Antibiotic Resistance and Global Health: Challenges in Achieving SDG 3 through Effective Environmental Sterilization Practices

*Woro Hapsari[1], Sajidan [2], Suranto[3], Nur Hafidha Hikmayani[4]

[1] Environmental Science Doctoral Programme, Universitas Sebelas Maret, Jl. Ir Sutami 36, Surakarta 57126, Jawa Tengah, Indonesia.
[2] Biology Education, Teacher Training and Education, Universitas Sebelas Maret Jl. Ir Sutami 36 , Surakarta 57126, Jawa Tengah, Indonesia.
[3] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret Jl. Ir Sutami 36 , Surakarta 57126, Jawa Tengah, Indonesia.
[4] Faculty of Medicine, Universitas Sebelas Maret Jl. Ir Sutami 36, Surakarta 57126, Jawa Tengah, Indonesia.

worohapsari0@gmail.com

Abstract. Sterilization is essential for minimizing pathogen exposure on medical instruments used in patient care. The effectiveness of sterilization significantly influences the development and spread of microorganism resistance in the environment. The third Sustainable Development Goal (SDG) focuses on ensuring good health and well-being for all individuals. Antibiotic resistance poses a critical challenge to global health, complicating efforts to reduce mortality from infections and degenerative diseases. This study analyzes the presence of microorganisms and antibiotic resistance patterns on medical instruments before and after sterilization, offering insights into bacterial spread. Antibiotic resistance testing was performed using in vitro culture methods, Gram staining, and bacterial identification with the Vitek 2 system. Before sterilization, *Staphylococcus hominis ssp. hominis* was identified with a 99% probability, along with Bacillus sp. on Nal Puder instruments, while *Pseudomonas stutzeri* (Gram-negative) was found on instrument trays, also at 99% probability. Following sterilization and a 90-day storage period, Staphylococcus hominis ssp. hominis was again detected in an open container with a probability of 97%. Antibiotic sensitivity testing (AST) revealed an increase in sensitive antibiotics from 12 types before sterilization to 14 types afterward. The Minimum Inhibitory Concentration (MIC) for Benzylpenicillin decreased from 0.25 µg/mL (resistant) to ≤0.03 µg/mL (sensitive). These findings highlight the importance of effective sterilization practices in controlling the spread of resistant microorganisms, supporting global efforts to achieve health-related SDGs and enhance infection control in healthcare environments.

Keywords: Antibiotic resistance, sterilization, SDGs.

S. G. Prakoso et al. (eds.), *Proceedings of the 8th International Conference on Social and Political Sciences (ICoSaPS 2024)*, Advances in Social Science, Education and Humanities Research 903,
https://doi.org/10.2991/978-2-38476-368-9_2

1 Introduction

The COVID-19 pandemic has significantly impacted global health, both through the virus itself and the increase in antibiotic resistance. Many hospitalized patients experience secondary infections, often leading to excessive and inappropriate antibiotic use. This situation contributes to the development and spread of antibiotic resistance (AMR), which poses a serious challenge in healthcare environments. [1].

Healthcare-Associated Infections (HAIs) are a major issue in hospitals, occurring in various patient care areas. [2] [3]Environmental contamination plays a critical role in the occurrence of HAIs, [4], and the World Health Organization (WHO) notes that HAIs are responsible for high morbidity and mortality rates worldwide. . [5][6] [7] The greatest health threat related to HAIs is antibiotic resistance, which is estimated to have caused 1.27 million deaths in 2019, with projections of 10 million deaths by 2050 if inappropriate antibiotic use continues. [10]Despite the life-saving potential of antibiotics over the past 80 years, increasing bacterial resistance levels threaten the effectiveness of antibiotics for previously treatable bacterial infections. [11]. [12].

Bacteria possess the ability to adapt over time, allowing them to develop resistance to antibiotics. [13]. The spread of resistance genes from environmental bacteria to human pathogens can be minimized through vector control and management of abiotic factors such as waste, soil, and water. [14] [15] Contamination of medical instruments can serve as a breeding ground for pathogenic microorganisms. Effective sterilization processes are crucial for eliminating potential infectious contaminants on medical instruments and breaking the chain of infection. [16] [18] If not performed properly, contaminants can proliferate and form biofilms, [14]., making bacteria more resistant to treatment. [19] [20] [22][23] Environmental prevention and control are vital in reducing the spread of resistant bacteria. [21] [24]

In the context of Sustainable Development Goal (SDG) 3, which aims to ensure healthy lives, the challenge of antibiotic resistance is highly relevant. [25] Environmental control efforts through effective sterilization practices can contribute to achieving this goal. This study aims to examine patterns of contamination and antibiotic resistance on medical devices, [26] as well as their implications for decontamination processes and infection control in hospitals. It is hoped that the findings of this research will inform policy directions for developing more effective and sustainable infection control strategies, thereby enhancing environmental management in healthcare services.

2 Literature review

Antimicrobial resistance (AMR) is a pressing global issue that requires a One Health approach, linking human, animal, and environmental health. Excessive use of antimicrobials in healthcare and agriculture has contributed to the development and spread of bacterial resistance. Bacterial resistance is defined as the natural ability of bacteria to evade the effects of antimicrobials, occurring through various mechanisms such as enzyme production that degrades antibiotics, changes in cell membrane permeability, and structural modifications of drug targets. [27][28].

One of the primary causes of the spread of antibiotic resistance genes (ARG) is poor infection control practices and inappropriate antimicrobial use. In this context, sterilization processes are crucial for eliminating all forms of microbial life, including spores, which can increase the risk of infection. [28][29].Various sterilization methods, such as steam, dry

heat, ethylene oxide gas, and chemicals, are employed to break the chain of resistant bacteria transmission. [30][33].
Antimicrobial susceptibility testing (AST) also plays an important role in determining effective therapies and supporting the achievement of Sustainable Development Goal 3 related to health and well-being. Through this testing, more precise treatment decisions can be made, contributing to a reduction in mortality rates from infectious diseases and enhancing public health. [29][31]. However, antibiotic resistance in the environment can exacerbate global health problems, making it vital to monitor and control its spread. [32].
Pathogenic microorganisms residing in environments such as soil and water also contribute to infection spread. Research on the impact of human activities on these reservoirs aligns with SDG 6, which emphasizes the importance of good sanitation and water management to prevent disease transmission. [31]. The spread of resistant bacteria through wastewater and food highlights the complex interactions between human health and the environment. [32]. This situation illustrates the challenges in achieving SDG 12 regarding responsible consumption and production, which emphasizes the need for sustainable resource use in medical practices. Understanding the mechanisms and factors influencing AMR, as well as its public health impacts, is crucial for formulating more effective strategies to control antimicrobial resistance spread. [34].

3 Methods

This study was conducted in vitro in a clinical microbiology laboratory to evaluate the presence and resistance of bacteria on seven types of medical instruments. The instruments sampled included anatomical tweezers, surgical tweezers, artery clamps, open containers, instrument trays, Nal Puder, and tissue scissors. To begin the research, preparation of tools and materials was carried out. The tools used included matches, petri dishes, a biosafety cabinet, a spirit lamp, sterile containers, inoculating loops, and sterile swabs. Required materials included aquabidest and blood agar media.
Once all tools and materials were ready, samples were collected from each instrument. These samples were incubated for 24 hours at 37°C. After incubation, Gram staining was performed to identify bacterial species. This procedure utilized a microscope and glass slides, along with several reagents: crystal violet, Lugol's iodine, acetone, and safranin, concluding with rinsing using aquabidest.
For bacterial identification and resistance testing, a single colony of bacteria was taken and divided into two tubes. The first tube was prepared for identification testing, while the second was for antibiotic resistance testing. Each tube was filled with a 0.45% NaCl solution at pH 5.0, where the bacterial colony was homogenized to create a uniform suspension.
The turbidity of the inoculum was measured using a Densichek device. The measurement procedure involved inserting the tube into the measurement hole on the Densichek and rotating it for two seconds. The measurement results were compared to McFarland turbidity standards, which range from 0.05–0.63 for Gram-positive bacteria and 1.8–2.2 for yeast. After identification, antibiotic sensitivity testing was performed using test strips. The second tube was used to determine the bacteria's sensitivity to various antibiotics. The Vitek 2 card was placed in the correct order; the blue tubing was used for identification, and the gray tubing for Antimicrobial Susceptibility Testing (AST).

4 Result and Discussion

Table 1. Results of in vitro microbiological tests showing bacterial identification on medical instruments before sterilization using the Vitek 2 system.

No	Medical Instrument	Bacterial Subspecies	Probability
1	Bak instrumen	*Psedumonas Stutzery*	99%
2	Nal puder	*Staphylococcus hominis ssp hominis*	99%

In this study, the identification of microorganisms on medical instruments yielded significant results. *Pseudomonas stutzeri* was detected on the instrument tray with a probability of 99%. This bacterium is classified as Gram-negative, aerobic, and non-fluorescent, which are common characteristics within the Pseudomonas genus. On the other hand, the Nal Puder instrument identified Staphylococcus hominis ssp. hominis with the same probability of 99%. This bacterium is Gram-positive and belongs to the *Staphylococcus* genus. These identification results reflect a high level of confidence, with the Vitek 2 system demonstrating accuracy ranging from 97% to 99%. These findings underscore the importance of utilizing accurate microbiological identification methods to detect contaminants on medical instruments, which can contribute to infection control and the prevention of pathogen spread in healthcare settings.

Table 2. AST Results from the Vitek 2 System for Medical Instruments - Instrument Tray with Gram Negative Bacteria *Pseudomonas stutzeri*.

No	Antimicrobial	*MIC (µg/mL)	Interpretation
1	Piperacillin / Tazobactam	<= 4	Sensitif
2	Ceftazidime	<=1	Sensitif
3	Cefriaxone	<=1	Sensitif
4	Cefepime	<=1	Sensitif
5	Aztrenonam	<=1	Sensitif
6	Meropenem	<=0,25	Sensitif
7	Amikacin	4	Sensitif
8	Gentamycin	<=1	Sensitif
9	Ciprofloxacin	<=0,25	Sensitif
10	Tigecycline	<=0,5	Sensitif
11	Trimethoprim/ Sulfamethoxazole	<=20	Sensitif

From the AST results obtained using the Vitek 2 system, Pseudomonas stutzeri showed sensitivity (S) to eleven types of antibiotics. This indicates that Pseudomonas stutzeri is highly responsive to antibiotics, reflecting a good sensitivity profile for effective inhibition against the bacteria.

Table 3: Antibiotic Resistance Testing (AST) Results for Medical Instruments Before Sterilization Using the Vitek 2 System - Nal Puder Instrument with Gram-Positive Coccus *Staphylococcus hominis sp. hominis*

No	Antimicrobial	*MIC (µg/mL)	Interpretation
1	Benzylpenicilin	0,25	*Resisten*
2	Oxacillin	<=0,25	Sensitif
3	Gentamicin	<=0,5	Sensitif
4	Ciprofloxacin	<=0,5	Sensitif
5	Levofloxacin	<=0,12)	Sensitif
6	Moxifloxacin	<=0,25	Sensitif
7	Erytrhromycin	<=0,25*	*Intermediate*
8	Clindamycin	>=8	*Resisten*
9	Quinupristin / Dalfopristin	1	Sensitif
10	Linezolid	2	Sensitif
11	Vancomycin	<=0,5	Sensitif
12	Tetracyclin	>=16	*Resisten*
13	Tigecycline	<=0,12	Sensitif
14	Nitrofurantoin	<=16	Sensitif
15	Rifampicin	<=0,5	Sensitif
16	Trimethoprim / Sulfamethoxazole	<=10	Sensitif

The results of the Antibiotic Susceptibility Testing (AST) using the Vitek 2 system indicate that Staphylococcus hominis ssp. hominis exhibited resistance (R) to several antibiotics, including benzylpenicillin, clindamycin, and tetracycline. This resistance suggests that the bacteria cannot be effectively eliminated by antibiotics that were previously effective for treating infections, complicating infection control efforts. Additionally, the testing showed an intermediate (I) interpretation for erythromycin, indicating that this antibiotic may still be effective, but its efficacy is limited. Treatment may be successful if administered at higher doses or in areas of the body where the drug concentration can reach adequate levels. This intermediate category also suggests the potential for developing resistance, which could affect the antibiotic's effectiveness. On the other hand, the sensitive (S) interpretation indicates that the microbes are still highly responsive to certain antibiotics, demonstrating a good inhibitory effect. These results highlight the importance of monitoring antibiotic resistance to ensure appropriate therapies are employed for controlling infections caused by this bacterium.

Table 4: In Vitro Microbiological Testing Results - Identification of Bacteria on Medical Instruments Before Sterilization Using the Vitek 2 System

Medical Instrument	Bacterial Subspecies	Probability
Open container	*Staphylococcus hominis ssp hominis*	97

Table 5: Antibiotic Resistance Testing (AST) Results for Medical Instruments After Sterilization Using the Vitek 2 System - Open Container Instrument with Gram-Positive Coccus *Staphylococcus hominis ssp. Hominis*

No	Antimicrobial	*MIC (µg/mL)	Interpretation
1	Benzylpenicillin	< 0,03	Sensitif
2	Oxacillin	<=0,25	Sensitif
3	Gentamycin	<=0,5	Sensitif
4	Ciprofloxacin	<=0,5	Sensitif
5	Levofloxacin	<=12	Sensitif
6	Moxifloxacin	<0,25	Sensitif
7	Erytromycin	>=8	*Resisten*
8	Clindamycin	>=8	*Resisten*
9	Quinupristin/ Dalfopristin	<=0,25	Sensitif
10	Linezolid	2	Sensitif
11	Vancomycin	<=0,5	Sensitif
12	Tetracycline	<=1	Sensitif
13	Tigecycline	<=0,12	Sensitif
14	Nitrofurantoin	<=16	Sensitif
15	Rifampicin	<=0,5	Sensitif
16	Trimethoprim /Sulfamethoxazole	<=10	Sensitif

MIC : Minimum Inhibitory Concentration

The Antibiotic Susceptibility Testing (AST) results using the Vitek 2 system indicated a change in antibiotic sensitivity patterns, with the number of sensitive antibiotics increasing from 12 types before sterilization to 14 types after sterilization. This finding highlights a shift in resistance patterns, particularly concerning benzylpenicillin. Before sterilization, the Minimum Inhibitory Concentration (MIC) for benzylpenicillin was recorded at 0.25 µg/mL, indicating resistance. However, after sterilization, the MIC significantly decreased to ≤0.03 µg/mL, showing that the bacteria are now sensitive to this antibiotic. This change underscores the importance of sterilization in controlling antibiotic resistance and enhancing treatment efficacy.

Antibiotic resistance is a global health issue that threatens the achievement of the Sustainable Development Goals (SDGs), particularly in relation to health and well-being (SDG 3). This research emphasizes the importance of infection control through effective sterilization practices as a strategy to address this challenge. The increasing

antibiotic resistance, as observed in *Staphylococcus hominis ssp hominis* resistant to benzylpenicillin and clindamycin, presents difficulties in treating infections.
This bacterium displays a varied resistance pattern, reflecting the impact of inappropriate antibiotic use and ineffective infection control measures. In a global context, such resistance can lead to increased morbidity and mortality, along with higher healthcare costs. Conversely, the study results indicate that *Pseudomonas stutzeri* remains sensitive to many antibiotics, providing hope that appropriate interventions can improve the situation. [33][34][35],
However, the resistance patterns observed in Staphylococcus hominis necessitate ongoing monitoring and stricter infection control strategies. [36] [37] [38][39]The aforementioned findings demonstrate a more diverse resistance profile, with the bacterium resistant to benzylpenicillin and clindamycin, [40]presenting potential issues in treating infections caused by this strain. Nevertheless, this bacterium remains sensitive to several critical antibiotics, including oxacillin, gentamicin, and ciprofloxacin. The intermediate interpretation for erythromycin indicates the need for special attention when administering antibiotics, as there is a potential risk for developing resistance in the future. [41]
The results of this study have implications for infection control, emphasizing the importance of implementing strict sterilization procedures to manage the infection risks associated with medical devices. The decrease in pathogens and changes in antibiotic sensitivity patterns following the sterilization process indicate that effective interventions can enhance patient safety. Additionally, strict monitoring of antibiotic resistance patterns should be an integral part of infection control policies in hospitals. [43] [23]By continuously monitoring and evaluating antibiotic resistance, healthcare facilities can take proactive steps to prevent the spread of infections and resistance. [44]

5 Conclusion

Antibiotic resistance is a serious challenge that requires global attention. This study demonstrates that infection control through effective sterilization practices can be a crucial strategy in achieving SDG 3. By reducing resistance and enhancing treatment efficacy, we can protect public health and ensure the sustainability of global health systems. Collaborative efforts focused on good infection control practices are essential steps to tackle the challenge of antibiotic resistance in the future.

6 Acknowledgement

Foundation of Trisanja Husada Education, Slawi, Tegal Regency, Indonesia. PhD supervisor in Environmental Science Universitas Sebelas Maret Surakarta.

References

1. Langford, B. J., *et al.*, “Antibiotic resistance associated with the COVID-19 pandemic: a systematic review and meta-analysis,” *Clin. Microbiol. Infect.*, vol. 29, no. 3, pp. 302–309, 2023, doi: 10.1016/j.cmi.2022.12.006.

2. Suleyman, G., Alangaden, G., and Bardossy, A. C., "The Role of Environmental Contamination in the Transmission of Nosocomial Pathogens and Healthcare-Associated Infections," *Curr. Infect. Dis. Rep.*, vol. 20, no. 6, 2018, doi: 10.1007/s11908-018-0620-2.
3. van Seventer, J. M., and Hochberg, N. S., *Principles of Infectious Diseases: Transmission, Diagnosis, Prevention, and Control*, Second Edi., vol. 6. Elsevier, 2016. doi: 10.1016/B978-0-12-803678-5.00516-6.
4. Shaw, K., "Prevention by breaking the chain of infection," *Nurs. Times*, vol. 112, no. 39–40, pp. 12–15, 2016, [Online]. Available: https://insights.ovid.com/nursing-times/nrtm/2016/10/120/prevention-breaking-chain-infection/17/00006203
5. Khammarnia, M., *et al.*, "Systematic review and meta-analysis of hospital acquired infections rate in a middle east country (1995-2020)," *Med. J. Islam. Repub. Iran*, vol. 35, no. 1, pp. 1–9, 2021, doi: 10.47176/mjiri.35.102.
6. Mukherjee, D., "The review on Epidemiology, Prevention, Control and Surveillance of Nosocomial Infections," 2020.
7. Danasekaran, R., Mani, G., and Annadurai, K., "Letter to the Editor Prevention of healthcare-associated infections : protecting patients , saving lives," vol. 1, no. 1, pp. 67–68, 2014, doi: 10.5455/2394-6040.ijcmph20141114.
8. Maguire van Seventer, J., and Hochberg, N. S., "Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information," *Int. Encycl. Public Heal.*, vol. 6, no. 2, pp. 22–39, 2017.
9. Despotovic, M., de Nies, L., Busi, S. B., and Wilmes, P., "Reservoirs of antimicrobial resistance in the context of One Health," *Curr. Opin. Microbiol.*, vol. 73, p. 102291, 2023, doi: 10.1016/j.mib.2023.102291.
10. Hutchings, M., Truman, A., and Wilkinson, B., "Antibiotics: past, present and future," *Curr. Opin. Microbiol.*, vol. 51, no. Figure 1, pp. 72–80, 2019, doi: 10.1016/j.mib.2019.10.008.
11. Pulingam, T., *et al.*, "Antimicrobial resistance: Prevalence, economic burden, mechanisms of resistance and strategies to overcome," *Eur. J. Pharm. Sci.*, vol. 170, p. 106103, 2022, doi: 10.1016/j.ejps.2021.106103.
12. Prestinaci, F., Pezzotti, P., and Pantosti, A., "Antimicrobial resistance: A global multifaceted phenomenon," *Pathog. Glob. Health*, vol. 109, no. 7, pp. 309–318, 2015, doi: 10.1179/2047773215Y.0000000030.
13. Uddin, T. M., *et al.*, "Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects," *J. Infect. Public Health*, vol. 14, no. 12, pp. 1750–1766, 2021, doi: 10.1016/j.jiph.2021.10.020.
14. Sahoo, K. C., Tamhankar, A. J., Johansson, E., and Lundborg, C. S., "Antibiotic use, resistance development and environmental factors: A qualitative study among healthcare professionals in Orissa, India," *BMC Public Health*, vol. 10, no. 1, p. 629, 2010, doi: 10.1186/1471-2458-10-629.
15. Mancuso, G., Midiri, A., Gerace, E., and Biondo, C., "Bacterial antibiotic resistance: the most critical pathogens," *Pathogens*, vol. 10, no. 10, pp. 1–14, 2021, doi: 10.3390/pathogens10101310.
16. Bashaw, M. A., and Keister, K. J., "Perioperative strategies for surgical site infection prevention," *AORN J.*, vol. 109, no. 1, pp. 68–78, 2019, doi: 10.1002/aorn.12451.
17. Solon, J. G., and Killeen, S., "Decontamination and sterilization," *Surg. (United Kingdom)*, vol. 37, no. 1, pp. 51–57, 2019, doi: 10.1016/j.mpsur.2018.11.002.
18. Rutala, W. A., Morelli, L., Weber, D. J., and Thomann, C. A., "Effects of long-term storage on sterility of medical supplies," *Am. J. Infect. Control*, vol. 34, no. 4, p. 248, 2006, doi: 10.1016/j.ajic.2005.09.008.
19. Rubak, P., *et al.*, "Can a humid storage environment of surgical instruments before reprocessing increase patient safety and durability of instruments?," *J. Hosp. Infect.*, vol.

122, pp. 64–71, 2022, doi: 10.1016/j.jhin.2022.01.012.
20. Khatoon, Z., McTiernan, C. D., Suuronen, E. J., Mah, T. F., and Alarcon, E. I., "Bacterial biofilm formation on implantable devices and approaches to its treatment and prevention," *Heliyon*, vol. 4, no. 12, p. e01067, 2018, doi: 10.1016/j.heliyon.2018.e01067.
21. Zheng, D., Liwinski, T., and Elinav, E., "Interaction between microbiota and immunity in health and disease," *Cell Res.*, vol. 30, no. 6, pp. 492–506, 2020, doi: 10.1038/s41422-020-0332-7.
22. Paharik, A. E., Horswill, A. R., Roy, J., and City, I., "response," vol. 4, no. 2, pp. 1–48, 2016, doi: 10.1128/microbiolspec.VMBF-0022-2015.The.
23. Andersson D. I., and Hughes, D., "Selection and transmission of antibiotic-resistant bacteria," *Microb. Transm.*, pp. 117–137, 2019, doi: 10.1128/9781555819743.ch7.
24. Manaia, M., "Assessing the Risk of Antibiotic Resistance Transmission from the Environment to Humans: Non-Direct Proportionality between Abundance and Risk," *Trends Microbiol.*, vol. 25, no. 3, pp. 173–181, 2017, doi: 10.1016/j.tim.2016.11.014.
25. McMichael, C., "Water, sanitation and hygiene (WASH) in schools in low-income countries: A review of evidence of impact," *Int. J. Environ. Res. Public Health*, vol. 16, no. 3, pp. 1–21, 2019, doi: 10.3390/ijerph16030359.
26. Nwobodo, D. C., *et al.*, "Antibiotic resistance: The challenges and some emerging strategies for tackling a global menace," *J. Clin. Lab. Anal.*, vol. 36, no. 9, pp. 1–10, 2022, doi: 10.1002/jcla.24655.
27. WHO, F., "One Health and the United Nations," 2023.
28. Awaludin and Mudayana, A. A., "Penerapan Manajemen CSSD (Central Sterile Supply Department)/ Unit Sterilisasi Sentral Di RSU PKU Muhammadiyah Bantul Yogyakarta," *Ber. Kedokt. Masy.*, vol. 02, no. 02, p. 2016, 2017.
29. Rutala, W. A., Donskey, C. J., and Weber, D. J., "Disinfection and sterilization: New technologies," *Am. J. Infect. Control*, vol. 51, no. 11, pp. A13–A21, 2023, doi: 10.1016/j.ajic.2023.01.004.
30. Kartikasari, D., and Wardhani, V., "Should the Central Sterile Supply Department in Every Hospital?," *J. Medicoeticolegal dan Manaj. Rumah Sakit*, vol. 9, no. 1, pp. 61–75, 2020, doi: 10.18196/jmmr.91117.
31. Checinska, A., Paszczynski, A., and Burbank, M., "Bacillus and other spore-forming genera: Variations in responses and mechanisms for survival," *Annu. Rev. Food Sci. Technol.*, vol. 6, pp. 351–369, 2015, doi: 10.1146/annurev-food-030713-092332.
32. Ozbek, A., Aktaş, O., and Uyanik, M. H., "A Case of Pseudomonas stutzeri Bacteremia in a Patient with Hematologic Malignancy," no. March, 2010, [Online]. Available: https://www.researchgate.net/publication/312499081
33. Lalucat, J., Bennasar, A., Bosch, R., García-Valdés, E., and Palleroni, N. J., " Biology of Pseudomonas stutzeri ," *Microbiol. Mol. Biol. Rev.*, vol. 70, no. 2, pp. 510–547, 2006, doi: 10.1128/mmbr.00047-05.
34. Ranieri, L., López-Salguero, S., Galván, Y. G., and Andrés, M., "A Case Report: Pseudomonas Stutzeri, An Unusual Cause Of Septic Arthritis," *Rev. Colomb. Reumatol.*, vol. 27, no. 3, pp. 215–217, 2020, doi: 10.1016/j.rcreu.2019.09.002.
35. Khan, N. T., "Pseudomonas stutzeri-an opportunistic pathogen," *J. Appl. Biotechnol. Bioeng.*, vol. 9, no. 3, pp. 83–84, 2022, doi: 10.15406/jabb.2022.09.00289.
36. Zheng, Y., He, L., Asiamah, T. K., and Otto, M., "Colonization of medical devices by staphylococci," *Environ. Microbiol.*, vol. 20, no. 9, pp. 3141–3153, 2018, doi: 10.1111/1462-2920.14129.
37. Turbawaty, D. K., Logito, V., and Tjandrawati, A., "Methicillin-Resistant Staphylococcus aureus (MRSA) Patterns and Antibiotic Susceptibility in Surgical and Non-Surgical Patients in a Tertiary Hospital in Indonesia," *Maj. Kedokt. Bandung*, vol. 53, no. 3, pp. 148–154, 2021, doi: 10.15395/mkb.v53n3.2396.
38. Gilad, J., and Schwartz, D., "Identification of Staphylococcus species with the VITEK 2

system: The case of Staphylococcus hominis [7]," *J. Clin. Microbiol.*, vol. 45, no. 2, p. 685, 2007, doi: 10.1128/JCM.02228-06.
39. Nassar, M. S. M., Hazzah, W. A., and Bakr, W. M. K., "Evaluation of antibiotic susceptibility test results: How guilty a laboratory could be?," *J. Egypt. Public Health Assoc.*, vol. 94, no. 1, pp. 1–5, 2019, doi: 10.1186/s42506-018-0006-1.
40. Appalaraju, B., and Jayakumar, S., "Inducible clindamycin resistance in Staphylococcus aureus isolated from clinical samples," *J. Commun. Dis.*, vol. 42, no. 4, pp. 263–268, 2010, doi: 10.4103/0974-2727.78558.
41. Haque, M., Sartelli, M., Mckimm, J., and Bakar, M. A., "Infection and Drug Resistance Dovepress Health care-associated infections-an overview," *Infect. Drug Resist.*, vol. 11, no. 1, pp. 2321–2333, 2018, [Online]. Available: http://dx.doi.org/10.2147/IDR.S177247
42. Larsson, D. G. J., and Flach, C. F., "Antibiotic resistance in the environment," *Nat. Rev. Microbiol.*, vol. 20, no. 5, pp. 257–269, 2022, doi: 10.1038/s41579-021-00649-x.
43. Nadgir, C. A., and Biswas, D. A., "Antibiotic Resistance and Its Impact on Disease Management," *Cureus*, vol. 15, no. 4, 2023, doi: 10.7759/cureus.38251.
44. Kotwani, A., Joshi, J., and Kaloni, D., "Pharmaceutical effluent: a critical link in the interconnected ecosystem promoting antimicrobial resistance," *Environ. Sci. Pollut. Res.*, vol. 28, no. 25, pp. 32111–32124, 2021, doi: 10.1007/s11356-021-14178-w.