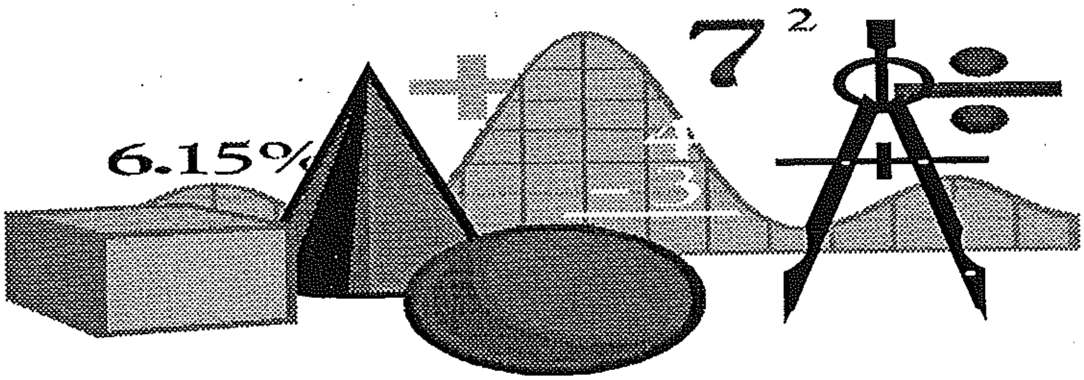
CT VALUES

Calculating and Reporting



Prepared by
Donna Marlin
Drinking Water Branch
Division of Water

Revised March 24, 1999

EDUCATION PAYS

TABLE OF CONTENTS AND ILLUSTRATIONS

WHAT ARE CT VALUES?

INTRODUCTION

The United States Environmental Protection Agency enacted the Surface Water Treatment Rule (SWTR) on June 29, 1989. The SWTR went into effect December 31, 1990.

The purpose of the SWTR is to protect the public, as much as possible, from waterborne diseases caused by pathogens such as Giardia Lamblia cysts, Legionella, and viruses. Waterborne diseases are caused by the acute infectious illness associated with the ingestion of water that is deficient in treatment.

The SWTR requires minimum removal efficiencies of certain pathogens found in drinking water through the use of specified techniques in the treatment process. The Commonwealth of Kentucky requires **ALL** surface water plants and groundwater systems under the direct influence of surface water to provide complete treatment (flocculation, sedimentation and filtration). Therefore, these two types of systems must comply with the SWTR.

GOAL (REQUIREMENTS)

The SWTR designates using CT Values as a measure of the performance of a water treatment system. This treatment technique requires that pathogens (disease-causing microorganisms) must be removed or inactivated by ALL public water systems affected by this rule.

CT Values are specified in the SWTR for Giardia Lamblia cysts and viruses only since these pathogens are generally more resistant to disinfectants than other waterborne pathogens. This has been shown by studies which conclude that Giardia and viruses are among the most resistant disease-causing microorganisms in water. As a conclusion, systems that remove or inactivate these pathogens are probably removing or inactivating other organisms as well. The microorganisms can be removed through the sedimentation/filtration process and inactivated through disinfection. The term inactivation is used because a microorganism can be kept from causing disease without actually killing it.

The rule does not name a particular method of treatment because of the variety of water qualities, local conditions, and possible methods of treatment. The rule does not contain many operation and monitoring requirements.

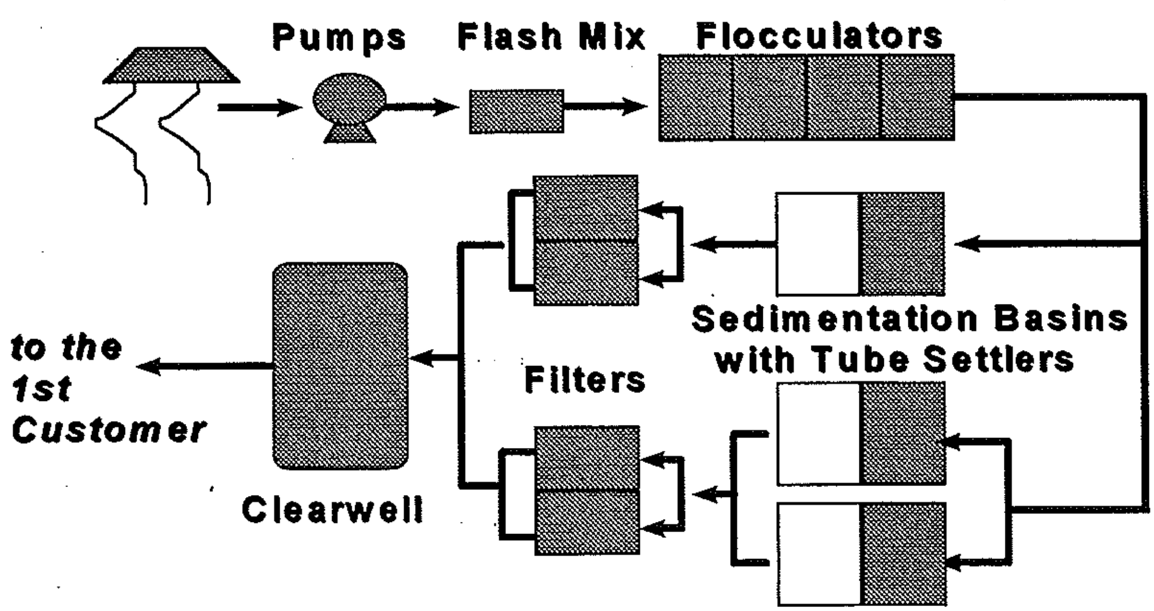
There are relatively simple, inexpensive tests available for detecting the presence of coliform bacteria which systems may use as a check of the treatment process. In addition, it is quite simple to check each stage of treatment for organism removal by using the standard plate count. However, coliform bacteria does not indicate the presence of Giardia, viruses, and other microorganisms. There are specific laboratory tests for these microorganisms which are considered too costly and too difficult to perform for most water systems. As a result, emphasis is placed on the use of CT Values as a condition for compliance rather than establishing a maximum contaminant level (MCL) for microorganisms.

The SWTR requires systems to ensure that a total of 99.9% (3-Log) removal/inactivation of Giardia cysts and a total of 99.99% (4-Log) removal/inactivation of viruses be achieved daily whenever water is being treated. For simplicity, the Log number expresses Log-reduction by how many nines are in the percentage as shown in Table 1.

Table 1. Reduction expressed as Log-Removal and Percentage.

LOG-REMOVAL	PERCENTAGE (%)
1	90%
2	99%
3	99.9%
4	99.99%

FIGURE 1. Complete Water Treatment Plant



CT VALUE COMPONENTS

There are two components to consider in calculating CT Values. The removal (Log-reduction) portion and the inactivation (Log-inactivation) portion.

LOG-REDUCTION

To determine the removal part, first answer the question "Does your system use complete treatment?" (Figure 1 on page 2 is an example of a complete water treatment plant.) If you answer no, then a removal credit may or may not be given to your system. You will need to contact our office at (502) 564-3410 for an evaluation. If your answer is yes, then a maximum removal credit of 2-Log for Giardia cysts and viruses may be applied to your water treatment plant provided that all of the following criteria applies:

1. Disinfect at or prior to the flash (rapid) mix. Alternate disinfectant practices may meet this criteria on a case by case basis.
2. Turbidity of the settled water (prior to filtration) is less than 2 NTUs measured every four hours.
3. The turbidity level of a system's combined filtered water at each plant must be less than or equal to 0.3 NTU in at least 95% of the measurements taken each month, and the turbidity level of a system's combined filtered water at each plant must at no time exceed 1 NTU.
4. All equipment must be in working order.
5. Operators must be properly certified for the size of plant and the plant must be staffed according to 401 KAR 8:030.

If you have any questions concerning this criteria, please contact this office at (502) 564-3410 for assistance.

If your system has been given the maximum 2-Log credit the remaining Log-reduction must be achieved in the inactivation process as shown in Table 2.

TABLE 2. Surface Water Treatment goals expressed in credits for Log-reduction and the required Log-inactivation.

PATHOGEN	SWTR GOALS	REMOVAL CREDIT	REQUIRED INACTIVATION
Giardia cysts	3-Log	2-Log	1-Log
Viruses	4-Log	2-Log	2-Log

The required inactivation necessary to achieve SWTR goals shall be met by disinfection up to the first customer. Keep in mind that the first customer may be the water treatment plant itself.

LOG-INACTIVATION

The calculated CT Value is a measurement of the strength or concentration of disinfectant and the contact time needed to inactivate Giardia cysts and viruses. Possible disinfectants include chlorine, chloramine, chlorine dioxide, ozone, and ultraviolet light. Please note that chlorine will not inactivate cryptosporidium. Cryptosporidium must be removed physically by flocculation and sedimentation.

The calculated CT Value is obtained by the following formula:

CT = concentration x contact time x baffling factor

where:

Concentration is the disinfectant measured in mg/L.
Contact time is the time in minutes the disinfectant remains in contact with the water through a specific unit or zone in your system.
The baffling factor is a factor applied to the unit based upon the design of the unit. More information is provided in the next section.

The required CT Value is obtained from tables which are provided by the United States Environmental Protection Agency. Tables have been extracted for 1-Log inactivation and are located in Appendix A.

BAFFLING FACTOR (BF)

There are two methods of determining the contact time through a treatment unit - (1) theoretical or (2) actual tracer studies. The theoretical method to determine contact time through treatment units is based on baffling factors. This method is used because of the amount of time, manpower, money, and equipment necessary to perform tracer studies.

Tracer studies are tests to introduce a known amount of a tracer chemical into the flow at the inlet of a treatment unit. By examining the chemical residual at the outlet, the time it takes for the chemical to flow through the unit can be calculated.

According to the SWTR, the contact time (T) for the unit is the time at which 10% of the amount of water entering the inlet has passed through to the outlet. This theoretical time is called T_{10}.

Factors that impact contact time include the following:

1. flow rate,
2. water level in the unit,
3. shape of the unit,

4. inlet/outlet locations,
5. baffle types and locations,
6. whether the unit is filling or emptying,
7. sludge depth,
8. seasonal variations, and
9. thermal stratification.

As a result of various tracer studies, three baffling classifications are introduced by the SWTR in addition to the unbaffled and the perfect (plug flow) classifications. Table 3 describes each of the five classifications of baffling factors and provides the factor associated with each classification. Diagrams for the poor, average, and superior classifications are located in Appendix B.

The baffling factor is a ratio based on tracer studies and determined by the following design characteristics:

1. length to width ratio,
2. degree of baffling within the unit or reservoir, and
3. the effect of the inlet/outlet configuration.

The contact time in treatment units can often be improved by baffling the unit, redesigning of the inlet/outlet configuration, or changing existing baffling. Baffles in reservoirs should be cleaned periodically and be designed in hinged or removable sections.

TABLE 3. Baffling Classifications

CONDITION	**FACTOR** (T_{10}/T)	**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 ration (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

FACTORS AFFECTING BAFFLING

The following are factors that affect CT Values:

1. Type of disinfectant
   a. Chlorine - performance is influenced by the temperature and pH of the water.
      If your system meets the Log-inactivation achieved for Giardia cysts, then the system will automatically meet the SWTR for viruses. This fact is demonstrated in Table 4. As a result you need to use the CT Value required for Giardia cysts instead of the CT Value required for viruses. This situation is not necessarily true for other types of disinfectants as displayed in Tables 5 and 6.

TABLE 4. Example of a water treatment plant using free chlorine as a disinfectant. Assume 2-Log removal credit, pH is 8, residual is 1.0 mg/l, and water temperature is 0.5°C or 32.9°F.

PATHOGENS	REQUIRED INACTIVATION	CT REQUIRED
Giardia cysts	1-Log	101
Viruses	2-Log	6

   b. Chloramines - weaker disinfectant than chlorine, chlorine dioxide, or ozone. It is particularly weak in inactivating some viruses. Its performance is influenced by water temperature and pH outside of the normal operating range of 6-9.

      If your system meets the Log-inactivation for Giardia cysts, then the system will not automatically meet the SWTR for viruses. This fact is demonstrated in Table 5. You need to use the higher CT Value required after comparing the CT Value required for Giardia cysts to the CT Value required for viruses.

TABLE 5. Example of a water treatment plant using chloramines as a disinfectant. Assume 2-Log removal credit, pH is 8 and water temperature is 10°C (50°F).

PATHOGENS	REQUIRED INACTIVATION	CT REQUIRED
Giardia cysts	1-Log	615
Viruses	2-Log	643

c. Chlorine dioxide - less stable than chlorine or chloramine (may not be able to maintain disinfectant residual required throughout the distribution system).

If your system meets the Log-inactivation for Giardia cysts, then the system will not automatically meet the SWTR for viruses. This fact is demonstrated in Table 6. In this example you need to use the CT Value required for viruses instead of the CT Value required for Giardia because that number is higher. If the plant is assigned the maximum 2-Log removal credit, then you calculate the required CT Value for Giardia cysts because all those numbers are higher.

TABLE 6. Example of a plant using chlorine dioxide as a disinfectant. Assume pH is 8 and water temperature is 5°C or 41°F.

PATHOGENS	REQUIRED INACTIVATION	CT REQUIRED
Giardia cysts	3-Log	26
Viruses	4-Log	33.4

d. Ozone - extremely reactive and dissipates quickly after application. If your system meets the Log-inactivation for Giardia cysts, then the system will not automatically meet the SWTR for viruses. This fact is demonstrated in Table 7. As a result you use the higher CT Value required after comparing the CT Value required for Giardia cysts to the CT Value required for viruses.

TABLE 7. Example of a water treatment plant using ozone as a disinfectant. Assume 2-Log removal credit, pH is 8, and water temperature is less than 10°C (50°F).

PATHOGENS	REQUIRED INACTIVATION	CT REQUIRED
Giardia cysts	1-Log	0.48
Viruses	2-Log	0.5

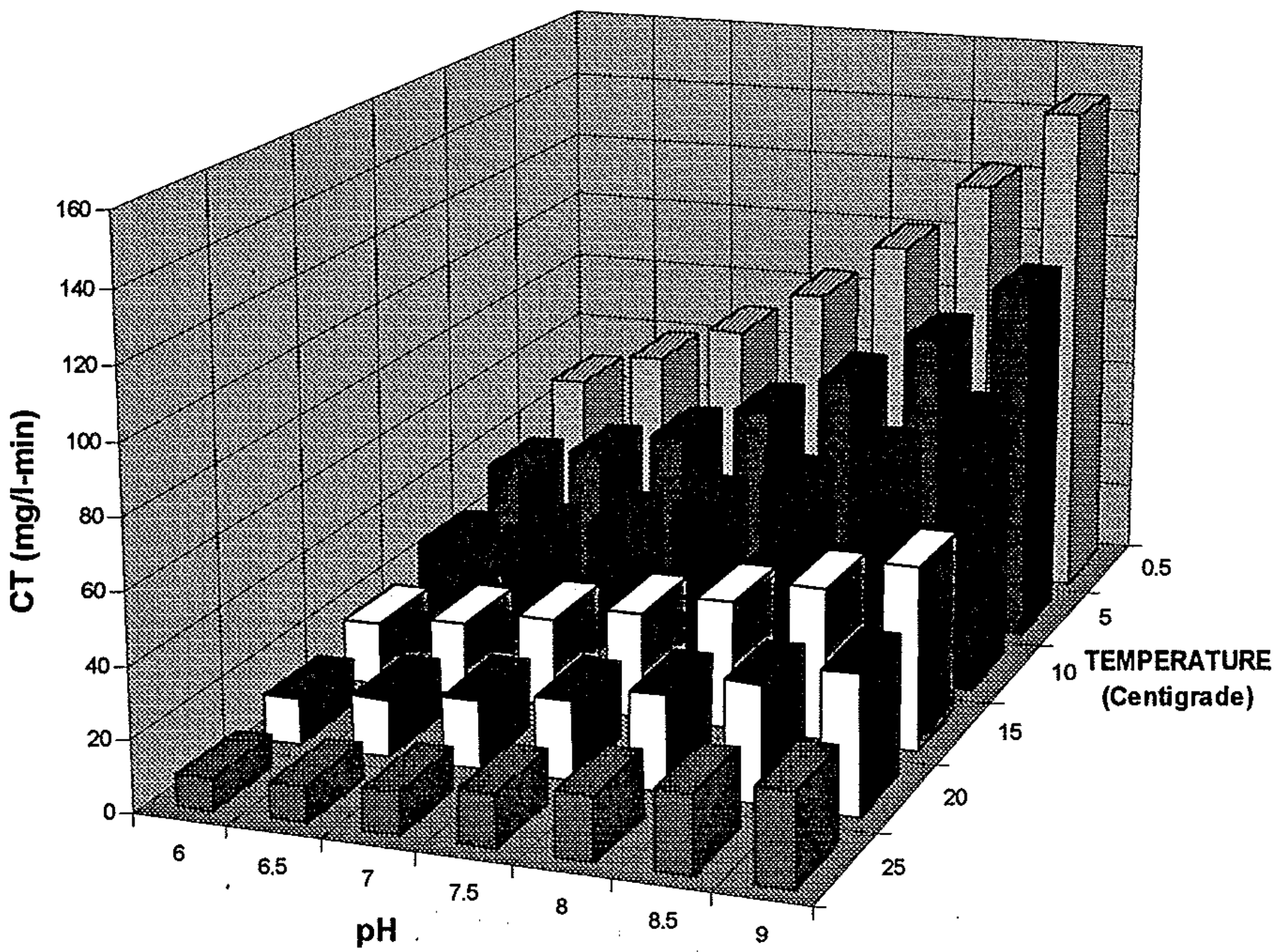
e. Ultraviolet light (UV) - not considered effective for inactivating Giardia cysts.

f. Combination of disinfectants - for example, a system may chlorinate at the intake and feed ammonia later to form chloramines.

2. Water temperature - Higher CT Values are required in cold water to get the same level of Log-reduction as in warmer temperatures. As you can see in Figure 2, the warmer the temperature the lower the CT requirement.

3. pH - Figure 2 demonstrates that chlorinated water at a higher pH requires a higher required CT Value. For other disinfectants, pH is not a factor except for outside the normal operating range of 6-9 when chloramines are utilized.

FIGURE 2. Required 1-LOG CT Values at Chlorine Residual = 1.0 mg/l



HOW DO YOU CALCULATE CT VALUES?

First, you must know the following:

1. Peak flow rate (gallons per minute or gpm) - If your raw water flow rate is different from the finished water flow rate, you must use the different rate where appropriate. Another option is to use the higher value to simulate your worst condition possible.

2. Water temperature (Centigrade or Celsius) - If the temperature is measured in degrees (°F) Fahrenheit, then use the conversion equation: Centigrade = (°F - 32) / 1.8

3. pH

4. Disinfectant residual (milligrams per liter or mg/L)

5. Capacity of all detention facilities (gallons or gal) - You are allowed to include all storage tanks and piping up to the first customer, but after the first injection point of the disinfectant.

<u>HELPFUL HINTS</u>

The following helpful hints located in this section are intended to provide you with some guidance in the CT Value process. They are designed for the goal of protecting the public as much as possible.

Before actually trying to tackle the CT calculations, you should draw a schematic or flow chart of your system. Next label the known parameters such as pipe diameters and the dimensions of sedimentation basins. Label your disinfection injection points as well as disinfection residual sampling points.

Use your schematic to make a daily worksheet for your calculations. You should use the low level for your clearwell volume for the worst case of the day. You should also note the sludge depth in any unit, such as sedimentation basin, and subtract that volume from the total volume calculated.

Another hint is to study the units or components separately. Your calculated CT Values may be higher in this case. This fact means that your system may meet the SWTR compliance requirements easier.

Always calculate for the conservative side because if you can prove your system meets the SWTR under the worst conditions, then it should meet the rule at all other times during that individual day. For example, you take a chlorine residual reading and it is somewhere between 0.6 mg/L and 0.8 mg/L. When you look up the required CT Value from the table in Appendix A, you should look up the CT Value required for 0.8 mg/L because that required value is higher than the CT Value required for the 0.6 mg/L. For your calculated CT Value you should use the lesser chlorine residual to be on the conservative side.

Suppose your system uses chlorine as a disinfectant. You take the water temperature and conclude that it is 8 °C. This temperature puts you between the 5 °C and the 10 °C chart in Appendix A. To be on the conservative side, you should always use the higher required CT Value. In the case of temperature, the higher CT Value occurs at lower temperatures as is shown in Figure 2. Therefore, use the chart for 5 °C.

Again suppose your system uses chlorine as a disinfectant. You measured the pH and determine that it is about 6.7. In the case of pH, the higher the pH the higher the CT Value required. This situation is displayed in Figure 2 as well. Therefore, in this case, you should use the CT chart in Appendix A that is closest to 6.7 but not lower than 6.7.

If you wanted to be exact in your calculations for the three previous examples, you may use a method called linear interpolation.

CT VALUE PROCEDURAL STEPS

1. Draw schematic.

2. Label schematic with known and unknowns.

3. Determine the CT Value required for you system.
   a. SWTR goals are shown in Table 2.
   b. Determine the plant's Log-removal credit.
   c. Subtract the Log-removal credit from the SWTR goal. This number is the Log-inactivation goal that must be met by your system.

4. Calculate the volume of all the basins.

5. Determine the baffling factor (BF) of each unit using Table 3.

6. Examine each unit or component.
   a. Calculate detention time (DT).
   b. Calculate the CT Value.
   c. Look up the required CT Value.

d. Calculate the individual Log-inactivation achieved. This number is determined by dividing the calculated CT Value by the CT Value required.

7. Total the Log-inactivation achieved.

8. Compare the total Log-inactivation achieved to the Log-inactivation goal (the number found in step 3).

    a. If the Log-inactivation goal is higher, your system does not meet the SWTR requirements.

    b. If the Log-inactivation achieved is higher, your system does meet the SWTR requirements.

    c. If the Log-inactivation achieved is equal to the CT Value required, then your system is meeting the SWTR requirements BUT just barely. You are leaving no room for error.

EXAMPLE PROBLEM

<u>GIVEN INFORMATION</u>

Your water source is 1 mile from the water treatment plant.

Gaseous chlorine is injected at the intake.
The raw water flow rate is 695 gpm.
The pH is measured at 8.
The water temperature is 0.5° C or 32.9° F.

Your water treatment plant uses complete treatment and is assigned the maximum 2-Log reduction credit.

The chlorine residual is measured after the filter at 0.6 mg/L.
Gaseous chlorine is injected on top of the filter.

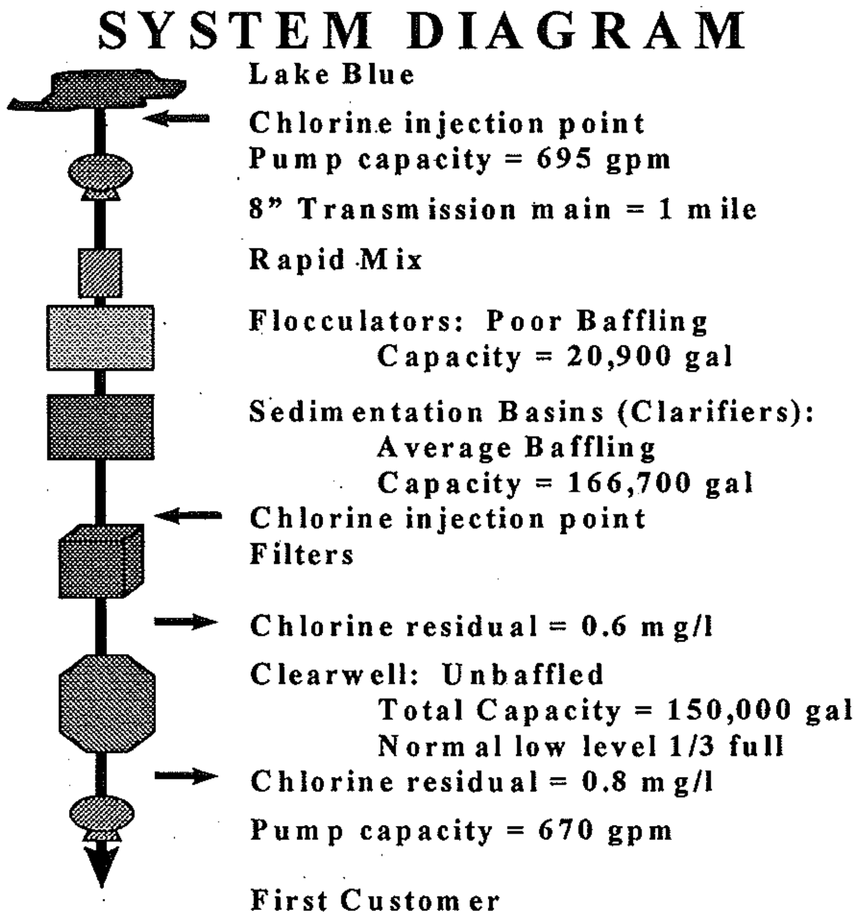
The chlorine residual is measured again after the clearewell and is found to be 0.8 mg/L.
The finished water flow rate is 670 gpm.

CT VALUE PROCEDURAL STEPS

1. Draw schematic (see Figure 3).

2. Label schematic with known and unknowns (see Figure 3).

FIGURE 3. Water treatment system schematic.



3. Determine the CT Value required for your system.
   a. SWTR goals, as shown Table 2.
   b. Determine the plant's Log-removal credit.
   c. Subtract the Log-removal credit from the SWTR goal. This number is the Log-inactivation goal that must be met by your system as shown below.

PATHOGEN / SWTR GOALS	- REMOVAL CREDIT	= INACTIVATION
Giardia cysts / 3-Log	- 2-Log	= 1-Log
Viruses / 4-Log	- 2-Log	= 2-Log

4. Calculate the volume of each basin.

NOTE: Remember, you can only use the volumes of basins after the first injection point of disinfect and only up to the first customer.

a. Transmission main: $V = ¶ \times r^2 \times L$

where: V is the water volume (cu ft)
¶ is the constant (3.142)
r is the radius (ft)
L is the length (ft)

Pipe radius: pipe diameter / 2 = 8 in/2 = 4 in
Convert to feet: 4 in x 1 ft/12 in = 0.333 ft

Length of pipe: 1 mile = 5,280 ft
Calculate volume: $V = 3.142 \times (0.333 \text{ ft})^2 \times 5{,}280 \text{ ft}$
V = 1,843 cu ft

Convert to gallons: 1 cu ft = 7.48 gal
V = 1,843 cu ft x 7.48 gal
V = 13,786 gal

b. Flash mix: For this example the volume for this unit is not calculated because by Kentucky's design criteria the time through this unit cannot exceed one (1) minute. This time is not a factor in most cases.

c. Flocculator: Given as 20,900 gal

d. Sedimentation: Given as 166,700 gal

e. Filter: For this example the volume of the filter is not calculated because the time through this unit usually does not contribute much in the calculated total CT Value. The theoretical value for filter volumes can be obtained by subtracting the volume of the filter media, gravel, and underdrains from the unit's total volume.

f. Clearwell: Given as 150,000 gal total but the low level is only 1/3 of the clearwell capacity. The usable capacity is 50,000 gallons.

5. Determine the baffling factor (BF) for each unit using Table 3.

Reference diagrams are located in Appendix B. For this example, the values for the basins as determined in step 4 are compiled in Table 8.

Table 8. Detention Facilities

UNIT	CAPACITY (gal)	BAFFLING FACTOR (BF)
1. Transmission Main	13,786	1.0
2. Flocculator	20,900	0.3
3. Clarifier	166,700	0.5
4. Clearwell	50,000	0.1

NOTE: If you wish to utilize the filters in your calculations, filters are considered to generally have superior baffling conditions.

6. Examine each unit or component.
   a. Calculate detention time (DT). Detention time is calculated by taking the capacity of the unit (gal) and dividing it by the flow rate (gpm).
      1. Transmission main: DT = 13,786 gal / 695 gpm
         DT = 19.836 min
      2. Flocculator: DT = 20,900 gal / 695 gpm
         DT = 30.072 min
      3. Sedimentation: DT = 166,700 gal / 695 gpm
         DT = 239.856 min
      4. Clearwell: DT = 50,000 gal / 670 gpm
         DT = 74.627 min

   b. Calculate the CT Value (CT). The calculated CT Value is obtained by multiplying the concentration of disinfectant (mg/L) by the detention time (min) by the baffling factor.
      1. Transmission main: CT = 0.6 mg/L x 19.836 min x 1.0
         CT = 11.902 mg/L-min
      2. Flocculator: CT = 0.6 mg/L x 30.072 min x 0.3
         CT = 5.413 mg/L-min
      3. Sedimentation: CT = 0.6 mg/L x 239.856 min x 0.5
         CT = 71.957 mg/L-min
      4. Clearwell: CT = 0.8 mg/L x 74.627 min x 0.1
         CT = 5.970 mg/L-min

   c. Look up the required 1-Log CT Value from Appendix A. Instructions are provided in Appendix A.
      1. Transmission main: req. CT = 95 mg/L-min
      2. Flocculator: req. CT = 95 mg/L-min
      3. Clarifier: req. CT = 95 mg/L-min
      4. Clearwell: req. CT = 98 mg/L-min

d. Calculate the Log-inactivation for each unit. This number is determined by dividing the calculated CT Value by the required CT Value.

1. Transmission main:

   Log-inactivation = 11.902 mg/L-min / 95 mg/L-min

   Log-inactivation = 0.125

2. Flocculator:

   Log-inactivation = 5.413 mg/L-min / 95 mg/L-min

   Log-inactivation = 0.057

3. Sedimentation:

   Log-inactivation = 71.957 mg/L-min / 95 mg/L-min

   Log-inactivation = 0.757

4. Clearwell:

   Log-inactivation = 5.970 mg/L-min / 98 mg/L-min

   Log-inactivation = 0.061

7. Total the Log-inactivation achieved.

1.	Transmission main:	0.125
2.	Flocculator:	0.057
3.	Sedimentation:	0.757
4.	Clearwell:	0.061
	Total:	1.000

8. Compare the total Log-inactivation achieved to the Log-inactivation goal (the number found in step 3). STEP 3 required 1-log inactivation.

   a. If the Log-inactivation goal is higher, your system does not meet the SWTR requirements.

   b. If the Log-inactivation achieved is higher, your system does meet the SWTR requirements.

   c. If the Log-inactivation achieved is equal to the Log-inactivation required, then your system is meeting the SWTR requirements BUT just barely.

CONCLUSION FOR THIS EXAMPLE

This water treatment plant was assigned the maximum 2-Log removal credit. From the CT calculations for the 1-Log inactivation the plant barely meets the SWTR requirements for this particular day, BUT the treatment techniques utilized by this system leave no room for error.

For example, suppose some of the plant's equipment were out of order. The plant could not then be given the 2-Log credit. Thereby, the Log-inactivation required would have been greater. Assuming that all other conditions remained the same, this plant would not have been in compliance with the SWTR because the Log-inactivation achieved would have been less than the Log-inactivation required.

For another scenario, assume the plant is given the 2-Log removal credit. The finished water main from the filter to the clearwell has been tapped to provide potable water to the water treatment plant itself. The first customer now becomes the water treatment plant. In calculating the CT Values for this situation you cannot include any portion of the clearwell capacity or any other unit that is after the plant tap for your Log-inactivation. Therefore, your total Log-inactivation achieved for your plant is as follows:

1.	Transmission main:	0.125
2.	Flocculator:	0.057
3.	Clarifier:	0.757
4.	Clearwell:	0.000
	Total:	0.939

This total indicated that you system did not meet the SWTR requirements on this day.

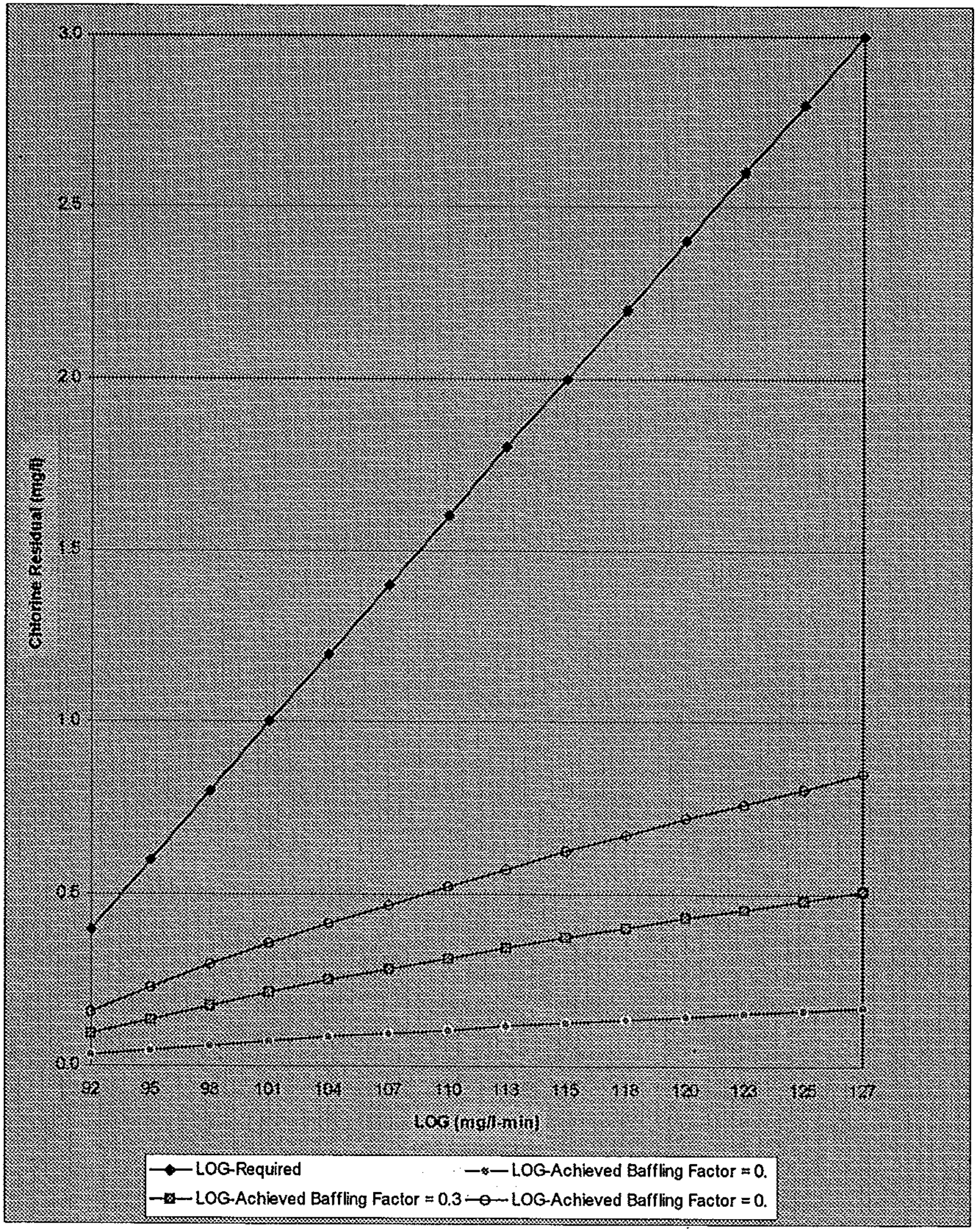
OTHER EXAMPLES

Let's look at another example. You use chlorine as a disinfectant and your plant has complete treatment and is assigned the maximum 2-Log reduction credit. The pH is 8.0 and the temperature is 0.5 °C (32.9 °F). You have completed your CT Value calculations and your comparison. You have determined that your system is not meeting the SWTR requirements. As a result, you decide to increase your chlorine concentration through your system.

Figure 4 demonstrates as you increase the amount of chlorine through your system, that it does not effectively help you to meet the SWTR requirements. This fact is because as you increase the chlorine residual, the required CT Value also increases.

In order for you to effectively meet the SWTR requirements you could consider adding or changing the baffling through the unit. As Figure 4 also shows, the calculated CT Values for the clearwell example approach the overall required CT Value as you change the baffling factor not the chlorine concentration.

Figure 4: Calculated and Required CT Values versus Chlorine Residuals.



CT VALUE REPORTING

There are basically two steps in setting up your facility's reporting procedures. First, you must submit to this office a flow diagram of your facility similar to Figure 3. The diagram shall begin at the raw water source and end with the first customer. The information required shall be reported as the worst case for the entire year. This means that if your system can meet the CT Value required for the worst case, then the system should meet the CT Value required at all times of the year. The information for the diagram shall include the following:

1. Type of units,
2. Number of each treatment processing units,
3. Dimensions of each unit,
4. Total capacity of treatment process units,
5. Disinfection application points,
6. Disinfection residual points,
7. Any flow splits,
8. Any sludge depth,
9. Description of flow pattern for each unit,
10. Your best estimate for the baffling factor,
11. Your best estimate for the Log-removal credit,
12. The person's name who prepared the diagram,
13. The day-time telephone number at which the preparer can be contacted,
14. The system's PWS ID #, and
15. Any other comments or necessary information.

Our office address is:

Department for Environmental Protection
Division of Water
Drinking Water Branch
14 Reilly Road
Frankfort KY 40601

The second step will be as follows:

1. Your diagram will be evaluated.
2. Your units will be assigned baffling factors.
3. Your removal process will be assigned a Log-removal credit.
4. You will receive a copy of the system diagram and the reporting form designed specifically for your system.
5. The form is to be completed daily and shall be submitted to this office monthly. It is due at the same time as the Monthly Operating Report (MOR).

If your system changes for any reason, then you need to revise your system diagram and submit it to this office. The following are some examples of where you will need to submit a revised diagram:

1. A treatment unit is taken out of service.
2. A treatment unit is added to the process.
3. Baffling of units is added or redesigned.
4. The point of injecting disinfectant is changed.
5. The point of a disinfectant residual is changed.

Table 9 is an example of site specific information that will be part of the CT Value Reporting Form.

TABLE 9. Site specific portion of the CT Value Reporting Form.

Units	Capacity	BF	Zone Factor	Zone
Unit 1	13, 786	1.0	13,786.0	1
Unit 2	675	0.1	67.5	1
Unit 3	20,900	0.3	6270.0	1
Unit 4	166,700	0.5	630.0	1

The capacity is the total capacity for that particular treatment process. BF is the assigned baffling factor for that particular treatment process. The Zone Factor is the capacity multiplied by the baffling factor. The Zone number is assigned to each treatment process. The Zone number is based on where the disinfectant is added to the system, where the disinfectant residual is measured, and whether the flow through the treatment process changes between treatment units.

REFERENCES

AWWA, *Surface Water Treatment: The New Rules*, Harry Von Huben, (1991)

USEPA, *Guidance Manual for Compliance with Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, (October 1990)

FORM

DAILY CT VALUE REPORTING FORM

FACILITY: Example Water System
PWS ID# 1234567

Log-removal credit applied: 2-Log
Log-inactivation required: 1-Log

	Capacity	BF	Zone Factor	Zone
Unit 1	13786	1	13786	1
Unit 2	0	0.1	0	1
Unit 3	20900	0.3	6270	1
Unit 4	166,700	0.5	83350	1
Unit 5	0	0.7	0	1

	Capacity	BF	Zone Factor	Zone
Unit 6	50000	0.1	5000	2
Unit 7	0	0.1	0	2
Unit 8	0			
Unit 9	0			
Unit 10	0			

	ZONE FACTOR TOTALS
ZONE 1	103406
ZONE 2	5000
ZONE 3	
ZONE 4	

COMPLETED BY: ____________ for the Month/Year of: ____________

DATE:	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	26	27	28	29	30	31
pH	8																														
Temperature	0.5																														
Flow Rate																															
Zone 1 rate	695																														
Zone 2 rate	670																														
Zone 3 rate																															
Zone 4 rate																															
Residual																															
Zone 1 Cl	0.6																														
Zone 2 Cl	0.8																														
Zone 3 Cl																															
Zone 4 Cl																															
Plant CT	ZONE FACTOR TOTAL x RESIDUAL / FLOW RATE																														
Zone 1 CT	89.3																														
Zone 2 CT	5.97																														
Zone 3 CT																															
Zone 4 CT																															
CT Required	USE CT TABLES																														
Zone 1 Req	95																														
Zone 2 Req	98																														
Zone 3 Req																															
Zone 4 Req																															
CT Ratio	PLANT CT / CT REQUIRED																														
Zone 1	0.94																														
Zone 2	0.06																														
Zone 3																															
Zone 4																															
TOTAL Ratio	1																														
Weekly Flag*																															

*Check worst weekly case.

APPENDIX A

THIS SECTION INCLUDES INSTRUCTIONS FOR USING THE REQUIRED CT VALUE TABLES AND THE TABLES THEMSELVES.

HOW TO USE THE CT VALUE REQUIRED TABLES

CHLORINE AS THE DISINFECTANT

1. You only need to look up Tables A-1 (for Giardia cysts) in the Appendix.
2. On Table A-1 look for your water temperature. Be sure that you pay close attention to the position of the decimal point. It is easy to look up 0.5° C rather than 5.0° C.
3. Next locate the column for the pH in question.
4. Go down the left column until you locate the correct chlorine concentration.
5. The number located there is your CT Value required. Record it.

CHLORAMINE AS THE DISINFECTANT

1. For Giardia cysts, look up Table A-3 in this Appendix.
2. Look down the first column and find the correct temperature.
3. Next look across that row from left to right until you are in the column with the 1-Log reduction.
4. The number located there is your CT Value required for Giardia. Record it.
5. For viruses, look up Table A-4 in the Appendix.
6. Look down the first column and find the correct temperature.
7. Next look across that row from left to right until you are in the column with the 1-Log reduction.
8. The number located there is your CT Value required for viruses. Record it.
9. Compare the number recorded in step 4 to the number recorded in step 8. Use the higher number as your CT Value required.

CHLORINE DIOXIDE AS THE DISINFECTANT

1. For Giardia cysts, look up Table A-5 in this Appendix.
2. Look down the first column and find the correct temperature.
3. Next look across that row from left to right until you are in the column with the correct Log-reduction.
4. The number located there is your CT Value required for Giardia. Record it.
5. For viruses, look up Table A-6 in this Appendix.
6. Look down the first column and find the correct temperature.
7. Next look across that row from left to right until you are in the column with the correct Log-reduction.
8. The number located there is your CT Value required for viruses. Record it.
9. Compare the number recorded in step 4 to the number recorded in step 8. Use the higher number as your CT Value required.

OZONE AS THE DISINFECTANT

1. Look up Table A-7 in this Appendix.
2. Look down the first column and find the correct temperature.
3. Next look across that row from left to right until you are in the column with the correct Log-reduction.
4. The number located there is your CT Value required for Giardia. Record it.
5. For viruses, look up Table A-8 in this Appendix.
6. Look down the first column and find the correct temperature.
7. Next look across that row from left to right until you are in the column with the correct Log-reduction.
8. The number located there is your CT Value required for viruses. Record it.
9. Compare the number recorded in step 4 to the number recorded in step 8. Use the higher number as your CT Value required.

ULTRAVIOLET LIGHT (UV) AS THE DISINFECTANT

1. Look up Table A-9 in this Appendix.
2. Look up correct column for Log-inactivation.
3. The number located there is your CT Value required for viruses. Record it. Remember there is not a Table for Giardia cysts because UV is ineffective on them.

TABLE A-1
1-LOG CT VALUES FOR INACTIVATION OF GIARDIA CYSTS BY FREE CHLORINE

Temperature = 0.5°C

Cl Conc. (mg/L)	pH <=6.0	6.5	7.0	7.5	8.0	8.5	>=9.0
0.4	46	54	65	79	92	110	130
0.6	47	56	67	80	95	114	136
0.8	48	57	68	82	98	118	141
1.0	49	59	70	84	101	122	146
1.2	51	60	72	86	104	125	150
1.3	52	61	74	89	107	129	155
1.6	52	63	75	91	110	132	159
1.8	54	64	77	93	113	136	163
2.0	55	66	79	95	115	139	167
2.2	56	67	81	99	118	142	170
2.4	57	68	82	99	120	145	174
2.6	58	70	84	101	123	148	178
2.8	59	71	86	103	125	151	181
3.0	60	72	87	105	127	153	184

Temperature = 5.0°C

Cl Conc. (mg/L)	pH <=6.0	6.5	7.0	7.5	8.0	8.5	>=9.0
0.4	32	39	46	55	66	79	93
0.6	33	40	48	57	68	81	97
0.8	34	41	49	58	70	84	100
1.0	35	42	50	60	72	87	104
1.2	36	42	51	61	74	89	107
1.3	36	43	52	62	76	91	110
1.6	37	44	53	64	77	94	112
1.8	38	45	54	65	79	96	115
2.0	39	46	55	67	81	98	118
2.2	39	47	56	68	83	100	120
2.4	40	48	57	70	84	102	123
2.6	41	49	58	71	86	104	125
2.8	41	49	59	72	88	106	127
3.0	42	50	61	74	89	108	130

Temperature = 10°C

Cl Conc. (mg/L)	pH <=6.0	6.5	7.0	7.5	8.0	8.5	>=9.0
0.4	24	29	35	42	50	59	70
0.6	25	30	36	43	51	61	73
0.8	26	31	37	44	53	63	75
1.0	26	31	37	45	54	65	78
1.2	27	32	38	46	55	67	80
1.3	27	33	39	47	57	69	82
1.6	28	33	40	48	58	70	84
1.8	29	34	41	49	60	72	86
2.0	29	35	41	50	61	74	88
2.2	30	35	42	51	62	75	90
2.4	30	36	43	52	63	77	92
2.6	31	37	44	53	65	78	94
2.8	31	37	45	54	66	80	96
3.0	32	38	46	55	67	81	97

Temperature = 15°C

Cl Conc. (mg/L)	pH <=6.0	6.5	7.0	7.5	8.0	8.5	>=9.0
0.4	16	20	23	28	33	39	47
0.6	17	20	24	29	34	41	49
0.8	17	20	24	29	35	42	50
1.0	18	21	25	30	36	43	52
1.2	18	21	25	31	37	45	53
1.3	18	22	26	31	38	46	55
1.6	19	22	26	32	39	47	56
1.8	19	23	27	33	40	48	58
2.0	19	23	28	33	41	49	59
2.2	20	23	28	34	41	50	60
2.4	20	24	29	35	42	51	61
2.6	20	24	29	36	43	52	63
2.8	21	25	30	36	44	53	64
3.0	21	25	30	37	45	54	65

Temperature = 20°C

Cl Conc. (mg/L)	pH <=6.0	6.5	7.0	7.5	8.0	8.5	>=9.0
0.4	12	15	17	21	25	30	35
0.6	13	15	18	21	26	31	36
0.8	13	15	18	22	26	32	38
1.0	13	16	19	22	27	33	39
1.2	13	16	19	23	28	33	40
1.3	14	16	19	23	28	34	41
1.6	14	17	20	24	29	35	42
1.8	14	17	20	25	30	36	43
2.0	15	17	21	25	30	37	44
2.2	15	18	21	26	31	38	45
2.4	15	18	22	26	32	38	46
2.6	15	18	22	27	32	39	47
2.8	16	19	22	27	33	40	48
3.0	16	19	23	28	34	41	49

Temperature = 25°C

Cl Conc. (mg/L)	pH <=6.0	6.5	7.0	7.5	8.0	8.5	>=9.0
0.4	8	10	12	14	17	20	23
0.6	8	10	12	14	17	20	24
0.8	9	10	12	15	18	21	25
1.0	9	10	12	15	18	22	26
1.2	9	11	13	15	18	22	27
1.3	9	11	13	16	19	23	27
1.6	9	11	13	16	19	23	28
1.8	10	11	14	16	20	24	29
2.0	10	12	14	17	20	25	29
2.2	10	12	14	17	21	25	30
2.4	10	12	14	17	21	26	31
2.6	10	12	15	18	22	26	31
2.8	10	12	15	18	22	27	32
3.0	11	13	15	18	22	27	32

TABLE A-2
CT VALUES FOR INACTIVATION OF VIRUSES BY FREE CHLORINE [1,2]

	LOG INACTIVATION					
	2.0		3		4	
	pH		pH		pH	
Temperature	6 to 9	10	6 to 9	10	6 to 9	10
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15

Notes:

1 Data adapted from Sobsey (1988) for inactivation of Hepatitus A Virus (HAV) at pH = 6, 7, 8, 9, and 10 and temperature = 5° C. CT Values include a safety factor of 3.

2 CT Values adjusted to other temperatures by doubling CT For each 10° C drop in temperature.

Round ↓ temp

TABLE A-3 AND TABLE A-4
CT VALUES FOR INACTIVATION OF GIARDIA CYSTS AND VIRUSES [1,2,3]
BY CHLORAMINE WITH pH 6 TO 9

TABLE A-3 for Giardia Cysts

	LOG INACTIVATION					
Temperature	0.5	1	1.5	2	2.5	3
1	635	1270	1900	2535	3170	3800
5	365	735	1100	1470	1830	2200
10	310	615	930	1230	1540	1850
15	250	500	750	1000	1250	1500
20	185	370	550	735	915	1100
25	125	250	375	500	625	750

TABLE A-4 for Viruses

	LOG INACTIVATION		
Temperature	2	3	4
1	1243	2063	2883
5	857	1423	1988
10	643	1067	1491
15	428	712	994
20	321	534	746
25	214	356	497

Notes:

1. Data adapted from Sobsey (1988) for inactivation of Hepatitus A Virus at pH = 8 and temperature = 5° C and assumed to apply for pHs in the range of 6 to 10.

2. CT Values adjusted to other temperatures by doubling CT for each 10° C drop in temperature.

3. This table of CT Values applies for systems using combined chlorine where chlorine is added prior to ammonia in the treatment sequence. CT values in this table should not be used for estimating the adequacy of disinfection in systems applying preformed chloramines or ammonia ahead of chlorine.

TABLE A-5 AND TABLE A-6
CT VALUES FOR INACTIVATION OF GIARDIA CYSTS AND VIRUSES [1,2] BY CHLORINE DIOXIDE WITH pH 6 TO 9

Table A-5 for Giardia Cysts

	LOG INACTIVATION					
Temperature	0.5	1	1.5	2	2.5	3
<=1	10	21	32	42	52	63
5	4.3	8.7	13	17	22	26
10	4	7.7	12	15	19	23
15	3.2	6.3	10	13	16	19
20	2.5	5	7.5	10	13	15
25	2	3.7	5.5	7.3	9	11

Table A-6 for viruses

	LOG INACTIVATION		
Temperature	2	3	4
<=1	8.4	25.6	50.1
5	5.6	17.1	33.4
10	4.2	12.8	25.1
15	2.8	8.6	16.7
20	2.1	6.4	12.5
25	1.4	4.3	8.4

Notes:

1 Data adapted from Sobsey (1988) for inactivation of Hepatitus A Virus (HAV) at pH = 6 and temperature = 5° C. CT Values include a safety factor of 2.

2 CT Values adjusted to other temperatures by doubling CT for each 10° C drop in temperature.

TABLE A-7 and TABLE A-8

CT VALUES FOR INACTIVATION OF GIARDIA CYSTS AND VIRUSES [1,2] BY OZONE WITH pH 6 TO 9

Table A-7 for Giardia Cysts

	LOG INACTIVATION					
Temperature	0.5	1	1.5	2	2.5	3
<=1	0.48	0.97	1.50	1.90	2.40	2.90
5	0.32	0.63	0.95	1.30	1.60	1.90
10	0.23	0.48	0.72	0.95	1.20	1.43
15	0.16	0.32	0.48	0.63	0.79	0.95
20	0.12	0.24	0.36	0.48	0.60	0.72
25	0.08	0.16	0.24	0.32	0.40	0.48

Table A-8 for viruses

	LOG INACTIVATION		
Temperature	2	3	4
<=1	0.9	1.4	1.8
5	0.6	0.9	1.2
10	0.5	0.8	1
15	0.3	0.5	0.6
20	0.25	0.4	0.5
25	0.15	0.25	0.3

Notes:

1 Data adapted from Roy (1982) for inactivation of poliovirus at pH = 7.2 and temperature = 5° C. CT Values include a safety factor of 3.

2 CT Values adjusted to other temperatures by doubling CT for each 10° C drop in temperature.

TABLE A-9

CT VALUES FOR INACTIVATION OF VIRUSES BY UV [1]

TABLE A-9 for viruses by UV

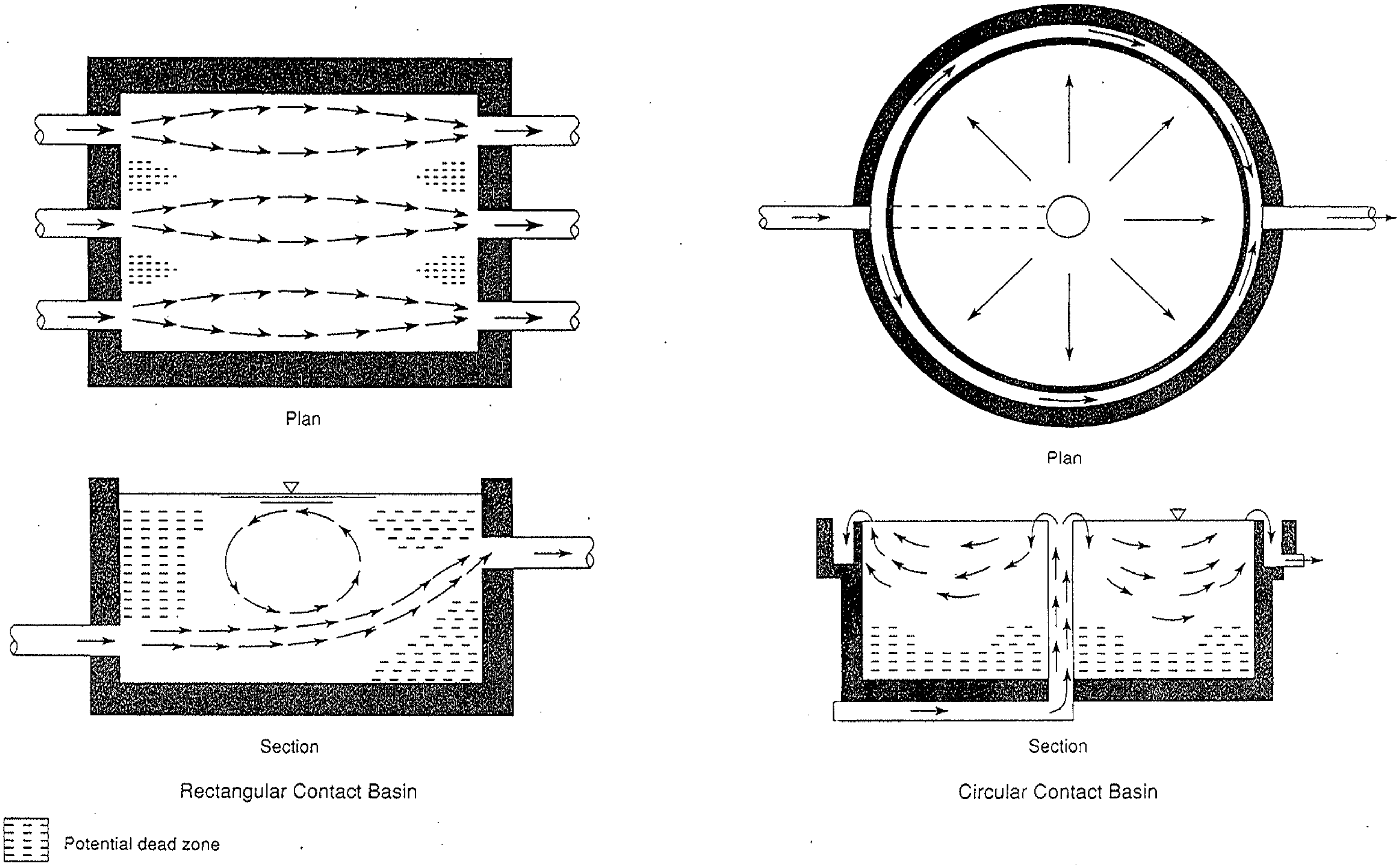
LOG INACTIVATION	
2	3
21	36

Note:

1 Data adapted from Sobsey (1988) for UV inactivation of Hepatitus A Virus (HAV). Units of CT Values are mW-sec/cm. CT Values include a safety factor of 3.

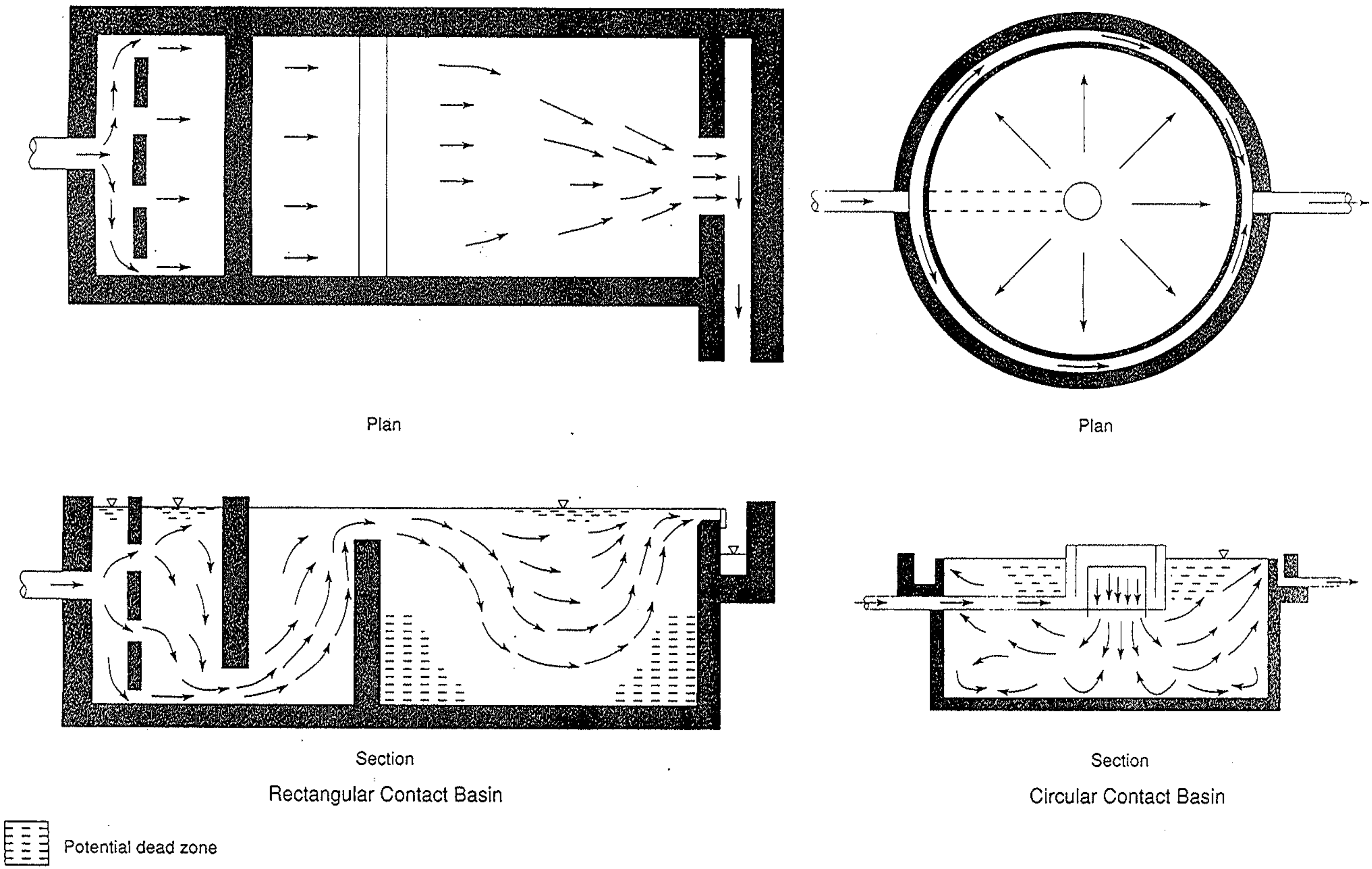
APPENDIX B

EXAMPLES OF POOR, AVERAGE, AND SUPERIOR BAFFLING CONDITIONS IN BASINS. The shaded areas indicated on the diagrams are dead space where no flow occurs. There are usually pockets with flows close to plug flow or perfect conditions and areas where mixed flow takes place in each unit.



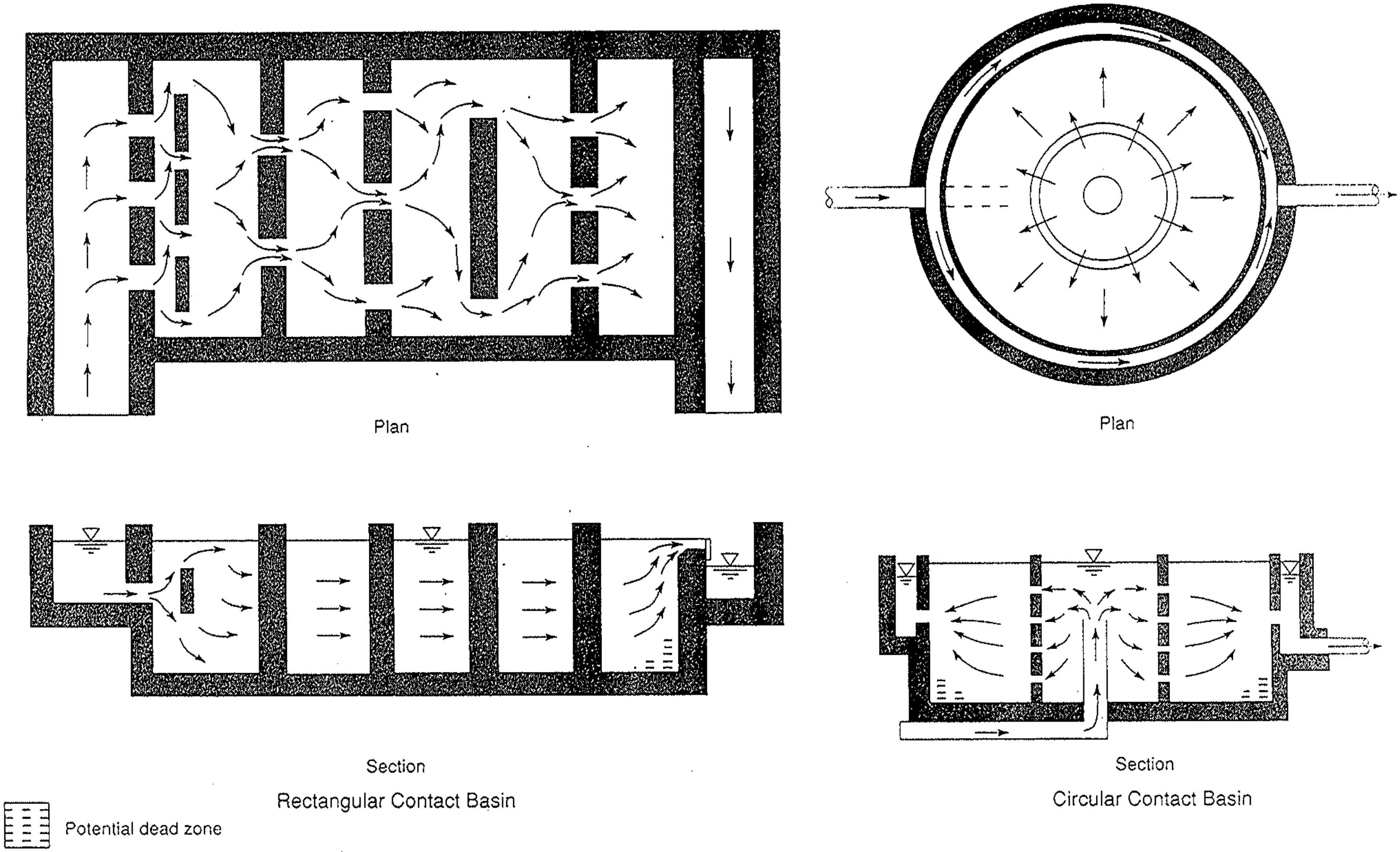
Source: Guidance Manual.

Examples of poor baffling conditions in basins.



Source: Guidance Manual.

Examples of average baffling conditions in basins.



Source: Guidance Manual.

Examples of superior baffling conditions in basins.