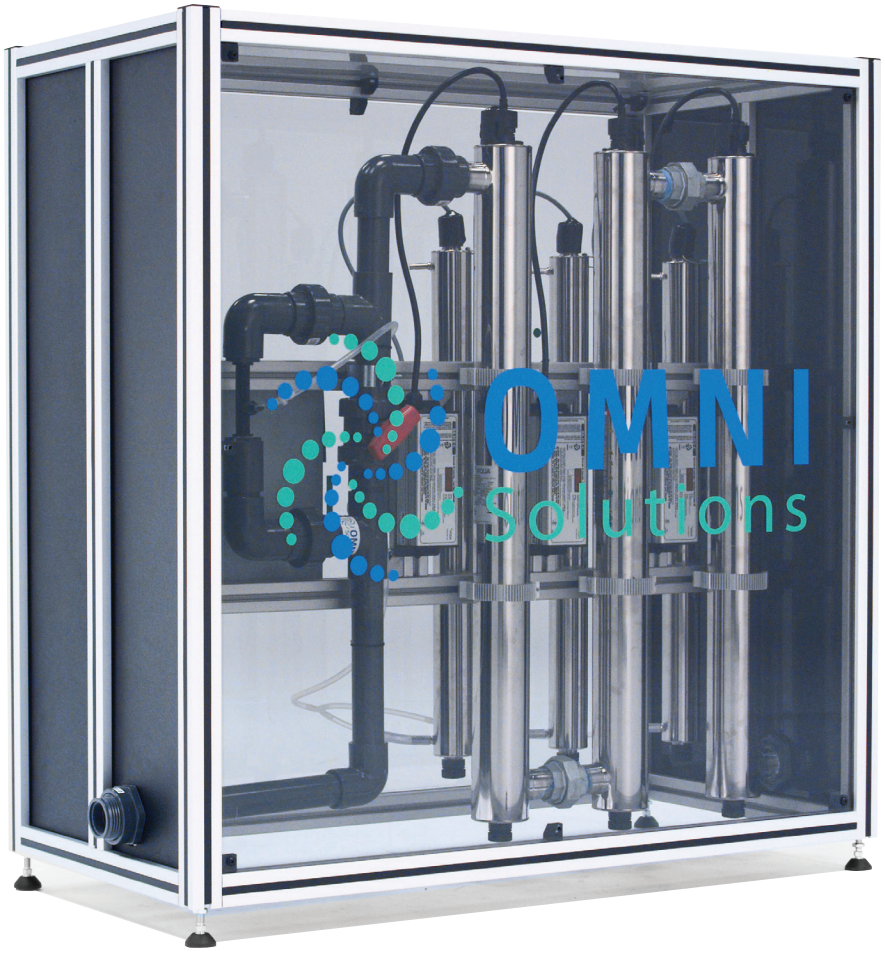
OMNI UV

antimicrobial dosage chart

UV Dose Required to Achieve Incremental Log Inactivation of Bacteria, Protozoa and Viruses[1]

Revised and Expanded by: Gabriel Chevrefils, B.Ing,[2] and Éric Caron, B.Sc.[2]
With earlier (1999) Contributions by: Harold Wright[3] and Gail Sakamoto[3] *And with Peer Review by:* Pierre Payment,[4] Benoit Barbeau[5] and Bill Cairns[3*]

Chaire de recherche en Eau Potable,
École Polytechnique de Montreal
Trojan Technologies Inc.,
London, ON, Canada
INRS- Institut Armand-Frappier
École Polytechnique de Montreal



BRIEF DESCRIPTION AND SELECTION CRITERIA FOR CONTENT OF THE TABLES

Tables 1-4 present a summary of published data on the Ultraviolet (UV) dose-response of various organisms that are pathogens, indicators, or organisms encountered in the application, testing of performance, and validation of UV disinfection technologies. The tables reflect the state of knowledge, but include the variation in technique and biological response that currently exists in the absence of standardized protocols. Users of the data for their own purposes are advised to exercise critical judgment in how they use the data.

In most cases, the data are generated from low pressure (LP) monochromatic mercury arc lamp sources for which the lamp fluence rate (intensity) can be measured empirically and multiplied by exposure time to obtain a dose. Earlier data do not always contain the correction factors that are now considered standard practice (Bolton and Linden 2003). Some data are from polychromatic medium pressure (MP) mercury arc lamps, and in some cases both lamp types are used. In a few cases, filtered polychromatic UV light is used to achieve a narrow band of irradiation around 254 nm. These studies are also designated as LP.

None of the data incorporate any impact of photorepair processes. Only the response to the inactivating UV dose is documented. The references from which the data are abstracted must be carefully read to understand how the reported doses are calculated and what the assumptions and procedures are in the calculation.

At the time this table was being prepared, a parallel initiative (Hijnen et al. 2006) was ongoing and is recommended to the reader.

TABLE 1. UV DOSES FOR MULTIPLE LOG REDUCTIONS FOR VARIOUS SPORES

		UV DOSE (FLUENCE) ((MJ/CM²) FOR A GIVEN LOG REDUCTION WITHOUT PHOTO-REACTIVATION							
SPORE	**LAMP TYPE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**REFERENCE**
Bacillus subtilis ATCC6633	N/A	36	48.6	61	78	–	–	–	Chang et al. 1985
Bacillus subtilis ATCC6633	LP	24	35	47	79	–	–	–	Mamane-Gravetz and Linden 2004
Bacillus subtilis ATCC6633	LP	22	38	>50	–	–	–	–	Sommer et al. 1998
Bacillus subtilis ATCC6633	LP	20	39	60	81	–	–	–	Sommer et al. 1999
Bacillus subtilis WN626	LP	0.4	0.9	1.3	2	–	–	–	Marshall et al., 2003

TABLE 2. UV DOSES FOR MULTIPLE LOG REDUCTIONS FOR VARIOUS BACTERIA

		UV DOSE (FLUENCE) ((MJ/CM²) FOR A GIVEN LOG REDUCTION WITHOUT PHOTO-REACTIVATION							
BACTERIUM	**LAMP TYPE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**REFERENCE**
Aeromonas hydrophila ATCC7966	LP	1.1	2.6	3.9	5	6.7	8.6	–	Wilson et al. 1992
Aeromonas salmonicida	LP	1.5	2.7	3.1	5.9	–	–	–	Liltved and Landfald 1996
Campylobacter jejuni ATCC 43429	LP	1.6	3.4	4	4.6	5.9	–	–	Wilson et al. 1992
Citrobacter diversus	LP	5	7	9	11.5	13	–	–	Giese and Darby 2000
Citrobacter freundii	LP	5	9	13	–	–	–	–	Giese and Darby 2000
Escherichia coli ATCC 11229	N/A	2.5	3	3.5	5	10	15	–	Harris et al. 1987
Escherichia coli ATCC 11229	N/A	3	4.8	6.7	8.4	10.5	–	–	Chang et al. 1985
Escherichia coli ATCC 11229	LP	<5	5.5	6.5	7.7	10	–	–	Zimmer et al. 2002
Escherichia coli ATCC 11229	MP	<3	<3	<3	<3	8	–	–	Zimmer et al. 2002
Escherichia coli ATCC 11229	LP	7	8	9	11	12	–	–	Hoyer 1998
Escherichia coli ATCC 11229	LP	3.5	4.7	5.5	6.5	7.5	9.6	–	Sommer et al. 2000
Escherichia coli ATCC 11229	LP	6	6.5	7	8	9	10	–	Sommer et al. 1998
Escherichia coli ATCC 11303	LP	4	6	9	10	13	15	19	Wu et al. 2005
Escherichia coli ATCC 25922	LP	6	6.5	7	8	9	10	–	Sommer et al. 1998
Escherichia coli C	LP	2	3	4	5.6	6.5	8 1	0.7	Otaki et al. 2003
Escherichia coli O157:H7	LP	1.5	3	4.	5	6	–	–	Tosa and Hirata 1999
Escherichia coli O157:H7	LP	<2	<2	2.5	4	8	17		Yaun et al. 2003
Escherichia coli O157:H7 CCUG 29193	LP	3.5	4.7	5.5	7	–	–	–	Sommer et al. 2000
Escherichia coli O157:H7 CCUG 29197	LP	2.5	3	4.6	5	5.5	–	–	Sommer et al. 2000
Escherichia coli O157:H7 CCUG 29199	LP	0.4	0.7	1	1.1	1.3	1.4	–	Sommer et al. 2000
Escherichia coli O157:H7 ATCC 43894LP	1.5	2.8	4.1	5.6	6.8	–	–	–	Wilson et al. 1992
Escherichia coli O25:K98:NM	LP	5	7.5	9	10	11.5	–	–	Sommer et al. 2000
Escherichia coli O26	LP	5.4	8	10.5	12.8	–	–	–	Tosa and Hirata 1999
Escherichia coli O50:H7	LP	2.5	3	3.5	4.5	5	6	–	Sommer et al. 2000
Escherichia coli O78:H11	LP	4	5	5.5	6	7		–	Sommer et al. 2000
Escherichia coli K-12 IFO3301	LP & MP	2	4	6	7	8.5	–	–	Oguma et al. 2002

TABLE 2. UV DOSES FOR MULTIPLE LOG REDUCTIONS FOR VARIOUS BACTERIA									
		UV DOSE (FLUENCE) ((MJ/CM^2) FOR A GIVEN LOG REDUCTION WITHOUT PHOTO-REACTIVATION							
BACTERIUM	**LAMP TYPE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**REFERENCE**
Escherichia coli K-12 IFO3301	LP & MP	2.2	4.4	6.7	8.9	11.0	–	–	Oguma et al. 2004
Escherichia coli K-12 IFO3301	LP	1.5	2	3.5	4.2	5.5	6.2	–	Otaki et al. 2003
Escherichia coli Wild type	LP	4.4	6.2	7.3	8.1	9.2	–	–	Sommer et al. 1998
Halobacterium elongata ATCC33173	LP	0.4	0.7	1	–	–	–	–	Martin et al. 2000
Halobacterium salinarum ATCC43214	LP	12	15	17.5	20	–	–	–	Martin et al. 2000
Klebsiella pneumoniae	LP	12	15	17.5	20	–	–	–	Giese and Darby 2000
Klebsiella terrigena ATCC33257	LP	4.6	6.7	8.9	11	–	–	–	Wilson et al. 1992
Legionella pneumophila ATCC 43660	LP	3.1	5	6.9	9.4	–	–	–	Wilson et al. 1992
Legionella pneumophila ATCC33152	LP	1.6	3.2	4.8	6.4	8.0	–	–	Oguma et al. 2004
Legionella pneumophila ATCC33152	MP	1.9	3.8	5.8	7.7	9.6	–	–	Oguma et al. 2004
Pseudomonas stutzeri	UVB	100	150	195	230	–	–	–	Joux et al. 1999
RB2256	UVB	175	>300	–	–	–	–	–	Joux et al. 1999
Salmonella spp.	LP	<2	2	3.5	7	14	29	–	Yaun et al. 2003
Salmonella anatum (from human feces)	N/A	7.5	12	15	–	–	–	–	Tosa and Hirata 1998
Salmonella derby (from human feces)	N/A	3.5	7.5	–	–	–	–	–	Tosa and Hirata 1998
Salmonella enteritidis (from human feces)	N/A	5	7	9	10	–	–	–	Tosa and Hirata 1998
Salmonella infantis (from human feces)	N/A	2	4	6	–	–	–	–	Tosa and Hirata 1998
Salmonella typhi ATCC 19430	LP	1.8	4.8	6.4	8.2	–	–	–	Wilson et al. 1992
Salmonella typhi ATCC 6539	N/A	2.7	4.1	5.5	7.1	8.5	–	–	Chang et al. 1985
Salmonella typhimurium (from human feces)	N/A	2	3.5	5	9	–	–	–	Tosa and Hirata 1998
Salmonella typhimurium (from human feces)	N/A	2	3.5	5	9	–	–	–	Tosa and Hirata 1998
Salmonella typhimurium (in act. sludge)	LP	3	11.5	22	50	–	–	–	Maya et al. 2003
Salmonella typhimurium	UVB	50	100	175	210	250	–	–	Joux et al. 1999
Shigella dysenteriae ATCC29027	LP	0.5	1.2	2	3	4	5.1	–	Wilson et al. 1992
Shigella sonnei ATCC9290	N/A	3.2	4.9	6.5	8.2	–	–	–	Chang et al. 1985
Staphylococcus aureus ATCC25923	N/A	3.9	5.4	6.5	10.4				Chang et al. 1985
Streptococcus faecalis ATCC29212	N/A	6.6	8.8	9.9	11.2	–	–	–	Chang et al. 1985
Streptococcus faecalis (secondary effluent)	N/A	5.5	6.5	8	9	12	–	–	Harris et al. 1987
Vibrio anguillarum	LP	0.5	1.2	1.5	2	–	–	–	Liltved and Landfald 1996
Vibrio cholerae ATCC25872	LP	0.8	1.4	2.2	2.9	3.6	4.3	–	Wilson et al. 1992
Vibrio natriegens	UVB	37.5	75	100	130	150	–	–	Joux et al. 1999
Yersinia enterocolitica ATCC27729	LP	1.7	2.8	3.7	4.6	–	–	–	Wilson et al. 1992

TABLE 3. UV DOSES FOR MULTIPLE LOG REDUCTIONS FOR VARIOUS PROTOZOA									
		UV DOSE (FLUENCE) ((MJ/CM^2) FOR A GIVEN LOG REDUCTION WITHOUT PHOTO-REACTIVATION							
PROTOZOAN	**LAMP TYPE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**REFERENCE**
Cryptosporidium hominis	LP & MP	3	5.8	–	–	–	–	–	Johnson et al. 2005
Cryptosporidium parvum, oocysts, tissue culture assay	N/A	1.3	2.3	3.2	–	–	–	–	Shin et al. 2001
Cryptosporidium parvum	LP & MP	2.4	<5	5.2	9.5	–	–	–	Craik et al. 2001
Cryptosporidium parvum	MP	<5	<5	<5	~6	–	–	–	Amoah et al. 2005
Cryptosporidium parvum	MP	<10	<10	<10	–	–	–	–	Belosevic et al. 2001
Cryptosporidium parvum	LP	1	2	<5	–	–	–	–	Shin et al. 2001
Cryptosporidium parvum	MP	1	2	2.9	4	–	–	–	Bukhari et al. 2004
Cryptosporidium parvum	LP	<2	<2	<2	<4	<10	–	–	Clancy et al. 2004
Cryptosporidium parvum	MP	<3	<3	3-9	<11	–	–	–	Clancy et al. 2000
Cryptosporidium parvum	LP	<3	<3	3-6	<16	–	–	–	Clancy et al. 2000
Cryptosporidium parvum	LP	0.5	1	1.4	2.2	–	–	–	Morita et al. 2002
Cryptosporidium parvum	LP	2	<3	<3	–	–	–	–	Zimmer et al. 2003
Cryptosporidium parvum	MP	<1	<1	<1	–	–	–	–	Zimmer et al. 2003
Encephalitozoon cuniculi, microsporidia	LP	4	9	13	–	–	–	–	Marshall et al. 2003
Encephalitozoon hellem, microsporidia	LP	8	12	18	–	–	–	–	Marshall et al. 2003
Encephalitozoon intestinalis, microsporidia	LP & MP	<3	3	<6	6	–	–	–	Huffman et al. 2002
Encephalitozoon intestinalis, microsporidia	LP	3	5	6	–	–	–	–	Marshall et al. 2003
Giardia lamblia,gerbil infectivity assay	LP	<0.5	<0.5	<0.5	<1	–	–	–	Linden et al. 2002b
Giardia lamblia	LP	<10	~10	<20	–	–	–	–	Campbell et al. 2002
Giardia lamblia	LP	<2	<2	<4	–	–	–	–	Mofidi et al. 2002
Giardia lamblia,excystation assay	N/A	> 63	–	–	–	–	–	–	Rice and Hoff 1981
Giardia lamblia, excystation assay	N/A	40	180	–	–	–	–	–	Karanis et al. 1992
Giardia muris, excystation assay	N/A	77	110	–	–	–	–	–	Carlson et al. 1985
G. muris, cysts, mouse infectivity assay	N/A	<2	<6 1	0 + tailing					Craik et al. 2000
Giardia muris	MP	1	4.5	28 + tailing					Craik et al. 2000
Giardia muris	MP	<10	<10	<25	~60	–	–	–	Belosevic et al. 2001
Giardia muris	LP	<1.9	<1.9	~2	~2.3	–	–	–	Hayes et al. 2003
Giardia muris	LP	<2	<2	<4	–	–	–	–	Mofidi et al. 2002
G. muris, cysts	MP	<5	<5	5	–	–	–	–	Amoah et al. 2005

TABLE 4. UV DOSES FOR MULTIPLE LOG REDUCTIONS FOR VARIOUS VIRUSES									
			UV DOSE (FLUENCE) ((MJ/CM^2) FOR A GIVEN LOG REDUCTION WITHOUT PHOTO-REACTIVATION						
VIRUS	**HOST**	**LAMP TYPE**	**1**	**2**	**3**	**4**	**5**	**6**	**REFERENCE**
PRD-1 (Phage)	S. typhimurium Lt2	N/A	9.9	17.2	23.5	30.1	–	–	Meng and Gerba 1996
B40-8 (Phage)	B. Fragilis	LP	11	17 2	3	29	35	41	Sommer et al. 2001
B40-8 (Phage)	B. fragilis HSP-40	LP	12	18	23	28	–	–	Sommer et al. 1998
MS2 (Phage)	Salmonella typhimurium WG49	N/A	16.3	35	57	83	114	152	Nieuwstad and Havelaar
MS2 DSM 5694 (Phage)	E. coli NCIB 9481	N/A	4	16	38	68	110	–	Wiedenmann et al. 1993
MS2 ATCC E. (Phage) 15977–B1	coli ATCC 15977-B1	LP	15.9	34	52	71	90	109	Wilson et al. 1992
MS2 NCIMB 10108 (Phage)	Salmonella typhimurium WG49	N/A	12.1	30.1	–	–	–	–	Tree et al. 1997
MS2 (Phage)	E. coli K-12 Hfr	LP	21	36	–	–	–	–	Sommer et al. 1998
MS2 (Phage)	E. coli CR63	N/A	16.9	33.8	–	–	–	–	Rauth 1965
MS2 (Phage)	E. coli 15977	N/A	13.4	28.6	44.8	61.9	80.1	–	Meng and Gerba 1996
MS2 (Phage)	E. coli C3000	N/A	35	–	–	–	–	–	Battigelli et al. 1993
MS2 (Phage)	E. coli ATCC 15597	N/A	19	40	61	–	–	–	Oppenheimer et al. 1993
MS2 (Phage)	E. coli C3000	LP	20	42	69	92	–	–	Batch et al. 2004
MS2 (Phage)	E. coli ATCC 15597	LP	20	42	70	98	133	–	Lazarova and Savoye 2004
MS2 (Phage)	E. coli ATCC 15977	LP	20	50	85	120	–	–	Thurston-Enriquez et al., 2003
MS2 (Phage)	E. coli HS(pFamp)R	LP	45	75	100	125	155	–	Thompson et al. 2003
MS2 (Phage)	E. coli C3000	LP	20	42	68	90	–	–	Linden et al. 2002a
MS2 (Phage)	E. coli K-12	LP	18.5	36	55	–	–	–	Sommer et al. 2001
MS2 (Phage)	E. coli NCIMB 9481	N/A	14		–	–	–	–	Tree et al. 2005
PHI X 174 (Phage)	E. coli WG5	LP	2.2	5.3	7.3	10.5	–	–	Sommer et al. 1998
PHI X 174 (Phage)	E. coli C3000	N/A	2.1	4.2	6.4	8.5	10.6	12.7	Battigelli et al. 1993
PHI X 174 (Phage)	E. coli ATCC15597	N/A	4	8	12	–	–	–	Oppenheimer et al. 1993
PHI X 174 (Phage)	E. coli WG 5	LP	3	5	7.5	10	12.5	15	Sommer et al. 2001
PHI X 174 (Phage)	E. coli ATCC 13706	LP	2	3.5	5	7	–	–	iese and Darby 2000
Staphylococcus aureus phage A 994 (Phage)	Staphylococcus aureus 994	LP	8	17	25	36	47	–	Sommer et al. 1989
Calicivirus canine	MDCK cell line	LP	7	15	22	30	36	–	Husman et al. 2004
Calicivirus feline	CRFK cell line	LP	7	16	25	–	–	–	Husman et al. 2004
Calicivirus feline	CRFK cell line	N/A	4	9	14	–	–	–	Tree et al. 2005
Calicivirus feline	CRFK cell line	LP	5	15	23	30	39	–	Thurston-Enriquez et al. 2003
Adenovirus type 2	A549 cell line	LP	20	45	80	110	–	–	Shin et al. 2005
Adenovirus type 2	Human lung cell line	LP	35	55	75	100	–	–	Ballester and Malley 2004
Adenovirus type 2	PLC / PRF / 5 cell line	LP	40	78	119	160	195	235	Gerba et al. 2002
Adenovirus type 15	A549 cell line (ATCC CCL-185)	LP	40	80	122	165	210	–	Thompson et al. 2003

TABLE 4. UV DOSES FOR MULTIPLE LOG REDUCTIONS FOR VARIOUS VIRUSES									
			UV DOSE (FLUENCE) ((MJ/CM^2) FOR A GIVEN LOG REDUCTION WITHOUT PHOTO-REACTIVATION						
VIRUS	**HOST**	**LAMP TYPE**	**1**	**2**	**3**	**4**	**5**	**6**	**REFERENCE**
Adenovirus type 40	PLC / PRF / 5 cell line	LP	55	105	155	–	–	–	Thurston-Enriquez et al. 2003
Adenovirus type 40	PLC / PRF / 5 cell line	LP	30	ND	ND 1	24	–	–	Meng and Gerba 1996
Adenovirus type 41	PLC / PRF / 5 cell line	LP	23.6	ND	ND	111.8	–	–	Meng and Gerba 1996
Poliovirus Type 1 ATCC Mahoney	N/A	N/A	6	14	23	30	–	–	Harris et al. 1987
Poliovirus Type 1LSc2ab ()	MA104 cell	N/A	5.6	11	16.5	21.5	–	–	Chang et al. 1985
Poliovirus Type 1 LSc2ab	BGM cell	LP	5.7	11	17.6	23.3	32	41	Wilson et al. 1992
Poliovirus 1	BGM cell line	N/A	5	11	18	27		–	Tree et al. 2005
Poliovirus 1	CaCo2 cell-line (ATCC HTB37)	LP	7	17	28	37	–	–	Thompson et al. 2003
Poliovirus 1	BGM cell line	LP	8	15.5	23	31	–	–	Gerba et al. 2002
Poliovirus Type Mahoney	Monkey kidney cell line Vero	LP	3	7	14	40	–	–	Sommer et al. 1989
Coxsackievirus B5	Buffalo Green Monkey cell line	N/A	6.9	13.7	20.6	–	–	–	Battigelli et al. 1993
Coxsackievirus B3	BGM cell line	LP	8	16	24.5	32.5	–	–	Gerba et al. 2002
Coxsackievirus B5	BGM cell line	LP	9.5	18	27	36	–	–	Gerba et al. 2002
Reovirus-3	Mouse L-60	N/A	11.2	22.4	–	–	–	–	Rauth 1965
Reovirus Type 1 Lang strain	N/A	N/A	16	36	–	–	–	–	Harris et al. 1987
Rotavirus SA-11	Monkey kidney cell line MA 104	LP	8	15	27	38	–	–	Sommer et al. 1989
Rotavirus SA-11	MA-104 cell line	N/A	7.6	15.3	23	–	–	–	Battigelli et al. 1993
Rotavirus SA-11	MA-104 cell line	N/A	7.1	14.8	25	–	–	–	Chang et al. 1985
Rotavirus SA-11	MA-104 cell line	LP	9.1	19	26	36	48	–	Wilson et al. 1992
Rotavirus	MA104 cells	LP	20	80	140	200	–	–	Caballero et al. 2004
Hepatitis A HM175	FRhK-4 cell	LP	5.1	13.7	22	29.6	–	–	Wilson et al. 1992
Hepatitis A	HAV/HFS/GBM	N/A	5.5	9.8	15	21	–	–	Wiedenmann et al. 1993
Hepatitis A HM175	FRhK-4 cell	N/A	4.1	8.2	12.3	16.4	–	–	Battigelli et al. 1993
Echovirus I	BGM cell line	LP	8	16.5	25	33	–	–	Gerba et al. 2002
Echovirus II	BGM cell line	LP	7	14	20.5	28	–	–	Gerba et al. 2002

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