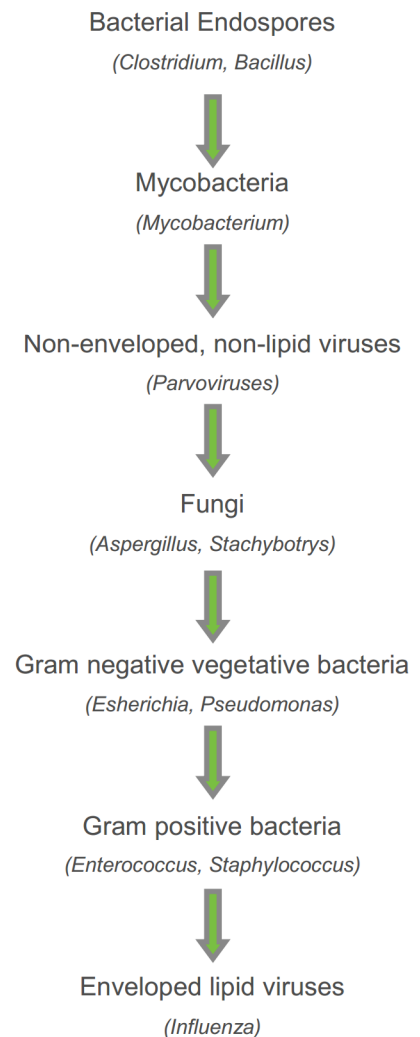


BIOLOGICAL EFFICACY LIST OF CHLORINE DIOXIDE

Chlorine dioxide gas is highly effective against fungi, viruses, bacteria and spores in both the laboratory and in real-world settings. Extensive testing has been done using chlorine dioxide on a multitude of specific organisms. That information can be found in each of the listed tables below. It is not a complete list of organisms in which chlorine dioxide gas is effective against, only a sample of organisms in which chlorine dioxide gas has been successfully tested against. To date, no organism tested against chlorine dioxide gas has been proved resistant. The Spaulding classification listed on the right lists organisms in order of decreasing resistance to sterilizing agents.

Spaulding classification



As testing is continually being performed on other organisms, updated data will be added to this list as the results come in. If an organism is not listed here, it does not necessarily mean that chlorine dioxide is ineffective against it. Please contact us to see if there is any data or information regarding your specific organism, or to arrange for specific organism testing

Bacteria	Ref.
<i>Blakeslea trispora</i>	28
<i>Bordetella bronchiseptica</i>	8
<i>Brucella suis</i>	30
<i>Burkholderia mallei</i>	36
<i>Burkholderia pseudomallei</i>	36
<i>Campylobacter jejuni</i>	39
<i>Clostridium botulinum</i>	32
<i>Corynebacterium bovis</i>	8
<i>Coxiella burnetii (Q-fever)</i>	35
<i>E. coli ATCC 11229</i>	3

Bacteria	Ref.
<i>E. coli ATCC 51739</i>	1
<i>E. coli K12</i>	1
<i>E. coli O157:H7 13B88</i>	1
<i>E. coli O157:H7 204P</i>	1
<i>E. coli O157:H7 ATCC 43895</i>	1
<i>E. coli O157:H7 EDL933</i>	13
<i>E. coli O157:H7 G5303</i>	1
<i>E. coli O157:H7 C7927</i>	1
<i>Erwinia carotovora (soft rot)</i>	21
<i>Franscicella tularensis</i>	30

Bacteria	Ref.
<i>Fusarium sambucinum</i> (dry rot)	21
<i>Fusarium solani</i> var. <i>coeruleum</i> (dry rot)	21
<i>Helicobacter pylori</i>	8
<i>Helminthosporium solani</i> (silver scurf)	21
<i>Klebsiella pneumonia</i>	3
<i>Lactobacillus acidophilus</i> NRRL B1910	1
<i>Lactobacillus brevis</i>	1
<i>Lactobacillus buchneri</i>	1
<i>Lactobacillus plantarum</i>	5
<i>Legionella</i>	38
<i>Legionella pneumophila</i>	42
<i>Leuconostoc citreum</i> TPB85	1
<i>Leuconostoc mesenteroides</i>	5
<i>Listeria innocua</i> ATCC 33090	1
<i>Listeria monocytogenes</i> F4248	1
<i>Listeria monocytogenes</i> F5069	19
<i>Listeria monocytogenes</i> LCD-81-861	1
<i>Listeria monocytogenes</i> LCD-81-886	19
<i>Listeria monocytogenes</i> Scott A	1
Methicillin-resistant <i>Staphylococcus aureus</i> (MRSA)	3
Multiple Drug Resistant <i>Salmonella typhimurium</i> (MDRS)	3
<i>Mycobacterium bovis</i>	8
<i>Mycobacterium fortuitum</i>	42
<i>Pediococcus acidilactici</i> PH3	1
<i>Pseudomonas aeruginosa</i>	3
<i>Pseudomonas aeruginosa</i>	8
<i>Salmonella</i>	1
<i>Salmonella</i> spp.	2
<i>Salmonella</i> Agona	1
<i>Salmonella</i> Anatum Group E	1
<i>Salmonella</i> Choleraesuis ATCC 13076	1
<i>Salmonella choleraesuis</i>	8
<i>Salmonella</i> Enterica (PT30) BAA-1045	1
<i>Salmonella</i> Enterica S. Enteritidis	13
<i>Salmonella</i> Enterica S. Javiana	13
<i>Salmonella</i> Enterica S. Montevideo	13
<i>Salmonella</i> Enteritidis E190-88	1
<i>Salmonella</i> Javiana	1
<i>Salmonella</i> newport	4
<i>Salmonella</i> Typhimurium C133117	1
<i>Salmonella</i> Anatum Group E	1
<i>Shigella</i>	38
<i>Staphylococcus aureus</i>	23
<i>Staphylococcus aureus</i> ATCC 25923	1
<i>Staphylococcus faecalis</i> ATCC 344	1
Tuberculosis	3
Vancomycin-resistant <i>Enterococcus faecalis</i> (VRE)	3
<i>Vibrio</i> strain Da-2	37

Bacteria	Ref.
<i>Vibrio</i> strain Sr-3	37
<i>Yersinia enterocolitica</i>	40
<i>Yersinia pestis</i>	30
<i>Yersinia ruckerii</i> ATCC 29473	31

Viruses	Ref.
Adenovirus Type 40	6
Calicivirus	42
Canine Parvovirus	8
Coronavirus	3
Feline Calici Virus	3
Foot and Mouth disease	8
Hantavirus	8
Hepatitis A Virus	3
Hepatitis B Virus	8
Hepatitis C Virus	8
Human coronavirus	8
Human Immunodeficiency Virus	3
Human Rotavirus type 2 (HRV)	15
Influenza A	22
Minute Virus of Mouse (Parovirus)(MVM-i)	8
Minute Virus of Mouse (Parovirus)(MVM-p)	8
Mouse Hepatitis Virus (MHV-A59)	8
Mouse Hepatitis Virus (MHV-JHM)	8
Mouse Parvovirus type 1 (MPV-1)	8
Murine Parainfluenza Virus Type 1 (Sendai)	8
Newcastle Disease Virus	8
Norwalk Virus	8
Poliovirus	20
Rotavirus	3
Severe Acute Respiratory Syndrome (SARS) Coronavirus	43
Sialodscryoadenitis Virus (Coronavirus)(SDAV)	8
Simian rotavirus SA-11	15
Theiler's Mouse Encephalomyelitis Virus (TMEV)	8
Vaccinia Virus	10

Algae/Fungi/Mold/Yeast	Ref.
<i>Alternaria alternata</i>	26
<i>Aspergillus aeneus</i>	28
<i>Aspergillus aurolatus</i>	28
<i>Aspergillus brunneo-uniseriatus</i>	28
<i>Aspergillus caespitosus</i>	28
<i>Aspergillus cervinus</i>	28
<i>Aspergillus clavatonanicus</i>	28
<i>Aspergillus clavatus</i>	28

Algae/Fungi/Mold/Yeast	Ref.
<i>Aspergillus egyptiacus</i>	28
<i>Aspergillus elongatus</i>	28
<i>Aspergillus fischeri</i>	28
<i>Aspergillus fumigatus</i>	28
<i>Aspergillus giganteus</i>	28
<i>Aspergillus longivesica</i>	28
<i>Aspergillus niger</i>	12
<i>Aspergillus ochraceus</i>	28
<i>Aspergillus parvathecicus</i>	28
<i>Aspergillus sydowii</i>	28
<i>Aspergillus unguis</i>	28
<i>Aspergillus ustus</i>	28
<i>Aspergillus versicolor</i>	28
<i>Botrytis species</i>	3
<i>Candida spp.</i>	5
<i>Candida albicans</i>	28
<i>Candida dubliniensis</i>	28
<i>Candida maltosa</i>	28
<i>Candida parapsilosis</i>	28
<i>Candida sake</i>	28
<i>Candida sojae</i>	28
<i>Candida spp.</i>	5
<i>Candida tropicalis</i>	28
<i>Candida viswanathil</i>	28
<i>Chaetomium globosum</i>	7
<i>Cladosporium cladosporioides</i>	7
<i>Debaryomyces etchellsii</i>	28
<i>Eurotium spp.</i>	5
<i>Fusarium solani</i>	3
<i>Lodderomyces elongisporus</i>	28
<i>Mucor circinelloides</i>	28
<i>Mucor flavus</i>	28
<i>Mucor indicus</i>	28
<i>Mucor mucedo</i>	28
<i>Mucor rademosus</i>	28
<i>Mucor ramosissimus</i>	28
<i>Mucor satumus</i>	28
<i>Penicillium chrysogenum</i>	7
<i>Penicillium digitatum</i>	3
<i>Penicillium herquei</i>	28
<i>Penicillium spp.</i>	5
<i>Phormidium boneri</i>	3
<i>Pichia pastoris</i>	3
<i>Poitrasia circinans</i>	28
<i>Rhizopus oryzae</i>	28
<i>Roridin A</i>	33
<i>Saccharomyces cerevisiae</i>	3
<i>Stachybotrys chartarum</i>	7
<i>T-mentag (athlete's foot fungus)</i>	3
<i>Verrucarin A</i>	33

Bacterial Spores	Ref.
<i>Alicyclobacillus acidoterrestris</i>	17
<i>Bacillus coagulans</i>	12
<i>Bacillus anthracis</i>	10
<i>Bacillus anthracis Ames</i>	30
<i>Bacillus atrophaeus</i>	14
<i>Bacillus atrophaeus ATCC 49337</i>	31
<i>Bacillus megaterium</i>	12
<i>Bacillus polymyxa</i>	12
<i>Bacillus pumilus ATCC 27142</i>	12
<i>Bacillus pumilus ATCC 27147</i>	11
<i>Bacillus subtilis (globigii) ATCC 9372</i>	11
<i>Bacillus subtilis ATCC 19659</i>	31
<i>Bacillus subtilis 5230</i>	12
<i>Clostridium sporogenes ATCC 19404</i>	12
<i>Geobacillus stearothermophilus ATCC 12980</i>	11
<i>Geobacillus stearothermophilus ATCC 7953</i>	31
<i>Geobacillus stearothermophilus VHP</i>	11
<i>Bacillus thuringiensis</i>	18

Chemical Decontamination	Ref.
Mustard Gas	
Ricin Toxin	10
dihyronicotinamide adenine dinucleotide	24
microcystin-LR (MC-LR)	25
cylindrospermopsin (CYN)	25

Beta Lactams	Ref.
Amoxicillin	29
Ampicillin	29
Cefadroxil	29
Cefazolin	29
Cephalexin	29
Imipenem	29
Penicillin G	29
Penicillin V	29

Protozoa	Ref.
<i>Chironomid larvae</i>	27
<i>Cryptosporidium</i>	34
<i>Cryptosporidium parvum Oocysts</i>	9
<i>Cyclospora cayetanensis oocysts</i>	41
<i>Giardia</i>	34

Microsporidia	Ref.
<i>Encephalitozoon intestinalis</i>	27

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References:

1. Selecting Surrogate Microorganism for Evaluation of Pathogens on Chlorine Dioxide Gas Treatment, Jeongmok Kim, Somi Koh, Arpan Bhagat, Arun K Bhunia and Richard H. Linton. Purdue University Center for Food Safety 2007 Annual Meeting October 30 - 31, 2007 at Forestry Center, West Lafayette, IN.
2. Decontamination of produce using chlorine dioxide gas treatment, Richard Linton, Philip Nelson, Bruce Applegate, David Gerrard, Yingchang Han and Travis Selby.
3. Chlorine Dioxide, Part A Versatile, High-Value Sterilant for the Biopharmaceutical Industry, Barry Wintner, Anthony Contino, Gary O'Neill. BioProcess International DECEMBER 2005.
4. Chlorine Dioxide Gas Decontamination of Large Animal Hospital Intensive and Neonatal Care Units, Henry S. Luftman, Michael A. Reqits, Paul Lorcheim, Mark A. Czarneski, Thomas Boyle, Helen Aceto, Barbara Dallap, Donald Munro, and Kym Faylor. Applied Biosafety, 11(3) pp. 144-154 © ABSA 2006
5. Efficacy of chlorine dioxide gas as a sanitizer for tanks used for aseptic juice storage, Y. Han, A. M. Guentert*, R. S. Smith, R. H. Linton and P. E. Nelson. Food Microbiology, 1999, 16, 53161
6. Inactivation of Enteric Adenovirus and Feline Calicivirus by Chlorine Dioxide, Jeanette A. Thurston-Enriquez, Charles N., Haas, Joseph Jacangelo, and Charles P. Gerba. APPLIED AND ENVIRONMENTAL MICROBIOLOGY, June 2005, p. 3100-3105.
7. Effect of Chlorine Dioxide Gas on Fungi and Mycotoxins Associated with Sick Building Syndrome, S. C. Wilson,* C. Wu, L.A. Andriychuk, J. M. Martin, T. L. Brasel, C. A. Jumper, and D. C. Straus. APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Sept. 2005, p. 5399-5403.
8. BASF Aseptrol Label
9. Effects of Ozone, Chlorine Dioxide, Chlorine, and Monochloramine on *Cryptosporidium parvum* Oocyst Viability, D. G. KORICH, J. R. MEAD, M. S. MADORE, N. A. SINCLAIR, AND C. R. STERLING. APPLIED AND ENVIRONMENTAL MICROBIOLOGY, May 1990, p. 1423-1428.
10. NHRSC's Systematic Decontamination Studies, Shawn P. Ryan, Joe Wood, G. Blair Martin, Vipin K. Rastogi (ECBC), Harry Stone (Battelle). 2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials Sheraton Imperial Hotel, Research Triangle Park, North Carolina June 21, 2007.
11. Validation of Pharmaceutical Processes 3rd edition, edited by Aaloco James, Carleton Frederick J. Informa Healthcare USA, Inc., 2008, p267
12. Chlorine dioxide gas sterilization under square-wave conditions. Appl. Environ. Microbiol. 56:514-5191990. Jeng, D. K and Woodworth, A. G.
13. Inactivation kinetics of inoculated *Escherichia coli* O157:H7 and *Salmonella enterica* on lettuce by chlorine dioxide gas. Food Microbiology Volume 25, Issue 2. February 2008, Pages 244-252. Barakat S. M. Mahmoud and R. H. Linton.
14. Determination of the Efficacy of Two Building Decontamination Strategies by Surface Sampling with Culture and Quantitative PCR Analysis. APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Aug. 2004, p. 4740-4747. Mark P. Buttner. Patricia Cruz, Linda D. Stetzenbach, Amy K. Klima-Comba, Vanessa L. Stevens, and Tracy D. Cronin
15. Inactivation of Human and Simian Rotaviruses by Chlorine Dioxide. APPLIED AND ENVIRONMENTAL MICROBIOLOGY, May 1990, p. 1363-1366. YU-SHIAW CHEN AND JAMES M. VAUGHN
16. Information obtained from CS1 internal testing with Pharmaceutical customer.
17. Efficacy of chlorine dioxide gas against *Alicyclobacillus acidoterrestris* spores on apple surfaces, Sun-Young Lee, Genesis Iris Dancer, Su-sen Chang, Min-Suk Rhee and Dong-Hyun Kang, International Journal of Food Microbiology, Volume 108, issue 3, May 2006 Pages 364-368
18. Decontamination of *Bacillus thuringiensis* spores on selected surfaces by chlorine dioxide gas, Han Y, Applegate B, Linton RH, Nelson PE. J Environ Health. 2003 Nov;66(4):16-21.
19. Decontamination of Strawberries Using Batch and Continuous Chlorine Dioxide Gas Treatments, Y Han, T.L. Selby, K.K.Schultze, PE Nelson, RH Linton. Journal of Food Protection, Vol 67, NO 12, 2004.
20. Mechanisms of Inactivation of Poliovirus by Chlorine Dioxide and Iodine, MARIA E. ALVAREZ AND R. T. O'BRIEN, APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Nov. 1982, p. 1064-1071
21. The Use of Chlorine Dioxide in potato storage, NORA OLSEN, GALE KLEINKOPF, GARY SECOR, LYNN WOODDELL, AND PHIL NOLTE, University of Idaho, BUL 825.
22. Protective effect of low-concentration chlorine dioxide gas against influenza A virus infection Norio Ogata and Takashi Shibata Journal of General Virology (2008), 89, 60-67
23. Preparation and evaluation of novel solid chlorine dioxide-based disinfectant powder in single-pack Zhu M, Zhang LS, Pei XF, Xu X. Biomed Environ Sci. 2008 Apr;21(2):157-62.
24. Chlorine dioxide oxidation of dihydronicotinamide adenine dinucleotide (NADH), Bakmutova-Albert EV, Margerum DW, Auer JG, Applegate BM. Inorg Chem. 2008 Mar 17;47(6):2205-11. Epub 2008 Feb 16.
25. Oxidative elimination of cyanotoxins: comparison of ozone, chlorine, chlorine dioxide and permanganate, Rodriguez E, Onstad GD, Kull TP, Metcalf JS, Acero JL, von Gunten U., Water Res. 2007 Aug;41(15):3381-93. Epub 2007 Jun 20.
26. Inhibition of hyphal growth of the fungus *Alternaria alternata* by chlorine dioxide gas at very low concentrations, Morino H, Matsubara A, Fukuda T, Shibata T. Yakugaku Zasshi. 2007 Apr;127(4):773-7. Japanese.
27. Inactivation of Chironomid larvae with chlorine dioxide, Sun XB, Cui FY, Zhang JS, Xu F, Liu LJ., J Hazard Mater. 2007 Apr 2;142(1-2):348-53. Epub 2006 Aug 18.
28. Information obtained from CS1 decontamination at Pharmaceutical facility.
29. Information obtained from CSI beta-lactam inactivation at Pharmaceutical facility.
30. Decontamination of Surfaces Contaminated with Biological Agents using Fumigant Technologies, S Ryan, J Wood, 2008 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials Sheraton Imperial Hotel, Research Triangle Park, North Carolina September 24, 2008.
31. Sporicidal Action of CD and VHP Against Avirulent *Bacillus anthracis* - Effect of Organic Bio-Burden and Titer Challenge Level, Vipin K. Rastogi, Lanie Wallace & Lisa Smith, 2008 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials Sheraton Imperial Hotel, Research Triangle Park, North Carolina September 25, 2008.
32. *Clostridium Botulinum*, ESR Ltd, May 2001.
33. Efficacy of Chlorine Dioxide as a Gas and in Solution in the Inactivation of Two Trichothecene Mycotoxins, S. C. Wilson, T. L. Brasel, J. M. Martin, C. Wu, L. Andriychuk, D. R. Douglas, L. Cobos, D. C. Straus, International Journal of Toxicology, Volume 24, issue 3 May 2005, pages 181 - 186.
34. Guidelines for Drinking-water Quality, World Health Organization, pg 140.
35. Division of Animal Resources Agent Summary Sheet, M. Huerkamp, June 30, 2003.
36. NRT Quick Reference Guide: Glanders and Melioidosis
37. Seasonal Occurrence of the Pathogenic *Vibrio* sp. of the Disease of Sea Urchin *Strongylocentrotus intermedius* Occurring at Low Water Temperatures and the Prevention Methods of the Disease, K. TAJIMA, K. TAKEUCHI, M. TAKAHATA, M. HASEGAWA, S. WATANABE, M. IQBAL, Y. EZURA, Nippon Suisan Gakkaishi VOL.66;NO.5;PAGE.799-804(2000).
38. Biocidal Efficacy of Chlorine Dioxide, TF-249, Nalco Company, 2008.
39. Sensitivity of *Listeria monocytogenes*, *Campylobacter jejuni* and *Escherichia coli* Stec To Sublethal Bactericidal Treatments and Development of increased Resistance After Repetitive Cycles of Inactivation, N. Smigic, A. Rajkovic, H. Medic, M. Uyttendaele, F. Devlieghere, Oral presentation. FoodMicro 2008, September 1st - September 4th, 2008, Aberdeen, Scotland.
40. Susceptibility of chemostat-grown *Yersinia enterocolitica* and *Klebsiella pneumoniae* to chlorine dioxide, M S Harakeh, J D Berg, J C Hoff, and A Matin, Appl Environ Microbiol. 1985 January; 49(1): 69-72.
41. Efficacy of Gaseous Chlorine Dioxide as a Sanitizer against *Cryptosporidium parvum*, *Cyclospora cayentanensis*, and *Encephalitozoon intestinalis* on Produce, Y. Ortega, A. Mann, M. Torres, V. Cama, Journal of Food Protection, Volume 71, Number 12, December 2008, pp. 2410-2414.
42. Inactivation of Waterborne Emerging Pathogens by Selected Disinfectants, J. Jacangelo, pg 23.
43. SARS Fact Sheet, National Agricultural Biosecurity Center, Kansas State University.