Banua: Jurnal Kesehatan Lingkungan
e-ISSN 2797-8184 | p-ISSN 2797-8176
Volume 5 Issue 2, 2025, page 83-92
DOI: 10.33860/bjkl.v5i2.4219
Website:http://jurnal.poltekkespalu.ac.id/index.php/bjkl/
Publisher: Poltekkes Kemenkes Palu

Original Article

Variation in Ultraviolet (UV-C) Contact Time Using Solar Panels on the Reduction of Total Coliform in Clean Water at PT. X, Sumedang Regency

Nina Kaniawati*, Muhamad Iqbal, Lubis Bambang Purnama, Neneng Yety Hanurawaty
Department of Environmental Health, Poltekkes Kemenkes Bandung, West Java, Indonesia
*Corresponding author: ninakaniawati135@gmail.com

ARTICLE INFO

Article History:
Received: 2025-09-15
Accepted : 2025-10-09
Published: 2025-10-27

Keywords:

Clean water;
coliform;
ultraviolet-c;
solar panels;
contact time

ABSTRACT

Background: Water contaminated with Total Coliform can lead to diseases such as diarrhea, cholera, dysentery, and other gastrointestinal infections. Preliminary testing of water at PT. X revealed a Total Coliform count of 56 CFU/100 ml, surpassing the safe threshold for clean water. This study aims to evaluate the effect of varying ultraviolet (UV-C) light contact times—90, 120, and 150 seconds—on the reduction of Total Coliform in clean water.
Methods: An experimental post-test with a control group design was used. The sample size was determined by the number of treatment groups and repetitions, resulting in a total of 24 samples. Grab sampling was employed for sample collection.
Results: The average Total Coliform count in the control group was 56 CFU/100 ml. After UV-C treatment, the counts decreased to 32 CFU/100 ml at 90 seconds, 11 CFU/100 ml at 120 seconds, and 0 CFU/100 ml at 150 seconds. One-way ANOVA analysis yielded a p-value of 0.001, indicating a significant effect of UV-C contact time on the reduction of Total Coliform in clean water at PT. X, Sumedang Regency.
Conclusion: Disinfection using UV-C light with a contact time of 150 seconds is recommended.

INTRODUCTION

Clean water is a vital resource utilized to meet daily human needs, adhering to the health quality standards established by the Ministry of Health, and is considered safe for drinking upon boiling (Aba et al., 2023; Tripathi, 2023). Water intended for hygiene and sanitation is defined as water used for personal and domestic cleanliness (Ersel, 2015; Permenkes, 2017; Sultana et al., 2022). Water is essential for human life, as the body is largely composed of it: approximately 55–60% in adults, 65% in children, and 80% in infants. Human water requirements are diverse, covering drinking, cooking, bathing, and washing (Widyawati, 2019).

One key indicator of water pollution is biological assessment, which evaluates contamination based on the presence of microorganisms, particularly pathogenic bacteria like Coliform. This microbiological parameter is a primary indicator of pollution from domestic, industrial, or agricultural waste (Bylund et al., 2017; Korajkic, McMinn, & Harwood, 2018; Saputri & Efendy, 2020; Some et al., 2021). The presence of Total Coliform above permissible limits suggests fecal contamination in the water system, posing risks of diseases such as diarrhea and cholera (Syafarida, Jati, & Sulastri, 2022). According to the Minister of Health Regulation No. 2 of 2023, the standard for E. coli and Coliform in water for hygiene and sanitation must be 0 CFU/100 ml (Kementerian Kesehatan, 2023). However, test results from PT. X in Sumedang Regency in June 2025 showed a Total Coliform level of 56 CFU/100 ml, indicating that the water used for various industrial purposes failed to meet safety standards.

The presence of Coliform bacteria signals sanitation contamination from human or animal feces or decaying plant matter, which can lead to waterborne diseases (Banseka & Tume, 2024; Li & Liu, 2019). Therefore, preventive measures are necessary to improve water quality, with disinfection being a primary method (Backer, Derlet, & Hill, 2024). Common disinfection techniques include boiling, chlorination, ozonation, and ultraviolet irradiation. Ultraviolet (UV-C) disinfection is a cost-effective, rapid, and safe option because it adds no chemicals, thereby preserving the water's original color, taste, and odor. Its limitations, however, include the need for electricity and reduced effectiveness against certain spores and viruses (Abboushi, Rodriguez-Feo Bermudez, Tuenge, & Arnold, 2025; Khan, Mumtaj, Khan, Ahmad, & Alqahtani, 2025; Sliney & Stuck, 2021)

The bactericidal mechanism of UV-C radiation involves its ability to penetrate microbial cell walls and alter their nucleic acids by forming thymine dimers. This damage to DNA and RNA inhibits replication, neutralizes pathogenic properties, and ultimately leads to cell death (Dinny, Teguh, Yosephina, & Agus, 2019). Since Coliform bacteria contain DNA, they are susceptible to inactivation by UV-C radiation (Ningsih, Karmini, & Hidayah, 2021). A study by Sari et al. (2021) demonstrated that a 30-second UV-C exposure reduced E. coli levels from 23 CFU/100 ml to 0 CFU/100 ml. Similarly, a preliminary trial by the researcher on July 2, 2025, showed a reduction in Total Coliform from 56 CFU/100 ml to 0 CFU/100 ml after 150 and 180 seconds of exposure.

This study aims to determine the effect of varying ultraviolet (UV-C) exposure times on the reduction of Total Coliform in the clean water at PT. X, Sumedang Regency, using contact times of 90, 120, and 150 seconds. The system is powered by solar panels, which were chosen as a renewable and environmentally friendly energy source to reduce dependence on the conventional power grid. Furthermore, solar panels offer long-term operational cost efficiency, making them highly relevant for supporting the sustainability of industrial processes like those at PT. X.

METHODS

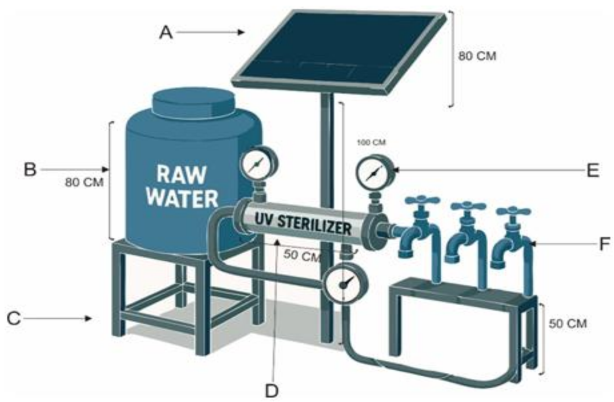
This study employed an experimental design using a post-test with control group, conducted in July 2025 at PT. X, Sumedang Regency. Samples were collected using the grab sampling method from a bore well, which serves as the company's primary source of clean water. The bore well water was utilized for production, sanitation, and domestic needs within the industrial area. The surrounding environment includes both domestic and industrial activities, which may contribute to potential contamination. Initial testing results showed a temperature range of 27.0–27.6°C, total dissolved solids (TDS) below 500 mg/L, pH between 7.0–7.2, and turbidity levels of 1–2 NTU, all of which meet the physical quality standards for clean water. However, the Total Coliform count was 56 CFU per 100 ml, exceeding the maximum permissible limit of 0 CFU per 100 ml as stipulated in the Minister of Health Regulation No. 2 of 2023. All tests were conducted using water from the same source (PT. X bore well). The control sample consisted of water without UV-C exposure, while the treatment samples were exposed to UV-C radiation with contact time variations of 90, 120, and 150 seconds. Examinations were carried out for physical parameters (temperature, TDS, pH, and turbidity) before and after treatment, as well as for Total Coliform counts, following ISO 9308-1:2014. Data were analyzed univariately to describe the variables and bivariately using one-way ANOVA to assess differences among treatments.

Equipment and Material Preparation Stage

a. Ultraviolet (UV-C) Lamp
Prepare an ultraviolet (UV-C) lamp with a wavelength of approximately 254 nm. Connect the lamp's electrical system to a battery powered by a solar panel, and ensure it is placed in a dry area to prevent contact with water.

b. Solar Panel and Electrical System
Prepare a solar panel with sufficient capacity to supply energy to the UV-C lamp. Connect the solar panel to a storage battery through a charge controller. Use an inverter if necessary to convert direct current (DC) to alternating current (AC). The battery functions as an energy reserve when sunlight is unavailable.

c. Supporting System
Equip the system with a water pump to channel the sample into the sterilization chamber, and install a digital timer connected to a relay or switch to control the UV-C exposure duration. Use a solenoid valve (automatic faucet) with appropriate pipe sizes (½" or ¾") to regulate water flow automatically.

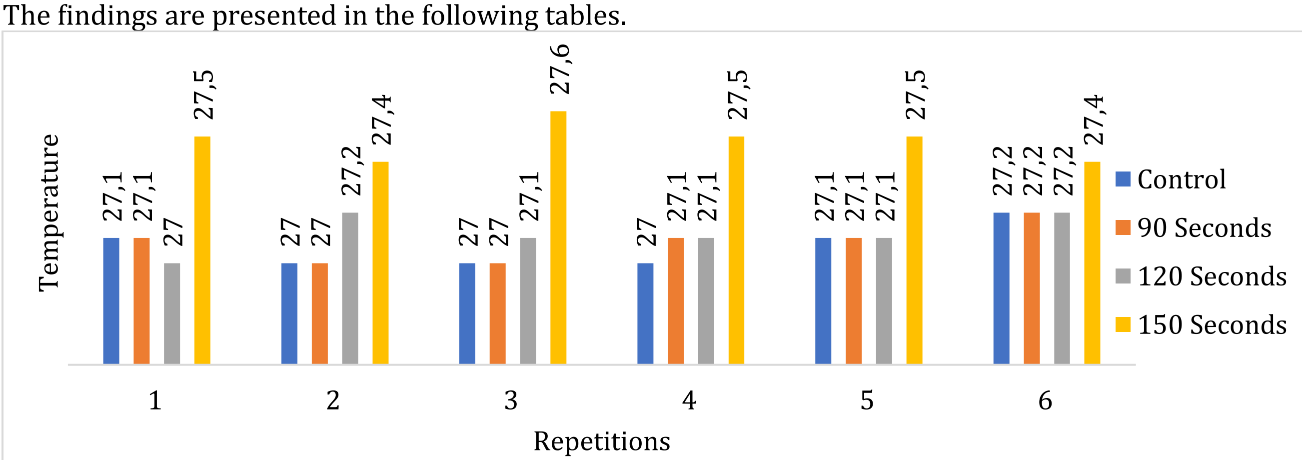


A = Solar Panel
B = Initial Clean Water Tank
C = Iron Frame
D = Ultraviolet (UV-C) Lamp
E = Automatic Timer
F = Output Water Faucet

Figure 1. Equipment Design

RESULTS

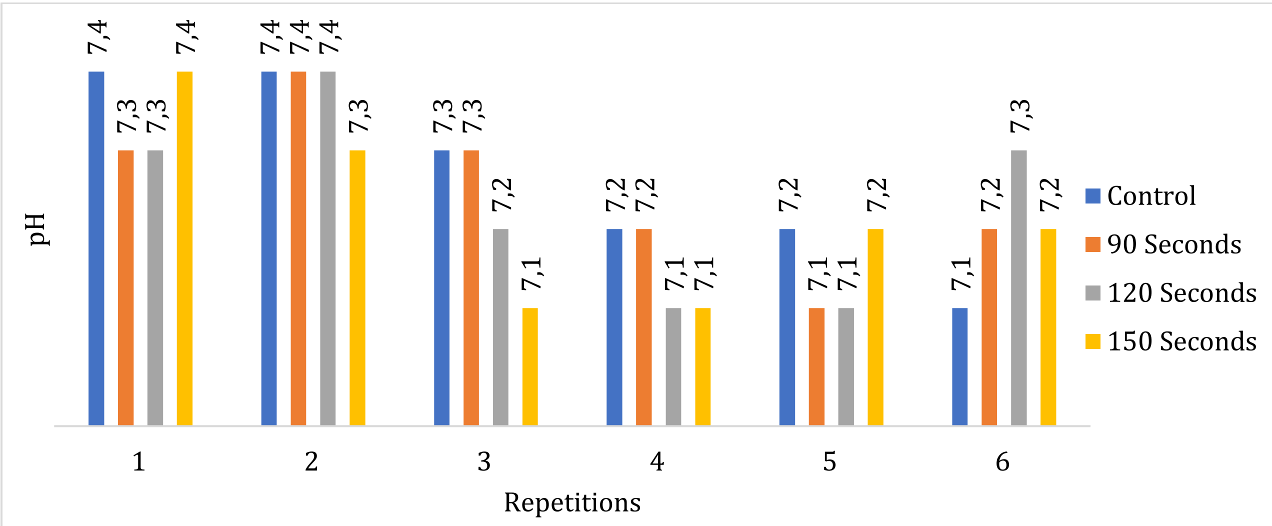
The findings are presented in the following tables.



Source: Primary Data, 2025

Figure 2. Measurement Results of Clean Water Temperature Based on Ultraviolet-C Contact Time at PT. X, Sumedang Regency

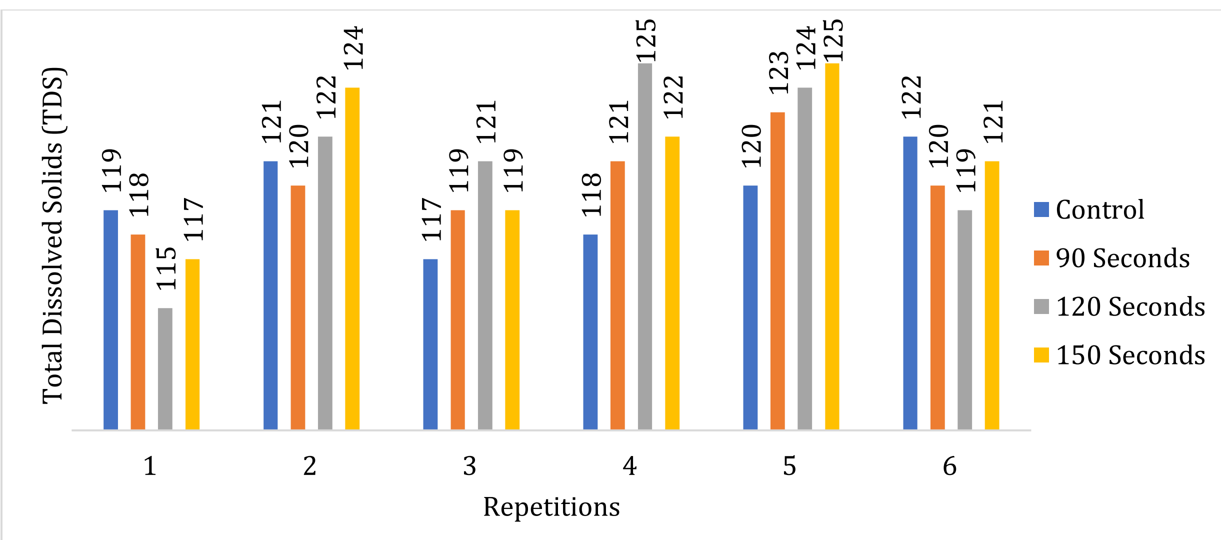
Table 1 shows the general characteristics of respondents. Most respondents were female (64.7%), aged 40–59 years (58.7%), and housewives (57.3%). A majority reported healthy lifestyles (55.3%) and healthy dietary patterns (62.7%). Hypertension was found in 65 respondents (43.3%), while 58% were classified as having abnormal nutritional status



Source: Primary Data, 2025

Figure 3. Measurement Results of Clean Water pH Based on Ultraviolet-C Contact Time at PT. X, Sumedang Regency

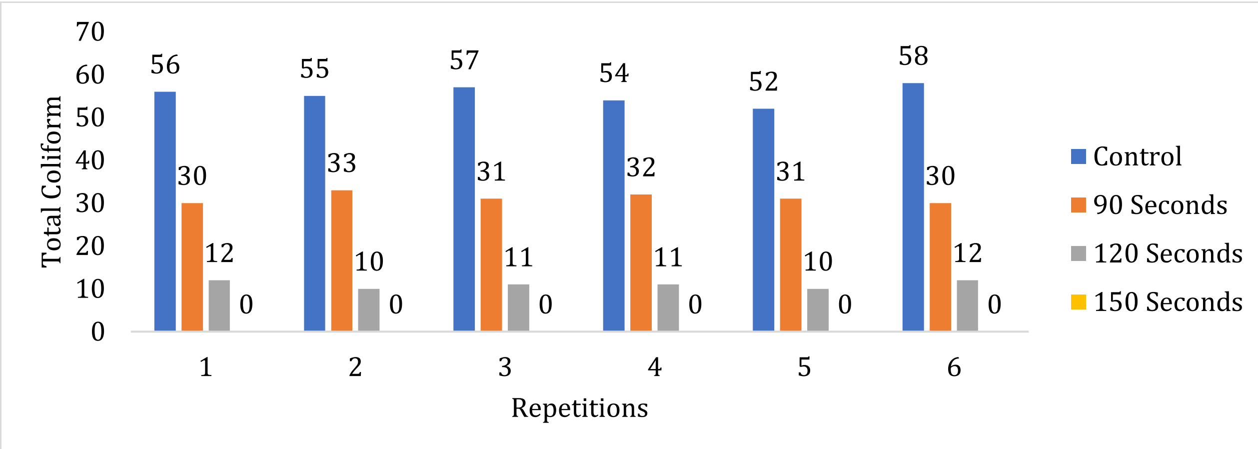
Based on the table above, the minimum pH value in the control sample, as well as at 90 seconds, 120 seconds, and 150 seconds of contact time, was 7.1, while the maximum pH value in the control sample and at 90, 120, and 150 seconds of contact time was 7.4.



Source: Primary Data, 2025

Figure 4. Measurement Results of Total Dissolved Solids (TDS) in Clean Water Based on UV-C Exposure Time at PT. X, Sumedang Regency

Based on the table above, the minimum TDS value in the control sample was 118 mg/L, at a contact time of 90 seconds was 118 mg/L, at 120 seconds was 115 mg/L, and at 150 seconds was 117 mg/L. Meanwhile, the maximum TDS value in the control sample was 122 mg/L, at a contact time of 90 seconds, was 123 mg/L, at 120 seconds, was 125 mg/L, and at 150 seconds was 125 mg/L.



Source: Primary Data, 2025

Figure 5. Results of Total Coliform Examination in Clean Water Based on Ultraviolet-C Exposure Time at PT. X, Sumedang Regency

Based on the table above, the average Total Coliform count in the control sample was 56 CFU/100 ml. In the treatment with a contact time of 90 seconds, the average count was 32 CFU/100 ml, representing a 43.7% reduction. At a contact time of 120 seconds, the average count decreased to 11 CFU/100 ml, corresponding to a 64.7% reduction, while at 150 seconds, the Total Coliform count reached 0 CFU/100 ml, indicating a 100% reduction.

Table 1. Results of One-Way ANOVA Test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3887.125	3	1295.708	257.000	0.001
Within Groups	100.833	20	5.042		
Total	3987.958	23			

Source: Primary Data, 2025

Based on the results of the bivariate analysis using the One-Way ANOVA test, the significance value was found to be < 0.05. Therefore, it can be concluded that there is a significant effect of the independent variable on the dependent variable, namely the reduction of Total Coliform in clean water at PT. X, Sumedang Regency.

Table 2. Results of the Post Hoc Test

Variations in Contact Time		***Mean Differece* (I-J)**	**Sig.**
Contact Time of 90 Seconds	Contact Time of 120 Seconds	-20.16667*	0.001
	Contact Time of 150 Seconds	-31.16667*	0.001
Contact Time of 120 Seconds	Contact Time of 90 Seconds	20.16667*	0.001
	Contact Time of 150 Seconds	-11.00000*	0.001
Contact Time of 150 Seconds	Contact Time of 90 Seconds	31.16667*	0.001
	Contact Time of 120 Seconds	11.00000*	0.001

Source: Primary Data, 2025

Based on the results of the Post Hoc test for the contact time variations of 90, 120, and 150 seconds of ultraviolet-C exposure, each treatment exhibited a statistically significant difference in reducing the Total Coliform count. The findings indicate that the 150-second UV-C contact time was the most effective in decreasing Total Coliform levels in clean water at PT. X, Sumedang Regency.

DISCUSSION

Effect of Temperature on the Reduction of Total Coliform in Clean Water

Water temperature plays a crucial role in the effectiveness of ultraviolet-C (UV-C) disinfection. Although the primary mechanism of UV-C radiation involves damaging microbial DNA through the formation of thymine dimers that inhibit replication, the physical condition of bacterial cells can also be influenced by water temperature. The optimal temperature range for effective UV-C radiation is generally between 20°C and 30°C. Within this range, the bacterial cell wall structure remains relatively stable without undergoing extreme changes, allowing UV-C rays to penetrate the cell nucleus more efficiently and enhancing the inactivation process (A., As, & Setiadi, 2014).

Temperature measurements of the clean water at PT. X in Sumedang Regency were conducted before and after treatment. Measurements taken over six replicates showed a temperature range of 27.0–27.6°C. These direct field measurements indicate that the water temperature complied with the stipulations of Indonesian Ministry of Health Regulation No. 2 of 2023, which mandates that permissible water temperature should be approximately ±3°C of the ambient air temperature. Furthermore, after exposure to ultraviolet (UV-C) irradiation, the water temperature did not exhibit any significant deviation from the control water temperature. The results of this study demonstrate that at a water temperature of approximately 27.0–27.6°C, the Total Coliform count decreased from 56 CFU/100 mL to 32 CFU/100 mL at a contact time of 90 seconds, 11 CFU/100 mL at 120 seconds, and 0 CFU/100 mL at 150 seconds. This suggests that deviations from the optimal temperature range can reduce the efficacy of UV-C disinfection. At lower temperatures (<20°C), bacterial cell walls tend to become more rigid, thereby impeding the penetration of UV-C radiation into the cell nucleus. Conversely, at elevated temperatures (>30°C), excessive heat can induce protein denaturation and alterations in the cell membrane, which may render some bacterial species more resistant or induce cellular stress that affects their sensitivity to UV-C radiation. Consequently, maintaining water temperature within an optimal range is crucial for ensuring consistent and effective disinfection performance.

The Influence of pH on Total Coliform Reduction in Clean Water

pH measurements of the clean water at PT. X in Sumedang Regency were conducted both before and after treatment. The measurements, performed in six replicates, yielded a pH range of 7.1 to 7.4. These direct field measurements confirm that the water's pH level complied with the requirements stipulated by Indonesian Ministry of Health Regulation No. 2 of 2023, which sets the permissible pH range for water between 6.5 and 8.5. Furthermore, following disinfection using ultraviolet (UV-C) light, no significant change in the water's pH was observed.

The Influence of Total Dissolved Solids (TDS) on the Reduction of Total Coliform in Clean Water

TDS (Total Dissolved Solids) measurements of the clean water in the kitchen of PT. X, Sumedang Regency, were conducted before and after treatment. Measurements taken across six replicates yielded a TDS range of 115-125 mg/L. These direct field measurements confirm that the TDS level of the water complies with the standards set by Indonesian Ministry of Health Regulation No. 2 of 2023, which stipulates a permissible TDS level of <300 mg/L. Furthermore, following disinfection using ultraviolet (UV-C) light, no significant change in the TDS of the clean water was observed. The low TDS value indicates that the water contains a low concentration of dissolved substances, such as salts, metals, and inorganic minerals (Navratinova & Tri, 2019).

Total Coliform in Clean Water at PT. X, Sumedang Regency, Before and After UV Irradiation

Laboratory analysis revealed that the initial Total Coliform count in the clean water at PT. X, Sumedang Regency, was 56 CFU/100 mL. This value exceeds the maximum permissible limit for clean water quality as stipulated by the Indonesian Ministry of Health Regulation No. 2 of 2023, which is 0 CFU/100 mL. This condition indicates that the water at this location is microbiologically non-compliant and can serve as a vehicle for transmitting waterborne diseases, such as diarrhea, dysentery, cholera, and other gastrointestinal illnesses. Following treatment with ultraviolet (UV-C) irradiation powered by solar panels, a significant reduction in Total Coliform was observed. At a contact time of 90 seconds, the average Total Coliform count decreased to 32 CFU/100 mL. With an extended contact time of 120 seconds, the count was further reduced to 11 CFU/100 mL. Finally, at the maximum contact time of 150 seconds, the average Total Coliform count reached 0 CFU/100 mL.

This reduction is attributed to the mechanism of ultraviolet (UV-C) light at a wavelength of 254 nm, which can damage the DNA and RNA structures of bacteria, including the Coliform group. The UV-C radiation induces the formation of abnormal bonds between thymine bases (thymine dimers) within the bacterial DNA strand. The formation of these thymine dimers disrupts the processes of DNA replication and transcription. Consequently, the microorganisms lose their ability to reproduce, ultimately leading to irreversible cell death (Gao, Zhao, & Li, 2025; Kumar & Tripathi, 2025; Thorpe, McKinlay, Richards, Sang, & Stewart, 2024).

The bactericidal process induced by ultraviolet (UV-C) light operates without the need for additional chemicals, rendering it a highly efficient and environmentally friendly method. UV-C exposure causes direct damage to the microbial cell nucleus without generating harmful by-products. Consequently, the application of UV-C irradiation constitutes a highly effective disinfection method for reducing microbiological contamination, including Total Coliform. The efficacy of UV-C in reducing Total Coliform is a significant advantage, as the treatment is relatively straightforward and simple to manage. Furthermore, this method does not produce hazardous by-products, is non-toxic, and does not impart any adverse effects on the water's taste or odour. Additional benefits include a short required contact time, ease of operation and maintenance of the equipment, and a long operational lifespan (Labina & Purnomo, 2022). Therefore, the application of UV-C irradiation presents a viable and effective solution for addressing the clean water issue at PT. X in Sumedang Regency.

The observed reduction of Total Coliform bacteria in the clean water at PT. X, Sumedang Regency, is attributed to the germicidal mechanism of ultraviolet (UV-C) radiation. UV-C radiation is a form of electromagnetic energy capable of penetrating the cell walls of microorganisms. The subsequent absorption of this UV-C radiation by bacterial DNA induces molecular damage that inhibits the microorganisms' ability to replicate, leading to their effective inactivation [15]. The formation of covalent bonds between adjacent pyrimidine bases, particularly thymine, constitutes the primary mechanism of bacterial inactivation. Pyrimidines exhibit strong absorption of ultraviolet-C (UV-C) radiation at 254 nm. This photochemical reaction generates reactive thymine species that form thymine dimers, creating structural distortions in the DNA helix. These lesions ultimately impair the accuracy of bacterial DNA replication, leading to lethal mutagenesis and effective microbial elimination from the water (Labina & Purnomo, 2022).

The efficacy of ultraviolet (UV-C) radiation absorption by bacterial DNA molecules is dependent on the wavelength of the UV-C light. The most potent germicidal activity occurs within the wavelength range of 250 nm to 265 nm. This study utilized a UV-C lamp emitting at a wavelength of 254 nm, which falls within this optimal range. Beyond the wavelength parameter, the success in reducing Total Coliform bacteria observed in this study is also attributed to the variable contact time between the UV-C radiation and the bacterial cells (Dramicanin et al., 2025).

Study Limitations

This study has several limitations: (1) The experimental design used a post-test with control group approach, which only measures the effect of treatment after exposure without considering baseline differences, so it cannot fully describe the trend of bacterial reduction over time; (2) The study was conducted only in one industrial site (PT. X, Sumedang Regency), which may limit the generalizability of the findings to other locations with different water characteristics or contamination sources; (3) Environmental factors such as turbidity, dissolved organic matter, or lamp aging that could influence UV-C effectiveness were not analyzed in detail, potentially introducing uncontrolled confounding effects; (4) The study focused solely on Total Coliform without including other indicator microorganisms such as E. coli or heterotrophic bacteria, which could provide a broader understanding of disinfection efficiency; and (5) This study did not assess the long-term operational performance or energy efficiency of the solar panel-powered UV-C system under field conditions. Future studies are recommended to include more diverse sampling sites, analyze additional microbial indicators, and evaluate the long-term sustainability and cost-effectiveness of solar-based UV-C disinfection systems.

CONCLUSION

The Total Coliform count in the clean water supply of PT. X Sumedang Regency was measured at 52–58 CFU/100 ml prior to disinfection treatment with ultraviolet (UV-C) light. Following UV-C irradiation powered by a solar panel, a significant reduction in coliform concentration was observed across different contact times. Specifically, a contact time of 90 seconds yielded a Total Coliform count of 30–33 CFU/100 ml, while 120 seconds resulted in 10–12 CFU/100 ml. Crucially, a contact time of 150 seconds achieved a complete elimination, registering 0 CFU/100 ml. The results suggest that PT. X Sumedang Regency can adopt this study's findings as a viable alternative for the microbiological purification of clean water. The most effective protocol utilizes a 15-watt UV-C light source for 150 seconds at an exposure distance of 2 cm, powered by solar energy, to achieve a 100% reduction in Total Coliform. For future research, it is recommended to investigate other factors that may influence disinfection effectiveness, such as the water turbidity level, variations in UV-C lamp power, or different exposure distances. This is essential to ascertain the consistency of the results under varying water quality conditions and equipment configurations.

Author's Contribution Statement: Nina Kaniawati, Muhamad Iqbal, and Lubis Bambang Purnama played key roles in conceptualizing the idea and designing the research methodology. Nina Kaniawati and Neneng Yety Hanurawaty contributed to data analysis and drafted the article. Nina Kaniawati was responsible for the final editing before the article was submitted to the journal.

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding Source: This research was self-funded by the authors.

Acknowledgments: The authors wish to express their sincere appreciation to PT. X in Sumedang Regency for granting permission to conduct the Field Learning Practice and carry out this thesis. The authors are also profoundly grateful to the lecturers and Educational Laboratory Staff of the Department of Environmental Health, Poltekkes Kemenkes Bandung, for their guidance, unwavering support, and insightful advice, which were instrumental in the successful completion of this study.

BIBLIOGRAPHY

A., S., As, Z. A., & Setiadi, G. (2014). Efektivitas "Portable UV Disinfection" dalam Menurunkan Angka Bakteri (Escherichia Coli Spp) pada Air Minum. *Jurnal Kesehatan Lingkungan: Jurnal Dan*

Aplikasi Teknik Kesehatan Lingkungan, *11*(2), 223–230. https://doi.org/10.31964/JKL.V11I2.15
Aba, L., Mulidin, M., Sety, L. O. M., Yuniar, N., Sahidin, L. O., Andimbara, L. O., & Irfan, I. (2023). Penyuluhan Pemanfaatan Air Bersih dan Sosialisasi Bimbingan Teknis Pengolahan Air Bersih dengan Metode Aerasi-Filtrasi untuk Meningkatkan Derajat Kesehatan Masyarakat. *Indonesia Berdaya*, *5*(1), 119–126. https://doi.org/10.47679/ib.2024661
Abboushi, B., Rodriguez-Feo Bermudez, E., Tuenge, J., & Arnold, G. (2025). GUV Installations Demonstrate Effectiveness and Exposure Safety in Field Settings. *Environmental Science & Technology*, *59*(17), 8640–8650. https://doi.org/10.1021/ACS.EST.4C10774
Backer, H. D., Derlet, R. W., & Hill, V. R. (2024). Wilderness Medical Society Clinical Practice Guidelines on Water Treatment for Wilderness, International Travel, and Austere Situations: 2024 Update. *Wilderness and Environmental Medicine*, *35*(1_suppl), 45S-66S. https://doi.org/10.1177/10806032231218722
Banseka, Y. J., & Tume, S. J. P. (2024). Coliform Bacteria Contamination of Water Resources and Implications on Public Health in Fako Division, South West Region, Cameroon. *Advances in Environmental and Engineering Research 2024, Vol. 5, 010*, *5*(2), 1–13. https://doi.org/10.21926/AEER.2402010
Bylund, J., Toljander, J., Lysén, M., Rasti, N., Engqvist, J., & Simonsson, M. (2017). Measuring sporadic gastrointestinal illness associated with drinking water - An overview of methodologies. *Journal of Water and Health*, *15*(3), 321–340. https://doi.org/10.2166/WH.2017.261
Dinny, H. N. A., Teguh, P. B., Yosephina, S. A., & Agus, S. S. (2019). Variasi Jarak Penyinaran Lampu Uv Terhadap Penurunan Angka Kuman Pada Alat Makan. *Jurnal Riset Kesehatan Poltekkes Depkes Bandung*, *11*(2), 150–154. https://doi.org/https://doi.org/10.34011/juriskesbdg.v11i2.724
Dramicanin, M. D., Brik, M. G., Antic, Z., Banica, R., Mosoarca, C., Dramicanin, T., … Suta, M. (2025). Pr3+ Visible to Ultraviolet Upconversion for Antimicrobial Applications. *Nanomaterials 2025, Vol. 15, Page 562*, *15*(7), 562. https://doi.org/10.3390/NANO15070562
Ersel, M. (2015). Water and sanitation standards in humanitarian action. *Turkish Journal of Emergency Medicine*, *15*(Suppl 1), 27–33. https://doi.org/10.5505/1304.7361.2015.48753
Gao, Y., Zhao, X., & Li, C. (2025). The evolution of irreversible cell differentiation under cell death effect. *PloS One*, *20*(8). https://doi.org/10.1371/journal.pone.0315255
Kementerian Kesehatan. (2023). Permenkes No. 2 Tahun 2023 tentang Kesehatan Lingkungan, yang mengatur standar baku mutu dan persyaratan kesehatan untuk berbagai media lingkungan. *Kemenkes Republik Indonesia*, (55), 1–175.
Khan, S., Mumtaj, Z. A., Khan, A. R., Ahmad, N., & Alqahtani, D. A. (2025). A review of conventional and non-conventional disinfection methods for treating potable water and wastewater. *International Journal of Chemical Reactor Engineering*, *23*(8), 895–916. https://doi.org/10.1515/IJCRE-2024-0235/Machinereadablecitation/Ris
Korajkic, A., McMinn, B. R., & Harwood, V. J. (2018). Relationships between microbial indicators and pathogens in recreational water settings. *International Journal of Environmental Research and Public Health*, *15*(12). https://doi.org/10.3390/IJERPH15122842
Kumar, N., & Tripathi, K. (2025). Effects of ultraviolet (UV) radiation on microbial growth: Mechanisms, responses, and applications. *Biotechnology Lab Techniques: Culture Media, Microscopy, and Microbial Analysis*, 57–59. https://doi.org/10.70593/978-93-49307-52-0_7
Labina, H. F., & Purnomo, Y. S. (2022). Penyisihan Bakteri E. Coli Menggunakan Radiasi Sinar Ultraviolet Dan Semikonduktor Tio2 Pada Air Sumur Desa Kenongo, Sidoarjo. *Envirous*, *2*(2). https://doi.org/10.33005/envirous.v2i2.95
Li, D., & Liu, S. (2019). Water Quality Monitoring in Aquaculture. *Water Quality Monitoring and Management*, 303–328. https://doi.org/10.1016/B978-0-12-811330-1.00012-0
Navratinova, S., & Tri, J. (2019). Hubungan Desinfeksi Sinar Ultraviolet (UV) dengan Kualitas Bakteriologi Air minum pada Depot Air Minum Isi Ulang (DAMIU) (Studi di Kecamatan

Pontianak Selatan Kota Pontianak). *Jurnal Kesehatan Masyarakat*, *7*(1), 2356–3346. https://doi.org/https://doi.org/10.14710/jkm.v7i1.23011
Ningsih, D. U. R., Karmini, M., & Hidayah, N. (2021). Perbedaan Daya Lampu Ultraviolet-C Terhadap Penurunan Jumlah Bakteri Coliform Pada Air Bersih Di Industri Logam. *Jurnal Riset Kesehatan Poltekkes Depkes Bandung*, *13*(2), 422–426. https://doi.org/10.34011/juriskesbdg.v13i2.1931
Permenkes. Permenkes Nomor 32 Tahun 2017 Tentang Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua dan Pemandian Umum. , Peraturan Menteri kesehatan Republik Indonesia § (2017).
Saputri, E. T., & Efendy, M. (2020). Kepadatan bakteri coliform sebagai indikator pencemaran biologis di perairan p. *Juvenil:Jurnal Ilmiah Kelautan Dan Perikanan*, *1*(2), 243–249. https://doi.org/10.21107/juvenil.v1I2.7579
Sari, D. I., Septiati, Y. A., & Setyoko, S. (2021). Perbedaan Lama Penyinaran Uv-C Terhadap Reduksi Jumlah Escherichia Coli Pada Air Bersih Dapur Pt. Xyz. *Jurnal Kesehatan Siliwangi*, *2*(2), 537–542. https://doi.org/10.34011/jks.v2i2.719
Sliney, D. H., & Stuck, B. E. (2021). A Need to Revise Human Exposure Limits for Ultraviolet UV-C Radiation†. *Photochemistry and Photobiology*, *97*(3), 485–492. https://doi.org/10.1111/PHP.13402
Some, S., Mondal, R., Mitra, D., Jain, D., Verma, D., & Das, S. (2021). Microbial pollution of water with special reference to coliform bacteria and their nexus with environment. *Energy Nexus*, *1*, 100008. https://doi.org/10.1016/J.NEXUS.2021.100008
Sultana, R., Nahar, N., Luby, S. P., Swarna, S. T., Gurley, E. S., Tamason, C. C., … Jensen, P. K. M. (2022). Measuring Water Quantity Used for Personal and Domestic Hygiene and Determinants of Water Use in a Low-Income Urban Community. *International Journal of Environmental Research and Public Health*, *19*(23). https://doi.org/10.3390/ijerph192315656
Syafarida, U. Y., Jati, D. R., & Sulastri, A. (2022). Analisis Hubungan Konstruksi Sumur Gali dan Sanitasi Lingkungan Terhadap Jumlah Bakteri Coliform Dalam Air Sumur Gali (Studi Kasus: Desa PAL IX, Kecamatan Sungai Kakap). *Jurnal Ilmu Lingkungan*, *20*(3), 437–444. https://doi.org/10.14710/jil.20.3.437-444
Thorpe, D., McKinlay, M., Richards, J., Sang, K., & Stewart, M. E. (2024). The Lived Experience of Autistic Adults in Employment: A Systematic Search and Synthesis. *Autism in Adulthood : Challenges and Management*, *6*(4), 495–509. https://doi.org/10.1089/aut.2022.0114
Tripathi, D. R. (2023). Safe Drinking Water-Threats of Pollution to Potable Water For The Community. *Journal of Survey in Fisheries Sciences*. https://doi.org/10.53555/G86WES45
Widyawati. (2019). *Kebutuhan Air Bersih Bagi Manusia*. Penerbit Citra Ilmu.