksil	2.80 (1) (2)
Oksigen (atomik)	2.42 (2)
Persulfat	2.1 (1)
Ozon	2.1 (1)
Hidrogen peroksida	1.8 (1)
Peroksimonosulfat	1.8 (1)
Permanganat	1.7 (1)
Klorin Dioksida	1.5 (1)
Hipoklorit	1.49 (2)
Klorin	1.4 (1)
Oksigen (molekular)	1.23 (2)

Source : (1) [12] (2) [13]

1.2.2. Mechanism of AOPs

In this AOP method, hydroxyl radicals are produced through a three-stage process [14], which are:

a. Initiation Stage: Initiation is the initial stage in radical formation. This stage usually involves homolytic cleavage, which is difficult to achieve due to energy barriers. Factors such as high temperatures or catalysts play a role in triggering this stage.
b. Propagation Stage: This is the stage in which a chain reaction of free radical formation occurs. The reactive free radicals formed will react with stable molecules and produce new free radicals. This stage often involves hydrogen abstraction or the addition of radicals to double bonds.
c. Termination Stage: This is the final stage in radical reactions. In this stage, the radical reaction stops when two radicals react with each other and produce non-radical molecules.

Hydroxyl radicals are strong oxidants capable of breaking down compounds that cannot be oxidized using ordinary or conventional oxidizing agents. Hydroxyl radicals have an oxidation potential of 2.33 V, enabling them to remove organic molecules very quickly and easily because they aggressively attack existing organic molecules. The following are the forms of attack carried out by hydroxyl radicals on organic compounds [9], which are:

a. Radical Addition

The addition of hydroxyl radicals to unsaturated organic compounds will produce organic radical compounds that can be oxidized into final products. The addition of radicals is much faster than hydrogen abstraction. In the following reaction, organic compounds are represented as R.

$$R + HO \bullet \rightarrow ROH \bullet$$

b. Hydrogen Abstraction

Hydrogen atoms are removed from organic compounds using hydroxyl radicals. The removal of hydrogen atoms results in the formation of organic radical compounds, initiating a chain reaction in which organic radical compounds react with oxygen, producing free radicals that can react with other organic compounds, and so on.

$$R + HO \bullet \rightarrow R \bullet + H_2O$$

c. Electron transfer

Through electron transfer, the valence of ions can increase. Oxidation of negative monovalent ions will produce atoms or free radicals. The notation "n" in the following reaction represents the charge carried by the organic reactant R.

$$R + HO \bullet \rightarrow R^{n-1} + OH^-$$

d. *Radical Combination*

Two radicals can combine to form a stable product.

$$HO \bullet + HO \bullet \rightarrow H_2O_2$$

The mechanism of the AOPs method consists of three stages [15], which are:

- The formation of strong oxides such as hydroxyl radicals
- The reaction between organic compounds in wastewater and strong oxides, producing biodegradable intermediate products
- Mineralization reactions occur, namely the formation of water, carbon dioxide, and inorganic salts in intermediate products with strong oxides

1.2.3. H_2O_2-UV

The combination of UV light and hydrogen peroxide can produce OH radicals. UV light acts as a natural disinfectant that reduces organic pollutants [10]. The main chemical reactions that occur in this system are described below:

$$H_2O_2 + hv \rightarrow 2 \bullet OH$$

Through radiation effects, peroxide molecules form OH radicals. This decomposition is associated with the Haber-Weiss mechanism, which begins with the cleavage of the O-O bond [10] [16]. Further chemical OH production is carried out by the following reaction:

$$H_2O_2 + OH \rightarrow H_2O + HO_2$$
$$H_2O_2 + HO_2 \rightarrow H_2O + O_2 + OH$$

However, in some cases, radical recombination occurs as follows:

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$$\bullet OH + HO \rightarrow H_2O_2$$
$$\bullet OH + HO_2 \rightarrow H_2O + O_2$$
$$HO_2 + HO_2 \rightarrow H_2O_2 + O_2$$

Many factors influence the effectiveness of the above reaction, such as hydrogen peroxide concentration, UV radiation source, temperature, process pH, and contact time between wastewater and light [10].

1.3. Research Objective

This study analyzes the effectiveness of the H_2O_2-UV process in reducing COD, Ammonia (NH_3-N), and Total Coliform levels in wastewater from the Final Clarifier outlet of the IPLT Keputih.

2. MATERIALS AND METHODS

The reactor used consists of a temporary collection tank + pH tank with a capacity of 40L, an H_2O_2 agitator tank with a capacity of 2L, and a UV lamp reactor. With a capacity of 3L. In this test, the waste is placed in the waste collection tank, then the initial pH is checked, followed by the addition of H_2SO_4 to adjust the sample to pH 6. The sample is then pumped to the H_2O_2 reactor tank, where H_2O_2 solution is injected into the H_2O_2 reactor. The following is a picture of the reactor design used in this study.

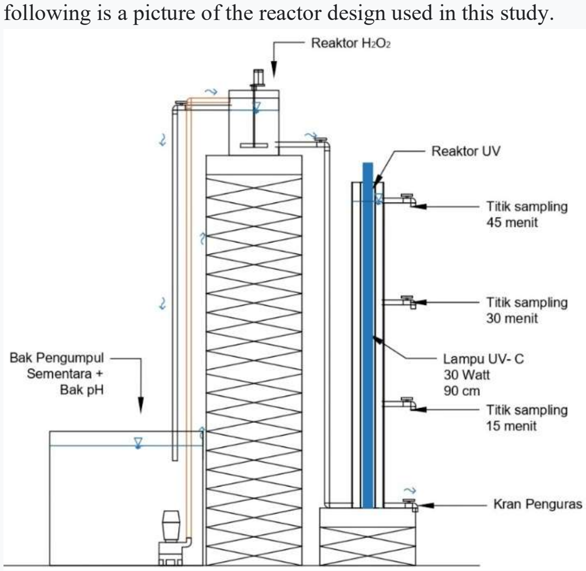

Figure 1 Research Reactor Design

This study will use a continuous system in which wastewater will be collected and H_2SO_4 will be added to bring the pH of the wastewater to +- 6. The water will then be pumped to the H_2O_2 reactor and injected with H_2O_2 solutions with varying concentrations of 0.1%, 0.3%, 0.5%, and 0.7%. In the H_2O_2 reactor, agitation will be performed to homogenize the wastewater with the solution at a speed of 100 RPM. The water will then be flowed into the UV reactor with contact times varying between 15, 30, and 45 minutes.

3. RESULT AND DISCUSSION

3.1. Initial Characteristics of Wastewater

The wastewater used in this study was liquid waste from the IPLT Keputih in the form of outlet from the final Clarifier unit. In addition to analyzing the parameters of total coliform, ammonia (NH_3-N), and COD, this study also analyzed the pH parameter. In this study, acidification was carried out before core processing so that the pH results before and after H_2O_2-UV processing can be seen in Table 2.

Table 2 Characteristics of Wastewater Outlet Final Clarifier Unit of the IPLT

Parameter	Quality Standard (PermenLHK No.68 Tahun 2016)	Satuan	Concentration H_2O_2 (%)			
			0,1	0,3	0,5	0,7
pH	6-9	-	7,1			
Total Coliform	3000	MPN/ 100 mL	5750	6014	6282	6300
Amonia (NH_3-N)	10	mg/L	12.4	16.8	21.1	21.4
COD	100	mg/L	450	680	1700	2200

Source: Researcher Data, 2025

The table shows that the pH value meets the applicable quality standards of 6-9. However, other pollutant parameters show very high values. The total coliform population, which reaches thousands of MPN/100mL, also confirms the high level of fecal contamination, making disinfection necessary. Ammonia values between 12.4 and 21.4 mg/L indicate a nutrient load that can cause eutrophication. High COD concentrations identify the presence of high levels of organic compounds, requiring further oxidation processes to degrade them.

3.2. Total Coliform Bacteria Removal in the H_2O_2-UV Process

The *Total Coliform* values before treatment at each concentration of 0.1%, 0.3%, 0.5%, and 0.7% were 5750, 6014, 6282, and 6300 MPN/100 mL, respectively. The samples were also tested for *Total Coliform* bacteria levels after undergoing H_2O_2-UV treatment. The results of the *Total Coliform* bacteria parameter testing for each sample are shown in Table 3.

Based on the table above, it can be seen that the use of H_2O_2-UV is very effective in reducing total coliform parameters. The percentage of removal achieved was 68,09%-99.24%. The total coliform concentration results after treatment in each variation met the applicable quality standard limit of <3000 MPN/100 mL. The following is a graph of the percentage reduction in total coliform bacteria against variations in H_2O_2 concentration and against variations in UV light contact time.

Table 3 Total coliform Levels in IPLT Wastewater for Each Treatment Variation of H_2O_2-UV

UV exposure time	Concentration H_2O_2							
	0,1%		0,3%		0,5%		0,7%	
	Total coliform Count	% Removal	Total coliform Count	% Removal	Total coliform Count	% Removal	Total coliform Count	% Removal
Start	5750		6014		6282		6300	
15 minute	1835	68.09%	1776	70.47%	1694	73.03%	1102	82.51%
30 minute	1407	75.53%	1248	79.25%	1063	83.08%	511	91.89%
45 minute	1125	80.43%	837	86.08%	616	90.19%	48	99.24%

Source: Researcher Data, 2025

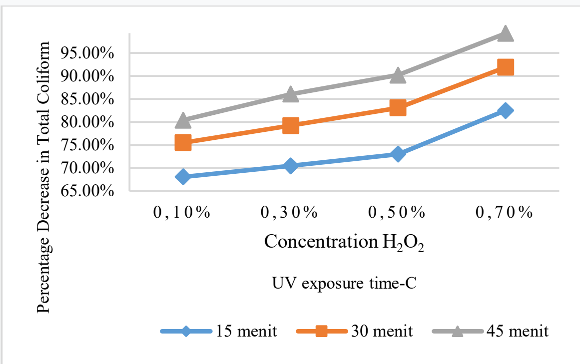

Figure 2 Total Coliform Removal Against H_2O_2 Concentration
Source: Researcher Data, 2025

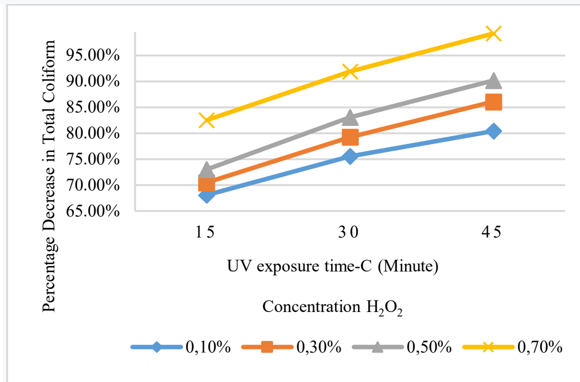

Figure 3 Total coliform Removal Against UV Light Contact Time
Source: Researcher Data, 2025

Based on the two graphs above, it is known that the higher the concentration and the longer the UV light contact time, the higher the level of elimination. The high effectiveness of total coliform reduction in this treatment is due to two mechanisms. Namely, the chemical action of hydrogen peroxide, which can inhibit the synthesis and function of bacterial nucleic acids through damage to the cell wall [17]. As well as the action of UV light, which can break DNA and RNA bonds, thereby preventing the growth of total coliform bacteria [18].

3.3. *Ammonia (NH_3-N) Removal in the H_2O_2-UV Process*

The results of ammonia (NH_3-N) measurements in IPLT wastewater at different H_2O_2 concentrations showed varying results. The lowest concentration was observed in the 0.1% H_2O_2 concentration treatment, which decreased from 12.4 mg/L to 2.2 mg/L, or a removal rate of 82.26% with a UV exposure time of 45 minutes. Meanwhile, the highest H_2O_2 concentration had a removal percentage of 88.32%, from 21.4 mg/L to 2.5 mg/L. The results of ammonia observations in IPLT wastewater during treatment using H_2O_2-UV can be seen in Table 4.

Table 4 Ammonia (NH3-N) Levels in IPLT Wastewater for Each Treatment Variation of H_2O_2-UV

UV exposure time	Concentration H_2O_2							
	0.1%		0.3%		0.5%		0.7%	
	Ammonia Count	% Removal	Ammonia Count	% Removal	Ammonia Count	% Removal	Ammonia Count	% Removal
Start	12.4		16.8		21.1		21.4	
15 minute	3.7	70.16%	4.1	75.60%	4.6	78.20%	3.4	84.11%
30 minute	3.2	74.19%	3.4	79.76%	3.7	82.46%	2.9	86.45%
45 minute	2.2	82.26%	2.6	84.52%	2.8	86.73%	2.5	88.32%

Source: Researcher Data, 2025

Based on the analysis of ammonia parameters, the treatment results in the table show that the ammonia value has met the liquid waste quality standards stipulated in Regulation of the Minister of Environment and Forestry No. 68 of 2016, which is below 10 mg/L. This achievement identifies the effectiveness of the H_2O_2-UV process in degrading organic pollutants to a level that is permitted for discharge into the environment.

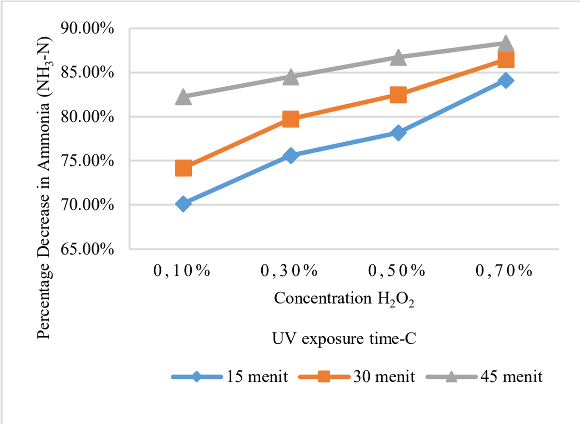

Figure 4 Ammonia (NH_3-N) Removal Against H_2O_2 Concentration
Source: Researcher Data, 2025

Based on the graphs shown in Figures 4 and 5, there is an increase in the percentage of removal with increasing H_2O_2 concentration and UV light contact time. The mechanism of NH_3-N removal occurs gradually and will be oxidized into NH_2 radicals [19]. The following is the reaction:

$$NH_3 + \bullet OH \rightarrow \bullet NH_2 + H_2O$$
$$\bullet NH_2 + H_2O_2 \rightarrow \bullet NHOH + H_2O$$
$$\bullet NH_2 + \bullet OH \rightarrow \bullet NH_2OH$$

Next, unstable $NH_2OH_2^-$ decomposes into NO_2^-, which will be oxidized into NO_3^-. The •OH radical produced by H_2O_2 photolysis can oxidize NH_3 into NO_2^- and then into NO_3^-. Thus, ammonia can be removed under UV irradiation in the presence of H_2O_2 [19][20][21].

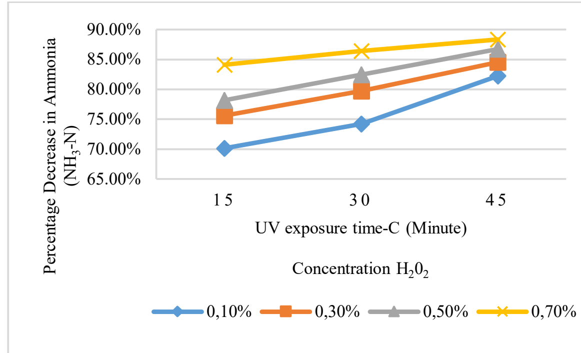

Figure 5 Ammonia (NH_3-N) Removal Against UV Light Contact Time
Source: Researcher Data, 2025

3.4. *COD Removal in the H_2O_2-UV Process*

The efficiency of the H_2O_2-UV process in COD removal was observed at varying H_2O_2 concentrations (0.1-0.7%) and contact times of 15-45 minutes. Based on advanced oxidation theory, an increase in H_2O_2 concentration is expected to increase the production of hydroxyl radicals (•OH) that play a role in degrading organic compounds. The results of observing the process performance on COD removal are presented in Table 5.

Table 5 COD Levels in IPLT Wastewater for Each Treatment Variation of H_2O_2-UV

UV exposure time	Concentration H_2O_2							
	0,1%		0,3%		0,5%		0,7%	
	COD Count	% Removal	COD Count	% Removal	COD Count	% Removal	COD Count	% Removal
Start	5040		6048		9152		9576	
15 minute	3360	40.00%	2688	55.56%	3328	63.64%	4536	52.63%
30 minute	2352	53.33%	2352	61.11%	2912	68.18%	3780	60.53%
45 minute	1680	66.67%	1344	77.78%	1872	79.55%	2520	73.68%

Source: Researcher Data, 2025

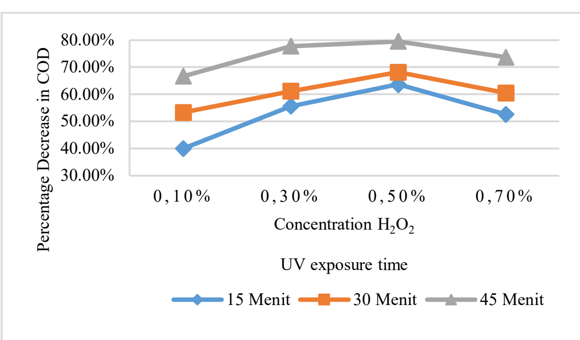

Figure 6 COD Removal Against H_2O_2 Concentration
Source: Researcher Data, 2025

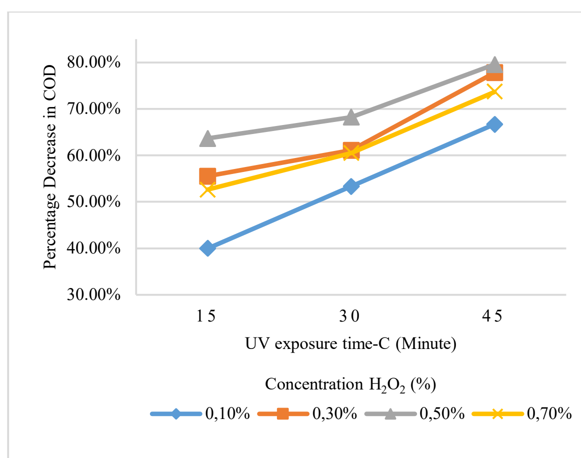

Figure 7 COD Removal Against UV Light Contact Time
Source: Researcher Data, 2025

Based on Table 4 and Figures 6 and 7, it can be seen that COD removal efficiency increases with increasing contact time and H_2O_2 concentration up to the optimum point. At a H_2O_2 concentration of 0.5% with a contact time of 45 minutes, the highest removal efficiency of 79.55% was obtained. The mechanism involved two main reaction mechanisms, namely addition reaction on double bonds and hydrogen abstraction reaction [22]. The following are the reactions that occurred:

$$Polutan\ organik \rightarrow aldehida \rightarrow asam\ karboksilat \rightarrow CO_2\ dan\ H_2O$$

This process converts organic pollutants into simpler compounds until they eventually become carbon dioxide and water [23], which are harmless to the environment. However, at a concentration of 0.7%, there is a decrease in efficiency compared to 0.5%, which is thought to be caused by the scavenging effect where excess H_2O_2 consumes •OH radicals. Therefore, when testing residual COD, H_2O_2 will consume $K_2Cr_2O_7$, causing a green color change reaction when $K_2Cr_2O_7$ solution is added and potentially increasing the COD value. The following is the reaction that occurs (Chavoshani et al., 2016):

$$K_2Cr_2O_7 + 3H_2O_2 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O + 3O_2$$

4. CONCLUSION

Based on the results of the study, it can be concluded that the H_2O_2-UV-based Advanced Oxidation Process (AOP) is effective in degrading pollutants in wastewater. The removal efficiency increases with increasing UV contact time and H_2O_2 concentration up to an optimum point. The best operating conditions are achieved at a H_2O_2 concentration of 0.5% and an irradiation time of 45 minutes, with a removal percentage of 79.55% for COD, while for ammonia and total coliform parameters, the optimum conditions were obtained at an H_2O_2 concentration of 0.7% and a UV contact time of 45 minutes, with a removal rate of 88.32% for ammonia (NH_3-N) and 99.24% for total coliform. Increasing the H_2O_2 concentration to 0.7% did not significantly improve efficiency; in fact, it tended to decrease for the COD parameter, which was thought to be due to the presence of residual H_2O_2 during the COD test, which consumed the $K_2Cr_2O_7$ solution. Thus, H_2O_2-UV technology has proven to be a viable alternative for tertiary treatment to improve effluent quality to meet environmental standards.

REFERENCE

[1] R. Riyana Agustien, P. Soewondo, and A. Sudradjat, “Development of audit technology approach for performance improvement of faecal sludge treatment plant (IPLT) (Case study: IPLT Bawang in Tangerang City and IPLT Pecuk in Indramayu District),” in *MATEC Web of Conferences*, EDP Sciences, Jan. 2018. doi: 10.1051/matecconf/201814704001.

[2] S. Insyirah Medina, M. Apriani, T. Azis Ramadhani, P. Studi Teknik Pengolahan Limbah, J. Teknik Permesinan Kapal, and P. Perkapalan Negeri Surabaya, “Kajian Dampak Lingkungan Akibat Penambahan Unit Dissolved Air Flotation di IPLT Keputih,” 2025.

[3] P. Kadek, Y. Ryanita, N. Arsana, N. Ketut, and A. Juliasih, “Fitoremediasi Dengan Tanamana Air Untuk Mengolah Air Limbah Domestik,” vol. 11, Oct. 2020.

[4] S. Sulistia and A. C. Septisya, “Analysis of domestic office wastewater quality,” *J Environ Eng*, vol. 12, pp. 41–57, 2020.

[5] R. Rasawula Lukman, Y. Eka Pratiwi, and Rosdiana, “Evaluasi Teknik Operasional dari Kinerja Instalasi Pengolahan Lumpur Tinja di Kota Kendari,” 2021.

[6] G. Dian and W. Herumurti, “Evaluasi Kinerja Instalasi Pengolahan Lumpur Tinja IPLT,” *Jurnal Teknik ITS*, vol. 5, pp. 2337–3539, 2016.

[7] F. P. Putra, “Kajian Perbaikan Proses Pengolahan Lumpur Tinja Kota Surabaya Dan Optimasi Retribusi Pengelolaannya,” 2019.

[8] M. T. Albanjari, “Evaluasi Kinerja Pengolahan Lumpur Tinja Pada Seksi Pengelolaan Limbah Cair Instalasi Pengolahan Lumpur Tinja (PLC-IPLT) Keputih Surabaya,” 2021.

[9] Metcalf & Eddy, *Wastewater engineering Treatment and Resource recovery*, 5th ed. New York: Mc-Graw-Hill Education, 2014.

[10] P. K. Pandis *et al.*, “Key Points of Advanced Oxidation Processes (AOPs) for Wastewater, Organic Pollutants and Pharmaceutical Waste Treatment: A Mini Review,” Feb. 01, 2022, *MDPI*. doi: 10.3390/chemengineering6010008.

[11] X. R. Xu, X. Y. Li, X. Z. Li, and H. Bin Li, “Degradation of melatonin by UV, UV/H2O2, Fe2+/H2O2 and UV/Fe2+/H2O2 processes,” *Sep Purif Technol*, vol. 68, no. 2, pp. 261–266, Aug. 2009, doi: 10.1016/j.seppur.2009.05.013.

[12] S. Guerra-Rodríguez, E. Rodríguez, D. N. Singh, and J. Rodríguez-Chueca, “Assessment of sulfate radical-based advanced oxidation processes for water and wastewater treatment: A review,” Dec. 11, 2018, *MDPI AG*. doi: 10.3390/w10121828.

[13] M. Hassaan, A. El Nemr, and M. A. Hassaan, “Advanced Oxidation Processes for Textile Wastewater Treatment,” *International Journal of Photochemistry and Photobiology*, vol. 2, no. 3, pp. 85–93, 2017, doi: 10.11648/j.ijpp.20170203.13.

[14] M. L. Nabila, “Kajian Penerapan Metode Advanced Oxidation Processes (AOPs) pada Pengolahan Limbah Cair di Indonesia,” Surabaya, Jul. 2022.

[15] F. Mazille and D. Spuhler, “Advanced Oxidation Processes,” Sustainable Sanitation and Water Management.

[16] A. S. Stasinakis, “Use Of Selected Advanced Oxidation Processes (AOPs) For Wastewater Treatment - A Mini Review,” *Global NEST Journal*, vol. 10, no. 3, pp. 376–385, Jul. 2008, Accessed: Mar. 16, 2025. [Online]. Available: https://scispace.com/pdf/use-of-selected-advanced-oxidation-processes-aops-for-1rzldijq9f.pdf

[17] M. Huda *et al.*, “Pengaruh Madu Terhadap Pertumbuhan Bakteri Gram Positif (Staphylococcus Aureus) Dan Bakteri Gram Negatif (Escherichia Coli) Effect On The Growth Of Honey gram-positive bacteria (Staphylococcus aureus) and Gram-negative bacteria (Escherichia coli),” 2013.

[18] C. Ruiz-Díez, M. Navarro-Segarra, R. Barrena, T. Gea, and J. P. Esquivel, “Optimization of UV-C pulsed radiation strategy for a high-efficiency portable water

 https://doi.org/10.29165/ajarcde.v10i1.912

sterilizer," *Environ Technol Innov*, vol. 31, Aug. 2023, doi: 10.1016/j.eti.2023.103199.

[19] R. N. Córdova, M. E. Nagel-Hassemer, W. G. Matias, J. M. Muller, and A. B. de Castilhos Junior, "Removal of organic matter and ammoniacal nitrogen from landfill leachate using the UV/H2O2 photochemical process," *Environmental Technology (United Kingdom)*, vol. 40, no. 6, pp. 793–806, Mar. 2019, doi: 10.1080/09593330.2017.1408692.

[20] N. A. Urbina-Suarez, A. F. Barajas-Solano, A. Zuorro, and F. Machuca, "Advanced Oxidation Processes with Uv-H2O2 for Nitrification and Decolorization of Dyehouse Wastewater," *Chem Eng Trans*, vol. 95, pp. 235–240, 2022, doi: 10.3303/CET2295040.

[21] N. A. Urbina-Suarez, G. L. López-Barrera, J. B. García-Martínez, A. F. Barajas-Solano, F. Machuca-Martínez, and A. Zuorro, "Enhanced UV/H2O2 System for the Oxidation of Organic Contaminants and Ammonia Transformation from Tannery Effluents," *Processes*, vol. 11, no. 11, Nov. 2023, doi: 10.3390/pr11113091.

[22] W. J. Masschelein, *Ultraviolet Light In Water and Wastewater Sanitation*. CRC Press, 2018.

[23] Environmental Protection Agency (EPA), *Water Treatment Manual: Disinfection*. Ireland: Environmental Protection Agency (EPA), 2011. [Online]. Available: www.epa.ie