Compendium of Thermal Death Points of Living Organisms

Every living organism has a thermal death point. The same process for treating bed bugs will also kill, and in some cases, completely eradicate other organisms. Generally speaking, treatments with air temperatures of 66˚C/150˚F for 2 hours will be lethal for most organisms. In laboratory testing with Dr. Walter Ebling, professor of entomology at UCLA, nearly all metamorphic stages of insects died at 120˚F in 30 minutes or less, except for the egg stage. The eggs required an hour at this temperature. Remember, field conditions are not controlled as are conditions in the lab. The times and temperatures listed in the Compendium are not generic air temperatures. These conditions must be met where the organism is found and may require significantly more time to reach the stated thermal levels.

This Compendium includes common microorganisms and insects and also lists many less common organisms. These include insects, bacteria, fungi, protozoa, helminthes and viruses. Many of these are human pathogens, and a number of them are considered pathogens for animal, avian or plant, or some combination.

This information comes from studies for food pasteurization, sewage treatment, pest control, soil pasteurization and compost and timber sterilization. This Compendium also includes additional results from recent field studies by Dr. Michael R. Linford.

The cited thermal death points for any given organism may vary from source to source because control parameters and study conditions may vary from study to study.

Common Organism	Group	Affects	Thermal Death Point	Time Required	Reference/Source [1]
Bed bug (adults and nymphs), *Cimex lectularius*	Pests	Human	60.5˚C/141˚F	23 min	Linford, 2013
Bed bug (eggs), *Cimex lectularius*	Pests	Human	60.5˚C/141˚F	59 min	Linford, 2013
American dust mite, *Dermatophagoides farinae*	Pests	Human	60˚C/140˚F	60 min	Ogg, 1997
Cockroach, American, *Periplaneta americana*	Pests	Damage - Food	66˚C/150˚F	32 min/68 min eggs	Linford, 2013
Cockroach, Oriental, *Blatta orientalis*	Pests	Damage - Food	63˚F/145˚F	20 min/45 min eggs	Linford, 2013
Cockroach, German, *Blatella germanica*	Pests	Damage - Food	65˚C/149˚F	24 min/55 min eggs	Linford, 2013
Carpet beetle, *Anthrenus verbasci*	Pests	Damage - Fibers	49˚C/147˚F	20 min/60 min eggs	Linford, 2013
Flea (eggs)	Pests	Vector	68˚C/155˚F	65 min	Linford, 2013
Flea (adults and larvae)	Pests	Vector	68˚C/155˚F	21 min	Linford, 2013
Flour beetle (adult), *Triboltum confusum*	Pests	Damage - Food	54.4˚C/130˚F	4 min	Quarles, 2006; Forbes, Ebeling, 1987
Human body louse, *Pediculus humanus*	Pests	Vector	46.6˚C/116˚F	60 min	Mellanby, 1932
Indian meal moth, *Plodia interpunctella*	Pests	Damage - Food	53˚C/126˚F	7 min/45 min eggs	Linford, 2013
Spiders (adult)	Pests	Human	66˚C/150˚F	23 min	Linford, 2013
Spiders (eggs)	Pests	Human	66˚C/150˚F	52 min	Linford, 2013
Webbing clothes moth, *Tineola bisselliella*	Pests	Damage - Fibers	53˚C/127˚F	7 min/40 min eggs	Linford, 2013
Bacillus coli (E. coli)	Bacteria	Human	60˚C/140˚F	10 min	Hampil, 1932; Loeffler, 1886
Bacillus typhosus, Salmonella	Bacteria	Human	56˚C/133˚F 63˚C/145˚F	10 min 4 min	Hampil, 1932; Sternburg, 1887 Hampil, 1932; Orskov, 1926
Shigella, Dysentery bacilli	Bacteria	Human	58-60˚C/140˚F	10 min	Hampil, 1932; Runge & O'Brien, 1924
Escherichia coli	Bacteria	Human	60˚C/140˚F 70˚C/158˚F 75˚C/167˚F	105 min 45 min 15 min	Abbott, 2009
Hemophilus influenzae	Bacteria	Human	62˚C/144˚F	2 min	Hampil, 1932; Onorato, 1902
Klebsiella pneumoniae	Bacteria	Human	60˚C/140˚F 70˚C/158˚F	105 min 45 min	Abbott, 2009
Listeria monocytogenes	Bacteria	Human	63˚C/145˚F	30 min	Rowan, 1998

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Common Organism	Group	Affects	Thermal Death Point	Time Required	Reference/Source [1]
Meningococci	Bacteria	Human	60˚C/140˚F	1 min	Hampil, 1932; Bettencourt and Franca, 1904
Mycobacterium tuberculosis	Bacteria	Human	70˚C/158˚F	20 min	Jones & Martin, 2003; Stern, 1974
Pneumococci	Bacteria	Human	60˚C/140˚F	30 min	Hampil, 1932; Baggar, 1926
Salmonella typhi	Bacteria	Human	60˚C/140˚F 70˚C/158˚F	30 min 4 min	Jones & Martin, 2003; Stern, 1974
Methicillin Resistant *Staphylococcus aureus* (MRSA)	Bacteria	Human	50˚C/122˚F 70˚C/158˚F	24 hr 45 min	Abbott, 2009
Staphylococcus aureus	Bacteria	Human	63˚C/145˚F	20 min	Dumalisile, et al., 2005
Vancomycin Resistant *Enterococcus*	Bacteria	Human	50˚C/122˚F 70˚C/158˚F	24 hr 45 min	
Vibrio cholera	Bacteria	Human	55˚C/131˚F	1 min [2]	Gerba, 1997; Roberts & Gilbert, 1979
Schistosoma eggs	Helminths	Human	50˚C/122˚F	60 min	Feachem, 1983
Trichinella spiralis	Helminths	Human	72˚C/162˚F	60 min	Jones & Martin, 2003; Golueke, 1982
Cryptosporidium parva	Protozoa	Human	72.4˚C/162.3˚F	1 min	Gerba, 1997; Fayer, 1994
Entamoeba histolytica	Protozoa	Human	60˚C/140˚F	1 min	Feachem, 1983
Trypanosoma cruzi	Protozoa	Human, Avian	45˚C/113˚F	60 min	Von Brand, 1946
Epstein-Barr Virus	Virus	Human	60˚C/140˚F	30 min	Health Canada, 2007
Hantavirus Pulmonary Syndrome (HPS)	Virus	Human	60˚C/140˚F	30 min	Health Canada, 2007
Hepatitis A	Virus	Human	70˚C/158˚F	10 min	Gerba, 1997; Siegl et al., 1984
Highly Pathogenic Avian Influenza (HPAI)	Virus	Human, Avian	56˚C/133˚F	15 min	TIP, 2000; Blaha, 1989
Infectious bronchitis	Virus	Human, Avian	56˚C/133˚F	15 min	Otsaki, 1979
Parvoviruses	Virus	Human, Avian	60˚C/140˚F	30 min	TIP, 2000; Gough et al., 1981
Rotavirus	Virus	Human	63˚C/145˚F	30 min	Feachem, 1983, p188; G.N. Woode

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Pathogen/Organism: Lab Studies	Group	Affects	Thermal Death Point	Time Required	Reference/Source [1]
Agrilus planipennis Emerald ash borer	Pests	Plant	71˚C/160˚F	75 min	APHIS Factsheet, 2009
American dust mite, *Dermatophagoides farinae*	Pests	Human	50˚C/122˚F 60˚C/140˚F	30 min 8 min	Chang, 1998
Anoplophora glabripennis Asian longhorned beetle	Pests	Plant	71˚C/160˚F	75 min	APHIS Factsheet, 2009
Bed bug, *Cimex lectularius*	Pests	Human	39-40˚C/111-113˚F		Getty, 2006; Usinger, 1966
Bed bug (adults and nymphs), *Cimex lectularius*	Pests	Human	>40˚C/113˚F	15 min	Getty, 2006; Gulmahamad, 2002
Bed bug (eggs), *Cimex lectularius*	Pests	Human	>40˚C/113˚F	1 hr	Getty, 2006; Gulmahamad, 2002
Cockroach, German, *Blatella germanica*	Pests	Vector	54.4˚C/130˚F	7 min	Quarles, 2006; Forbes, Ebeling, 1987
Dermanyssus gallinae, Chicken Mite or Poultry Red Mite	Pests	Vector Human Avian	45˚C/113˚F	2 hr	Nordenfors, 1999
Dermatophagoides pteronyssinus European Dust Mite	Pests	Human	60˚C/140˚F	60 min	Ogg, 1997
Incisitermes minor, Western Drywood Termite	Pests	Damage - Structural	54.4˚C/130˚F	6 min	Quarles, 2006; Forbes, Ebeling, 1987
Lithepuhema humile, Argentine Ant	Pests	Damage - Structural	54.4˚C/130˚F	1 min	Quarles, 2006; Forbes, Ebeling, 1987
Lyctus Powder Post Beetle All Forms	Pests	Damage - Structural	54.4˚C/130˚F	2½ hr	Parkin, 1937; Fisher, 1928
Lyctus Powder Post Beetle Larvae	Pests	Damage - Structural	52˚C/125˚F	2-4 hr	Parkin, 1937
Rat flea (larvae), *Xenopsylla cheopis*	Pests	Vector	39.4˚C/103˚F	1 hr	Mellanby, 1932
Rat flea (adult), *Xenopsylla cheopis*	Pests	Vector	40.6˚C/105˚F	1 hr	Mellanby, 1932
Tetropium fuscum Brown Spruce Longhorn Beetle Larvae	Pests	Damage- Structural	50˚C/122˚F 55˚C/131˚F	30 min 15 min	Mushrow, 2004
Tinibrio molitor Yellow Mealworm	Pests	Damage - Food	42.8˚C/109˚F	1 hr	Mellanby, 1932
Acinetobacter baumannii	Bacteria	Human	63˚C/145˚F	15 min	Dumalisile, et al., 2005
Aeronomas hydrophila	Bacteria	Human	50˚C/122˚F	3 min [2]	Gerba, 1997; Gordon et al., 1992
Bacillus anthracis	Bacteria	Human	140˚C/284˚F	3 hr	Hampil, 1932; Koch, 1881
Bacillus pestis (Yersinia)	Bacteria	Human	60˚C/140˚F	2 min	Hampil, 1932; Gladin, 1898
Bacterium tularense	Bacteria	Human	56˚C/133˚F	10 min	Hampil, 1932; McCoy, 1912
Brucella abortus	Bacteria	Human	61˚C/142˚F	3 min	Jones & Martin, 2003; Golueke, 1982

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Pathogen/Organism: Lab Studies	Group	Affects	Thermal Death Point	Time Required	Reference/Source [1]
Brucella abortus	Bacteria	Human	55˚C/130˚F 65˚C/149˚F	60 min 3 min	Jones & Martin, 2003; Stern, 1974
Brucella abortus or suis	Bacteria	Human	55˚C/130˚F 60˚C/140˚F	60 min 3 min	Jones & Martin, 2003; Day & Shaw, 2000
Brucella melitensis	Bacteria	Human Animal	55˚C/130˚F 60˚C/140˚F	30 min 15 min	Hampil, 1932; Zwick & Wedeman, 1913
Burkholderia mallei	Bacteria	Human Bio Warfare	55˚C/130˚F	10 min	Health Canada, 2007
Campylobacter spp.	Bacteria	Human	75˚C/167˚F	1 min	Gerba, 1997; Bandres et al., 1988
Chlamydia psittaci	Bacteria	Human, Avian	56˚C/133˚F	5 min	TIP, 2000; Anderson et al., 1997
Chryseobacterium meningosepticum	Bacteria	Human	63˚C/145˚F	15 min	Dumalisile, et al., 2005
Corynebacterium diphtheriae	Bacteria	Human	55˚C/130˚F 70˚C/158˚F	45 min 4 min	Jones & Martin, 2003; Stern, 1974
Escherichia coli	Bacteria	Human	45˚C/113˚F 60˚C/140˚F 65˚C/149˚F 70˚C/158˚F 75˚C/167˚F	24 hr 105 min 45 min 45 min 15 min	Abbott, 2009
Escherichia coli	Bacteria	Human	60˚C/140˚F	45 min	Padhye & Doyle, 1992
Escherichia coli	Bacteria	Human	65˚C/149˚F	1 min	Gerba, 1997; Bandres et al., 1988
Escherichia coli	Bacteria	Human	60˚C/140˚F 70˚C/158˚F	60 min 5 min	Jones & Martin, 2003; Stern, 1974
Escherichia coli	Bacteria	Human	55˚C/130˚F 60˚C/140˚F	60 min 20 min	Jones & Martin, 2003; Day & Shaw, 2000
Escherichia coli	Bacteria	Human	55˚C/130˚F 60˚C/140˚F	60 min 20 min	Jones & Martin, 2003; Golueke, 1982
Escherichia coli	Bacteria	Human	63˚C/145˚F	25 min	Dumalisile, et al., 2005

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Pathogen/Organism: Lab Studies	Group	Affects	Thermal Death Point	Time Required	Reference/Source [1]
Klebsiella pneumoniae	Bacteria	Human	45˚C/113˚F 60˚C/140˚F 65˚C/149˚F 70˚C/158˚F	24 hr 105 min 45 min 45 min	Abbott, 2009
Legionella	Bacteria	Human	66˚C/142˚F	.45 min [2]	Gerba, 1997; Sarden et al., 1989
Legionella pneumophila	Bacteria	Human	60˚C/140˚F	30 min	Stout, et al., 1986
Listeria monocytogenes	Bacteria	Human	63˚C/145˚F	20 min	Dumalisile, et al., 2005
Mycobacterium avium sub. paratuberculosis	Bacteria	Human	62˚C/144˚F 71˚C/160˚F	23 min 73 sec	Sung & Collins, 1998
Mycobacterium diphtheriae	Bacteria	Human	55˚C/130˚F 70˚C/158˚F	45 min 4 min	Jones & Martin, 2003; Stern, 1974
Mycobacterium spp. M. avium	Bacteria	Human	70˚C/158˚F	2 min 2.3 min [2]	Gerba, 1997; Robbecke and Buchhottz, 1992
Mycobacterium avium sub .paratuberculosis	Bacteria	Human	72˚C/162˚F	15 sec	Pearce, 2001
Mycobacterium tuberculosis	Bacteria	Human	63˚C/145˚F	3 min	Hampil, 1932; North & Park, 1925
Mycobacterium tuberculosis	Bacteria	Human	63˚C/145˚F 72˚C/162˚F	30 min 15 sec	Connor, 2007
Paratyphoid bacilli	Bacteria	Human	60˚C/140˚F 63˚C/145˚F	20 min 3 min	Hampil, 1932; Krumwiede & Noble, 1921 Hampil, 1932; Orskov, 1926
Pasteurella multocida	Bacteria	Human and Avian	56˚C/133˚F 60˚C/140˚F	15 min 10 min	TIP, 2000; Rimler and Glisson, 1998
Pasteurella spp.	Bacteria	Human	55˚C/131˚F	15 min	Health Canada, 2007
Pseudomonas aeruginosa	Bacteria	Human	45˚C/113˚F 60˚C/140˚F 65˚C/149˚F 70˚C/158˚F	4 hr 75 min 45 min 45 min	Abbott, 2009
Pseudomonas aeruginosa	Bacteria	Human	60˚C/140˚F	<10 min	Spinks, et al., 2003
Pseudomonas putida	Bacteria	Human	63˚C/145˚F	20 min	Dumalisile, et al., 2005

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Salmonella	Bacteria	Human	60˚C/140˚F	1 hr	Feachem, 1983
Salmonella sp.	Bacteria	Human	65˚C/149˚F	1 min	Gerba, 1997; Bandres et al., 1988
Salmonella newport	Bacteria	Human	60˚C/140˚F 65˚C/149˚F	40 min 30 min	Wiley & Westerberg (1969)
Shigella sp.	Bacteria	Human	50˚C/122˚F	1 hr	Jones & Martin, 2003; Stern, 1974
Shigella sp.	Bacteria	Human	55˚C/131˚F	1 hr	Feachem, 1983
Shigella spp.	Bacteria	Human	65˚C/149˚F	1 min	Gerba, 1997; Bandres et al., 1988
Staphylococci	Bacteria	Human	62˚C/144˚F	10 min	Hampil, 1932; Sternburg, 1887
Staphylococcus aureus	Bacteria	Human	45˚C/113˚F 50˚C/122˚F 60˚C/140˚F 65˚C/149˚F 70˚C/158˚F	96 hr 48 hr 105 min 45 min 45 min	Abbott, 2009
Staphylococcus aureus	Bacteria	Human	50˚C/122˚F	10 min	Jones & Martin, 2003; Golueke, 1982
Staphylococcus aureus	Bacteria	Human	63˚C/145˚F	20 min	Dumalisile, et al., 2005
Streptococci	Bacteria	Human	60˚C/140˚F	30 min	Hampil, 1932; Ayers & Johnson, 1918
Streptococcus pyogenes	Bacteria	Human	54˚C/129˚F	10 min	Jones & Martin, 2003; Golueke, 1982
Streptococcus pyogenes	Bacteria	Human	55˚C/131˚F	10 min	Jones & Martin, 2003; Day & Shaw, 2000
Vibrio cholerae	Bacteria	Human	55˚C/131˚F	15 min	Hampil, 1932; Kitasato, 1889
Yersinia enterocolitica	Bacteria	Human	60˚C/140˚F	30 min	Gerba, 1997; Frazier and Westhoff, 1988
Coxiella burnetii	Bacteria Rickettsia	Human Q Fever	63˚C/145˚F	30 min	Connor, 2007
Coxiella burnetii	Bacteria Rickettsia	Human Q Fever	63˚C/145˚F	30 min	Health Canada, 2007
Alternaria alternata	Fungi	Human	63˚C/145˚F	25 min	Domsch, 1993; Page 37
Aspergillus fumigatus	Fungi	Human	65˚C/149˚F [3]	30 min	Bollen, 1969

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Aspergillus niger	Fungi	Human	63˚C/145˚F	25 min	Domsch, 1993; Page 102
Aspergillus ustus	Fungi	Human	62˚C/144˚F	25 min	Domsch, 1993; Page 119
Candida albicans	Fungi/Yeast	Human	70˚C/158˚F	60 min	Wiley & Westerberg (1969)
Candida lipolytica	Fungi/Yeast	Human	63˚C/145˚F	15 min	Dumalisile, et al., 2005
Chaetomium spp.(Soft rot)	Fungi	Human	55˚C/131˚F	30 min	Bollen, 1969
Cladosporium herbarum	Fungi	Human	50˚C/122˚F	10 min	Ridley and Crabtree, 2001
Cladosporium herbarum	Fungi	Human	60˚C/140˚F	30 min	Bollen, 1969
Fusarium cincinatum	Fungi	Human, Plant	60˚C/140˚F	10 min	Ridley, G. unpublished data
Fusarium oxysporum	Fungi	Human	60˚C/140˚F	30 min	Bollen, 1969
Fusarium redolens	Fungi	Plant	60˚C/140˚F	30 min	Bollen, 1969
Lasiodiplodia theobromae formerly *Botryodiplodia theobromae*	Fungi	Plant, Human	60˚C/140˚F	10 min	Ridley and Crabtree, 2001
Myrothecium verrucaria	Fungi	Plant	60˚C/140˚F	30 min	Bollen, 1969
Oőmycetes	Fungi	Plant, Human	50˚C/122˚F	30 min	Bollen, 1969
Penicillium corylophilum	Fungi	Plant	60˚C/140˚F [3]	30 min	Bollen, 1969
Penicillium funiculosum	Fungi	Human	70˚C/158˚F [3]	30 min	Bollen, 1969
Peniophora spp.	Fungi	Plant	54.4˚C/130˚F	15 min	Morrell, 1990
Penicillium lapidosum	Fungi	Plant	70˚C/158˚F [3]	30 min	Bollen, 1969
Phialaphora mustea	Fungi	Plant	60˚C/140˚F [3]	30 min	Bollen, 1969
Phoma herbarum	Fungi	Human	75˚C/167˚F [3]	30 min	Bollen, 1969
Poria carbonica	Fungi	Plant	60˚C/140˚F 70˚C/158˚F	3 hr 60 min	Morrell, 1987
Poria placenta	Fungi	Plant	60˚C/140˚F 65.5˚C/150˚F	6 hr 3 hr	Morrell, 1987
Preussia fleischhakii	Fungi	Plant	60˚C/140˚F	30 min	Bollen, 1969

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Rhinocladiella mansonii	Fungi	Plant	60˚C/140˚F	30 min	Bollen, 1969
Serpula lacrymans (Dry rot)	Fungi	Structure	45˚C/113˚F 50˚C/122˚F	3 hr 1 hr	Miric & Willeitner (1984)
Sordaria carbonaria	Fungi	Plant	65˚C/149˚F	30 min	Bollen, 1969
Sordaria spp.	Fungi	Plant	60˚C/140˚F	30 min	Bollen, 1969
Sporormia aemulans	Fungi	Plant	65˚C/149˚F	30 min	Bollen, 1969
Stachybotrys atra (S. chartarum)	Fungi	Human	60˚C/140˚F	30 min	Bollen, 1969
Stachybotrys chartarum	Fungi	Human	60˚C/140˚F	30 min	Domsch, 1993; Page 745
Stereum sanguinolentum	Fungi	Plant	54.4˚C/130˚F	15 min	Bollen, 1969
Stemphyium botryosum	Fungi	Plant	60˚C/140˚F [3]	30 min	Morrell, 1990
Trichocladium piriformis	Fungi	Plant	80˚C/176˚F [3]	30 min	Bollen, 1969
Trichoderma lignorum	Fungi	Plant, some Human	55˚C/131˚F	30 min	Bollen, 1969
Zygorhynchus moelleri	Fungi	Plant	55˚C/131˚F	30 min	Bollen, 1969
Ascaris lumbricoides	Helminths	Human	55˚C/131˚F	60 min	Bollen, 1969
Ascaris lumbricoides eggs	Helminths	Human	50˚C/122˚F 55˚C/131˚F	60 min 7 min	Feachem, 1983
Necator americanus	Helminths	Human	50˚C/122˚F	50 min	Jones & Martin, 2003; Stern, 1974
Opisthorchis spp.	Helminths	Human	56˚C/133˚F	30 min	Jones & Martin, 2003; Stern, 1974 Health Canada, 2007
Taenia saginata	Helminths	Human	71˚C/160˚F	5 min	Jones & Martin, 2003; Golueke, 1982
Taenia saginata	Helminths	Human	71˚C/160˚F	5 min	Jones & Martin, 2003; Golueke, 1982
Taenia saginata	Helminths	Human	70˚C/158˚F	5 min	Jones & Martin, 2003; Stern, 1974
Entamoeba histolytica	Protozoa	Human	60˚C/140˚F	1 min	Gerba, 1997; Chang, 1943
Entamoeba histolytica cysts	Protozoa	Human	50˚C/122˚F	5 min	Jones & Martin, 2003; Stern, 1974
Giardia lamblia	Protozoa	Human	60˚C/140˚F	2-3 min	Univ of Utah, 2005

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Giardia Lamblia	Protozoa	Human	50˚C/122˚F	1 min [2]	Gerba, 1997; Cerva, 1955
Toxoplasma gondii Oocysts	Protozoa	Human	>66˚C/151˚F	10 min	Health Canada, 2007
Adenovirus	Virus	Human	60˚C/140˚F	20 min	Gerba, 1997; Mahnel, 1977
Avian pneumovirus	Virus	Avian	56˚C/133˚F	30 min	TIP, 2000; Collins, 1986
Cercopithecine Herpes Virus 1	Virus	Human Animal	60˚C/140˚F	30 min	Health Canada, 2007
Coronovirus	Virus	Human	55˚C/131˚F	2 min	Gerba, 1997; Laude, 1981
Coxsackievirus	Virus	Human	60˚C/140˚F	30 min	Health Canada, 2007
Cytomegalovirus	Virus	Human	60˚C/140˚F	30 min	Health Canada, 2007
Ebola virus	Virus	Human	60˚C/140˚F	60 min	Health Canada, 2007
Echovirus	Virus	Human	50˚C/122˚F	2 hr	Health Canada, 2007
Enterovirus 70	Virus	Human	60˚C/140˚F	30 min	Health Canada, 2007
Enteroviruses, Reoviruses and Adenoviruses (All)	Virus	Human	60˚C/140˚F	2 hr	Feachem, 1983
Hepatitis A	Virus	Human	70˚C/158˚F	4 min	Health Canada, 2007
Newcastle Disease Virus (NDV)	Virus	Human, Avian	60˚C/140˚F 70˚C/158˚F	1 hr 50 sec	TIP, 2000; Foster & Thompson, 1957
Norwalk virus	Virus	Human	>60˚C/140˚F	>30 min	Health Canada, 2007
Poliovirus	Virus	Human	60˚C/140˚F	25 min	Gerba, 1997; Larkin and Fasolitis, 1979
Poliovirus 1	Virus	Human	55˚C/131˚F 60˚C/140˚F	30 min 5 min	Feachem, 1983, p163; Wiley & Westerberg, 1969
Poxviruses	Virus	Human, Avian	60˚C/140˚F	8 min	TIP, 2000; Tripathy, 1993
Reovirus	Virus	Human	60˚C/140˚F	20 min	Gerba, 1997; Mahnel, 1977
Rotavirus	Virus	Human	50˚C/122˚F	30 min	Gerba, 1997 ; Estes, et al., 1979
Viruses (Most)	Virus	Human	70˚C/158˚F	20 min	Jones & Martin, 2003; Day & Shaw, 2000
Viruses (Most)	Virus	Human	70˚C/158˚F	25 min	Jones & Martin, 2003; Stern, 1974

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[1] *Lists the reference cited in this document and the original reference cited in the referenced document. For example, the Gerba document lists numerous primary sources.*

[2] *Time for 90% inactivation of microorganism.*

[3] *Maximum Temperature "Heat Tolerant" Species Survived (Thermal death point not reached)*

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References cited

Larry Chase was the original aggregator of this Compendium's sources and information.

Abbott, Sean P., (2009). "Bacterial Efficacy Testing." Unpublished research, Natural Link MOLD LAB, Inc., Sparks, NV.

APHIS Factsheet (2009). "Questions and Answers: Heat-Treatment Requirement for Canadian Firewood." United States Department of Agriculture, Animal and Plant Health Inspection Service.

Bollen, G. (1969). "The Selective Effect of Heat Treatment on the Microflora of a Greenhouse Soil." Neth. Journal of Plant Pathology. 75(1969):157-63.

Chang, J.C.S., L.G. Arlian, J.S. Dippold, C.M. Rapp, and d.L. Vyszenski-Moher. (1998). "Survival of the house dust mite, Dermatophagoides farinae, at high temperatures (40-80˚C). Indoor Air 8:34-38.

Connor, D., (2007). In: "You Are What You Eat". Taken from Auburn University, Detection and Food Safety. http://www.eng.auburn.edu/~wfgale/usda_course/section0_5_page_3.htm.

Domsch, K.H.; Gams, W.; Anderson, T. (1993 Reprint). Compendium of Soil Fungi. Vol 1 & 2. Academic Press, London, UK. Dumalisile, P.; Witthuhn, R. C.; Britz, T. J. (2005). "Impact of different pasteurization temperatures on the survival of microbial contaminants isolated from pasteurized milk." International Journal of Dairy Technology, Vol. 58, No 2, May 2005. Feachem, R. et al, (1983) Sanitation and Disease Health Aspects of Excreta and Wastewater Management, Wiley, Dorchester, England.

Forbes, C.F. and W. Ebeling. 1987. Update: Use of heat for elimination of structural pests. IPM Practitioner 9(8):1-5.

Gerba, C.P. et al. (1997). "Evaluation of Microbial Removal/Inactivation by the Innowave 240®. Dept. of Soil, Water and Environmental Science, Univ. of Arizona. Tucson, AZ.

Getty, G. (2006). Email Correspondence citing: Harland, H. (2004). "Ectoparasites, Part Three: Bed Bugs and Kissing Bugs", The Mallis Handbook of Pest Control, 9th Edition, Pest Control Technology.

Hampil, B. (1932). "The Influence of Temperature on the Life Processes and Death of Bacteria", The Quarterly Review of Biology, Vol 7. No. 2 (172-196).

Health Canada, Office of Laboratory Security (2007). Material Safety Data Sheet – Infectious Substances. http://www.phac- aspc.gc.ca/msds-ftss/msds43e.html.

Jones, P. and Martin, M. (2003). Research Report - A Review of the Literature on the Occurrence and Survival of Pathogens of Animals and Humans in Green Compost. The Waste and Resources Action Programme, The Old Academy, Banbury, Oxon, UK.

Linford, Michael R., (2013). Field study of thermal death points.

Mellanby, K. (1932). The Influence of Atmospheric Humidity on the Thermal Death Point of a Number of Insects", Journal of Experimental Biology, 9(2):222-231.

Miric, M., and H. Willeitner (1984). "Lethal temperature for some wood-destroying fungi with respect to eradication by heat treatment." Intl. Res. Group Wood Pres. IRG/WP/1229.

Morrell, Jeffrey J. (1990). "Conserving Energy by Environmentally Acceptable Practices in Maintaining and Procuring Transmission Poles." Tenth Annual Report, Department of Forest Products, Oregon State University, Corvallis, OR.

Morrell, Jeffrey, et al. (1987). "Controlling Decay Fungi Colonizing Air-Seasoned Douglas-Fir Heartwood with High Temperature Exposures." Forest Research Laboratory, Oregon Sate University, Corvallis, OR.

Mushrow, L., et al, (2004). "Heat as a phytosanitary treatment for the brown spruce longhorn beetle." The Forestry Chronicle. 80(2): 224-228.

Nordenfors, H. et al, (1999). "Effects of Temperature and Humidity on Oviposition, Molting, and Longevity of Dermanyssus gallinae (Acari: Dermanyssidae). J. Medical Entomology. 36(1): 68-72.

Ogg, B. (1997). "House Dust Mites." B-Facts, University of Nebraska Cooperative Extension in Lancaster County, Lincoln, NE. Otsuki, K. et al, (1979). "Studies on Avian Infectious Bronchitis Virus". Archives of Virology. 60(1):25-32.

Padhye, N.V. and Doyle, M.P. 1992. "Escherichia coli 0157:H7: Epidemiology, pathogenesis, and methods for detection in foods". J. Food Protect. 55(7):555-565.

Parkin, E. (1937). "The Kiln-Sterilization of Timber Infested by Lyctus Powder-Post Beetles." Forestry. 11(1):32-39.

Pearce, L., et al. (2001). "Effect of Turbulent-Flow Pasteurization on Survival of Mycobacterium avium subsp. Paratuberculosis Added to Raw Milk." Applied and Environmental Microbiology, 67(9):3964-3969.

Quarles, W. (2006). "Thermal Pest Eradication in Structures." The IPM Practitioner. 28(5/6):1-8.

Ridley, G., and Crabtree, R. (2001) "Temperature mortality thresholds for insects and fungi." Forest Research, NZ, Unpublished Report.

Ridley, G., Unpublished data. This was formed as a part of the Ridley and Crabtee, 2001, research, but produced too late to be included in the report.

Rowan, N.J. and Anderson, J.G. (1998). "Effects of Above-Optimum Growth Temperature and Cell Morphology on Thermotolerance of Listeria monocytogenes Cells Suspended in Bovine Milk." Applied and Environmental Microbiology. 64(6):2065-71.

Spinks, A.T.; Dunstan, R.H.; Coombes, P.; Kuczera, G. (2003). "Thermal Destruction Analyses of Water Related Pathogens at Domestic Hot Water System Temperatures." The Institution of Engineers, Australia, 28th International Hydrology and Water Resources Symposium, 10-14 November 2003, Wollongong, NSW.

Sung, N. and Collins, M. (1998). "Thermal Tolerance of Mycobacterium paratuberculosis." Applied and Environmental Microbiology. 64(3):999-1005.

Stout, J.E.; Best, M.G.; Yu, V.L. (1986). "Susceptibility of Members of the Family Legionellaceae to Thermal Stress: Implications for Heat Eradication Methods in Water Distribution Systems."

Applied and Environmental Microbiology, Aug. 1986, p. 396-399.

Technical Issues Paper. (2000). The Importation of Non-Viable Eggs and Products Containing Egg. Agriculture, Fisheries and Forestry, Australia.

University of Utah. Wilderness Medicine, (2005) University of Utah, School of Medicine.

Von Brand, T. et al, (1946). "Observations on the Respiration of Trypanosoma cruzi in Culture". The Journal of General Physiology, August 1946, p169.

Wiley, B. and Westerberg, S. (1969). "Survival of Human Pathogens in Composted Sewage." Applied Microbiology, 18(6):994-1001.