California Department of Public Health Webcast

Evaluation and Design of Small Water Systems

Analytical Methods and Process Calculations

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Lecture Objectives

- Learn how to use the Hach DR 890
- Learn typical on-line instrumentation
- Learn about CT calculations and chloramines design

Hach DR 890 Colorimeter-Overview

- Used to test grab samples in the field for parameters which can change
- Never assume that what you hear is correct in the field
- Always verify on-line instruments to see if they are calibrated
- Obtain information on specific parameters of concern (i.e., arsenic)

Water Quality Testing Kit

Key Features

- The DR/890 Colorimeter tests for 90+ methods with automatic wavelength detection
- Ready-to-use out of the box
- Easy-to-use software, preprogrammed methods, and prepared reagents
- Data logging capabilities
- Readout in concentration, ABS, and %T
- Dustproof, waterproof, shockproof, and worry free

Testing Methods

- Hach programmed and user-entered program options are available on this instrument.
- The Procedures Manual supplied at the time of purchase contains all currently available Hach programmed methods.
- Up to ten user-programmed methods may be entered into the instrument.

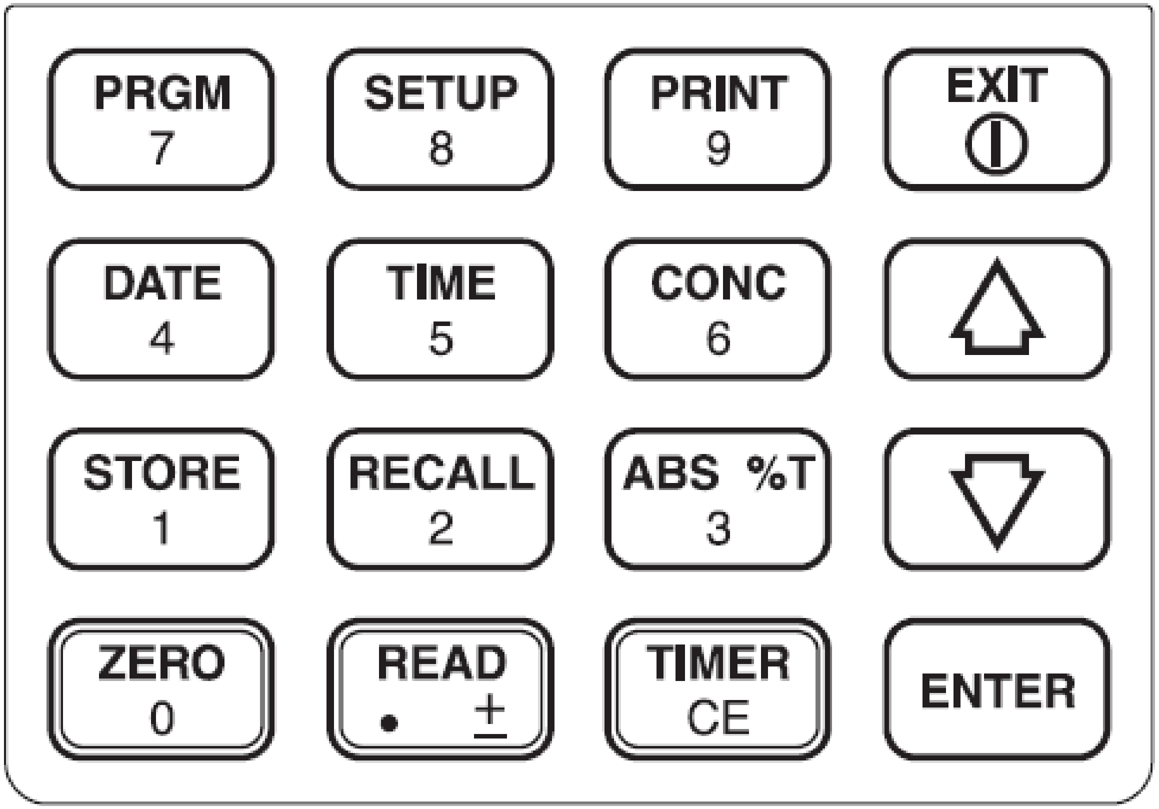
Standard Accessories

- **Sample Cells** – (2) round, with 10 mL, 20 mL and 25 mL marks
- **COD/TNT Adapter** for use with 16 mm vials used in COD and Test ‘N Tube methods
- **Batteries** – (4) AA alkaline
- **Documentation Package** – Includes instrument and procedures manual

Optional Accessories

- Immunoassay Tube Adapter
- Rechargeable Alkaline Batteries
- External Alkaline Battery Charger
- Data transfer Adapter (for RS232 interface)
- HachLink™ Software
- Portable Printer
- Instrument Case
- DR/Check™ ABS Standard

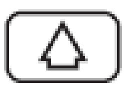
Keypad


PRGM
7
SETUP
8
PRINT
9
EXIT
DATE
4
TIME
5
CONC
6
STORE
1
RECALL
2
ABS %T
3
ZERO
0
READ
• ±
TIMER
CE
ENTER

Keypad Functions

KEY	DESCRIPTION
PRGM 7	Allows the user to select a program. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen.
SETUP 8	Accesses the SETUP menu (the SETUP icon illuminates in the upper left-hand corner of the display screen). The setup menu provides access to options such as reagent blank, standard adjust, user-entered programs, and instrument configurations. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen.
PRINT 9	Prints currently displayed data. In the RECALL menu, prints recalled data. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen.
EXIT ⏻	Use this key to turn the instrument on and, when the instrument is on and the EXIT icon is not illuminated, press this key to turn the instrument off. When the EXIT icon is illuminated at the base of the display screen, the **EXIT** key cancels the current entry or selection.

Keypad Functions

KEY	DESCRIPTION
DATE 4	Displays the current date. In the **RECALL** menu, displays the date the recalled sample was stored. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen. Used to set the current date from the **SETUP** menu.
TIME 5	Displays the current time. In the **RECALL** menu, displays the time the recalled sample was stored. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen. Used to set the current time from the **SETUP** menu.
CONC 6	When performing an analysis, this key displays the concentration value of the reading. Used as a toggle key to access alternate chemical forms, if available. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen.
	Scrolls up through selected menus or stored data.
STORE 1	When performing an analysis, this key allows the user to store a current reading in one of 99 sample locations. The user can store the reading as numbers 1-99 by pressing **ENTER**. Use the up and down arrow keys to find unused storage numbers or use numeric keys to enter a sample number. Also used as a numeric key function when the "#" icon is illuminated at the base of the display screen.

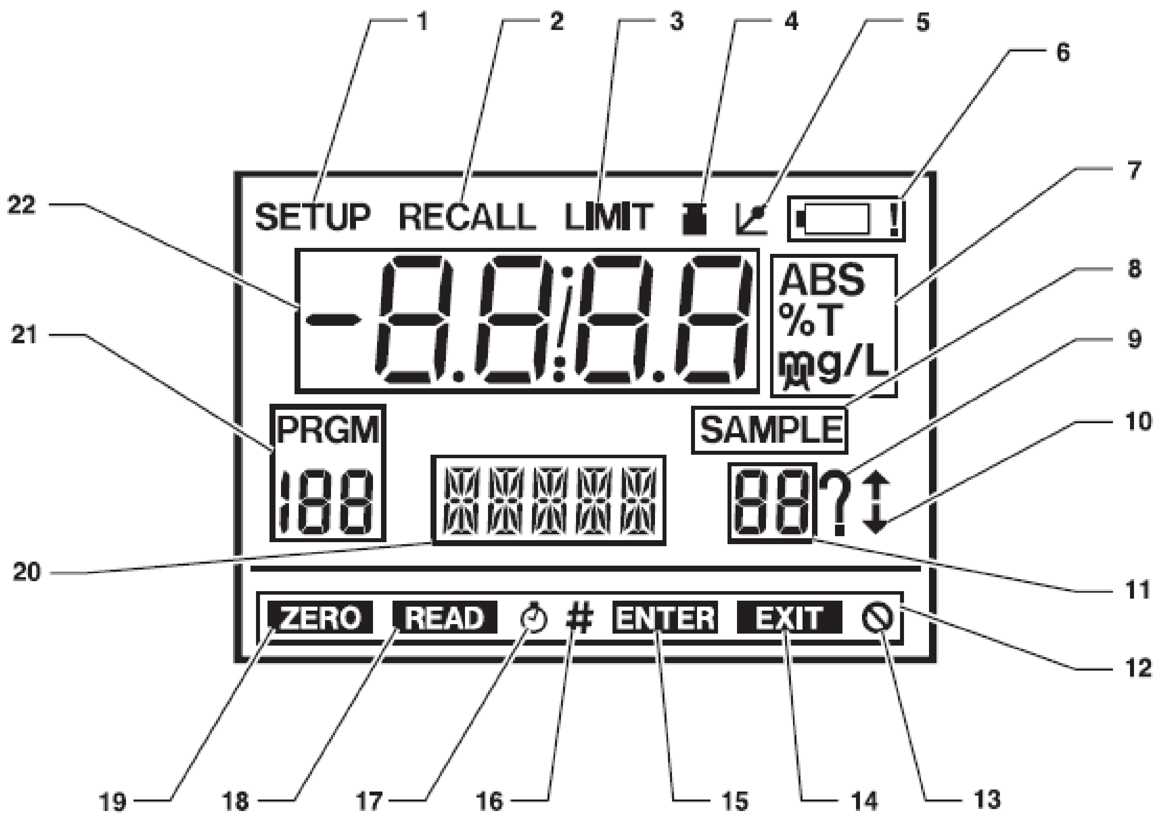
Keypad Functions

RECALL 2	Begins the retrieval of stored sample readings (**RECALL** icon illuminates in the upper-left portion of the screen). Also used as a numeric key function when the “#” icon is illuminated at the base of the display screen.
ABS %T 3	Toggles between displaying Absorbance and % Transmittance. Also used as a numeric key function when the “#” icon is illuminated at the base of the display screen.
▽	Scrolls down through selected menus or stored data.
ZERO 0	Zeros the instrument on the current sample blank. Also used as a numeric key function when the “#” icon is illuminated at the base of the display screen.
READ . ±	When the **READ** icon is illuminated at the base of the display screen, this key reads and displays the sample concentration. Also used as a numeric key function when the “#” icon is illuminated at the base of the display screen; the first press is a decimal, the second press toggles the value sign.

Keypad Functions

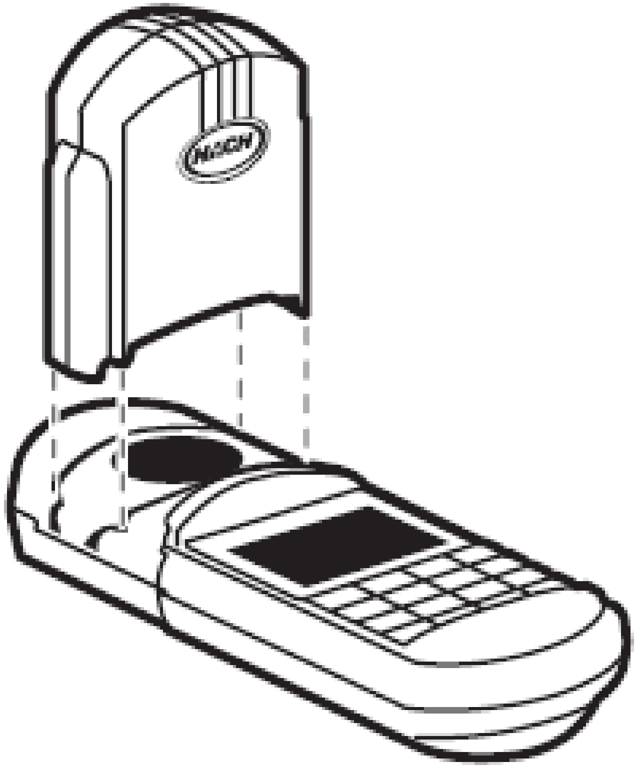
TIMER CE	If using a Hach-stored program, the **TIMER** key automatically sets the appropriate reaction time. If not in a Hach-stored program, the **TIMER** key allows the user to set a timer. When the "#" icon is illuminated at the base of the display screen**, CE** clears the most recent level of action (deletes the whole entry, not just the last number).
ENTER	Within a menu, selects the displayed menu item. During numeric entry, accepts the displayed value.

Screen Indicators



Inserting Sample Containers

Light Shield Placement



General Procedure

Step	Action/Keystroke	Display
1. Turn power on.	Press the **EXIT/I/O** key.	The instrument defaults to and displays the initial screen of the last program used. EXAMPLE: If program 20 was the last program in use, the instrument will automatically recall program 20.
2. Select the Program number to be used.	Press the **PGRM** key, then enter the program number and press the **ENTER** key.	After the **PGRM** key is pressed, a blinking cursor appears with a question mark. Enter the desired program number. Press **ENTER** to confirm this action and recall the desired program number.
3. As needed, set, then start the **TIMER**.	Press the **TIMER** key. In a Hach-stored program, the timer automatically defaults to the appropriate reaction time. Press **ENTER** to start the timer.	The entered or programmed reaction time will display and count down to zero.

General Procedure

4. ZERO the instrument using the sample blank.	Insert blank and press **ZERO.**	After the **ZERO** key is pressed, the instrument zeros on the sample cell.
5. Obtain reading in concentration, absorbance, or % transmittance.	Place the prepared sample into the cell holder. Press **READ**.	The instrument reads the sample and displays the results.

Error Codes

ERROR Code Number	Error Code Type	Corrective Action
1	Unconfigured instrument	Contact Hach Instrument Service Department
2	Could not read program data	Contact Hach Instrument Service Department
3	Could not write program data	Contact Hach Instrument Service Department
4	Measurement battery error	Replace instrument batteries
5	Measurement A/D error	Contact Hach Instrument Service Department
6	Measurement offset error	Check to be sure instrument light shield (cap) is correctly installed
7	Measurement low light error	Check for light path blockage Zero is out of instrument range; dilute to within range Contact Hach Instrument Service Department
8	Measurement over-range error	Make sure instrument cap is properly installed Contact Hach Instrument Service Department

Laboratory Exercise

- Free Chlorine
- Total Chlorine
- Iron
- Manganese
- Nitrate
- Nitrite
- Hardness
- pH
- Ammonia

Hach Manual

- Available online at www.hach.com

(course website will have direct link to manual)

Parameter	Pages	Method
Free Chlorine	143 – 150	8021
Total Chlorine	151 - 156	8167
Hardness	229 – 232	8030
Iron	245 – 251	8008
Manganese	271 – 274	8034
Nitrate	297 – 303	8039
Nitrite	329 – 334	8507
pH	465 – 467	10076
NH_3 - N	353 – 357	10023

Typical On-Instrumentation

List of most common on line instruments

- Total and free chlorine
- Turbidity
- Particle counting
- Fluoride
- TOC
- Streaming current detector

Issues with on-line instruments

- Representative sampling location
- Length of run to instrument
  - Delay in readings
  - Cleanliness of sample line
  - Design of sample line

- Critical nature of sampling/calibration
- Routine maintenance critical
- Grab sampling for verification
- Duplicate instruments for verification

Total and Free Chlorine Residual

- Measures free and total chlorine on line
- Critical for control of chlorine residual
- Used at plant influent and effluent
- Used in distribution system at chlorine booster stations
- Analyzers also available for ozone and chlorine dioxide

Turbidimeter

- Used for raw and finished water
- Can be configured for control loops (alarms, auto shut down)
- Used on IFEs or CFE

Particle Counting

- Used in same application points as turbidimeter
- Most popular on membrane filtration systems
- Detects membrane fiber breaks or early filter breakthroughs

Fluoride

- On line monitoring of fluoride to avoid under or over feed
- Typically not seen in small water systems due to system size and cost

TOC analyzer

- Used for enhanced coagulation monitoring at influent and effluent of sedimentation basins
- Alerts for source water changes in TOC

Streaming Current Detector (SCD)

- To detect changes in source water requiring jar testing
- Can be used to control coagulant feeds through a control loop to feed pumps

Log Removal Calculations

How do I determine percent and log removal?

Relationship between log and percent inactivation

Log inactivation is a measure of the percent of microorganisms that are inactivated during the disinfection process and is defined as:

$$\text{Log Inactivation} = \text{Log}\left(\frac{N_o}{N_T}\right)$$

Where,

N_o	=	initial (influent) concentration of viable microorganisms
N_T	=	concentration of surviving microorganisms
Log	=	logarithm to base 10

Log inactivation is related to the percent inactivation, defined as:

$$\text{Percent Inactivation} = \left(1 - \frac{N_T}{N_o}\right) * 100$$

Relationship between log and Percent Inactivation

$$\textbf{Percent Inactivation} = \left(1 - \frac{1}{10^{LogInactivation}}\right) \times 100$$

$$\textbf{Log Inactivation} = \log\left(\frac{100}{100 - PercentInactivation}\right)$$

Problem

What is the log removal for 90% inactivation?

Problem

Log inactivation = log(100/100-90)

Log inactivation = 1.0

What is the log removal for 95% inactivation?

Solution

Log inactivation = log(100/100-95)

Log inactivation = 1.3

Working Equations

Percent Inactivation $$= \left(1 - \frac{1}{10^{LogInactivation}}\right) \times 100$$

Log Inactivation $$= \log\left(\frac{100}{100 - PercentInactivation}\right)$$

Percent Inactivation

A utility wants to provide 0.5 log inactivation with disinfection. What is the percent inactivation they want to achieve?

Solution

% inactivation = $100 \times \left(1 - \frac{1}{10^{0.5}}\right)$

% activation = 68.3%

Calculating CT for disinfection

What is CT?

- CT is the concentration of disinfectant in contact with the water over a period of time.

CT = Concentration X Time

- Concentration is the disinfectant level leaving the disinfection chamber.
- Time is the estimated or measured time it takes for 10% of the water to pass through the basin called T_{10}

Step 1-Determine CT required

1. Determine maximum pH
2. Determine minimum temperature
3. Determine minimum chlorine residual
4. Determine required log removal

Instructions for using CT Tables

- **Target organism and the type of disinfectant. Most likely you will use the *Giardia* inactivation table for free chlorine.**

- **The tables are also temperature specific. You must use the table that corresponds to your measured minimum temperature.**

- **The tables are divided into pH sections. Locate the section of the table that corresponds to your measured maximum pH.**

Instructions for using CT Tables

- **Within the appropriate pH section, locate the column for your required disinfection Log inactivation for *Giardia*.**
- **Within the appropriate pH section, locate the row for your measured minimum free chlorine residual concentration on the left side of the table.**
- **Read the CT required value from the table where the chlorine residual row meets the required Log inactivation column.**

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE AT 5°C

Chlorine Concentration (mg/L)	pH <= 6 Log Inactivations						pH = 6.5 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
<= 0.4	16	32	49	65	81	97	20	39	59	78	98	117
0.6	17	33	50	67	83	100	20	40	60	80	100	120
0.8	17	34	52	69	86	103	20	41	61	81	102	122
1	18	35	53	70	88	105	21	42	63	83	104	125
1.2	18	36	54	71	89	107	21	42	64	85	106	127
1.4	18	36	55	73	91	109	22	43	65	87	108	130
1.6	19	37	56	74	93	111	22	44	66	88	110	132
1.8	19	38	57	76	95	114	23	45	68	90	113	135
2	19	39	58	77	97	116	23	46	69	92	115	138
2.2	20	39	59	79	98	118	23	47	70	93	117	140
2.4	20	40	60	80	100	120	24	48	72	95	119	143
2.6	20	41	61	81	102	122	24	49	73	97	122	146
2.8	21	41	62	83	103	124	25	49	74	99	123	148
3	21	42	63	84	105	126	25	50	76	101	126	151

Chlorine Concentration (mg/L)	pH = 7.0 Log Inactivations						pH = 7.5 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
<= 0.4	23	46	70	93	116	139	28	55	83	111	138	166
0.6	24	48	72	95	119	143	29	57	86	114	143	171
0.8	24	49	73	97	122	146	29	58	88	117	146	175
1	25	50	75	99	124	149	30	60	90	119	149	179
1.2	25	51	76	101	127	152	31	61	92	122	153	183
1.4	26	52	78	103	129	155	31	62	94	125	156	187
1.6	26	53	79	105	132	158	32	64	96	128	160	192
1.8	27	54	81	108	135	162	33	65	98	131	163	196
2	28	55	83	110	138	165	33	67	100	133	167	200
2.2	28	56	85	113	141	169	34	68	102	136	170	204
2.4	29	57	86	115	143	172	35	70	105	139	174	209
2.6	29	58	88	117	146	175	36	71	107	142	178	213
2.8	30	59	89	119	148	178	36	72	109	145	181	217
3	30	61	91	121	152	182	37	74	111	147	184	221

Chlorine Concentration (mg/L)	pH = 8.0 Log Inactivations						pH = 8.5 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
<= 0.4	33	66	99	132	165	198	39	79	118	157	197	236	47	93	140	186	233	279
0.6	34	68	102	136	170	204	41	81	122	163	203	244	49	97	146	194	243	291
0.8	35	70	105	140	175	210	42	84	126	168	210	252	50	100	151	201	251	301
1	36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43	87	130	173	217	260	52	104	156	208	260	312
1.2	37	74	[illegible]	[illegible]	[illegible]	[illegible]	45	89	134	178	223	267	53	107	160	213	267	320
1.4	38	76	[illegible]	[illegible]	[illegible]	[illegible]	46	91	137	183	228	274	55	110	165	219	274	329
1.6	39	77	[illegible]	[illegible]	[illegible]	[illegible]	47	94	141	187	234	281	56	112	169	225	281	337
1.8	40	79	[illegible]	[illegible]	[illegible]	[illegible]	48	96	144	191	239	287	58	115	173	230	288	345
2	41	81	[illegible]	[illegible]	[illegible]	[illegible]	49	98	147	196	245	294	59	118	177	235	294	353
2.2	41	83	124	165	207	248	50	100	150	200	250	300	60	120	181	241	301	361
2.4	42	84	127	169	211	253	51	102	153	204	255	306	61	123	184	245	307	368
2.6	43	86	129	172	215	258	52	104	156	208	260	312	63	125	188	250	313	375
2.8	44	88	132	175	219	263	53	106	159	212	265	318	64	127	191	255	318	382
3	45	89	134	179	223	268	54	108	162	216	270	324	65	130	195	259	324	389

CT $_{required}$

CT Achieved

$$\textbf{CT achieved} = \textbf{Disinfectant Conc.} \times \textbf{Fsc} \times \frac{\textbf{Total chamber volume}}{\textbf{Design Flow (gpm)}}$$

How do I determine T_{10}?

- T_{10} is equal to the short circuiting factor times the theoretical detention time of the disinfection chamber based on capacity and flow.
- The short circuiting factor, size of chamber, and design flow must be known.

Description of estimating T_{10}

Baffling Condition	T_{10}/T Ratio	Baffling Description
Unbaffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet or outlet with some intra- basin baffles
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra- basin baffles

Concepts on estimating Fsc

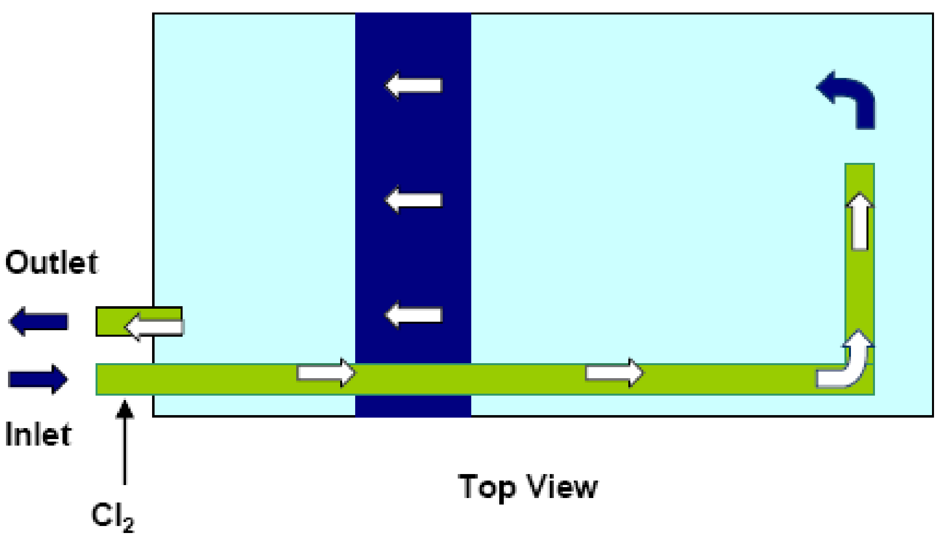
If a litre of water passes through the pipe, it comes out the other end as a litre of water. There is **No Mixing** and **No Short-Circuiting.** Water travels through the pipe as a unit.

All the water travels at an '**Average Velocity'** through the pipe.

Figure 1: Water Pipeline with No Mixing and No Short Circuiting (F_{SC} = 1.0)

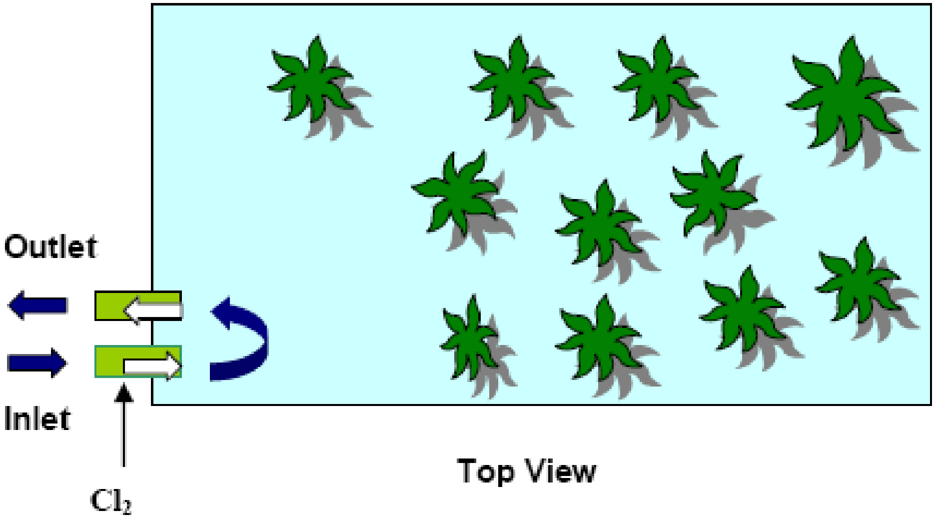
Reservoir with no short circuiting

Figure 2: Water Reservoir with No Mixing and No Short Circuiting (F_{SC} = 1.0)



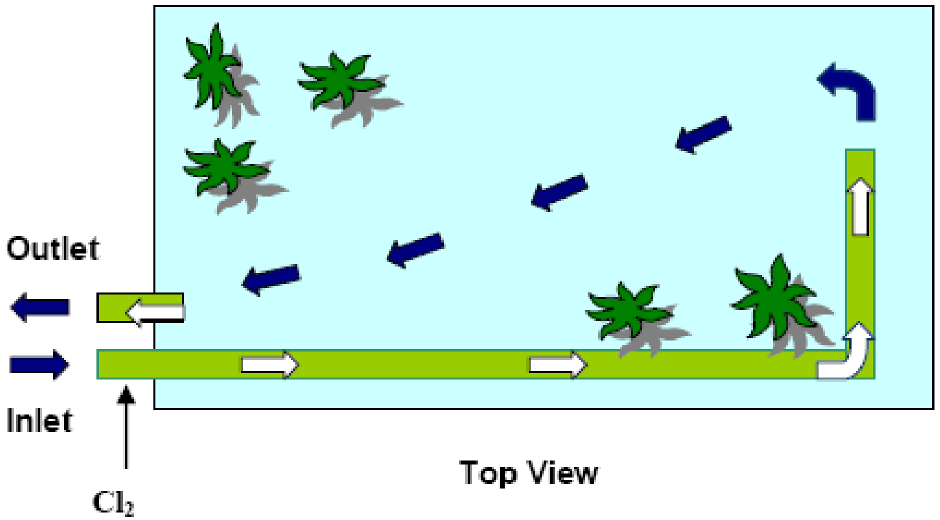
Short Circuiting Factors

Figure 8: Water Reservoir with Mixing and Short Circuiting (F_{SC} << 0.1)



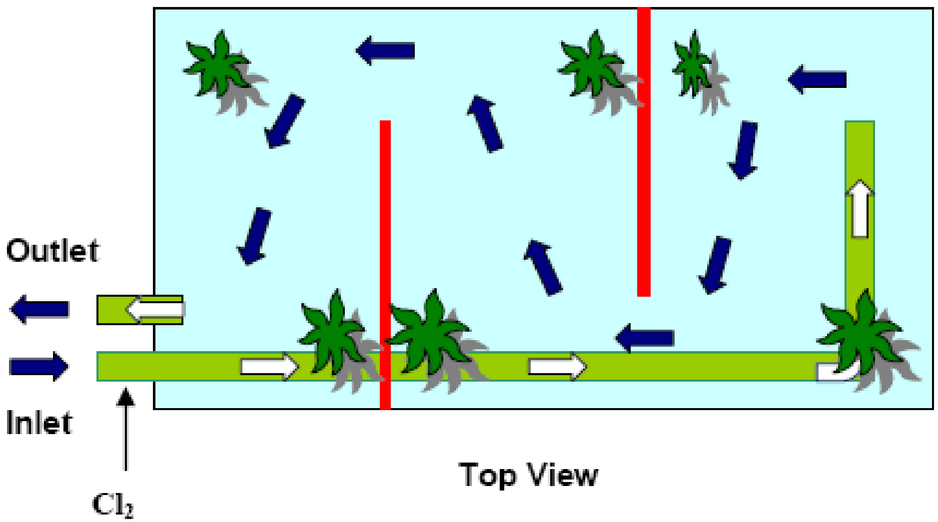
Short Circuiting Factors

Figure 9: Water Reservoir with Mixing and Short Circuiting (F_{SC} = 0.1)



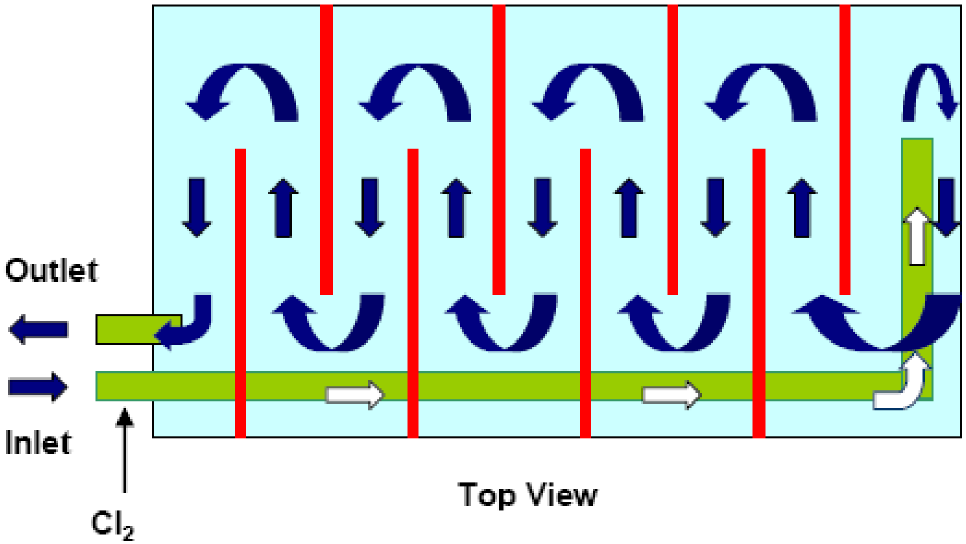
Short Circuiting Factors

Figure 10: Water Reservoir with Two Baffles Reduced Short Circuiting (F_{SC} = 0.3)



Short Circuiting Factors

Figure 11: Water Reservoir with Multiple Baffles with Minimal Short Circuiting (F_{SC} = 0.7[+])



Example of chlorine CT table for *Giardia*

CHLORINE CONCENTRATION (mg/L)	pH<=6 Log Inactivation						pH=6.5 Log Inactivation						pH=7.0 Log Inactivation						pH=7.5 Log Inactivation					
	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	12	24	37	49	61	73	15	29	44	59	73	88	17	35	52	69	87	104	21	42	63	83	104	125
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	36	54	71	89	107	21	43	64	85	107	128
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131
1	13	26	40	53	66	79	16	31	47	63	78	94	19	37	56	75	93	112	22	45	67	89	112	134
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	38	57	76	95	114	23	46	69	91	114	137
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	39	58	77	97	116	23	47	70	93	117	140
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	96	120	144
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	41	61	81	102	122	25	49	74	98	123	147
2	15	29	44	58	73	87	17	35	52	69	87	104	21	41	62	83	103	124	25	50	75	100	125	150
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	64	85	106	127	26	51	77	102	128	153
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	65	86	108	129	26	52	79	105	131	157
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131	27	53	80	107	133	160
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	67	89	112	134	27	54	82	109	136	163
3	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137	28	55	83	111	138	166

CHLORINE CONCENTRATION (mg/L)	pH=8.0 Log Inactivation						pH=8.5 Log Inactivation						pH=9.0 Log Inactivation					
	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	25	50	75	99	124	149	30	59	89	118	148	177	35	70	105	139	174	209
0.6	26	51	77	102	128	153	31	61	92	122	153	183	36	73	109	145	182	218
0.8	26	53	79	105	132	158	32	63	95	126	158	189	38	75	113	151	188	226
1	27	54	81	108	135	162	33	65	98	130	163	195	39	78	117	156	195	234
1.2	28	55	83	111	138	166	33	67	100	133	167	200	40	80	120	160	200	240
1.4	28	57	85	113	142	170	34	69	103	137	172	206	41	82	124	165	206	247
1.6	29	58	87	116	145	174	35	70	106	141	176	211	42	84	127	169	211	253
1.8	30	60	90	119	149	179	36	72	108	143	179	215	43	86	130	173	216	259
2	30	61	91	121	152	182	37	74	111	147	184	221	44	88	133	177	221	265
2.2	31	62	93	124	155	186	38	75	113	150	188	225	45	90	136	181	226	271
2.4	32	63	95	127	158	190	38	77	115	153	192	230	46	92	138	184	230	276
2.6	32	65	97	129	162	194	39	78	117	156	195	234	47	94	141	187	234	281
2.8	33	66	99	131	164	197	40	80	120	159	199	239	48	96	144	191	239	287
3	34	67	101	134	168	201	41	81	122	162	203	243	49	97	146	195	243	292

Example of chlorine CT table for viruses

	Temperature (°C)																									
Inactivation (log)	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
2	6.0	5.8	5.3	4.9	4.4	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0	1.0	1.0	1.0	1.0	1.0
3	9.0	8.7	8.0	7.3	6.7	6.0	5.6	5.2	4.8	4.4	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0
4	12.0	11.6	10.7	9.8	8.9	8.0	7.6	7.2	6.8	6.4	6.0	5.6	5.2	4.8	4.4	4.0	3.8	3.6	3.4	3.2	3.0	2.8	2.6	2.4	2.2	2.0

Example problem

Given water temperature of 10^0C

pH = 7.0

Residual = 0.8 mg/L

What is CT for 0.5 log *Giardia* inactivation

And what is CT for 2 log virus removal?

Solution

Giardia is 18 mg-min/L

Viruses is 3 mg-min/L

This is what is needed. You need now find how large a contact chamber you need.

Assume Fsc = 0.3

Flow = 100 gpm

Chlorine residual = 0.8 mg/L

CT Achieved

$$\text{CT achieved} = \text{Disinfectant Conc.} \times \text{Fsc} \times \frac{\text{Total chamber volume}}{\text{Design Flow (gpm)}}$$

Use chlorine for disinfectiion

***Giardia* SOLUTION:**

18/.8 mg/L = 22.5 minutes

22.5 minutes/0.3 = 75 minutes

Size in gallons = 75 x 100 gpm= 7,500 gallons

Virus SOLUTION:

3/.8 mg/L = 3.75 minutes

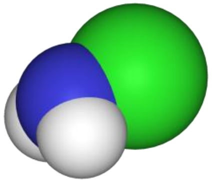
3.75 minutes/0.3 = 12.5 minutes

Size in gallons = 12.5 x 100 gpm= 1,250 gallons

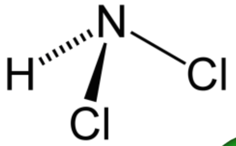
Design considerations for use of Chloramine Disinfectant

What are chloramines?

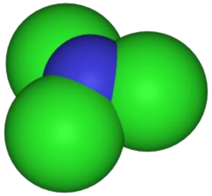
- **Chloramines -family of compounds used for disinfection.**
  - **Monochloramine - NH_2Cl**



  - **Dichloramine - $NHCl_2$**



  - **Nitrogen trichloride - NCl_3**



- **Chlorine + Ammonia = Chloramines**

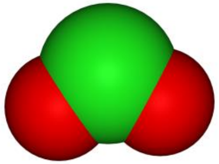
What are chloramines?

- Used in water treatment plants since 1930's
- Less effective than most other disinfectants and a weaker oxidant
- Use of chloramines results in decreased formation of many disinfection byproducts (DBPs)
- Tastes better than chlorine

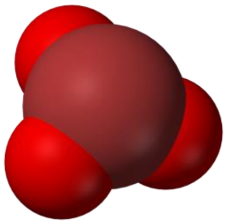
Why Change to Chloramination?

Other disinfectants have DBPs

- Chlorine
  - TTHMs
- Chlorine Dioxide

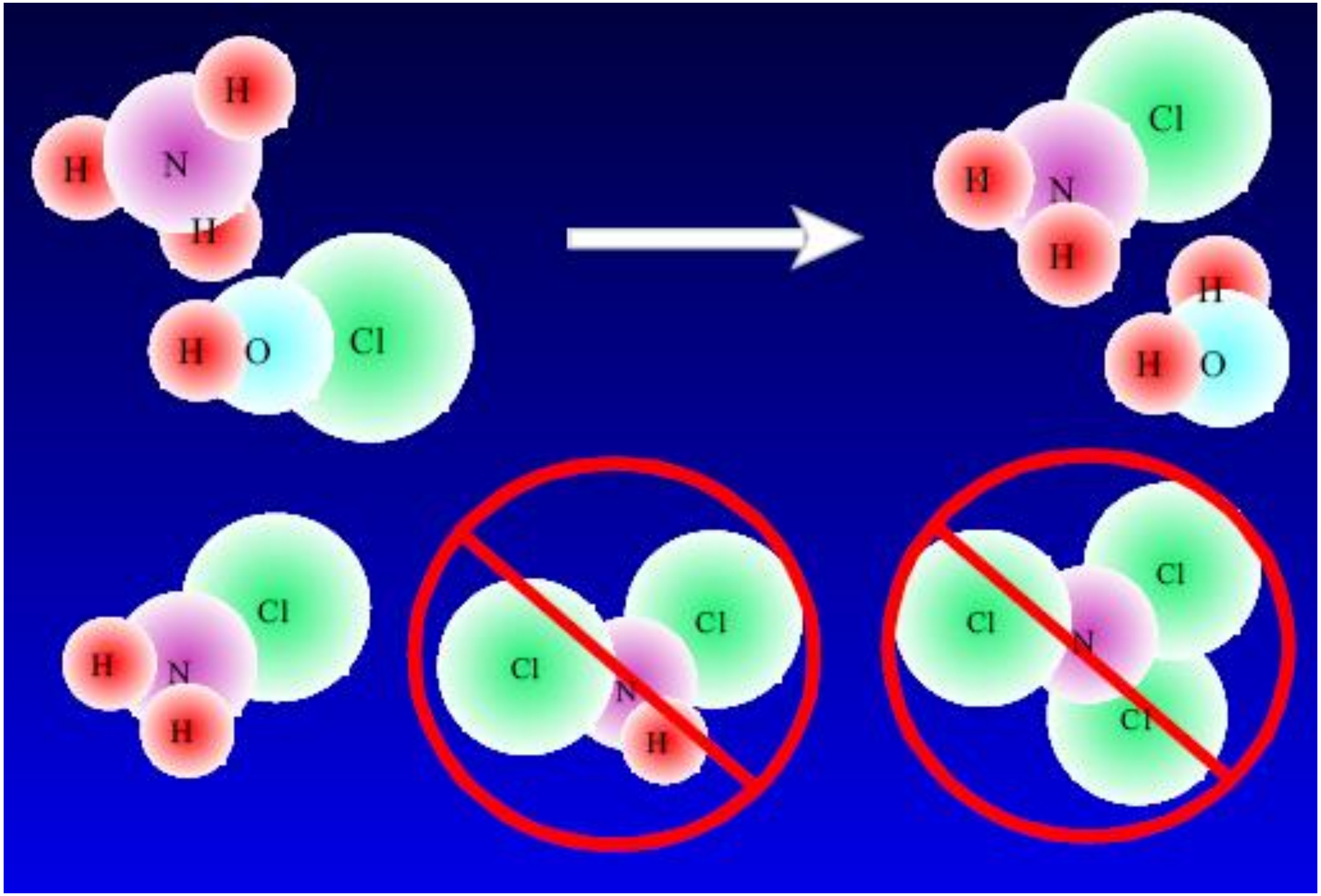


  - *Chlorite (ClO_2) - Acute respiratory*



- Ozone *Bromate*
  - *(BrO_3) - Strongly carcinogenic*
  - *HAAs - Carcinogenic*

Chloramine Chemistry



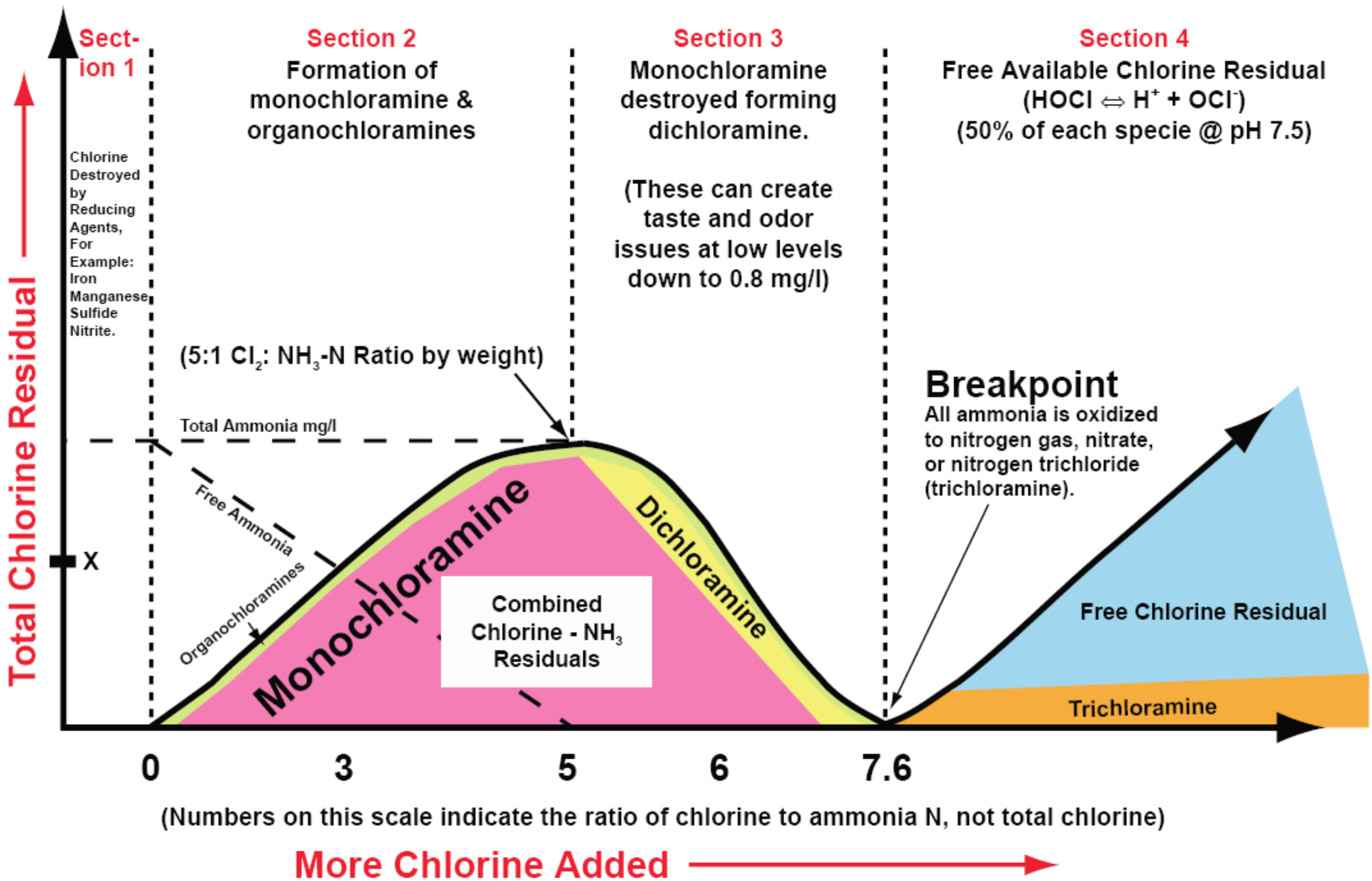
Chloramines reactions

$NH_3 + HOCl \rightarrow NH_2Cl + H_20$ (monochloramine)

$NH_2Cl + HOCl \rightarrow NHCl_2 + H_20$ (dichloramine)

$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$ (nitrogen trichloride)

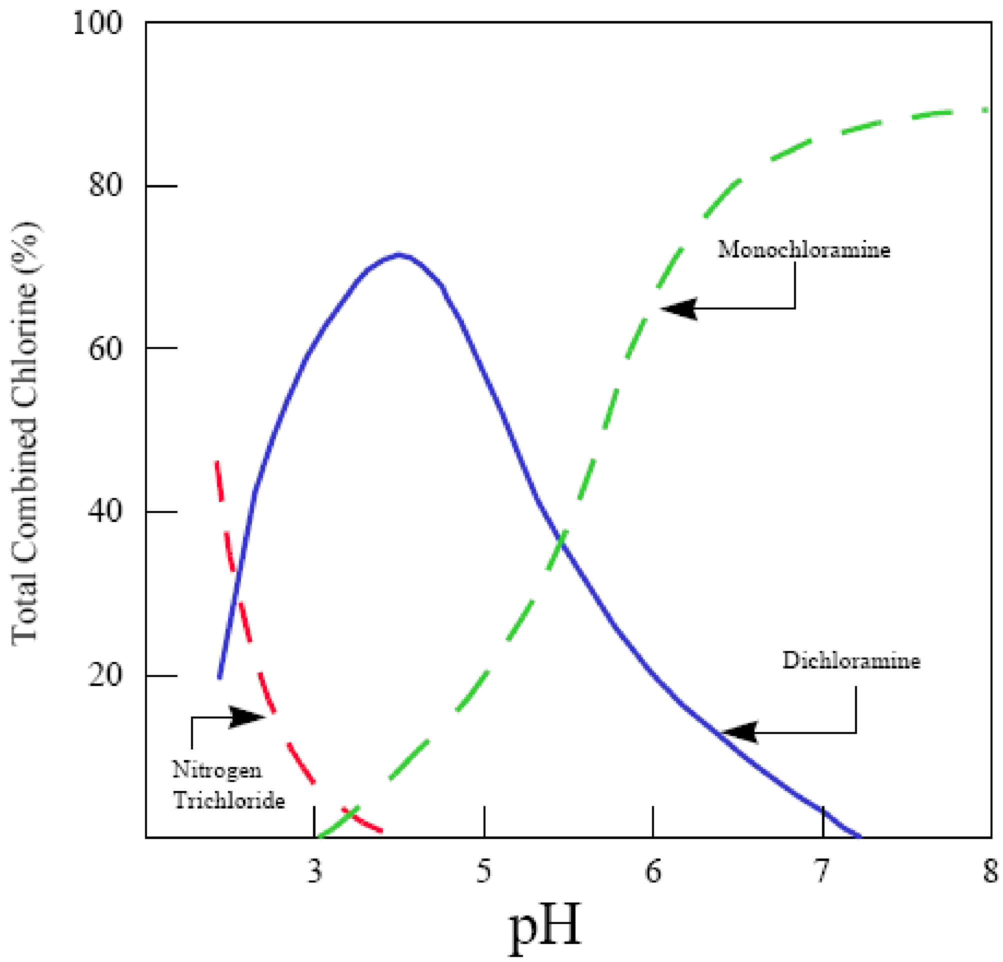
Breakpoint chloramination curve



Health Effects

- The ingestion of chloramines in drinking water poses little health risk to healthy people.
- Sensitive populations:
  - Dialysis patients
  - Aquatic organisms

Effect of pH on chloramine species



Implementation

- The key is the chlorine to ammonia ratio (your instructor recommends 5:1)
- Forms of Chlorine:
  - Sodium Hypochlorite
  - Gaseous Chlorine
- Forms of Ammonia (NH_3):
  - Anhydrous Ammonia (gas) more common for small water systems
  - Ammonium Hydroxide
  - Ammonium Sulfate (solid)
  - Ammonium Sulfate (liquid)

Implementation issues

- Reducing the risk to sensitive populations Chloramines can be removed from water by:
  - Granular activated carbon (GAC)
  - Green sand zeolite
  - Ascorbic acid (Vitamin C)
- Notifying dialysis facilities and fish hobbyists and stores of changes to water due to chloramination can reduce risks
  - Allows implementation of treatment devices

What to measure?

- Free chlorine
  - To find out how much NH3 to apply
- Free Ammonia (Optional)
  - To find out if we applied too much NH3
- Total Ammonia nitrogen
  - To determine the ratio
- Total Chlorine
  - To find out if total residual
- Nitrite in distribution system
  - To determine if nitrification is occurring.

Ammonium Hydroxide (NH_4OH)

- **Description**
  - Formed by reaction of NH_3 with water
  - Most commonly used in California, however gas is used for small water systems as well
  - NH_3 + H_2O 6 NH_4OH
  - Sold as 29-30% NH_3 mixtures (keep under 30%)

- **Storage**
  - Corrosive to some materials (*i.e.*, copper, aluminum, galvanized surfaces)
  - Usually stored in steel or fiberglass tanks
  - Should be kept cool due to low boiling point
  - Need back pressure device
  - The NH_3 vapors that form at high temperatures should be controlled/removed
  - **Keep away from chlorine!!**
  - Don’t mix chlorine concentrate with ammonia before chemical injection

Ammonium Hydroxide (NH_4OH)

- **Chemical feed equipment**
  - Must be compatible
  - Requires special materials
  - Positive displacement type
- **Distribution systems**
  - Will deteriorate rubber in sinks and toilets.
  - No red brass pumps
  - Use Buna-n rubber for gaskets in distribution system.
  - Complaints of black particulates are common.

Calculations

If you desire to feed 2 mg/L chloramines, then how much chlorine and how much ammonia as nitrogen is needed if you choose a ratio of 5:1?

Solution

Magic ratio = 5:1

$$\frac{2\,mg/L}{5} = \mathbf{0.4\ mg/L} \text{ ammonia as nitrogen}$$

Calculations

If you have a reading of 2 mg/L total chlorine and 0.5 mg/L total ammonia, how much free ammonia do you have?

Solution

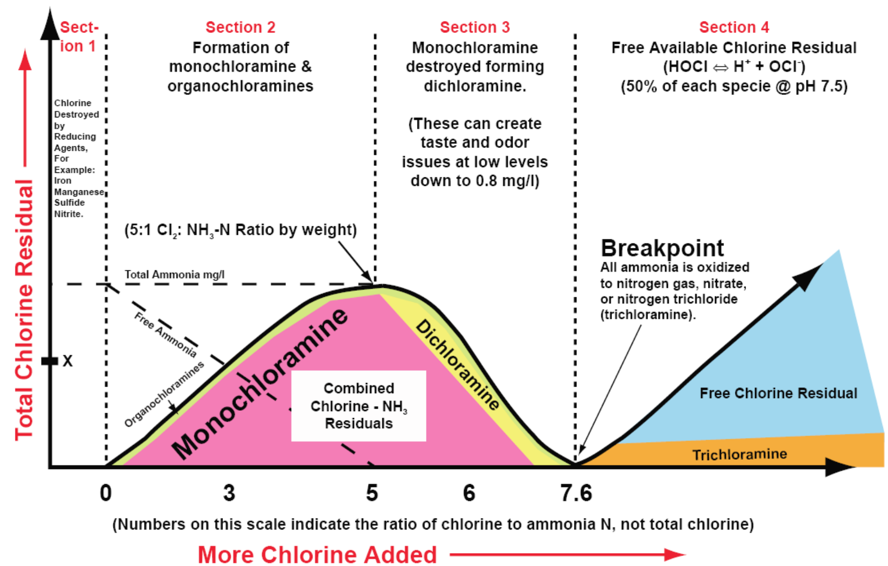
$$\frac{2\text{mg/L}}{5} = \mathbf{0.4\ mg/L} \text{ ammonia as nitrogen}$$

0.5 - 0.4 = 0.1 mg/L free ammonia

Questions

- Where on the break point curve are you for the following examples?

1. Free ammonia = >0 mg/L
2. Free ammonia = 0 mg/L
3. Free chlorine = 0 mg/L
4. Free chlorine > 0 mg/L
5. Ratio is 5:1



Example of chloramine CT table

	Temperature (°C)																								
Inactivation (log)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2	1,243	1,147	1,050	954	857	814	771	729	686	643	600	557	514	471	428	407	385	364	342	321	300	278	257	235	214
3	2,063	1,903	1,743	1,583	1,423	1,352	1,281	1,209	1,138	1,067	996	925	854	783	712	676	641	605	570	534	498	463	427	392	356
4	2,883	2,659	2,436	2,212	1,988	1,889	1,789	1,690	1,590	1,491	1,392	1,292	1,193	1,093	994	944	895	845	796	746	696	646	597	547	497

Giardia inactivation with chloramines

Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
0.5 log	635	365	310	250	185	125
1.0-log	1270	735	615	500	370	250
1.5-log	1900	1100	930	750	550	375
2.0-log	2535	1470	1230	1000	735	500
2.5-log	3170	1830	1540	1250	915	625
3.0-log	3800	2200	1850	1500	1100	750

At pH 6 - 9

Chloramine CT Calculations

0.5 log *Giardia* removal at 15 ^{0}C is 250 mg-min/L.

Assume residual @ 2 mg/L ; Fsc = 0.3; flow = 100 gpm

How large is your contact chamber?

Chloramine CT Calculations

SOLUTION:

250/2mg/L = 125 minutes

125 minutes/0.3 = 417 minutes

Size in gallons = 417 x 100 gpm= 41,700 gallons

CONCLUSION:

Must use chlorine for *Giardia* inactivation and use chloramine after clearwell

Chloramine CT Calculations

- Try chlorine @ CT = 18 for 0.5 log removal
- Assume 0.8 mg/L, pH 7.0, and other conditions the same

Use chlorine for disinfectiion

SOLUTION:

18/.8 mg/L = 22.5 minutes

22.5 minutes/0.3 = 75 minutes

Size in gallons = 75 x 100 gpm= 7,500 gallons

CONCLUSION:

Clearwell is sized more appropriately

Try Using a plug flow reactor

SOLUTION:

18/.8 mg/L = 22.5 minutes

22.5 minutes/1.0 = 22.5 minutes

Size in gallons = 22.5 x 100 gpm= 2,250 gallons

CONCLUSION:

There are many ways to go as long as you understand the fundamentals.

Ammonia gas feeder