Eradication of Antibiotic-Resistant E. coli, S. aureus, K. pneumoniae, S. pneumoniae, A. baumannii, and P. aeruginosa with Chlorine Dioxide In Vitro

George Georgiou
Principal Investigator
Agnieszka Kotzé
Researcher

Abstract

Bacterial Antibiotic Resistance (AMR) is a problem in all regions, with six pathogens accounting for 73.4% of deaths attributable to bacterial AMR, namely *Escherichia coli* (E. coli), *Staphylococcus aureus* (S. aureus), *Klebsiella pneumoniae* (K. pneumoniae), *Streptococcus pneumoniae* (S. pneumoniae), *Acinetobacter baumannii* (A baumannii), and *Psuedomonas aeruginosa* (P. aeruginosa). The World Health Organization instigated a Global Action Plan on AMR in 2021, which is still active - healthcare costs for AMR run into many billions of dollars worldwide. A Review on Antimicrobial Resistance commissioned by the British Government argued that AMR could kill 10 million people per year by 2050 and has emerged as one of the greatest public health threats of the 21st century. Just one AMR pathogen, *Methicillin-Resistant Staphylococcus aureus* (MRSA), caused more than 100,000 deaths worldwide, with the other four pathogens covered in this research causing as many deaths again. This research has focused on studying chlorine dioxide's effectiveness in eradicating five different AMR bacteria in vitro as a novel and effective treatment. This study used different chlorine dioxide concentrations with five antibiotic-resistant bacteria, ranging from 1 – 7 ppm concentrations. Disinfection studies were compared to controls, and the results demonstrated a greater than 95% disinfection with concentrations of 7 ppm. Chlorine dioxide is a size-selective antimicrobial agent that can kill micron-sized organisms rapidly but will not cause actual harm to much larger organisms like animals or humans as it cannot penetrate deeply into their living tissues. It is safe when used in low concentrations for short durations. Clinical trials must be undertaken to gain experience in the best dosages and protocols to eradicate antibiotic-resistant microorganisms from the body.

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Published Jul 29, 2023

DOI:
https://doi.org/10.18103/mra.v11i7.2.4218 (https://doi.org/10.18103/mra.v11i7.2.4218)

How to Cite

GEORGIOU, George; KOTZÉ, Agnieszka. Eradication of Antibiotic-Resistant E. coli, S. aureus, K. pneumoniae, S. pneumoniae, A. baumannii, and P. aeruginosa with Chlorine Dioxide In Vitro. **Medical Research Archives**, [S.l.], v. 11, n. 7.2, july 2023. ISSN 2375-1924. Available at: <https://esmed.org/MRA/mra/article/view/4218 (https://esmed.org/MRA/mra/article/view/4218)>. Date accessed: 28 apr. 2024. doi: https://doi.org/10.18103/mra.v11i7.2.4218 (https://doi.org/10.18103/mra.v11i7.2.4218).

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Issue

Vol 11 No 7.2 (2023): July Issue, Vol.11, Issue 7.2 (https://esmed.org/MRA/mra/issue/view/154)

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Research Articles

References

1. World Bank Group. Drug-resistant infections A Threat to Our Economic Future. Washington: International Bank for Reconstruction and Development/The World Bank. 2017. Retrieved from https://documents1.worldbank.org/curated/en/323311493396993758/pdf/final-report.pdf
2. United Nations. Sustainable development goals. (access 2023). Retrieved from United Nations: https://www.un.org/sustainabledevelopment/sustainable-development-goals/
3. Sharma P, & Towse A. New Drugs to Tackle Antimicrobial Resistance: Analysis of EU Policy Options. (2015 August 25). Retrieved from SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2640028
4. Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019. Lancet. 2022;399, 629-655.
5. Gatadi S, Gour J, & Nandu S. Natural product derived promising anti-MRSA drug leads: A review. Bioorganic & Medicinal Chemistry. 2019;27(17), 3760-3774.
6. Sharma P, & Towse A. New Drugs to Tackle Antimicrobial Resistance: Analysis of EU Policy

Options. 2015 August 25. Retrieved from SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2640028
7. Ventola CL. The antibiotic resistance crisis: part 1: causes and threats. Pharmacy & Therapeutics. 2015;40(4), 277–283.
8. Lobanovska M, & Pilla G. Penicillin's Discovery and Antibiotic Resistance: Lessons for the Future? Yale Journal of Biology and Medicine. 2017;90(1), 135–145.
9. Langdon A, Crook N, & Dantas G. The effects of antibiotics on the microbiome throughout development and alternative approaches for therapeutic modulation. Genome Medicine, 2016;8, 39.
10. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;17(396(10258):), 1204–1222.
11. Kramer, A., Schwebke, I., & Kampf, G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. MC Infectious Diseases. 2006;16(6), 130.
12. Khin M, Knowles SL, Crandall WJ, Jones Jr, DD, Oberlies NH, Cech NB., & Houriet J. Capturing the Antimicrobial Profile of Rosmarinus officinalis against Methicillin-resistant Staphylococcus aureus (MRSA) with Bioassay-guided Fractionation and Bioinformatics. Journal of Pharmaceutical & Biomedical Analysis, 2021;197, 113965.
13. Bodeker G, Ong CK, Grundy CK, Burford G, & Shein K. WHO global atlas of traditional, complementary and alternative medicine. Kobe, Japan: World Health Organization. 2005.
14. Bshabshe AA, Joseph MR, Awad El-Gied AA, Fadul AN, Chandramoorthy HC, & Hamid ME. Clinical Relevance and Antimicrobial Profiling of Methicillin-Resistant Staphylococcus aureus (MRSA) on Routine Antibiotics and Ethanol Extract of Mango Kernel (Mangifera indica L.). Biomed Research International, 2020, 4150678.
15. Zouhir A, Jridi T, Nefz A, Hamida JB, Sebei K, Nefzi A, Hamida JB, Sebei K. Inhibition of methicillin-resistant Staphylococcus aureus (MRSA) by antimicrobial peptides (AMPs) and plant essential oils. Pharmaceutical Biology. Volume 54, 2016; Issue 12.https://doi.org/10.1080/13880209.2016.1190763
16. CDSpure - https://aquarius-prolife.com/en/maltesian-mineral-solution/104-cdspure-6x5ml-ampoules
17. U.S. Environmental Protection Agency. Reregistration eligibility decision (RED) for chlorine dioxide and sodium chlorite (Case 4023). US Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances. Washington: Technical Report No. EPA/738/R-06/007. 2006, August.Retrieved from the United States Environmental Protection Agency: https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/red_PC-020503_3-Aug-06.pdf
18. Clordisys. DECONTAMINATION AND STERILIZATION EQUIPMENT AND SERVICES. 2014. Retrieved from clordisys: https://www.clordisys.com/
19. Jin RY, Hu SQ, & Chi ZC. Effect of chlorine dioxide gas treatment on surface sterilization of grape. Advanced Materials Research. 2011;236, 2939–2944.
20. Park SH, & Kang DH. Combination treatment of chlorine dioxide gas and aerosolized sanitizer for inactivating foodborne pathogens on spinach leaves and tomatoes. International Journal of Food Microbiology. 2015;207, 103–108.
21. Kalay TS, Kara Y, Karaoglu SA, & Kolaylı S. Evaluation of Stabilized Chlorine Dioxide in Terms of Antimicrobial Activity and Dentin Bond Strength. Combinatorial Chemistry & High Throughput Screening. 2022;25(9), 1427 - 1436.
22. Peleg AY, Seifert H, & Paterson DL. Acinetobacter baumannii: emergence of a successful pathogen. Clinical Microbiology Reviews. 2008;21, 538–582.
23. Lin MF, & Lan CY. (2014). Antimicrobial resistance in Acinetobacter baumannii: from bench to bedside. World Journal of Clinical Cases. 2014;2, 787–814.
24. De Oliveira DM, Forde BM, Kidd TJ, Harris PN, Schembri MA, Beatson SA, Walker MJ. Antimicrobial resistance in ESKAPE pathoge. Clinical Microbiology Review, 33(3), e00181-19.Diekema , D. J., Hsueh , P. R., Mendes , R. E., Pfaller , M. A., Rolston , K. V., Sader , H. S., & Jones, R. N. (2019). The microbiology of bloodstream infection: 20-year trends from the SENTRY Antimicrobial Surveillance Program. Antimicrobial Agents and Chemotherapy, 2020;63(7), e00355-19.
25. Diekema DJ, Hsueh PR, Mendes RE, Pfaller MA, Rolston KV, Sader HS, & Jones RN. The microbiology of bloodstream infection: 20-year trends from the SENTRY Antimicrobial Surveillance Program. Antimicrobial Agents and Chemotherapy, 2019;63(7), e00355-19.
26. Thom KA, Maragakis LL, Richards K, Johnson JK, Roup B, Lawson P. Maryland MDRO Prevention Collaborative. Assessing the burden of Acinetobacter baumannii in Maryland: a statewide cross-sectional period prevalence survey. Infection Control & Hospital Epidemiology,

2012;33(9), 883-888.
27. Quinn B, Rodman N, Jara E, Fernandez JS, Martinez J, Traglia GM. Ramírez MS. Human serum albumin alters specific genes that can play a role in survival and persistence in Acinetobacter baumannii. Scientific Reports. 2018; 8, 14741.
28. Lee CR, Lee JH, Park M, Park KS, Bae IK, Kim YB, Lee SH. Biology of Acinetobacter baumannii: Pathogenesis, antibiotic resistance mechanisms, and prospective treatment options. Frontiers in Cellular and Infection Microbiology. 2017;7, 55.
29. McConnell MJ, Actis L, & Pachón J. Acinetobacter baumannii: human infections, factors contributing to pathogenesis and animal models. FEMS Microbiology Reviews, 2013;37(2), 130–155.
30. World Health Organization. WHO publishes list of bacteria for which new antibiotics are urgently needed. 2017, February 27. Retrieved from World Health Organization: https://www.who.int/news/item/27-02-2017-who-publishes-list-of-bacteria-for-which-new-antibiotics-are-urgently-needed
31. Rangel K, Chagas TP, & De-Simone SG. Acinetobacter baumannii Infections in Times of COVID-19 Pandemic. Pathogens, 2021;10(8), 1006.
32. Alhashash F, Weston V, & Diggle M. Multidrug-Resistant Escherichia coli Bacteremia. Emerging Infectious Diseases, 2013;19(10), 1699–1701.
33. Kaper JB, Nataro JP., & Mobley HL. Pathogenic Escherichia coli. Nature Reviews Microbiology. 2004;2, 123-140.
34. Santos Braz V, Melchior K, & Moreira CG. Escherichia coli as a Multifaceted Pathogenic and Versatile Bacterium. Frontiers in Cellular and Infection Microbiology. 2020;10, 548492.
35. Aryal S. E. Coli (Escherichia Coli) - An Overview. 2020; December 23.Retrieved from microbe notes: https://microbenotes.com/escherichia-coli-e-coli/#habitat-of-e-coli
36. Wang G, Zhao G, Chao X, Xie L, & Wang H. The Characteristic of Virulence, Biofilm and Antibiotic Resistance of Klebsiella Pneumoniae. International Journal of Environmental Research and Public Health. 2020;17(17), 1-17.
37. Chew KL, Lin RT, & Teo JW. Klebsiella Pneumoniae in Singapore: Hypervirulent Infections and the Carbapenemase Threat. Frontiers in Cellular and Infection Microbiology. 2017;7, 515.
38. Russo TA, & Marr CM. Hypervirulent Klebsiella Pneumoniae. Clinical Microbiology Reviews. 2019;32(3), 1–4.
39. Ashurst JV, & Dawson A. Klebsiella Pneumonia. Treasure Island: StatPearls Publishing, 2022.
40. Jaradat ZW, Ababneh QO, Sha'aban ST, Alkofahi AA, Assaleh D, & Al Shara A. Methicillin-Resistant Staphylococcus aureus and public fomites: a review. Pathogens and Global Health. 2020;114(8), 426–450.
41. Siddiqui AH. & Koirala J. Methicillin-Resistant Staphylococcus Aureus. 2022. Retrieved from StatPearls: https://www.ncbi.nlm.nih.gov/books/NBK482221/
42. Belleza M. Methicillin-Resistant Staphylococcus Aureus (MRSA). 2021. Retrieved from Nurseslabs: https://nurseslabs.com/methicillin-resistant-staphylococcus-aureus-mrsa/
43. Alhazmi A. Pseudomonas aeruginosa – Pathogenesis and Pathogenic Mechanisms. International Journal of Biology. 2015;7(2), 44-67.
44. Wood SJ, Kuzel TM, & Shafikhani SH. Pseudomonas aeruginosa: Infections, Animal Modeling, and Therapeutics. Cells. 2023;12(1), 199.
45. Moradali MF, Ghods S, & Rehm BH. Pseudomonas aeruginosa Lifestyle: A Paradigm for Adaptation, Survival, and Persistence. Frontiers in Cellular and Infection Microbiology. 2017;7, 39.
46. Gale MJ, Maritato MS, Chen Y, & Abdulateef S. Pseudomonas aeruginosa causing inflammatory mass of the nasopharynx in an immunocompromised HIV infected patient: A mimic of malignancy. 2015;2, 40-43.
47. Gomila A, Carratalà J, Badia JM, Camprubí D, Piriz M, Shaw E, Biondo S. Preoperative oral antibiotic prophylaxis reduces Pseudomonas aeruginosa surgical site infections after elective colorectal surger. BMC Infectious Diseases, 2018;18, 507.
48. Agency for Toxic Substances and Disease Registry. Toxicological profile for chlorine dioxide and chlorite. 2004. Retrieved from Agency for Toxic Substances and Disease Registry: https://www.atsdr.cdc.gov/toxprofiles/tp160.pdf
49. Agency for Toxic Substances and Disease Registry. ToxFAQs™ for Chlorine Dioxide and Chlorite. 2004, September. Retrieved from Agency for Toxic Substances and Disease Registry : https://www.atsdr.cdc.gov/toxfaqs/tfacts160.pdf
50. World Health Organization. Chlorine Dioxide, Chlorite and Chlorate in Drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality. 2016. Geneva: World Health Organization.

51. Bajpai P. The Control of Microbiological Problems. Pulp and Paper Industry, 2015;103-195.
52. Pratima B. The Control of Microbiological Problems. Elsevier Public Health Emergency Collection, 2015;103–195.
53. Knapp JE, & Bettisti DL. Disinfection, Sterilization and Preservation (5th ed.). (S. S. Block, Ed.) Philadelphia, USA: Lippincott Williams & Wilkins, 2001.
54. Simpson G, Miller RF, Laxton GD, & Clements WR. A Focus on Chlorine Dioxide: The "Ideal" Biocide. New Orleans, USA, 1993.
55. Gunn JS, Bakaletz LO, & Wozniak DJ. What's on the outside matters: the role of the extracellular polymeric substance of Gram-negative biofilms in evading host immunity and as a target for therapeutic intervention. Journal of Biological Chemistry. 2016;291(24), 12538–12546.
56. Ramos-Gallardo G. Chronic wounds in burn injury: a case report on importance of biofilms. World Journal of plastic surgery, 2016;5(2), 175.
57. Hall CW, & Mah TFM. Molecular mechanisms of biofilm-based antibiotic resistance and tolerance in pathogenic bacteria. FEMS Microbiology Reviews, 2017;41(3), 276-301.
58. Insignares-Carrione E, Bolano Gomez B, Andrade Y, Callisperis P, Suxo MA, Arturo MA, & Camila GO. Determination of the Effectiveness of Chlorine Dioxide in the Treatment of COVID 19. Journal of Molecular and Genetic Medicine. 2021;15, S2.
59. Noszticzius Z, Wittmann M, Kály-Kullai K, Beregvári Z, Kiss I, Rosivall L, & Szegedi J. Chlorine Dioxide Is a Size-Selective Antimicrobial Agent. PLoS One, 2013;8(11), e79157.
60. Miura T, & Shibata T. Antiviral Effect of Chlorine Dioxide against Influenza Virus and Its Application for Infection Control. The Open Antimicrobial Agents Journal. 2010;2, 1.
61. Sanekata T, Fukuda T, Miura T, Morino U, Lee C, Maeda K, Shibata T. Evaluation of the antiviral activity of chlorine dioxide and sodium hypochlorite against feline calicivirus, human influenza virus, measles virus, canine distemper virus, human herpesvirus, human adenovirus, canine adenovirus and canine parvovirus. Biocontrol Science, 2010;15(2), 45-49.
62. Ma JW, Huang BS, Hsu CW, Peng CW, Cheng ML, & Kao JY. Efficacy and Safety Evaluation of a Chlorine Dioxide Solution. International Journal of Environmental Research & Public Health. 2017;14(3), 329.
63. Ofori I, Maddila S, Johnson L, & Jonnalagadda SB. Chlorine dioxide inactivation of Pseudomonas aeruginosa and Staphylococcus aureus in water: The kinetics and mechanism. Journal of Water Processing Engineering. 2018;26, 46–54.
64. Ogata N, & Shibata T. Protective effect of low-concentration chlorine dioxide gas against influenza A virus infection. The Journal of General Virology. 2008;89, 60-67.
65. Georgiou G. MRSA eradication using chlorine dioxide. Journal of Bacteriology & Mycology: Open Access, 2021;9(3), 115-120.
66. Young RO. Chlorine Dioxide (CLO2) As a Non-Toxic Antimicrobial Agent for Virus, Bacteria and Yeast (Candida Albicans). International Journal of Vaccines & Vaccination, 2016, October 8;2(6), 11-12.
67. Vobolex. Bolivia Law LAW NO. 1351. 2020, October 14. Retrieved from Vobolex: https://www.vobolex.org/bolivia/ley-no-1351-del-14-de-octubre-de-2020/
68. Aparicio-Alonso M, Domínguez-Sánchez CA, & Banuet-Martínez M. COVID19 Long Term Effects in Patients Treated with Chlorine Dioxide. INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS. 2021;4, 1159-1167.
69. Daniel FB, Condie LW, Robinson M, Stober JA, York GR, Olsen RG, & Wang S R. Comparative subchronic toxicity studies of three disinfectants. Journal of the American Water Works Association. 1990;82(10), 61-69.
70. Scatina J, Abdel-Rahman MS, & Gold E. The inhibitory effect of alcide®, an antimicrobial drug, on protein synthesis in Escherichia coli. Journal of Applied Toxicology. 1985;5(6), 388-394.
71. ATTC - https://www.atcc.org/microbe-products/bacteriology-and-archaea#t=productTab&numberOfResults=24
72. https://logosbio.com/
73. Noszticzius Z, Wittmann M, Kály-Kullai K, Beregvári Z, Kiss I, Rosivall L, & Szegedi J. Chlorine Dioxide Is a Size-Selective Antimicrobial Agent. PLoS One, 2013;8(11), e79157.
74. Georgiou G. Eradication of Borrelia Burgdoferi in vitro using Chlorine Dioxide: A Novel Approach, Medical Research Archives. 2022;[online] 10(11). https://doi.org/10.18103/mra.v10i11.3279
75. Official Gazette of Bolivia. LAW No. 1351. 2020, October 14. Retrieved from Derechoteca: https://www.derechoteca.com/gacetabolivia/ley-no-1351-del-14-de-octubre-de-2020/
76. Humble J. (access 2023). MMS testimonials. Retrieved from MMS testimonials: https://mmstestimonials.co/

Information

Online ISSN: 2375-1924
Print ISSN: 2375-1916
PubMed ID: 101668511