DISINFECTION

CE421/521
Environmental Biotechnology
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History of Disinfection

- Disinfection = process designed for the deliberate reduction of pathogenic organisms.
- Disinfection of water supplies by c_______________ began in Chicago and New Jersey in 1908, within 2 years chlorination of w_________ s____________ was practiced in N.Y., Montreal, Milwaukee, Cleveland, Nashville, Baltimore, and Cincinnati.
- By 1918, over 1000 ________ treating more than ____ bgd were chlorinating their water supplies.
- While, other processes (e.g., coagulation, sedimentation, filtration) may achieve p__________________ reduction, that is not their primary goal.
- Concept of disinfection preceded knowledge of b_________ as the causative agent of many diseases. In 1832, Averill proposed the chlorine disinfection of human wastes to prevent epidemics.
- C______________ addition to water treatment only became accepted after litigation regarding its efficacy.

History of Disinfection

- Most water utilities currently rely on c_____________ or h_______________ disinfection.
- Other choices are a_________________ + chlorine (chloramination), chlorine d____________, o______________, and UV.
- Current challenges in water treatment continues to be p_______________ pathogens (*Cryptosporidium* and *Giardia*) and v______________ contaminants (Norwalk virus), as well as reducing disinfection b_______________ (DBPs).
- New challenges are the removal of e______________ disruptors, pharmaceuticals, a_____________, r__________.

Water Utility Disinfection Practices (AWWA, 1989)

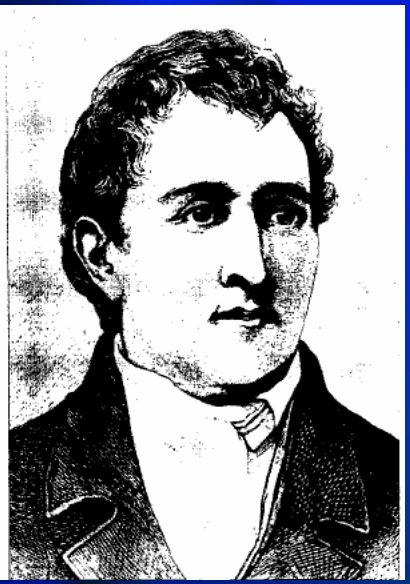
Process	No ammonia	Ammonia
Chlorine alone		
Gas	67%	19..8%
Hypochlorite	6%	0.8%
Chlorine and ClO_2	3.4%	1.5%
Ozone	0.4%	
Other	0.8%	

www.bcwwa.org/magazine/2003-2004 /fall2003/images/

www.mwdslc.org/VirtualTour/wwwroot/educational/images/cl2_cylinders.jpg

http://www.ci.la-porte.in.us/wwtp/disinfection-1.jpg

Chlorine



Swedish pharmacist Carl Wilhelm Scheele.

- Chlorine g__________ first prepared by Scheele in 1774, but not recognized as a chemical element until 1808. Scheele called it dephlogisticated marine acid.
- Early (1825) uses of chlorine gas include J__________________ water (chlorine gas dissolved in alkaline potassium solution) in France for waste treatment and as a prophylactic against the c_____________ epidemic (major epidemic in 1831).

Chlorine Dioxide

- First produced by Davy in 1811 from the reaction of p______________ chlorate and hypochloric acid.
- Not used widely until the i________________ production of sodium chlorite from which chlorine dioxide can be readily made.
- Used widely as a bleaching agent in the p___________ and p_____________ industry, slow to be adopted by water treatment industry.
- Chlorine dioxide is used in fewer than _______ plants in U.S. Used in approximately _______ plants in Europe.

Ozone

- Discovered in __________ by Van Marum
- Named by Schlonbein in _____________.
- First electric d_______________ ozone generator constructed by Siemens in 1857.
- First c____________________ application occurred in 1893 at Oudshoorn, Netherlands.
- Nice, France is the oldest (1906) c___________________ user of ozone for water treatment.
- First use in the U.S. in New York City (Jerome Park Reservoir) for t_______ and o__________ removal in 1906.
- By 1987, approximately ________ plants in U.S. use ozone as a disinfectant and/or for taste and odor removal. More recent interest since the 1993 outbreak of *Cryptosporidium* in Milwaukee.

Ultraviolet (UV) Radiation

- UV (short wavelength) r______________ (primarily associated with sunlight) long known to have biocidal effects
- By 1940 d_____________ guidelines for UV disinfection were proposed.
- Accepted use for disinfection on p____________ ships.
- – Little e________________________ in water treatment industry, but that may be changing

Theory of Disinfection

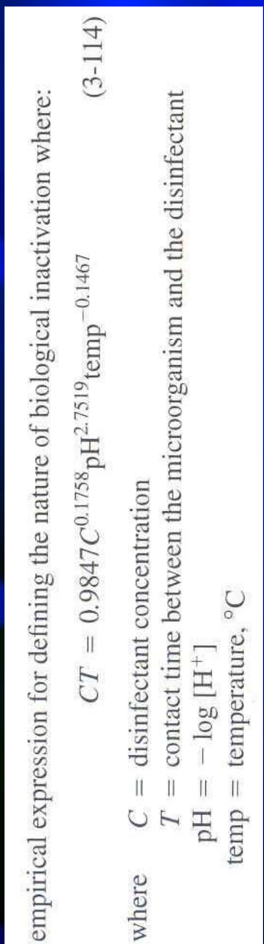
- Chick's Law: $$\frac{dN}{dt} = -kN$$
- rate, k, is a function of c_________________ and t_______________ (i.e., CT) and type of organism
- CT concept: $CT=0.9847C^{0.1758}pH^{2.7519}temp^{-0.1467}$

  where C = chlorine residual concentration ($C \leq 4.23$ mg/L)

  T= contact time between microbe and disinfectant to inactivate 99.99%

  temp = temperature in the range of 0.5-5.0 °C

  pH in the range of 6-8



empirical expression for defining the nature of biological inactivation where:

$$CT = 0.9847C^{0.1758}\text{pH}^{2.7519}\text{temp}^{-0.1467} \qquad (3\text{-}114)$$

where C = disinfectant concentration

T = contact time between the microorganism and the disinfectant

pH = $-\log[H^+]$

temp = temperature, °C

Effects of Turbidity

- shields pathogens
- turbidity itself has a chlorine demand
- interferes with detection of coliforms
- clumping and aggregation interferes with disinfection

CT Concept

TABLE 3-21
CT values for 99.99 percent *Giardia* cyst inactivation

	Temperature					
	0.5°C	5°C	10°C	15°C	20°C	25°C
Chlorine dioxide	81	54	40	27	21	14
Ozone	4.5	3	2.5	2	1.5	1
Chloramines	3800	2200	1850	1500	1100	750

Source: Guidance Manual for Compliance with Filtration and Disinfection Requirements for Public Drinking Water Systems Using Surface Water Sources, October 1989.

CT Table

TABLE 3-20

CT values (in mg/L · min) for inactivation of *Giardia* cysts by free chlorine at 10°C

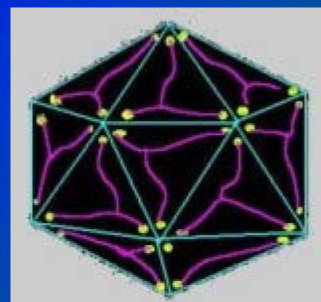
Chlorine concentration mg/L	pH = 6.0 Log inactivations						pH = 7.0 Log inactivations						pH = 8.0 Log inactivations						pH = 9.0 Log inactivations					
	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
≤0.4	11	23	34	46	57	69	18	33	33	70	82	105	25	51	76	101	126	152	35	70	105	140	175	210
0.6	12	25	37	49	62	74	19	38	56	75	94	113	27	54	81	109	136	163	38	75	113	150	188	225
0.8	13	26	39	52	65	78	20	40	59	79	99	119	29	57	86	114	143	171	40	79	119	153	198	237
1.0	13	27	40	54	67	81	21	41	62	82	103	123	30	59	89	119	149	178	41	82	123	164	205	247
1.2	14	28	42	56	69	83	21	42	64	85	106	127	31	61	93	126	161	194	42	85	127	170	212	255
1.4	14	29	43	57	71	86	22	44	65	87	109	131	32	63	95	126	158	189	44	87	131	174	218	262
1.6	15	29	44	58	73	88	22	45	67	89	112	134	32	65	97	129	161	194	45	89	134	179	223	268
1.8	15	30	45	60	75	90	23	46	68	91	114	137	33	66	99	132	165	198	46	91	137	182	228	273
2.0	15	30	46	61	76	91	23	46	70	93	116	139	34	67	101	134	168	201	46	93	139	186	232	278
2.2	15	31	46	62	77	93	24	47	71	95	118	142	34	68	102	137	171	205	47	94	142	189	236	283
2.4	16	31	47	63	79	94	24	48	72	96	120	144	35	69	104	139	173	208	47	94	142	189	236	283
2.6	16	32	48	64	80	96	24	49	73	97	122	146	35	70	105	141	176	211	49	97	146	194	243	292
2.8	16	32	48	65	81	97	25	49	74	99	123	148	36	71	107	142	178	214	49	98	148	197	246	295
3.0	16	33	49	65	82	98	25	50	75	100	125	150	36	72	108	144	180	216	50	100	150	199	249	299

Source: U.S. Environmental Protection Agency, *Guidance Manual for Compliance with Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, Criteria and Standards Division, Office of Drinking Water (U.S.E.P.A. NTIS Publication No. PB 90-148016), Washington, DC: U.S. Government Printing Office, October, 1979.

Theory of Disinfection

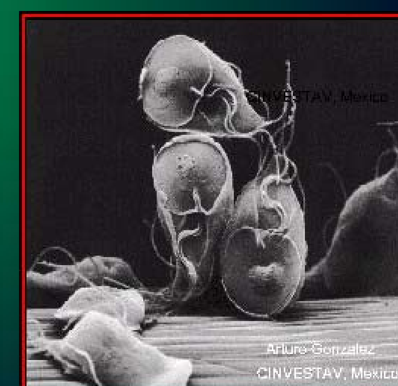
- Biocides — interact with a target on cell, possible targets include:
  - cytoplasmic membrane
  - peptidoglycan layer
  - outer membrane
  - structural proteins
  - thiol groups of enzymes
  - nucleic acids

Susceptibility depends on microorganism

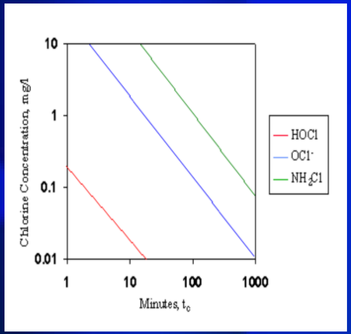


least resistant | most resistant

vegetative bacteria < enteric viruses < spore forming bacteria < protozoan cysts



Typical disinfectants



- **Chlorine:**
  - $Cl_2 + H_2O \qquad HOCl + Cl^-$

- **Chloramines**
  - Chloramination began in Denver, CO and Ottowa Canada in 1917. Both employed pre-reaction of the chemicals prior to their addition to the treated water. Sometime later, preammoniation (adding ammonia prior to chlorine) was practiced. Shortages of ammonia in World War II, caused the practice to diminish, but concern over DBPs has caused an increased interest.
  - $NH_3 + HOCl \rightarrow NH_2Cl + H_20$
  - $NH_2Cl + HOCl \rightarrow NHCl_2 + H_20$
  - $NHCl_2 + HOCl \rightarrow NCl_3 + H20$

Ozonation

- strong o___________, but no residual
- no THM f_____________, but other (non-chlorinated) DBPs possible
- often used as a p_______________ disinfectant

Chlorine Dioxide

- strong oxidant, but not a powerful as O___
- dose limited to 1.0 mg/L due to health concerns of chlorite and c___________
- residual is not long l___________

UltraViolet Light

- uses thin layer of water and mercury vapor arc l__________ emitting UV in the range of 0.2 to 0.29 micron
- depth of light p______________ limited to 50 t 80 mm
- powerful, but no r_______________

Disinfectant Strength

in general:

ozone > chlorine dioxide > chlorine > chloramines

Ozonation

- strong o__________, but no residual
- no THM f____________, but other (non-chlorinated) DBPs possible
- often used as a p_____________ disinfectant

Chlorine Dioxide

- strong oxidant, but not a powerful as O___
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Breakpoint chlorination