

JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

EVALUATING THE EFFICACY OF SURFACE DISINFECTION BY COMMERCIAL ANTIBACTERIAL WIPES USING EN 16615 METHOD

Rashika Safrin[*1] and Linnett Naveena*[2]

Address(es):
[1,2] **Department of Microbiology, Ethiraj College for Women, Chennai.**

*Corresponding author: sowbar07@gmail.com

https://doi.org/10.55251/jmbfs.14264

ARTICLE INFO

Received 19. 4. 2026
Revised 31. 7. 2026
Accepted 13. 11. 2026
Published xx.xx.201x

Regular article

OPEN ACCESS

ABSTRACT

Antibacterial and disinfectant wipes are pre-moistened with active compounds, including alcohol, quaternary ammonium chloride, and hydrogen peroxide, to eradicate microorganisms. This study aimed to assess the bactericidal efficacy of four brands of disinfectant wipes and verify the absence of microbial contamination in unused wipes. Unused wipes were evaluated for color change and turbidity in Dey-Engley neutralizing broth to detect any contamination. The Modified EN 16615 4-field test was utilized to determine the bactericidal efficacy of wipes against *Pseudomonas aeruginosa, Staphylococcus aureus*, and *Escherichia coli*. Additionally, the ability of the wipes to disrupt and eradicate biofilms formed by *Pseudomonas aeruginosa* was assessed. The results indicated no microbial contamination in the unused wipes. The brands of wipes that contained polyaminopropyl biguanide, benzalkonium chloride and benzalkonium bromide demonstrated biofilm inhibition to the extent of 68.28% and 69.35%, respectively. All four brands exhibited effective bactericidal activity against all three tested bacterial strains and met the ≥ 5 log reduction criteria of the EN 16615 test in Field 1. Cross-contamination was observed in adjacent fields (F2–F4) with two brands of wipes, the key ingredients being alcohols. Future research should also consider real-world variability, including inconsistent wiping pressure, contact time, and diverse surface types (plastic, steel, glass, and porous materials).

Keywords: disinfectant wipes, EN 16615, microbial contamination, bactericidal activity, cross-contamination, biofilm assay

INTRODUCTION

Surfaces in hospital environments can harbor microorganisms capable of causing infections. Implementing effective cleaning and disinfection practices, such as using antibacterial and disinfectant wipes, is essential to mitigate the risk of infection **(Otter *et al.*, 2013; Boyce, 2016)**. Most commercially available wipes are pre-moistened with chemical disinfectants, including alcohol, quaternary ammonium compounds (QACs), and hydrogen peroxide. These agents chemically eradicate microbes, while wiping aids in their physical removal **(Rutala & Weber, 2019; Tarka *et al.*, 2019)**. Microbial contamination can occur in unused wet wipes due to manufacturing defects, inadequate preservation, or improper storage, potentially diminishing their antimicrobial efficacy **(Consumer Council 2023; Ziklo *et al.* 2024)**. Microorganisms within biofilms exhibit greater resistance to chemical disinfectants than planktonic cells, complicating their removal **(Donlan, 2002)**. Traditional methods expose microorganisms to disinfectants in a liquid form but fail to replicate real-world wiping, surface interactions, and microbial transfer. To address this issue, the EN 16615 test method has been adopted to evaluate wipes both chemically and mechanically by measuring the microbial reduction and transfer across adjacent fields **(Tarka *et al.*, 2019; Tyski *et al.*, 2021)**. This study evaluated commercially available antibacterial and disinfectant wipes, focusing on three key aspects: microbial contamination of unused wipes, efficacy against biofilm-forming bacteria, and bactericidal effectiveness under standardized EN 16615 conditions.

MATERIALS AND METHODS

Disinfectant and Antibacterial wipes

Four commercially available antibacterial and disinfectant wipes were evaluated in this study.

Table 1 Formulation of the commercially available wipes

Wipes	Ingredients	Contact Time (as per label/claims)
A	Water, Sodium Benzoate, Citric Acid, Propylene Glycol, polyaminopropyl Biguanide, PEG-40 Hydrogenated castor oil, Benzalkonium chloride	Not mentioned
B	Alcohol, Benzalkonium Bromide, silver ions, pure water	Not mentioned
C	67% isopropyl alcohol, Benzalkonium chloride, Glycerin, PEG 7, Glyceryl cocoate, RO water, fragrance	Not mentioned
D	Aqua, phenoxyethanol, Sodium Benzoate, PEG -40 Hydrogenated Castor oil, Benzalkonium chloride, Decyl Glycoside, Cetylpyridinium chloride, Fragrance, Aloe (*Aloe barbadensis)* leaf juice, Citric acid, Sodium hydroxide, limonene	5 Minutes

Evaluation of Microbial Contamination in Unused Antibacterial and Disinfectant Wipes

Unused wipes were aseptically sectioned under laminar airflow and placed into sterile bottles containing 10 ml of Dey-Engley neutralizing broth. This medium neutralizes any residual disinfectants or antimicrobial agents present in the wipes, thereby facilitating the recovery of any microorganisms present. All samples and controls were incubated at 37°C for 24 h (Remel/Thermo Scientific, 2007). Negative controls consisted solely of sterile Dey-Engley neutralizing broth to verify sterility, whereas positive controls were inoculated with *Escherichia coli* to confirm the medium's capacity to support microbial growth. Microbial proliferation was indicated by turbidity or a color change in the Dey-Engley neutralizing broth from purple to yellow **(Remel/Thermo Scientific, 2007; Liofilchem, 2013)**.

Evaluation of the efficacy of wipes against biofilms

Pseudomonas aeruginosa, a well-documented biofilm-forming bacterium, was used in the assay. The bacterial culture grown overnight in nutrient broth was diluted 1:10 in sterile nutrient broth to achieve an optimal bacterial density conducive to biofilm formation. A sterile glass slide was placed in a petri dish containing 15 ml of the diluted suspension and incubated statically at 37 °C for 48 hours to facilitate biofilm development. The slides were carefully removed, washed thrice with sterile saline to eliminate planktonic cells, and air-dried. The slides containing biofilms were subjected to a standardized wiping procedure in accordance with the EN 16615 test, with a contact time of 5 min. The slides were stained with 0.1% crystal violet for 15 min, washed with sterile distilled water, and air-dried. The retained dye was extracted using 95% ethanol, and the optical density was measured at 570 nm using a spectrophotometer to assess the biofilm biomass **(Marra *et al.*, 2023; Merritt *et al*., 2005; O'Toole, 2011)**.
Positive control slides without wipe treatment were stained and quantified to represent the total biofilm biomass on the slide. The negative controls consisted of sterile slides incubated in nutrient broth without bacterial inoculation. Ethanol was used as a blank to eliminate background absorbance.

Modified EN 16615 (4-field test)

A flat polyvinyl chloride (PVC) plate measuring 20×50 cm was used as the test surface. Four fields, each measuring 5 × 5 cm, were delineated. Field 1 was inoculated with 50 µL of a mixed bacterial culture comprising *Escherichia coli, Staphylococcus aureus*, and *Pseudomonas aeruginosa* at a concentration of 1.5×10^8 CFU/mL. The bacterial mixture was allowed to dry in a biosafety cabinet for approximately 1 h. A wipe was applied using a 2.5 kg weight block to ensure consistent pressure and moved with a single forward and backward stroke. After a contact time of 5 min, bacteria were recovered from each field using a cotton stick swab soaked in neutralizing broth. Samples were plated on selective media and quantified as CFU/mL. According to the EN 16615 acceptance criteria **(Tarka *et al*., 2019)**, a ≥5 $\log_{10}$ reduction in Field 1 and ≤50 CFU in adjacent fields were considered effective bactericidal activity. The EN 16615 protocol was adapted for the present study by replacing *Enterococcus hirae* with *Escherichia coli* as one of the test organisms. Furthermore, bovine serum albumin (BSA), typically used as an interfering agent to mimic organic contamination in the standard protocol, was excluded to assess the effectiveness of wipes on surfaces without organic soil load. The positive control consisted of samples taken from the unwiped field after 1 h, containing the bacterial mixture to demonstrate that the bacteria survived the drying period. Another control involved the direct inoculation of bacterial cultures onto selective media to confirm bacterial viability. The negative control comprised samples taken from fields other than Field 1 to confirm the absence of contamination, and uninoculated selective media plates were included to verify the sterility.

Statistical analysis

All experiments were conducted with independent biological replicates, and data are presented as mean ± standard error (SE) (n=3)**.** The effects of wipe type**,** bacterial species, and their interaction on bacterial log reduction were analyzed using two-way analysis of variance (ANOVA)**.** When significant main effects or interactions were detected, pairwise comparisons among estimated marginal means were performed using the emmeans package with Tukey's adjustment for multiple comparisons. Statistical significance was considered at $p < 0.05$. All analyses were performed using R software **(Version 2026.04.0+526).**

RESULTS

Intrinsic contamination of unused wipes

All four brands of unused wipes, when placed in sterile bottles containing Dey-Engley neutralizing broth, exhibited no microbial growth following incubation at 37 °C for 24 hours. The negative control samples, which consisted solely of sterile neutralizing broth, remained clear and purple, thereby confirming the sterility of the medium. In contrast, positive controls inoculated with *Escherichia coli* demonstrated turbidity and a color change from purple to yellow, thereby validating the medium's capacity to support microbial growth. These findings confirm both the sterility of the unused wipes and the efficacy of the Dey-Engley neutralizing broth in detecting microbial contamination.

Biofilm Inhibition Assay

Biofilms were effectively established by *Pseudomonas aeruginosa* on glass slides following a 48-hour period of static incubation at 37 °C. Positive control slides, which were not subjected to the wipe treatment, showed high optical density values at 570 nm, confirming substantial biofilm biomass. In contrast, slides subjected to the standardized wiping procedure according to the EN 16615 test exhibited a significant reduction in crystal violet retention, indicating effective removal or disruption of the biofilm. Wipes A and B showed strong antibiofilm activity, with 68.28% and 69.35% inhibition, respectively, while Wipes C and D demonstrated weaker inhibition, with 37.09% and 30.10% inhibition, respectively. Negative control slides incubated without bacterial inoculation showed negligible absorbance, validating the specificity of the assay and the absence of background staining.

Modified EN 16615 4 - field test:

Figure 2 illustrates the bacterial recovery outcomes from Field 1 following the application of wipes, assessed using the EN 16615 test. All four brands of wipes successfully achieved the requisite 5 $\log_{10}$ reduction in Field 1. Specifically, Wipe A accomplished reductions of 6.84 $\log_{10}$ for *Staphylococcus aureus*, 5.87 $\log_{10}$ for *Escherichia coli,* and 5.21 $\log_{10}$ for *Pseudomonas aeruginosa*, thereby meeting the EN 16615 field test criteria. Wipe B recorded reductions of 6.54 $\log_{10}$ for *Staphylococcus aureus*, 5.88 $\log_{10}$ for *Escherichia coli,* and 5.48 $\log_{10}$ for *Pseudomonas aeruginosa*. Wipe C achieved reductions of 5.35 $\log_{10}$ for *Staphylococcus aureus,* 5.27 $\log_{10}$ for *Escherichia coli,* and 5.12 $\log_{10}$ for *Pseudomonas aeruginosa*. Notably, Wipe D demonstrated the most significant reduction in *Staphylococcus aureus* at 6.92 $\log_{10}$, followed by a 6.88 $\log_{10}$ reduction in *Escherichia coli*, and a 5.97 $\log_{10}$ reduction in *Pseudomonas aeruginosa.*
Regarding the prevention of bacterial transfer to adjacent fields, Wipes A and D met the EN 16615 acceptance criterion of ≤50 CFU in adjacent fields, indicating effective prevention of microbial transfer (Table 2). Wipes B and C allowed the transfer of organisms to adjacent fields, exceeding the ≤50 CFU limit and failing to comply with the standard. The positive control showed bacterial growth, confirming that the Dey-Engley neutralizing broth effectively supported bacterial recovery and that the test organisms were resilient to the drying process. The negative control showed no growth, indicating the absence of external contamination and validating the sterility of the experimental setup.

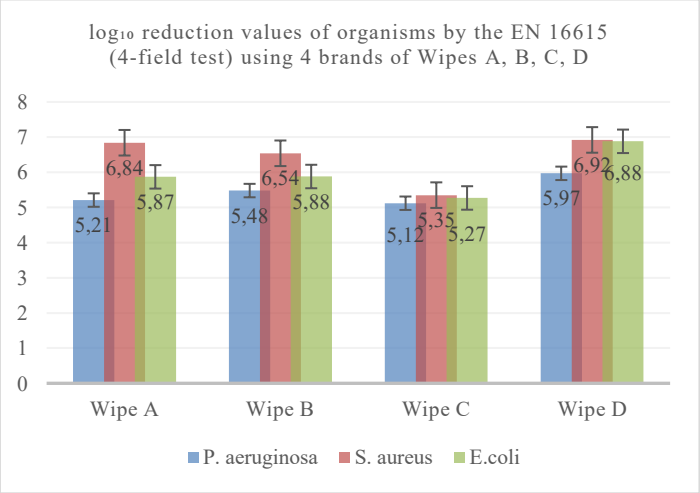


Figure 2 Graph showing the efficiency of four brands of wipes (A, B, C, and D) as log reduction values of test organisms.

Table 2 Log reduction (lgR) in Field 1 and bacterial spread on test fields F2–F4 per 25 cm^2 after wiping with wipes A–D at a contact time of 5 min. Test organisms: *P. aeruginosa* and *S. aureus, E. coli*

Wipes	*Pseudomonas aeruginosa*	*Staphylococcus aureus*	*Escherichia coli*
A	5.21 ± 0.01	6.84 ± 0.08	5.87 ± 0.04
F2-F4	0	0	0
B	5.48 ± 0.04	6.54 ± 0.06	5.88 ± 0.07
F2-F4	$32 * 10^2$	$31* 10^2$	$11* 10^2$
C	5.12 ± 0.05	5.35 ± 0.10	5.27 ± 0.15
F2-F4	$43* 10^2$	$76*10^2$	$47*10^2$
D	5.97 ± 0.18	6.92 ± 0.13	6.88 ± 0.04
F2-F4	0	0	0

Values represent mean ± SE (n=3)

Statistical analysis

A two-way ANOVA revealed significant main effects of wipe type ($F = 102.0$, $p < 0.001$) and bacterial species ($F= 105.8$, $p < 0.001$) on $\log_{10}$ bacterial reduction. In addition, a significant interaction between wipe type and bacterial species was observed ($F = 12.1$, $p < 0.001$), indicating that the antimicrobial efficacy of the wipes varied depending on the bacterial species tested.

Table 3 Table showing the estimated mean bacterial counts (log-transformed) of *Escherichia coli*, *Pseudomonas*, and *Staphylococcus aureus* for four different wipes (A, B, C, D). Table highlights the variation in bacterial reduction efficacy among species within each wipe type.

Wipe	*Escherichia coli*	*Pseudomonas*	*Staphylococcus aureus*
Wipe A	5.87[a]	5.21[b]	6.84[c]
Wipe B	5.88[a]	5.48[bc]	6.54[c]
Wipe C	5.27[a]	5.12[a]	5.35[a]
Wipe D	6.88[c]	5.97[b]	6.92[c]

Values represent mean ± SE. Different lowercase letters indicate significant differences among wipe formulations within each bacterial species based on Estimated Marginal Means with Tukey adjustment ($p < 0.05$)

These results indicate that wipe efficacy varies by both bacterial species and wipe type. Wipe D consistently demonstrated the highest bacterial log reductions across all three species, indicating superior efficacy in bacterial removal. Wipe C showed the lowest log reductions, suggesting the least effective performance. Wipes A and B had intermediate and comparable efficacy levels, generally better than Wipe C but lower than Wipe D. The statistical approach using emmeans and Tukey-adjusted pairwise comparisons support these conclusions.

DISCUSSION

This study evaluated the sterility, antimicrobial efficacy, and microbial transfer potential of four commercial wipes (A, B, C, and D) using the Dey-Engley Neutralizing broth, Standardized EN 16615 4-field test and biofilm assay. Unlike traditional quantitative suspension or carrier tests that lack mechanical action, the EN 16615 test evaluates both microbial killing and the potential transfer of microorganisms during wiping procedures. This leads to more accurate evaluations of disinfectant efficacy in real-world hygiene situations, reducing the risk of pathogen spread via ineffective wiping **(Becker *et al.*, 2019)**.

Microbial sterility of unused wipes

While assessing the sterility of unused fresh wipes, all four brands were found to be sterile, indicative of their manufacture under strict hygienic conditions. Research indicates that unused antibacterial wipes, when stored properly in sealed packaging, maintain sterility and avoid bacterial contamination because of the constitution and packaging design. The wipes used in this study contain combinations of Sodium Benzoate, Citric Acid, Propylene Glycol, polyaminopropyl Biguanide and alcohol, substance known to provide antimicrobial activity and help inhibit microbial growth on the wipe itself. Unopened wipes remain uncontaminated because of packaging integrity and antimicrobial agents **(Song *et al.*, 2019)**. Disinfection using impregnated wipes effectively reduces bacterial load but did not report contamination of the wipes themselves when unused and properly stored **(Koscova *et al.*, 2018).**

Antibiofilm activity and microbial killing

Strong antibiofilm activity by two brands of wipes against the tested pathogens was reported in this study. The active ingredients in these wipes, such as Sodium Benzoate, Citric Acid, Propylene Glycol, polyaminopropyl biguanide, and alcohol, are known antimicrobial agents that can be correlated with antibiofilm activity **(Rembe *et al.*, 2016)**. Though this biofilm assay does not quantify the viable cells and distinguish between viable and non-viable cells, it gives the percentage inhibition of biofilm formation which can be attributed to key mechanisms of biofilm inhibition such as modification of bacterial surface properties to inhibit initial adhesion, disruption of extracellular polysaccharide matrices and downregulation of quorum sensing and virulence factors vital for biofilm development **(Chen *et al.*, 2024., Liu *et al.*, 2022., She *et al.*, 2017).** Future studies focussed on viability specific assays of clinically relevant bacterial species would validate the usage of such antibacterial wipes.

While testing the efficiency of wipes in microbial killing, all the wipes showed excellent reduction in microbial load in Field 1, as evident by more than 5 $\log_{10}$ reduction of bacteria, which is a mandatory requirement of the EN 16615 4- field test. The main impact of killing arises from the impregnation of an antibacterial agent in the wipes. All the wipes used in this study contain potent antimicrobial agents that achieved the required level of killing. Alcohol-based wipes containing high concentrations of ethanol and isopropanol (e.g., 80% ethanol + 5% isopropanol) quickly inactivate bacteria and viruses, such as HIV and hepatitis viruses, enhancing their disinfection efficiency **(Moorer, 2003., Song *et al.*, 2019)**. It is also due to the mechanical wiping action since wiping not only physically removes microbes but also distributes the disinfectant evenly across surfaces, improving decontamination. The effective killing of microbes by the wipes can be also attributed to the material of the wipe fabric. All the wipes used in this study are made up of non-woven biodegradable spunlace fabric as mentioned in the specifications by the manufacturer. Though the exact material composition is not disclosed, except for Wipe C which is cotton, non-woven spunlace fabric are generally made of polyester -viscose - cotton combination which are known to hold large quantity of disinfectants and has good liquid release. Polyester-containing wipes retained and released antimicrobial agents more effectively than pure cellulose wipes. Consequently, polyester or polyester-blend wipes have shown better antimicrobial performance against both Gram-positive and Gram-negative bacteria **(Song *et al.*, 2019)**.

Prevention of microbial transfer

Wipes A and D showed superior performance not only in microbial reduction but also in preventing bacterial transfer from F2 to F4, meeting the ≤50 CFU criterion, which underscores their potential for effective contamination control. Besides containing antimicrobial compounds that can kill microbes, the prevention of microbial transfer in Wipes A and D may be attributed to the touch force, contact times, wiping action, surface moisture, surface chemistry, reduction in microbial integrity and de-entangling microbial adherence to surfaces. (Rane *et al.,* 2024). The disruption of the organic protective covering of microbes commonly encountered in health care environments (simulated by providing BSA-organic contamination under laboratory conditions) was not studied during this experiment.

CONCLUSION

The efficiency of commercial antibacterial wipes in eliminating microorganisms relies on the combination of potent antimicrobial agents, appropriate wipe materials that optimize active ingredient release, mechanical removal action, and formulation factors that provide immediate and residual antimicrobial activity. This multifaceted approach results in substantial reductions in microbial contamination on various surfaces, including those with potentially pathogenic and resistant microorganisms.

Under the standardized laboratory conditions employed in this study, certain disinfectant wipes effectively reduced microbial transfer across the test surface. However, these findings should be interpreted within the limitations of the experimental design which had taken into account only single wiping pressure, one contact time on one type of surface. As wipe performance may vary with the above-mentioned factors, variable wiping pressure, multiple contact times on different surface materials on many numbers of clinically relevant pathogenic species of microbes could be included in the future scope of similar studies. Investigations conducted under diverse practical conditions are warranted to validate the applicability of these findings in real-world settings.

Acknowledgement: The authors sincerely thank the college management for granting financial assistance to carry out this study as summer project.

REFERENCES

Becker, B., Henningsen, L., Paulmann, D., Bischoff, B., Todt, D., & Steinmann, J. (2019). Evaluation of the virucidal efficacy of disinfectant wipes with a test method simulating practical conditions. *Antimicrobial Resistance & Infection Control, 8*, 121. https://doi.org/10.1186/s13756-019-0569-4

Boyce, J. M. (2016). Modern technologies for improving cleaning and disinfection of environmental surfaces in hospitals. Antimicrobial Resistance & Infection Control, 5, 10. https://doi.org/10.1186/s13756-016-0111-x

Chen, C., Gu, Q., Ge, Y., Tian, J., Zhang, Y., Wang, T., Wang, C., Zhao, Y., Xu, H., & Fan, X. (2024). Antibiofilm Mechanisms of the Helical G3 Peptide against Staphylococcus epidermidis. *Langmuir : The ACS Journal of Surfaces and Colloids*, *40*(22), 11806–11816. https://doi.org/10.1021/acs.langmuir.4c01474

Consumer Council. (2023, July 18). Total bacterial count of 1 personal care wet wipes model exceeded maximum limit by almost 500 times. Consumer Council Press Release. https://www.consumer.org.hk/en/press-release/p-561-personal-care-wet-wipes

Donlan, R. M. (2002). Biofilms: Microbial life on surfaces. Emerging Infectious Diseases, 8(9), 881–890. https://doi.org/10.3201/eid0809.020063

Koščová, J., Hurníková, Z., & Pistl, J. (2018). Degree of bacterial contamination of mobile phone and computer keyboard surfaces and efficacy of disinfection with chlorhexidine digluconate and triclosan to its reduction. International Journal of Environmental Research and Public Health, 15(10), 2238. https://doi.org/10.3390/ijerph15102238

Liofilchem. (2013). Dey-Engley neutralizing broth technical sheet. https://www.liofilchem.com

Liu, X., Fan, D., Feng, X., Zheng, Y., Wegner, S. V., Liu, M., Chen, F., & Zeng, W. (2022). Breaching Bacterial Biofilm Barriers: Efficient Combinatorial Theranostics for Multidrug-Resistant Bacterial Biofilms with a Novel Penetration-Enhanced AIEgen Probe. *ACS Applied Materials & Interfaces*, *14*(37), 41671–41683. https://doi.org/10.1021/acsami.2c07378

Marra, D., Perna, I., Pota, G., Vitiello, G., Pezzella, A., Toscano, G., Luciani, G., & Caserta, S. (2023). Nanoparticle coatings on glass surfaces to prevent Pseudomonas fluorescens AR 11 biofilm formation. Microorganisms, 11(3), 621. https://doi.org/10.3390/microorganisms11030621

Merritt, J. H., Kadouri, D. E., & O'Toole, G. A. (2005). Growing and analyzing static biofilms. Current Protocols in Microbiology, 1(1), Unit 1B.1. https://doi.org/10.1002/9780471729259.mc01b01s00

Moorer, W. R. (2003). Antiviral activity of alcohol for surface disinfection. International Journal of Dental Hygiene, 1(3), 138–142. https://doi.org/10.1034/j.1601-5037.2003.00032.x

O'Toole, G. A. (2011). Microtiter dish biofilm formation assay. Journal of Visualized Experiments, (47), 2437. https://doi.org/10.3791/2437

Otter, J. A., Yezli, S., Salkeld, J. A., & French, G. L. (2013). Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. American Journal of Infection Control, 41(5), S6–S11. https://doi.org/10.1016/j.ajic.2012.12.004

Rane, D., Kerkar, S., Ramanan, S. R., & Kowshik, M. (2024). Superwettable surfaces and factors impacting microbial adherence in microbiologically-influenced corrosion: a review. World Journal of Microbiology and Biotechnology, 40(3), 98. https://doi.org/10.1007/s11274-024-03886-3

Remel/Thermo Scientific. (2007). Dey-Engley neutralizing broth product sheet. Thermo Fisher Scientific. https://www.thermofisher.com

Rembe, T. F., Zirkel, C., Huth, S., Walther, P., Mittlmeier, T., & Sroka, R. (2016). Antibacterial effects of Nd:YAG laser irradiation within root canal dentin. Lasers in Medical Science, 31(2), 371–377. https://doi.org/10.1007/s10103-015-1770-z

Rutala, W. A., & Weber, D. J. (2019). Best practices for disinfection of noncritical environmental surfaces and equipment in health care facilities: A bundle approach. American Journal of Infection Control, 47(S), A96–A105. https://doi.org/10.1016/j.ajic.2019.01.014

She, P., Wang, Y., Luo, Z., Chen, L., Tan, R., Wang, Y., & Wu, Y. (2017). Meloxicam inhibits biofilm formation and enhances antimicrobial agents efficacy by *Pseudomonas aeruginosa. Microbiology Open*, *7*(1), e00545. https://doi.org/10.1002/mbo3.545

Song, X., Vossebein, L., & Zille, A. (2019). Efficacy of disinfectant-impregnated wipes used for surface disinfection in hospitals: A review. Antimicrobial Resistance & Infection Control, 8, 139. https://doi.org/10.1186/s13756-019-0595-2

Tarka, P., Chojecka, A., Paduch, O., Nitsch-Osuch, A., Kanecki, K., & Kierzkowska, A. (2019). Antibacterial activity of ready-to-use alcohol-based commercial wipes according to EN 16615 carrier standard. International Journal of Environmental Research and Public Health, 16(18), 3475. https://doi.org/10.3390/ijerph16183475

Tyski, S., Grzybowska, W., & Bocian, E. (2021). Application of EN 16615 (4-field test) for the evaluation of the antimicrobial activity of selected commercial and self-made disinfectant wipes. International Journal of Environmental Research and Public Health, 18(11), 5932. https://doi.org/10.3390/ijerph18115932

Ziklo, N., et al. (2024). The influence of physical characteristics of wet wipe fabrics on preservation efficacy and microbial contamination risk. Cosmetics, 11(4), Article 106. https://doi.org/10.3390/cosmetics11040106