Safe Water System (SWS) – Effect of Chlorination on Inactivating Selected Pathogens

Chlorine inactivates most pathogens that cause diarrheal disease in humans. The table below details the effectiveness of chlorine against disease-causing bacteria, viruses, and protozoa. The Ct factor can be used to compare the effectiveness of chlorine against different pathogens, and is calculated by multiplying the concentration of chlorine needed to inactivate a certain percentage of the pathogens by the time the pathogen was exposed to that concentration of chlorine. Higher Ct factors indicate relatively higher resistance to chlorine, while lower Ct factors indicate relatively low resistance to chlorine. The Ct factors shown in the table below were calculated from data in peer-reviewed research articles (references below). The efficacy of disinfection using chlorine is dependent not only on the pathogen itself, but also on the pH and temperature of the water. In general, disinfection is more effective at higher temperatures and lower pH. Attachment to particulate matter, aggregation, encapsulation of the pathogen, ingestion by protozoa, and water turbidity may also affect chlorine efficacy. The results below reflect conditions of low water turbidity (<1 NTU), demand-free water systems. The Safe Water System accounts for variations in water quality by doubling the chlorine used in turbid drinking water. The maximum Ct factor created by adding 1.875mg/L sodium hypochlorite to water for 30 minutes (the minimum chlorine dosage recommended by the Safe Water System for clear, non-turbid, demand-free water) is 56.25 mg·min/L (Lantagne, in press). For turbid water, the dose is doubled to 3.75mg/L, with a resulting maximum Ct factor of 112.5 mg·min/L.

PATHOGEN	FROM WHO GUIDELINES FOR DRINKING-WATER QUALITY				CONCENTRATION OF CHLORINE (MG/L)	TIME OF CHLORINE EXPOSURE (MIN)	CT FACTOR	% INACTIVATION	VARIABLES AFFECTING CT FACTOR		PATHOGEN SUBCLASSIFICATION AND/OR EXPERIMENTAL DESIGN	SOURCE
	Health significance	Persistence in water supplies	Resistance to chlorine	Relative infectivity					Temp (°C)	pH		
BACTERIA												
Burkholderia pseudomallei	Low	May multiply	Low	Low	1.0	60	***60***	99%	22.0-25.0	6.25-7.0	45 pooled clinical and environmental samples	Howard, 1993
Campylobacter jejuni	High	Moderate	Low	Moderate	0.1	5	***0.5***	99-99.9%	25.0	8.0	Serotypes PEN1, PEN2, PEN3 isolated from patients	Blaser, 1986
Escherichia coli	High	Moderate	Low	Low	0.5	<0.5	***<0.25***	99.999999%	23.0	7.0	Strain ATCC 11229	Zhao, 2001
E. coli (enterohemorrhagic)	High	Moderate	Low	High	0.5	<0.5	***<0.25***	99.98-99.999999%	23.0	7.0	Strains isolated from six human patients	Zhao, 2001
Salmonella typhi	High	Moderate	Low	Low	0.05	20	***1***	99.2%	20-25	7.0	Two isolates – one from patient blood sample	Butterfield, 1943
Shigella dysenteriae.	High	Short	Low	Moderate	0.05	<1	***<0.05***	99.9%	20-25	7.0	Three isolates from patient stool samples	Butterfield, 1943
Shigella sonnei	-	-	-	-	0.5	1	***0.5***	99%	25.0	7.0	Water Engineering Research Laboratory isolate	King, 1988
Vibrio cholerae (smooth strain)	High	Short	Low	Low	0.5	<1	***<0.5***	100%	20.0	7.0	O1 El Tor Inaba strain N16961	Morris, 1993
Vibrio cholerae (rugose strain)	High	Short	Low	Low	2.0	20	***40***	99.999%	20.0	7.0	O1 El Tor Inaba strain N16961/Ru	Morris, 1993
Yersinia enterocolitica	High	Long	Low	Low	1.0	>30	***>30***	82-92%	20.0	7.0	3 strains: ATCC 9610 O:8, 632 O:25,35 and IM 69/85 O:3 Lis VIII	Paz, 1993
VIRUSES												
Enteroviruses												
Coxsackie A	High	Long	Moderate	High	0.46-0.49	0.3	***0.14-0.15***	99%	5.0	6.0	Coxsackie A9	Engelbrecht, 1980
Coxsackie B	High	Long	Moderate	High	0.48-0.50	4.5	***2.16-2.25***	99%	5.0	7.81-7.82	Coxsackie B5	Engelbrecht, 1980
Echovirus	High	Long	Moderate	High	0.48-0.52	1.8	***0.86-0.94***	99%	5.0	7.79-7.83	Serotype 5	Engelbrecht, 1980
Hepatitis A	High	Long	Moderate	High	0.41	<1	***<0.41***	99.99%	25.0	8.0	Strain from one patient sample	Grabow, 1983
Poliovirus	High	Long	Moderate	High	0.5	12.72	***6.36***	99.99%	5.0	6.0	Poliovirus type 1	Thurston-Enriquez, 2003
Adenoviruses	High	Long	Moderate	High	0.17	4.41	***0.75***	99.99%	5.0	7.0	Adenovirus 40	Thurston-Enriquez, 2003
Noroviruses	High	Long	Moderate	High	1.0	0.07	***0.07***	99.99%	5.0	7.0	Feline calicivirus used as a model	Thurston-Enriquez, 2003
Rotavirus	High	Long	Moderate	High	0.20	0.25	***0.05***	99.99%	4.0	7.0	Human rotavirus type 2 (Wa)	Vaughn, 1986
PROTOZOA												
Entamoeba histolytica	High	Moderate	High	Low	2.0	10	***20***	99%	27-30	7	Viability assessed by in vitro excystation assay	Stringer, 1975
Giardia lamblia	High	Moderate	High	Low	1.5	10	***15***	99.9%	25.0	7.0	Viability assessed by excystation	Jarroll, 1981
Toxoplasma gondii	High	Moderate	High	Unknown	100	1440	***>144,000***[1]	-	22.0	7.2	Viability assessed by mouse bioassay	Wainwright, 2007
Cryptosporidium parvum	High	Long	High	Low	80	90	***7,200***[1]	99%	25.0	7.0	Viability assessed by excystation and mouse viability assays	Korich, 1990

[1] Toxoplasma oocysts and cryptosporidium oocysts are highly resistant to chlorine disinfection. Chlorine alone should not be expected to inactivate these pathogens in drinking water. Filtering water supplies is recommended to physically remove the oocysts before chlorination if these pathogens are of concern.

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Complied December 20, 2007 by Amelia Kasper. Contact: safewater@cdc.gov