Protecting Water Quality by Optimizing the Operations and Maintenance of Distribution Systems

RCAP

RURAL COMMUNITY ASSISTANCE PARTNERSHIP

an equal opportunity provider and employer

Acknowledgements

This material is based upon work supported under a grant by the Utilities Programs, United States Department of Agriculture. Any opinions, findings, and conclusions or recommendations expressed in this material are solely the responsibility of the authors and do not necessarily represent the official views of the Utilities Programs.

This guide was written by the Rural Community Assistance Corporation (RCAC), the Western RCAP, on behalf of Rural Community Assistance Partnership, Inc.

The original materials that were used as a basis for this publication were developed by Oxenford Consulting, Stratus Consulting, Jacobs Engineering, RCAC and RCAP, with funding from the Capacity Building Unit, Colorado Department of Public Health and Environment (CDPHE).

The entire contents of this guide are available on the RCAP website at *www.rcap.org*

Protecting Water Quality by Optimizing the Operations and Maintenance of Distribution Systems

Rural Community Assistance Partnership, Inc.

1701 K St. NW, Suite 700
Washington, DC 20006
202/408-1273
800/321-7227 (toll-free)
info@rcap.org

www.rcap.org

Table of Contents

Introduction

This guide provides background information on how to maintain water quality in drinking water distribution systems and treated-water storage facilities by concentrating on common problems and challenges and identifying potential improvements and solutions. While the primary audience for this guide is operators of water distribution systems at utilities that serve up to 3,300 people, operators of larger systems and other stakeholders should also find it valuable.

This guide uses regulatory requirements and best practices of the drinking water community as the basis of its discussion of water distribution systems. It is intended to serve as a resource for an individual operator's study or as a reference text in a classroom or training setting. Each chapter lists learning objectives and includes activities and discussion topics to reinforce the concepts.

Several key methods of maintaining the water quality in distribution systems were identified in studies by the Water Research Foundation ("Criteria for Optimized Distribution Systems," Water Research Foundation Project #4109) and the Water Quality Control Division (WQCD) of the Colorado Department of Public Health and Environment ("Failure and Root Cause Analysis Project Report," 2009). The key factors identified in the studies include:

- preventing loss of pressure from pipe breaks, leaks, and power outages
- maintaining adequate disinfection in the distribution system
- monitoring and reporting water-quality parameters as required by regulations
- adequately covered and protected finished water storage
- producing a stable water product
- minimizing detention time
- keeping the distribution system clean
- implementing and emphasizing a cross-connection program
- operational and management planning, such as emergency-response and asset-management plans

This document is divided into two major sections:

1. Water Quality and Distribution Systems
2. Water Quality in Storage Facilities

SECTION 1

Water Quality and Distribution Systems

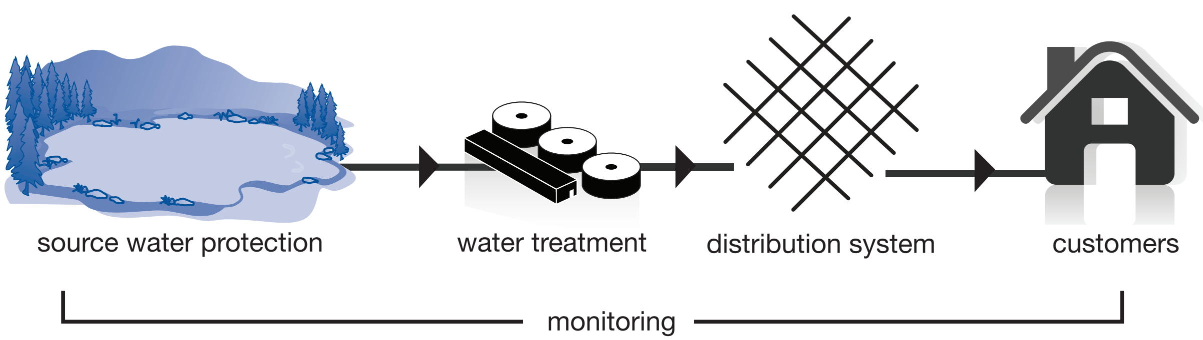
Chapter 1
The distribution system as a barrier to protect public health

Learning objectives:

- Identify issues in the distribution system that may impact public health
- Be able to describe the importance of the distribution system as a barrier for protecting public health

Multi-barrier approach

Ensuring a reliable supply of high-quality water is the top priority of a public water system and its operator(s). In addition to the human means of guarding water quality, there are scientific means as well. Drinking water is, in fact, a perishable good that can deteriorate in quality. A preservative—chlorine—is used to maintain its quality.



A multi-barrier approach is one that uses managerial and technical barriers to help prevent contamination at the source and during treatment and distribution to provide a safe supply of drinking water for consumers. Examples of these barriers include:

- source water protection
- water treatment
- disinfection
- distribution system integrity and water quality
- a mechanism for customer input
- monitoring of water quality
- skilled operator

Distribution system barriers

The barriers against contamination in the distribution system can be classified into two types–physical integrity and water quality. The main components of physical integrity include:

- main breaks/leaks
- cross connections
- storage tanks
- positive pressure in the system
- integrity of underground tanks and piping

Water-quality parameters that help maintain barriers against contamination include:

- disinfectant residual
- water age
- monitoring

It is also important to prevent changes to water quality, such as disinfection byproducts (DBP) formation, biological regrowth, nitrification, and lead and copper contamination.

According to the U.S. Environmental Protection Agency (EPA), 30 percent of all waterborne diseases are the result of distribution system issues. Therefore, it is very important to maintain the barriers to contamination within the distribution system.

Activity and discussion

Can you think of any distribution system issues that may have had an impact on public health:

- in your water system?
- in a system in your state, region, or elsewhere in the United States?

The Colorado Department of Public Health and Environment (CDPHE) conducted a study of failures in water systems in the state. Some of the most common failures related to distribution systems were:

- failure to maintain adequate disinfection residual
- loss of pressure
- failure to monitor
- uncontrolled cross connections
- inadequately covered finished water storage
- total coliform positives

How does this list compare to your list for your system, state, or region?

Chapter 2
Overview of regulations for distribution systems

CHAPTER 2

Learning objectives:

- Be able to describe the key distribution system-related regulations
- Be able to find regulations and utilize resources provided by the EPA

Regulatory themes

Regulations are designed to address acute and chronic health impacts. Acute events need immediate response, while chronic problems take longer to impact health. Acute events in a distribution system include loss of positive pressure, loss of disinfectant residual, or a positive repeat of total coliform or *E. coli* samples. Chronic problems include high lead and copper concentrations and high disinfection byproduct concentrations.

The primacy agency in your state or for your tribe can help you understand and comply with the regulations. However, regulations should be considered a minimum standard for good operations. The events in Alamosa, Colo., in 2008 are a good example. The water system was never out of compliance, but health officials noticed that people were getting sick with *Salmonella*. In the end, it was determined that poor operation and maintenance practices in the distribution system likely contributed to the outbreak. The events in Alamosa are presented in greater detail later in this guide.

These regulations affect distribution system operations:

- Total Coliform Rule
- Residual disinfectant concentration (Surface Water Treatment and Ground Water Rules)
- Ground Water Rule
- Lead and Copper Rule
- Stage 2 Disinfectants and Disinfection Byproducts Rule

Total Coliform Rule

The Total Coliform Rule (TCR) requires systems to monitor the presence of total coliform and *E. coli* bacteria in the distribution system. These organisms are an indicator of microbial contamination in the system. Total coliform (TC) is not a health threat in itself. However, TC can be used to indicate the possible presence of other potentially harmful bacteria. Fecal coliform or *E. coli* is a subset of total coliform. The presence of *E. coli* indicates fecal waste contamination.

Contamination can come from unprotected watersheds, improper well construction, main breaks, loss of positive pressure, cross connections, breach in storage-tank protection, etc.

Total coliform can come from many sources including:

- source water contamination
  - agricultural runoff
  - failure of septic tanks or sewer pipes
- contamination during treatment and storage
  - open or faulty storage reservoirs
  - animal droppings
  - vandalism
- infiltration from pipe leaks
- inadequate cleaning of new and repaired pipes
- cross connections
- bacterial growth in distribution system

Violations of the TCR can occur when the Acute Maximum Contaminant Level (MCL) is exceeded, when the Monthly MCL is exceeded, or when monitoring requirements are not met.

An acute MCL violation is defined as: when a routine sample *and* a repeat sample come back total coliform positive (TC+) *and* one has fecal or *E. coli* present.

A monthly MCL violation occurs when:

- there is more than one routine (with repeat) TC+ sample per month (for systems collecting fewer than 40 samples per month)
- there are more than 5 percent of the routine (with repeat) samples TC+ (for systems collecting 40 or more samples per month)

A failure-to-monitor violation occurs when either a routine or repeated sample is not collected or reported to the primacy agency.

What to do for an MCL violation

If you have an MCL violation, you should follow the regulations but also be proactive. Contact the primacy agency early. Plan ahead for how you will react. Specifically, you should:

For acute MCL violation:

- Notify the primacy agency no later than the end of next business day.
- Implement a “Tier 1 Public Notice.”
  - Provide a public notice no later than 24 hours after the system learns of the violation. (Details on the requirements for a Tier 1 Public Notice are available from your primacy agency.)
  - Consult with the primacy agency no later than 24 hours after the system learns of the violation. Comply with any resulting additional public notification requirements.

For monthly MCL violation:

- Notify the primacy agency no later than the end of next business day.
- Implement a “Tier 2 Public Notice.”
  - Provide a public notice no later than 30 days after the system learns of the violation. (Details on the requirements for a Tier 2 Public Notice are available from your primacy agency.)

For a failure-to-monitor (FTM) violation

- If the primacy agency did not receive the data, submit the data via email or fax.
  - If no sample was taken, follow the instructions outlined in the violation notice from the primacy agency. This includes public notice and other measures.
- Make sure sampling is scheduled and ready for the next monitoring period.

Potential causes of TCR violations

Violations of the Total Coliform Rule can be caused by a loss of disinfectant (usually chlorine) residual. Without a disinfectant residual, coliform bacteria can survive in the distribution system. Other violations can be caused by faulty sampling techniques leading to TC+ samples (false positive).

What do you do if you get TC+ samples?

If you get a positive total coliform result, you must resample and notify the primacy agency. Specifically:

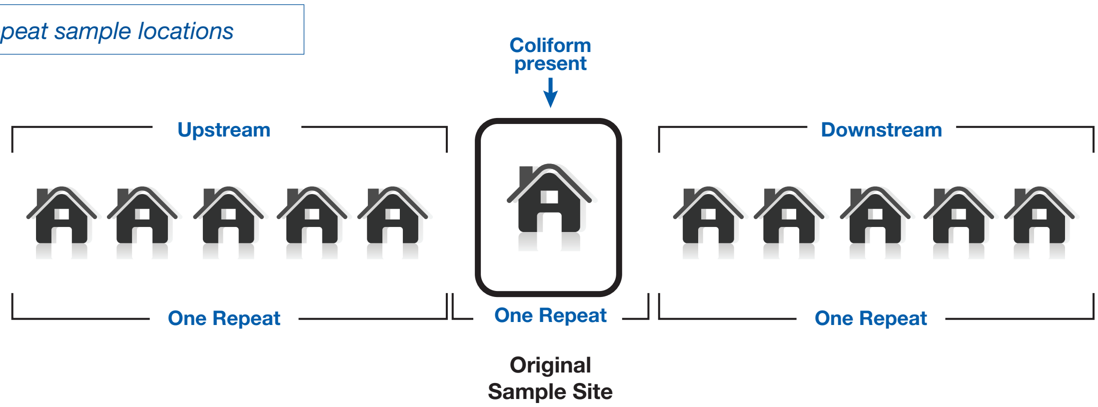
1. Take repeat samples within 24 hours.
   - If the system collects one sample per month or less: four repeats required
   - If the system collects more than one sample per month: three repeats required
2. Investigate the source of contamination to determine whether it is a system-wide or isolated (e.g., domestic plumbing) problem.
3. Notify the primacy agency by the end of the next business day.

Where do you collect repeat samples?

The first three repeat samples are collected at:

- the original TC-positive sample location
- a location within 5 service connections upstream
- a location within 5 service connections downstream
- the fourth sample (systems collecting 1 or fewer samples per month) is taken at a location that will help identify the area of contamination

TC repeat sample locations



If you get a TC positive and you are a ground water system, there are additional requirements that will be discussed later.

CHAPTER 2

Activity

As shown in the diagram, a sample is taken at house #7 that is total coliform positive. Answer the following questions:

- How many repeat samples are needed?
- Where do you take them?
- When should you take them?

See page 59 for suggested answers.

Here are some additional examples of total coliform sampling situations:

Case study #1

- A system serves 800 people
- 1 routine TC sample per month is required
- One routine sample is TC+, and fecal coliform is present
- Two of the four repeat samples are TC+, but fecal coliform is absent
- What are the consequences?

Consequences

1. The system should notify the primacy agency for the routine TC+ sample and repeat TC+ with FC+
2. Acute MCL violation (fecal coliform in routine sample, TC+ in repeat sample)
3. Notify primacy agency and the public immediately (Tier 1)
4. Take 5 samples in the next month
5. Investigate cause

Case study #2

- A system serves 3,000 people
- 3 routine TC samples per month are required
- One routine sample is TC+
- Two of the three repeat samples are TC+, but fecal coliform is absent
- What are the consequences?

Consequences

1. The system should notify the primacy agency for the routine TC+ sample and TC+ repeats
2. Monthly MCL violation (more than 1 TC+ sample in a month for a system taking less than 40 samples per month)
3. Notify primacy agency immediately
4. Notify public within 30 days (Tier 2)
5. Take 5 samples in the next month
6. Investigate cause

Case study #3

- A system serves 800 people
- 1 routine TC samples per month is required
- One routine sample is TC+, no fecal coliform present
- None of the four repeat samples are TC+
- What are the consequences?

Consequences

1. The system should notify the primacy agency for the routine TC+ sample
2. No MCL violation
1. 3. No public notification
4. No additional samples the following month

Residual disinfectant concentration

The Surface Water Treatment and Ground Water Rules contain the following requirements for the minimum concentration of disinfectant in distribution systems:

- Residual disinfectant concentration cannot be less that 0.2 mg/L entering the distribution system for more than 4 hours
  - If your disinfectant drops below this level for more than 4 hours, you must contact your primacy agency, whether or not the residual is restored.
- Residual disinfectant cannot be undetectable in more than 5 percent of samples *within* the distribution system.

Note: Your primacy agency will define "undetectable." It is usually based on the detection limits of the instrument used to measure disinfectant residual.

The regulations also specify a maximum residual disinfectant level (MRDL). The MRDL for chlorine or chloramines is 4.0 mg/L. If the concentrations are above these limits, the results can be an unpleasant chlorine taste, excessive disinfection-byproduct formation, and eye, nose, and stomach irritation.

Two additional points are important to remember regarding disinfectant concentrations in the distribution system. First, disinfectant residual *must* be measured at the same time and place as each sample taken to comply with the Total Coliform Rule. Second, chlorine decay can be an indicator of issues in the distribution system, including excessive water age and possible contamination.

Ground Water Rule (GWR)

The GWR is aimed at further reducing the risk of fecal-coliform contamination in the water system. It is a relatively new rule (December 2009) and is an extension of the Total Coliform Rule. The GWR consists of four major components:

1. sanitary survey
2. source water monitoring
3. corrective actions
4. compliance monitoring

Triggered monitoring is a component of the GWR that is important to distribution systems. If a routine total coliform sample comes back positive, you must sample all ground water sources in addition to the repeat samples in the distribution system.

Lead and Copper Rule (LCR)

Lead can cause damage to the brain, red blood cells, and kidneys, especially in children. Copper can cause stomach and intestinal distress, liver and kidney damage, and complications of Wilson's disease. The lead and copper regulations contain action levels (AL) rather than maximum contaminant levels. As the name implies, if a water system exceeds an AL for lead or copper, an action must be taken to lower the concentration. The ALs for lead and copper are:

- 0.015 mg/L for lead (Pb)
- 1.3 mg/L for Copper (Cu)

The ALs are based on the 90th percentile level of tap-water samples (explained below). An AL exceedance is not a violation but can trigger the requirement for actions.

Another unique characteristic of Pb and Cu samples is that they must be first-draw samples. That is, the sample is from the customer's tap, after water has been standing in the plumbing for at least 6 hours but no longer than 18 hours.

Lead and copper come from the corrosion of lead-containing solder, lead and copper pipes, and lead-containing plumbing fixtures. Lead and copper usually do not come from the source water. Rather, they are a result of corrosion in the distribution system, house plumbing, and fixtures.

Sampling for lead and copper

- must collect "first-draw" samples at buildings that are at a high risk of Pb/Cu contamination
- sample frequency based on system size
- compliance based on the 90th percentile

Explanation of the 90th percentile level: Multiply the number of valid samples by 0.9 (e.g., 10 samples x 0.9 = 9; thus, use 9th highest Pb and Cu test result to compare to AL). For 5 samples, average 4th and 5th highest results. For < 5 samples, use the highest result. This procedure is illustrated below.

What to do when the action level is exceeded

If the AL is exceeded, the system will need to solve the problem by evaluating the following:

- source water monitoring
- public notification
- lead and copper service-line replacement
- water-quality parameter monitoring, including pH and hardness
- corrosion-control treatment, including polyphosphate addition and pH adjustment
- determine if lead was used to seal some main distribution lines

There are several potential factors that may affect the lead and copper concentrations. Changing to another water source or seasonal changes in an existing source can change the water chemistry in the system. Changing the treatment process, treatment chemicals, or adding a new treatment process can also have an impact on LCR compliance. Your primacy agency must be notified if the source is changed or any treatment process is added or altered.

Lead and Copper Rule activity

To calculate the 90th percentile:

- Rank the samples according to their lead or copper concentrations.
- Find the "sample" for which:
  - 90 percent of all samples have a lower concentration
  - 10 percent of all samples have a higher concentration

Sample #	Lead (mg/L)
1	0.004
2	0.005
3	0.005
4	0.006
5	0.006
6	0.006
7	0.009
8	0.010
9	**0.011**
10	0.017

In this example, the 90th percentile is 0.011 mg/L

Another example problem:
Lead and Copper Rule

- What is the 90th percentile?
- Does this meet or exceed the regulations?

Sample #	Lead (mg/L)
1	0.004
2	0.005
3	0.008
4	0.011
5	0.017

Solution:

- Total of 5 samples
- Need 0.9 x 5 = "4.5th" sample
- 90th percentile = (Sample #4 + Sample # 5) / 2 = 0.014 mg/L
- Below, but very close to, the action level of 0.015 mg/L

Stage 2 Disinfectants and Disinfection Byproduct Rule (Stage 2 DBP rule)

There are two groups of regulated compounds in the Stage 2 DBP Rule:

- Total trihalomethanes (TTHM)
  - MCL = 80 µg/L = 0.080 mg/L
- Five haloacetic acids (HAA5)
  - MCL = 60 µg/L = 0.060 mg/L

Both of these groups of compounds are of concern because of an increased risk of cancer and other impacts. Note that the units are µg/L vs. mg/L (parts per billion vs. parts per million). Collectively, these compounds are referred to as disinfection byproducts or DBPs.

DBP formation depends on many factors, including:

- water age in distribution system and storage
- temperature and pH
- natural organic matter (NOM) concentration
- chlorine dose (at the water treatment plant and at chlorine booster facilities)

DBPs will form at the water treatment plant and in the distribution system as long as there is a chlorine residual and natural organic matter is present. A longer water age leads to higher DBP formation. A higher temperature speeds up the formation of DBPs. Higher pH, higher NOM concentration, and higher chlorine concentration all result in more DBPs being formed.

The Stage 2 DBP Rule requires that compliance sampling locations be selected based on an initial distribution system evaluation (IDSE). The IDSE characterizes DBP levels throughout the distribution system. Compliance samples are taken at customers' taps. Previously, in Stage 1, a running annual average (RAA) was used for all samples together. Stage 2 uses a locational running annual average (LRAA) in which a running annual average is calculated for each sampling location. The calculation of these averages is demonstrated below.

Compliance dates are listed in the first table below for the Stage 2 DBP Rule. For new systems, consult your primacy agency for IDSE deadlines and Stage 2 compliance dates. Consecutive systems follow the schedule of the largest system in the combined distribution system. For small systems, monitoring frequency depends on water source and populations served as shown in the second table below.

Compliance dates by system size

	≥ 100,000	50,000-99,999	10,000-49,999	< 10,000
Submit IDSE plan	October 1, 2006	April 1, 2007	October 1, 2007	April 1, 2008
Complete IDSE	September 30, 2008	March 31, 2009	September 30, 2009	March 31, 2010
Submit IDSE monitoring	January 1, 2009	July 1, 2009	January 1, 2010	July 1, 2010
Begin Stage 2 monitoring	April 1, 2012	October 1, 2012	October 1, 2013	October 1, 2013

Distribution system monitoring frequency

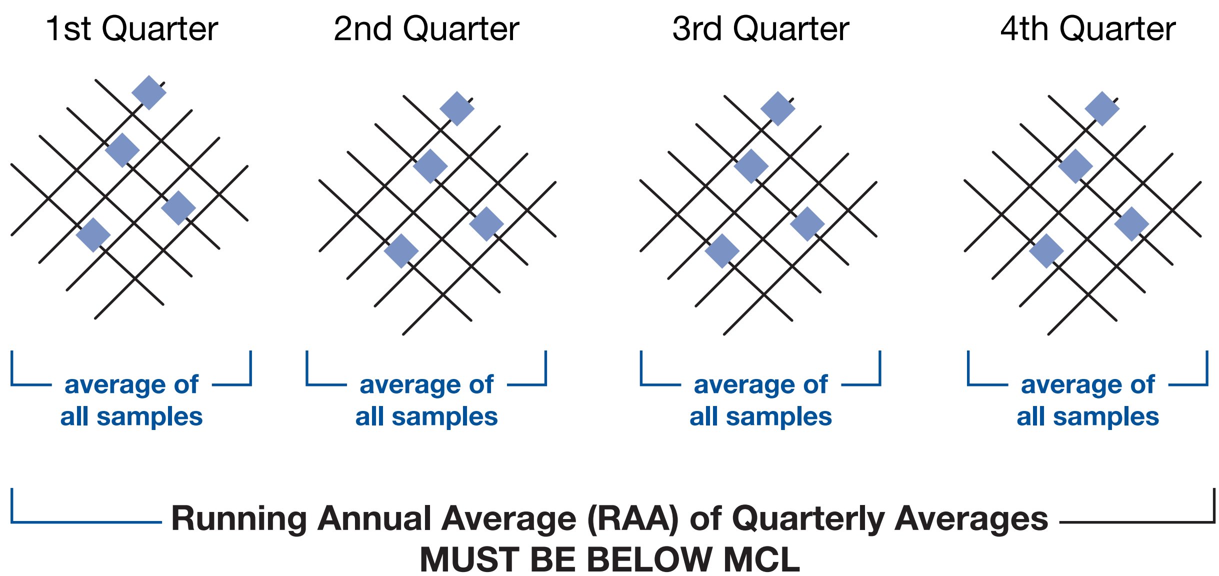
Source water type	Population size category	Monitoring frequency[2]	Total per monitoring period	Highest TTHM locations	Highest HAA5 locations
Subpart H[1]	<500	Yearly	2	1	1
	500-3,300	Every 90 days	2	1	1
	3,301-9,999	Every 90 days	2	1	1
Ground water	<500	Yearly	2	1	1
	500-9,999	Yearly	2	1	1

[1]Subpart H refers to systems using surface water or ground water under the direct influence of surface water.
[2]Samples must be taken during the month of highest DBP concentration or highest temperature.

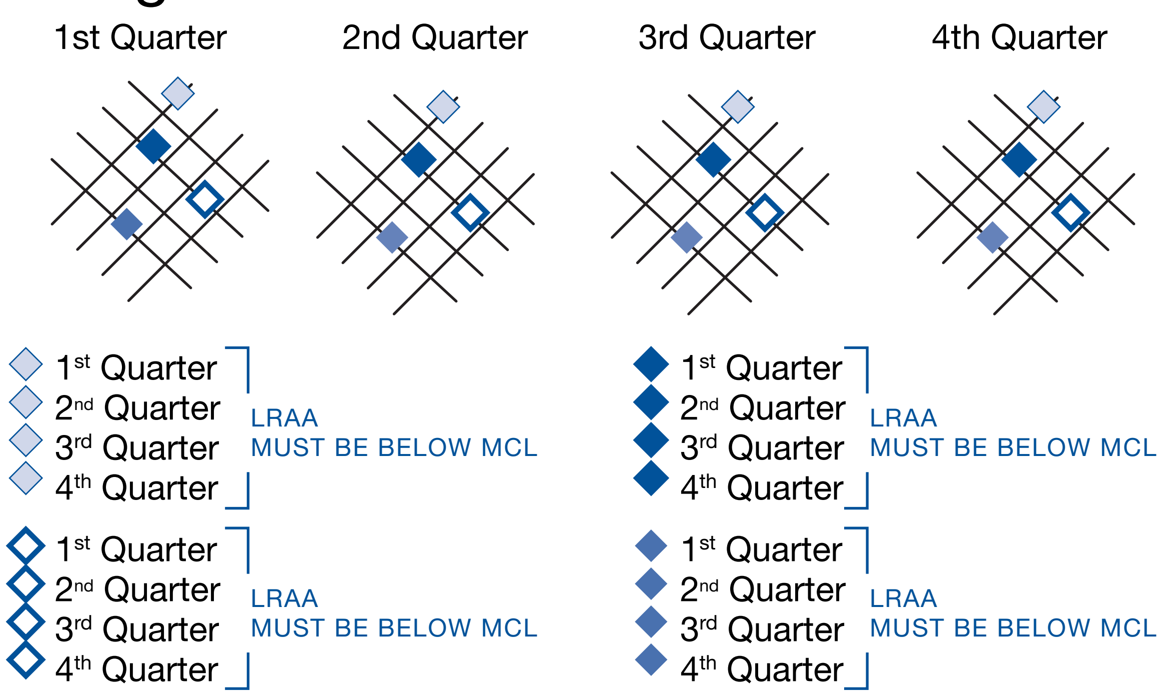
Compliance is based on locational running annual averages (LRAA) instead of running annual averages (RAA). These concepts are illustrated in the following diagrams and example problem.

RCAP

Stage 1 DBPR: RAA



Stage 2 DBPR: LRAA



CHAPTER 2

Example problem: LRAA

A system has recorded the following TTHM (µg/L) concentration from their sampling sites (SS):

	SS #1	SS #2	SS #3	SS #4
Qtr 1	55	75	76	65
Qtr 2	80	83	85	81
Qtr 3	95	102	93	86
Qtr 4	66	70	50	58

1. What is the running annual average (RAA) under the Stage 1 DBP Rule?
2. What is the locational running annual average (LRAA) under the Stage 2 DBP Rule?

A new set of TTHM results is included with the first quarter of the next year. What is the new locational running annual average (LRAA)?

	SS #1	SS #2	SS #3	SS #4
Qtr 1	55	75	76	65
Qtr 2	80	83	85	81
Qtr 3	95	102	93	86
Qtr 4	66	70	50	58
Qtr 1	43	51	54	51

See page 60 for answers.

Many other regulations are in place to ensure that the water delivered to customers is safe and of high quality. Other rules affecting water distribution systems include: Surface Water Treatment Rule, Long-Term 2 Enhanced Surface Water Treatment Rule, Arsenic Rule, and Information Collection Rule. More information can be obtained from your primacy agency.

Chapter 3
Water-quality parameters

Learning objectives:

- Be able to describe how different water-quality parameters affect distribution system operations

Water-quality parameters are important the protection of public health and compliance with regulations. Water quality also has an impact on distribution system operations and aesthetics, such as taste, odor, and color. This chapter discusses several chemical, physical, biological, and operational topics that can affect water quality, and as a result, the health of the people who drink water from your system.

pH

pH is a measurement of hydrogen ion concentration, represented by

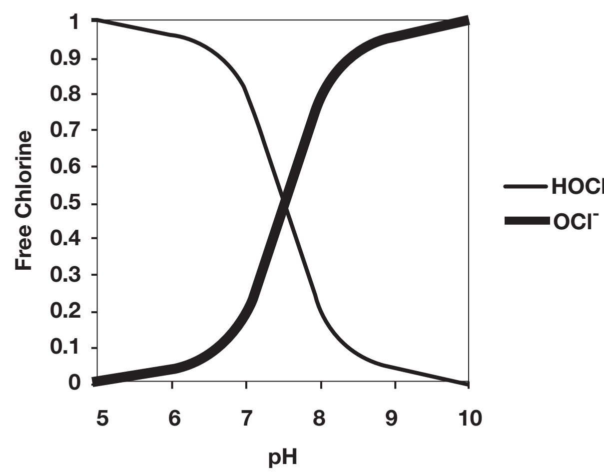
$$[H^+]$$

A higher $[H^+]$ results in a lower pH, which means that the water is more acidic. Conversely, a lower $[H^+]$ results in a higher pH, which means that the water is more basic. pH can range from 0 to 14, with 7 being neutral. Do not confuse pH with alkalinity. Water can have a high pH and still have a low alkalinity. EPA has set a secondary standard for pH to be between 6.5 and 8.5.

Impacts of pH

A pH that is high can precipitate excessive calcium carbonate in the distribution system and eventually restrict water flow in pipes. A pH that is low may corrode water pipes, causing red water issues from iron corrosion; restrict water flow with corrosion byproducts; lead to pipe failure and rupture; and cause lead and copper issues.

The pH also impacts the form that chlorine takes. At lower pH, chlorine in water is in the form of hypochlorous acid (HOCl). At higher pH, it is the form of hypochlorite ion (OCl^-). HOCl is a much better disinfectant, so chlorine is most effective between pH 5.5 and 7.5. On the other hand, chlorine lasts longer at higher pH. pH also has an impact on lead and copper. A higher pH will cause less corrosion and lower lead and copper concentrations.



Therefore, pH is a balancing act. If it's too high you can get deposits in pipes and reduced disinfectant effectiveness. If it's too low, you might see more corrosion, higher lead and copper, and lower chlorine concentrations in the extremes of the distribution system.

CHAPTER 4

Hardness

Hardness is the sum of (mainly) calcium [Ca^{2+}] and magnesium [Mg^{2+}] ions in water. The levels of hardness are described in the table below.

Hardness range (mg/L as $CaCO_3$)	Hardness description
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
> 300	Very hard

In general, surface water is usually softer, with snowmelt being the softest. Ground water is usually harder. Soft water may result in more problems with elevated lead and copper concentrations.

Impact of hardness

Excessive hardness can lead to calcium carbonate precipitation in pipes, which can restrict water flow over time.

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3(s)$$

The precipitation potential will increase with increasing [Ca^{2+}] and increasing pH. Hardness can also lead to the formation of soap scum.

pH and hardness

pH can be adjusted by adding an acid (such as hydrochloric or sulfuric acid) or a base (such as sodium hydroxide or lime). Excessive hardness can be removed by lime ($Ca(OH)_2$) softening through the following reaction:

$$Ca(OH)_2 + 2HCO_3- + Ca^{2+} \rightarrow 2CaCO_{3(s)} + 2H_2O$$

Activity

Discuss the following scenario:

- What would happen if you change water sources from a very hard groundwater to a lower pH, moderately-hard surface water?
- What would happen if the pH in your system changed?

See previous sections for answers.

Chlorine residual

Maintaining a chlorine residual in the distribution system is critical to ensuring that your water is bacteria-free. The maximum chlorine level is limited to 4.0 ppm under the maximum residual disinfectant level (MRDL). Too much chlorine can cause an unpleasant chlorine taste and the formation of excessive disinfection byproduct.

Chlorine decay

Chlorine degrades in the distribution system because of a reaction with natural organic matter (NOM) and/or pipe materials. Booster chlorination may be needed to maintain an adequate chlorine residual. However, rapid decay can be an indicator of a distribution system problem.

Chlorine residual mapping

Chlorine residual mapping is a visual representation of chlorine residual within the distribution system. It helps the operator understand the dynamics of chlorine residual. These dynamics can be a function of changes in weather, operational practices, or source water characteristics. You can produce a map by taking multiple chlorine residual measurements at many locations throughout your system every week for several months. This series of maps will show you how chlorine residual changes with the seasons and operational changes. The maps will also reveal areas of high- or low-chlorine residual.

Nitrification

Nitrification is a bacteria-driven process that converts ammonia to nitrate. It is a two-step process, first converting ammonia to nitrite, then converting nitrite to nitrate. Ammonia can occur naturally or may be added as part of a chloramination process. Chloramination is the intentional addition of ammonia and chlorine to the finished water, resulting in chloramines, which provide long-lasting disinfection and reduce the formation of disinfection byproducts. It is estimated that two-thirds of medium and large systems that chloraminate experience some degree of nitrification. Nitrification rates are affected by pH, temperature, and free ammonia concentration. Nitrification can be controlled through the use of flushing, booster chlorination, breakpoint chlorination (explained later), chlorite addition (chlorite is regulated), or pH adjustment.

Water age

Water age is the residence time of water in the distribution lines before reaching the customers. Depending on your system's configuration and how it is operated, some customers will get water that is older than the water that is delivered to other customers. Water age is affected by the water-production rate, pipeline and storage-tank operations, and water demand. Water demand is usually lower during the cold season when outside watering is reduced. High water age can result in the loss of chlorine residual, an increased risk of bacterial regrowth, increased DBP formation, and a higher chance of contamination. The American Water Works Association (AWWA) recommends a water age of less than seven days.

Activity

- Do you know the typical/average water age of your system?
- Where is your water age the highest?

Temperature

Water temperature can vary daily and seasonally. High water temperature can cause a quicker loss of chlorine residual, faster bacterial regrowth, higher disinfection byproduct formation, and nitrification. At low water temperatures, chlorine is less effective as a disinfectant.

Heterotrophic plate count

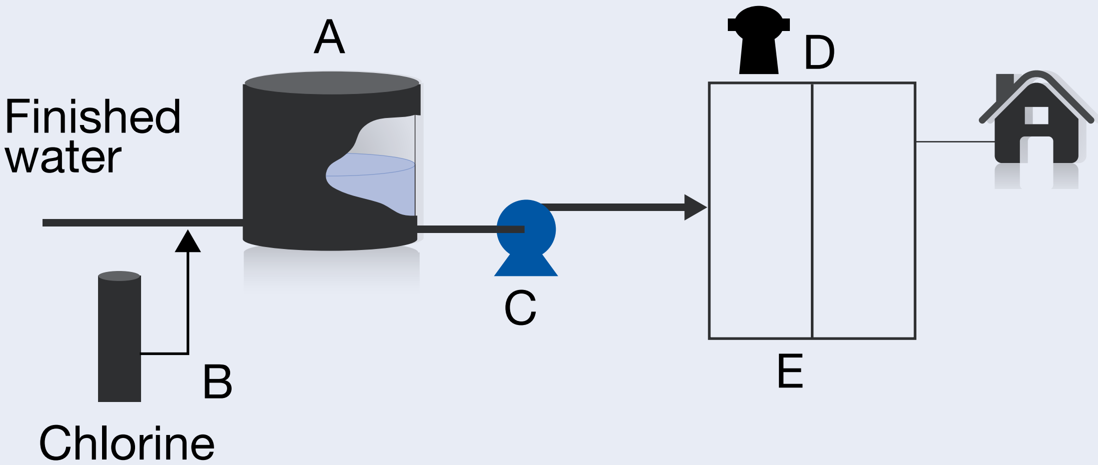
Heterotrophic plate count (HPC) is an estimate of the number of live heterotrophic bacteria in the distribution system. HPC is quantified as the number of colony-forming units (cfu) per mL of water. The presence of a high HPC is mostly associated with a loss of chlorine residual. HPC is a measure of many kinds of bacteria, not just coliform bacteria. HPC is an excellent indicator for nitrification in chloraminated systems. It can also be used to identify causes of low chlorine residual.

Taste and odor

You can have taste and odor issues from operational practices or source water contaminants. Improper dosing of disinfectant can cause a strong chlorine taste and smell. An earthy or musty odor can be the result of algae in the source water. Hydrogen sulfide in the source water can produce a swampy or rotten-egg odor. Taste and odor issues can be symptoms of other problems in the system. For example, excessive chlorine taste may indicate chlorine overfeed. A surge in turbidity or color may be due to flushing of hydrants or firefighting.

Customers can be a valuable source of water-quality information. You should track customer complaints and investigate the origin of each problem.

Activity



Describe how each of the following scenarios numbered below will affect water quality by answering the questions:

- What would be your concern?
- What should you monitor or do?

1. A fire breaks out at Point D
2. A chlorine metering pump breaks down at Point B
3. A booster pump breaks down at Point C
4. There is a main break at Point E
5. You have a rainy week during the summer
6. It's half time at the Super Bowl

Resources

Water Quality & Treatment: A Handbook of Community Water Supplies, 5th Edition, edited by Letterman, R.D. © 1999 McGraw-Hill

Chapter 4
Key distribution system components and their effects on water quality

Learning objectives:

- Be able to describe how components of the distribution system can impact water quality
- Be able to describe potential areas of water-quality concern in your system
- Be able to predict changes in water quality under various scenarios (e.g., change in source water, treatment, distribution-system operations)

Pipe systems are one of the major components of the distribution system that can affect water quality. A dead end in your pipe system can extend water age, which may result in a decay of chlorine residual and increased DBP formation. If there is a line break or other reason to close a valve and isolate the dead end, all customers on the dead end will lose water service. Some of the problems with dead ends can be solved with pipe loops, properly located flushing valves, and a well-designed and implemented flushing program. However, pipe loops are expensive. Flushing valves are moderately expensive and use water. Flushing programs require staff to implement them.

Pipe loops make the distribution system more robust. They allow more than one way for water to get to different points of distribution system. A loop can decrease water age, reduce chlorine decay, and potentially reduce DBP concentrations. The design of new facilities should be evaluated so that new dead ends are not added to the system. Oversized pipes designed for future demand can also result in elevated water age and poor flushing of solids.

The pipe material can also affect water quality. Iron, zinc-galvanized, lead, and copper pipes can corrode, resulting in metals leached into the water. Smooth pipes have less tendency for bacterial regrowth than rough pipes.

Valves are another important component in the system. They are the most commonly operated and widely dispersed components of distribution systems. The main types of valves are:

- pressure-reducing
- flow-control
- isolation
- pressure-regulating
- backflow-prevention
- air-release

Valves are used to isolate parts of the distribution system in case of leaks, maintenance, or water-quality emergencies. They are used to control flow and pressure and release air that can accumulate in high points of the distribution system. Closed valves can create artificial dead ends in the distribution system, resulting in stagnation, increased water age, biofilm development, and sediment build-up. If valves are opened or closed rapidly, water hammer can result.

In order to solve the potential problems with valves, they should be opened and closed slowly, exercised, and kept in the proper opened or closed position.

Cross connections are formed at any point in a water distribution system where chemical, biological, or other contaminants may come into contact with potable water. These contaminants can be drawn or pushed back into the water distribution system during a backflow event. Cross connections are discussed in greater detail later in this section.

The purpose of storage tanks is to improve system hydraulics, accommodate peak flow and fire flow, and buffer treatment needs. Water quality can be affected in storage tanks through:

- stratification
- inlet/outlet configuration
- external contamination
- loss of chlorine residual
- increased water age
- formation of DBPs

Tanks can be designed to prevent or reduce these problems, and existing tanks can be refit.

Common storage-tank problems include:

- finished water storage not covered
- cracks in the walls or storage cover
- access hatches and vents not protected with proper screen or other approved device
- storage facility not structurally sound
- vents do not terminate in a downward direction
- lack of normal maintenance and inspection schedule for storage tanks

The first five problems are equipment issues. The last problem is operational.

Water-quality problems can be corrected in storage tanks by water-level cycling (routine cycling and deep cycling), addition of baffles, change in orientation of inlet/outlet, booster chlorination, and inspection and maintenance. More detailed information can be found in **Section 2: Water Quality and Storage Facilities.**

Hydrants are used for fire protection and flushing. The use of hydrants has the potential to create cross connections; therefore, backflow-prevention devices should be used when appropriate. Hydrants are useful for scouring and cleaning. However, fire fighting can result in unplanned flushing. Hydrants make poor sampling points because water can be trapped in the barrel of the hydrant when closed, resulting in unrepresentative samples.

EPANET is a useful tool to identify vulnerable aspects of a distribution system, such as dead ends, pipe loops, and storage. It is free software that you can use to develop a hydraulic and water-quality model of your distribution system. It can be found at *www.epa.gov/nrmrl/wswrd/dw/epanet.html*

Activity

- Make a list of the three most-pressing water-quality issues (or questions you have about water quality) within your distribution system.
- Discuss their impacts if not addressed.
- How can you address them?

Chapter 5
Overview of disinfection

Learning objectives:

- Be able to discuss the basics of chlorination
- Be able to calculate the required chlorine dose for a given residual target under various operating conditions
- Be able to interpret residual results and adjust chlorine dose

Water is disinfected to kill pathogens, prevent biofilm buildup in the distribution system, and to protect the public from waterborne disease such as viruses, bacteria (e.g., total coliform), and protozoa.

What can happen with a lack of chlorination? One case of what happened in Alamosa, Colo., is explained in the news release below from Nov. 18, 2009, from the Colorado Department of Public Health and Environment.

Final Report on Alamosa Drinking Water Disease Outbreak Released

DENVER – The Colorado Department of Public Health and Environment today released its final report regarding the Salmonella outbreak that struck Alamosa in 2008. The outbreak resulted in hundreds of people in the community becoming ill and had a significant economic impact on the city.

By the time the outbreak subsided, there were 442 reported cases of illness, typically involving vomiting and diarrhea. There was one death associated with the outbreak. Overall, state health experts estimate that up to 1,300 people may have been ill in the town of 8,900. For about three weeks during the outbreak, Alamosa residents were advised to drink bottled water or boil their water, and many businesses temporarily closed.

The health department's final report provides a comprehensive look at the disease outbreak, the response to the outbreak, and the conclusion of the 18-month investigation into how the city's drinking water became contaminated. The investigation involved a detailed review of the water system; historical records; and interviews with city of Alamosa personnel, local health officials and responders to the outbreak.

"We believe the people in Alamosa deserve to know what happened, what was done about it and why it happened," said Ron Falco, Safe Drinking Water program manager in the Water Quality Control Division at the department.

The 65-page report concludes that animal waste most likely contaminated a concrete in-ground water storage tank that had

continued on next page...

Final Report on Alamosa Drinking Water Disease Outbreak Released (continued from page 21)

several holes and cracks. A water sample collected during the outbreak indicated that water in the tank contained bacteria. Additional site visits conducted in 2009 found animal footprints in the snow around the tank, and a photograph in July 2009 captured bird feces on a corner of the tank that was repaired at the time of the outbreak. While these observations were made in 2009, they likely are representative of the animal activity that could have contaminated the water supply in the tank in 2008.

"We cannot say with absolute certainty where the Salmonella came from because the actual contamination event was not directly observed, and probably occurred at least seven to 10 days before the outbreak was reported," Falco acknowledged. "But after weighing all the evidence, we believe that the most likely scenario is that contamination entered this in-ground storage tank."

The city commissioned an inspection of the in-ground storage tank in July 1997 by a professional tank inspection company. That inspection report noted cracking and problems with the corners of the tank, and recommended routine inspections for the future. It appears that the tank continued to deteriorate into 2008. The state did not know of the city's 1997 inspection findings, and its own inspections did not focus on storage tanks and distribution piping.

Alamosa was granted a waiver from state requirements to disinfect its drinking water in 1974, so water being served to the public in Alamosa at the time of the outbreak was not chlorinated. The investigation showed that only a small quantity of bird or animal feces contamination may have led to the salmonella outbreak. This kind of outbreak may have been very difficult to prevent in a system that did not chlorinate its water.

The state is continuing its review of all public drinking water systems with disinfection waivers, and has withdrawn 72 of them since the Alamosa outbreak. "This incident further underscores the long-accepted public health benefits associated with disinfecting drinking water," said Falco. "Chlorine is a highly effective means of destroying bacteria such as Salmonella."

The report also highlights how the department's Safe Drinking Water program historically has had staffing and funding challenges since its inception in the 1970s. Some new staff have been added to the program since the outbreak, but resource problems continue, with few solutions available during the current economic downturn. The Safe Drinking Water program is prioritizing the use of resources to enhance inspections of water storage tanks, escalate enforcement for systems that fail to correct problems found during inspections, and develop training to help water systems optimize storage tank and distribution piping operations and maintenance.

"I was very pleased with the department's response to the Alamosa Salmonella outbreak," said Chief Medical Officer Ned Calonge, interim executive director of the department. "Many, many employees from the department's environmental and public health divisions, as well as additional individuals in other state and local agencies teamed up to assist Alamosa in addressing its crisis as quickly as possible."

Activity

Consider these questions:

- What was the issue(s) that led to the outbreak in Alamosa?
- As an operator, what could have been done to prevent the outbreak?

See page 60 for answers.

Disinfection chemistry

Disinfection can be accomplished with chlorine, chloramines, chlorine dioxide, UV (ultraviolet disinfection), and ozone. Chlorine and chloramines are discussed in this chapter. UV and ozone do not provide residual disinfectant protection in the distribution system.

Chlorine is the most common disinfectant used in the United States. Chlorine comes in different forms, such as chlorine gas ($Cl_{2(g)}$), liquid bleach (sodium hypochlorite – NaOCl), and solid powder (high test hypochlorite (HTH) – $Ca(OCl)_2$). The following equation represents the reaction of chlorine gas in water:

$$Cl_{2(g)} + H_2O \rightarrow HCl + HOCl$$

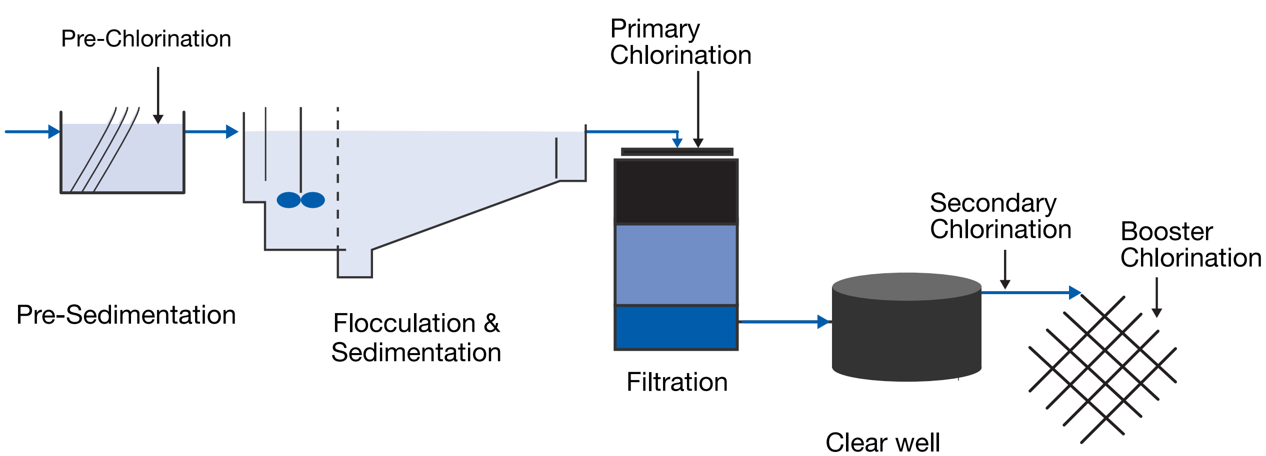
Hypochlorous acid (HOCl) further dissociates to hydrogen ion (H^+) and hypochlorite ion (OCl^-):

$$HOCl \leftrightarrow H^+ + OCl^-$$

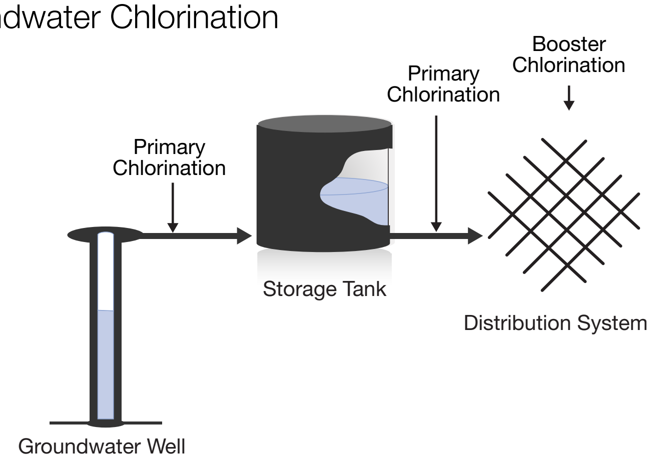
Equilibrium in this reaction is dependent on pH as shown in the graph on page 15. The HOCl concentration is higher at lower pH. The HOCl concentration is equal to OCl^- concentration at a pH of 7.5, and the OCl^- concentration is highest at higher pH. Because hypochlorous acid (HOCl) is a stronger disinfectant than hypochlorite ion (OCl^-), disinfection power decreases with increasing pH.

Chlorination is typically applied as shown in the figures below.

Typical Surface Water Chlorination



Typical Groundwater Chlorination



CHAPTER 5

Because chlorine decays in the distribution system, dosing chlorine within in the distribution system (booster chlorination) may be required to maintain an acceptable chlorine residual at all points in the system.

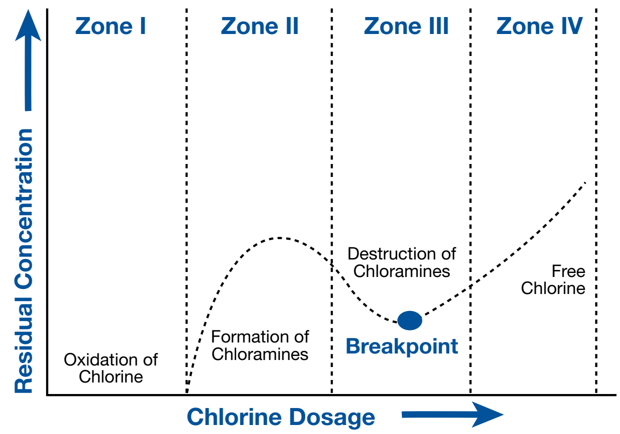
Chloramination occurs when free chlorine reacts with ammonia to form chloramines according to the following reactions:

- $HOCl + NH_3 \rightarrow NH_2Cl + H_2O$ (monochloramine)
- $NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$ (dichloramine)
- $NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$ (trichloramine)

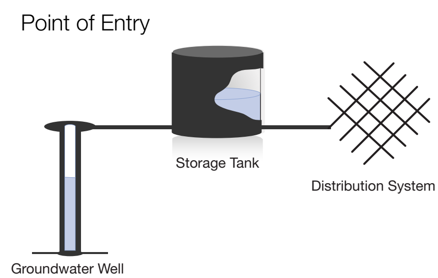
Typically, monochloramine is the dominant species. The sum of free chlorine and chloramines is called total chlorine. Chloramines are weaker disinfectants than free chlorine. Therefore, if chloramines are used, a higher concentration and/or longer contact time are required than chlorine to achieve the same level of disinfection. However, chloramines decay at a slower rate and last longer in the distribution system. Chloramines also produce very little TTHM and HAA5, so many utilities have switched to chloramination to comply with the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). On the down side, ammonia may cause biological growth or nitrification in the distribution system. If done incorrectly, "breakpoint" chlorination may occur, which leads to significant loss of chlorine (free and combined) according to the following equation:

$$2NH_2Cl + HOCl \rightarrow N_2 + 3H^+ + 3Cl^- + H_2O$$

Breakpoint chlorination occurs when the molar ratio of $HOCl:NH_3$ is about 1.5:1 to 2:1. Excess ammonia is usually added to avoid breakpoint chlorination. The figure below shows how breakpoint chlorination progresses as chlorine dosage is increased.



Disinfectant is monitored at the point of entry (as shown in the figure below) and at points within the distribution system.



Residual disinfectant concentration cannot be less that 0.2 mg/L entering the distribution system for more than four hours. According to the rounding rule, 0.15 mg/L is not below 0.2 mg/L, but 0.14 mg/L is. Disinfectant concentration must be monitored continuously for surface water systems and systems using ground water under the direct influence of surface water. The lowest value must be recorded each day. If the continuous monitoring equipment fails, a grab sample must be taken every four hours, but for no more than five working days. Continuous monitoring must be reestablished within five working days.

Residual disinfectant concentration cannot be undetectable in more than 5 percent of samples *within* the distribution system. If more than 5 percent of samples are without detectable chlorine for two consecutive months, a violation is issued. These samples should be taken from the same location and at the same time as total coliform samples required by the Total Coliform Rule.

Activity

Does your system apply chlorination?

- Where is it applied?
- Does your system do booster chlorination?
- What is your target dosage leaving the plant and in the distribution system?

If the disinfectant residual drops below 0.2 mg/L at the entry point to distribution system, call your primacy agency as soon as possible, and not later than the end of the next business day. They will need the following information:

- When did the disinfectant level drop below 0.2 mg/L?
- How long was it below 0.2 mg/L?
- What was the lowest disinfectant level?

If grab sampling is conducted, the system must take a grab sample every four hours until the residual concentration is at least 0.2 mg/L.

Chlorine decays over time in the distribution system. Inadequate Cl_2 residual may enable pathogens to survive or re-grow. It is important to maintain an acceptable residual at all locations at all times. How do you ensure the right dosage is applied? You should:

- measure Cl_2 residual in the distribution system
- store Cl_2 stock properly
- check Cl_2 stock strength regularly
- make sure the metering pump is working properly

Activity

Chlorine dose calculation 1

- What is the initial Cl_2 concentration if:
  - Stock chlorine solution is 10 percent
  - Flow rate is 200 gpm
  - Chlorine feed rate is 2 gph

Useful conversion factors

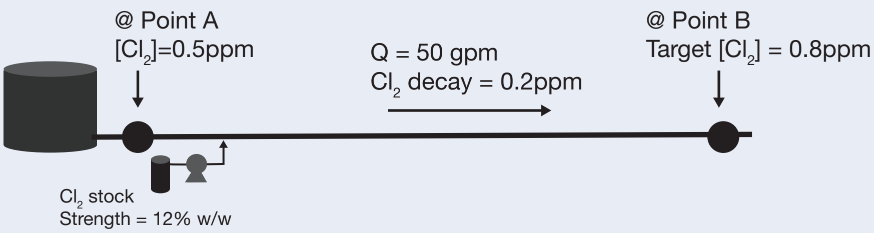
- 12.5% NaOCl = 125,000 ppm = 125,000 mg/L
- 10% NaOCl = 100,000 ppm = 100,000 mg/L
- 1 gallon = 3.78 liters

<u>Determine</u>

1) What is the necessary chlorine feed rate if you wanted an initial chlorine dose of 3 mg/L?
2) How many gallons of chlorine are used per day?
3) Per week

Chlorine dose calculation 2

1) What is the Cl_2 stock strength (in ppm)?
2) What should Cl_2 target be immediately after chlorine boosting (in ppm)?
3) What should the Cl_2 stock flow rate be (in gpd)?



See pages 60-61 for answers.

How to build a chlorine calibration column

Calibration columns provide a simple way to:

- monitor chemical dose rates
- fine tune chemical dose adjustments
- plan chemical deliveries

Measuring flow from the suction side of the pump is the most accurate method.

Concept

- Uses a volume-calibrated column to supply chemical to the metering pump
- Discharge from the column is timed
- Volume is determined from the difference in the start and stop levels of the column
- Chemical flow rate is then calculated as a function of discharge time and discharge volume

Materials needed

- 1/2-inch clear sched 40 (NSF 61-approved) PVC (around 12 inches costs $0.93)
- waterproof marker
- 3 ball valves (NSF 61-approved)
  - Can add more valves for increased access and maintenance
- miscellaneous PVC fittings
- tape measure
- calculator

How to build a column

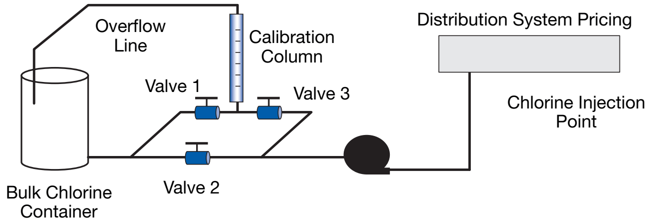
- Determine appropriate-sized PVC to use
  - For chlorine flow < 0.5 gph, use ¼-inch PVC
  - For chlorine flow 0.5 to 1.0 gph, use 3/8-inch PVC
  - For chlorine flow 1.0 to 1.5 gph, use ½-inch PVC
  - If flow < 0.5 gph, consider longer times for calibration
- Determine area of PVC
  - Area = ∏ x radius^2
    - Be sure to use the inner diameter of PVC
- Determine volume per inch of PVC
  - Volume = area x length
- Convert to milliliters
  - 1 inch^3 = 16.4 mL
- Cut approximately 12 inches of PVC
- Mark column at 1-inch intervals with sharpie
  - Use ½ inch and ¼ inch gradations for increased accuracy
- Once column is marked with graduations, write appropriate formulas on opposite side
  - 1-inch length = 0.29 in^3 = 4.76 mL.

    Note that these measurements are specific to this case
  - Gallons per hour (GPH) = [discharge volume (mL) ÷ draw time (sec)] x 0.952
    - Volume per inch (mL) x Number of inches discharged = discharge volume (mL)

Assemble the column

- Column must be located on the suction side of the metering pump
- When possible, place top of column below low level of chlorine tank so column fills hydraulically
- Insert ball valves for flow control at the following locations:
  - main line
  - both sides of the calibration column
  - more can be used as needed for maintenance and servicing
- Install a return line to the top of the tank if column has potential to overflow
- Column must be filled by hand if suction line enters top of bulk chlorine container

Calibration column schematic



- Fill column to desired level (by opening valve 1)
- Close valve 1 and 2, open valve 3
- At the same time you open valve 3, start a stop watch
- Allow 30 seconds to elapse
- Close valve
- Close valve 3, open valve 2 (valve 1 is already closed)
- Determine flow as per the formulas on the column

Calibration column example

- You begin a calibration when the initial reading of the column is 9.5 inches
- After 30 seconds the column reads 6.25 inches
- What is the chlorine feed rate in gallons per hour (GPH)?

Answer:

- Discharge volume = 3.25 inches
- 1 inch = 4.76 mL
  - 3.25 x 4.76 mL /inch = 15.47 ml
- GPH = [discharge volume (mL) ÷ draw time (sec)] x 0.952
- GPH = [15.47 mL ÷ 30 sec] x 0.952
- Feed rate = 0.5 GPH

Chapter 6
Disinfecting new pipe

Learning objectives:

- Be able to describe the steps for disinfecting new pipes

New water mains and those taken out of service should be disinfected before returning to service. For the detailed procedures and requirements see AWWA Standard C651-05 – Disinfecting Water Mains (standards are available on the AWWA website at *www.awwa.org* for purchase by AWWA members and non-members).

The following four-step process can ensure the lines have been properly disinfected prior to being placed into service.

1. Flush the line to remove any particulates
   - More effective than burning with chlorine
   - Velocity should be greater than 2.5 fps
   - Flush at least 2 times the volume of the pipe
2. Chlorinate
   - Should target a dose of 50 mg/L
   - A 5 mg/L residual should remain after 24 hours
   - A higher chlorine dose can be used in exchange for a shorter contact time
   - Do not use dry chlorine (HTH) as granules may not fully dissolve
3. Flush to remove chlorinated water (minimum of two full pipe volumes)
   - Chlorinated water must be dechlorinated prior to discharge
4. Refill the line and perform coliform sampling
   - If results are negative, the line is ready to be returned to service.
   - If results are positive, repeat from step 2.
   - If positive results continue, pigging or additional flushing may be necessary.

This four-step process can typically be accomplished for new pipes or routine repairs but is usually not an option for emergency repairs. As an alternative, you should maintain a minimal distribution system residual of 0.5 to 1.0 mg/L and increase the frequency of coliform sampling.

Activity

What do you do when you have a main break? Compare your standard operating procedures to those in Chapter 9.

Math exercise

- In a 12-inch diameter pipe, what flow rate is necessary to create a flushing velocity of 2.5 fps?
- What is the volume if the pipe is 150 feet long?
- How long should pipe be flushed to remove two full volumes?

See page 62 for answers.

Chapter 7
Monitoring to protect distribution system water quality

Learning objectives:

- Be able to describe how monitoring protects water quality

The Colorado Department of Public Health and Environment determined that 59 percent of the state's water systems had a monitoring violation between 2006 and 2008.

Monitoring is important because it can be used to:

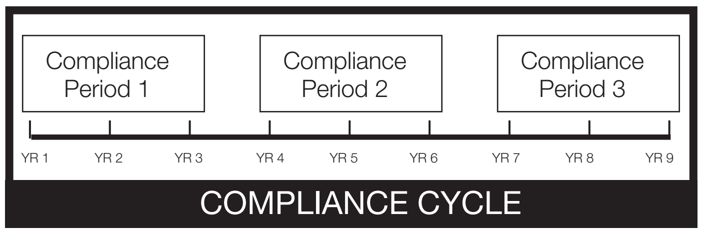
- identify issues before they become problematic
- verify that systems are working
- provide a last line of defense
- meet or exceed regulatory compliance

You must develop a monitoring plan based on the sampling schedule provided by your primacy agency. The frequency of each component is specific to your system. It is a good practice to monitor early in the week and early in the compliance period.

Sampling frequency can vary depending on the regulations. Initial monitoring starts when a new rule takes effect. Routine monitoring follows upon completion of initial monitoring and continues for the life of the rule. Increased monitoring may be required if concentrations exceed trigger levels. With some rules, reduced monitoring can be implemented if concentrations remain lower than the trigger value and if approved by the primacy agency. In special cases, special monitoring may be required.

In the regulations, a compliance cycle repeats every nine years starting in 1993.

There are three three-year compliance periods per compliance cycle.



Sampling locations are specified in your primacy agency's regulations. Some samples must be taken at the point of entry (POE), which is before the first customer. Others must be taken at representative sample sites, and others must be taken at the extremes of the distribution system.

In order to develop a coliform monitoring plan, you should know the minimum samples as required by the TCR and plan for more. The sampling sites should represent the range of water qualities in the distribution system. Be sure to include:

- water mains, branches, and dead ends
- locations where water mixes or where there is an interface between multiple sources
- locations of storage facilities
- locations of booster disinfections
- locations of critical facilities (e.g., hospitals)

The monitoring-plan template provided in Colorado is included at the end of this chapter. Your state may have a similar template.

Activity

Develop a coliform monitoring plan

- How many samples does your system currently collect?
- How were the sampling locations selected?
- If you plan to collect more samples, where will you collect them?

Chapter 8
Coliform sampling–best practices

Learning objectives:

- Be able to describe the importance of correct coliform sampling techniques
- Be able to describe the correct coliform sampling techniques and avoid faulty practices
- Be able to select appropriate taps for sampling

Collecting coliform samples correctly and properly is critical in protecting public health. Improper sampling is the most common reason for positive results (false positive). Repeated sampling requires extra effort, time, and money, and may lead to unnecessary MCL violations and subsequent corrective measures. Coliform bacteria can be found in the digestive tracts of animals and in their feces. They are found in soil, sediments, biofilms, untreated water, and on your hands. Samples can easily be contaminated from these sources.

Sample taps should *not* be:

- outdoors
- too close to the bottom of the sink
- swivel-type, with a single valve for both hot and cold water
- leaking or on a leaky pipe
- threaded in the interior
- upward flowing
- located in a room of questionable sanitary conditions
- attached to any household point-of-entry or point-of-use devices
- a faucet with an aerator that cannot be removed
- drinking fountains

Hot water is undesirable for sampling because bacteria can grow in the heater and contaminate samples. There is a high risk of contamination from water that has bounced off the ground or a dirty sink into the sampling container. Outside faucets have a high risk of external contamination (e.g., animals, weather).

The following 13 steps should be used when collecting coliform samples.

STEP 1

Assemble supplies.

- 125 mL *sterilized* plastic bottle
- dechlorination agent (do not rinse out bottle)
- label and lab form (chain of custody form)
- Wash hands thoroughly

STEP 2

Go to location(s) in sampling plan.

At the sample tap, be sure:

- Tap should be clean, in good repair, and free of attachments.
- Sample cold water only. Use valves that control hot and cold independently. (Do not use single-lever valves. Water heaters can be laden with bacteria.)
- Use a line directly connected to the main.
- Sample indoors, when possible.

STEP 3

Remove aerator, strainer, or hose.

- Those items can trap sediment or particulates.
- Biofilms can form in a hose.

STEP 4

Open cold water for 2 to 3 minutes.

- You want to get water that is representative of conditions in the water main.
- A good guide is to wait until the temperature stabilizes.
- Chlorine residual is an even better indicator that you are sampling water in the main, not just in the building.

STEP 5

Fill out label, tag, and lab form.

- in waterproof ink
- Write clearly.

STEP 6

Adjust flow to width of a pencil.

- You want a steady, controlled flow.
- Don't change the flow once you start sampling (this could dislodge microbial growth).

STEP 7

Remove the bottle cap.

- Be careful not to touch the inside of the bottle or bottle cap.
- Do not lay the cap down or put it in your pocket.
- Remember to keep things STERILE, STERILE, STERILE!!!

STEP 8

Fill bottle to the shoulder (or about ¼ inch from the top).

- Don't rinse the bottle.

STEP 9

Place cap on bottle and screw it down tightly.

- Again, think STERILE!

STEP 10

Turn the tap off and replace the aerator, strainer, or hose.

STEP 11

Check the information on the label.

STEP 12

Complete any additional lab forms.

- Fill out the chain-of-custody form.
- Make sure to write clearly in water proof ink.

STEP 13

Ice the sample and send to lab for processing within 30 hours.

- Refrigeration is recommended; fill the cooler with blue ice.
- The quicker your sample gets to the lab, the better.
- Use a certified laboratory for sample analysis.

Helpful hints

- Sample early in the week or month.
- If you feel something went wrong, resample.
  - Bottles are cheap, but false positive samples are not.

The operator is responsible for getting the results to the primacy agency. A failure-to-monitor violation occurs if no sample was taken or if the sample was taken but not reported. If a failure-to-monitor violation occurs, public notice and other measures will be required.

Resources

- A Small Systems Guide to the Total Coliform Rule: *www.epa.gov/ogwdw/disinfection/tcr/pdfs/small-tcr.pdf*

Chapter 9 Main breaks and their effects on water quality

Learning objectives:

- Be able to preserve water quality when responding to a water-main break
- Describe the difference between proactive and reactive responses

Main breaks happen because of aging infrastructure, frost load, pressure surge, mechanical damage, and vandalism. Aging infrastructure is often the underlying cause for main breaks. AWWA has noted "a significant water line bursts on average every two minutes somewhere in the country," and "$334.8 billion will be needed for pipe, treatment, storage, source, and other infrastructure over the 20-year period 2007-2026." The Water Research Foundation data showed that 0.5 percent of the distribution system piping is replaced each year. At that rate, it needs to have a 200-year life.

The consequences of main breaks are often safety hazards, flooding of the surrounding area, property damage, and traffic interruptions. In addition, customers will experience an interruption of water service, and the system will lose valuable finished water. High flows can cause high-velocity scouring of pipes, which may dislodge sediments and increase turbidity. A loss of pressure can allow contaminant intrusion and may require a bottled-water or boil-water order.

A protocol should be developed to respond to main breaks and limit adverse water-quality effects. The procedure should include measures to maintain positive pressure in the system (if possible), investigation of the location and extent of the break, notification of staff necessary for repair, public notification, notification of the primacy agency, flushing, disinfection, coliform sampling, and returning the main to service.

Long-term asset management is a proactive approach that can reduce costs and protect water quality. Buried pipes are the most costly assets of most water utilities, and the rate of pipe failure is greater than the pipe-renewal rate in most utilities. Therefore, setting priorities for main replacement and inclusion in a capital-improvement plan will save money in the long run and minimize threats to public health. EPA's Check Up Program for Small Systems (CUPSS) or another asset-management program can be used to plan the replacement of mains. Asset management is discussed later in this section.

Activity
Responding to a main break

You have a main break in your system

- Generate a list for responding, protecting public health, and restoring service.
- Put in order and prioritize.
- If you have a main break response protocol already in place, review it and suggest changes.

RCAP

Chapter 10
Cross-connection control

Learning objectives:

- Be able to describe what a cross connection is and recognize one
- Be able to describe the importance of cross-connection control
- Describe requirements for cross-connection control
- Be able to outline the emergency response in the event of a backflow

A cross connection is any point in a water distribution system where chemical, biological, or other contaminants may come into contact with potable water. Contaminants can be drawn or pushed back into the water distribution system during a backflow event. Cross connections are a dynamic problem because plumbing systems are constantly being installed, altered, and extended. In 2000, the Water Research Foundation (formerly AwwaRF) found that “over 100,000 new cross connections are formed each day.” They also stated that cross connections and backflow events are “the greatest contributing factor to waterborne disease outbreaks in the U.S.”

Contaminants can enter the distribution system through two mechanisms. Backsiphonage occurs when a negative or reduced pressure occurs in the supply piping, sucking non-potable fluids into the distribution system. The low pressure can be caused by a line break, fire flow, or improperly operated booster pumps. The other mechanism is backpressure. A backpressure condition exists when a non-potable system, connected to the potable system, is working under a higher pressure than the potable system. Without a backflow-prevention device in place, non-potable water will be forced into the potable system. Common examples of backsiphonage include lawn chemicals backflowing through a garden hose into indoor plumbing and potentially into the distribution system; “blue water” from a toilet flowing into a building’s water supply; and chemicals from industrial processes flowing into distribution-system mains. Backpressure examples include carbonated water from a restaurant’s soda dispenser entering a water system and backflow of a boiler’s corrosion-control chemicals into an office building’s water supply.

Blisters in Alabama

An Alabama business was once the source of backflow contamination. A tank of sodium hydroxide was being filled from the bottom through a fire hydrant. A water main broke while water was being added to the tank. As a result, the pressure dropped in the water main so that the head was below the level in the chemical tank and sodium hydroxide flowed into the 8-inch water main. People taking showers received skin blisters. A repair person working on the main was also burned. Many people went to the emergency room to be treated for chemical burns. In order to clean up the contamination, the water system had to be shut down and flushed. Customers lost confidence in their water system, and the system was issued numerous violations and fined.

Chemical contamination in Maryland

Paraquat, an herbicide, was being stored in an elevated storage tank that had a connection to the town's water system. The valve connecting the tank to the water system had been left open. A pump failed in the town's water system, temporarily reducing the pressure in the system. When the head in the system dropped below the water level in the tank, the herbicide mixture entered the distribution system. The contamination was not detected, and when the pressure was restored, the herbicide spread throughout the system. The state put a ban on drinking the water, and it became a major news story. Fortunately, no one was injured.

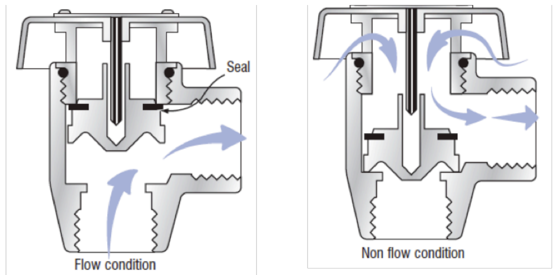
Propane gas in the water lines in Connecticut

Propane was being purged from a large storage tank using a fire hydrant connection. The pressure in the distribution system was 65 psi. The pressure in the propane tank increased to over 90 psi and pushed propane into the distribution system. Hundreds of people were evacuated and two houses burned.

These and more case studies can be found in the EPA Cross-Connection Control Manual listed in the Resources section the end of this chapter.

Cross-connection control devices – in order of increasing protection:

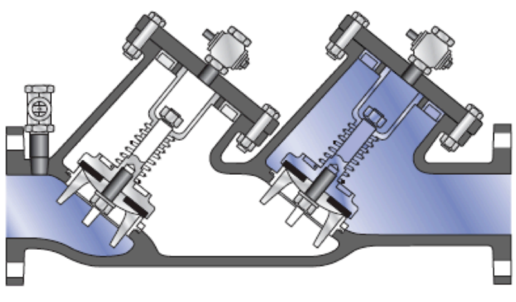
Atmospheric vacuum breaker



Not designed to protect against back pressure conditions

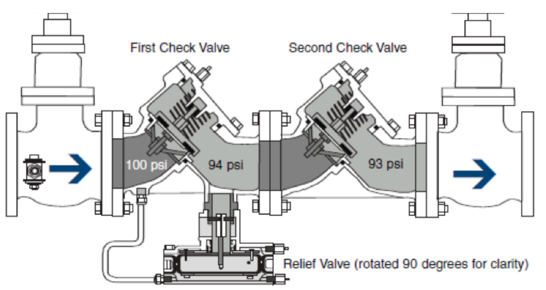
USEPA, Cross Connection Control Manual

Double check valve



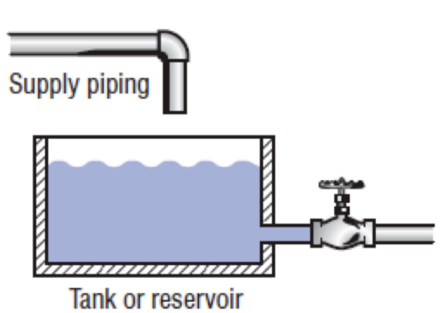
USEPA, Cross Connection Control Manual

Reduced pressure principle backflow preventer



USEPA, Cross Connection Control Manual

Air gap



USEPA, Cross Connection Control Manual

An air gap should be two pipe diameters above the top of the tank.

Systems are required to identify potential hazardous cross connections, and they must require the system's users to install and maintain containment devices on any cross connections. Containment devices should be approved by the system. All containment devices should be tested and maintained at least annually thereafter by a certified cross-connection control technician.

For more information see the *EPA's Cross-Connection Control Manual*.

Activity

Cross-connection control

Rank potential cross-connection hazard levels:

You want to protect the public's health by ensuring that every connection to your water system has the appropriate backflow device. In doing that, you have to balance the public's health against the desire by everyone not to pay for more protection than is required. Using the letters for the three possible levels of hazard, indicate for each location in the table below (all are in the same town) its level.

Level of hazard:

H: High—toxic; serious health affects all the way up to death

L: Low—non-toxic; pollutants affecting odor, taste, or aesthetics that do not impact human health

N: None—no possible present or future risk of contamination

Customer type	Ranking
Private residence	
Gas station/convenience store	
Private residence (home business artist)	
Car wash (4 stalls)	
Duplex rental	
Grocery store (water boiler heat)	
Private residence (the mayor's house)	
Hardware store	
Church (2-story with beautiful windows)	
Mortuary	
Ice cream shop/dairy products	
City park (bathroom and sprinklers)	
City pool	
RV park	
Farm supply store	
Family-style restaurant	

See page 62 for answers.

Choose the right BPD to match potential hazards:

The following businesses and potential water-contaminant sources have been determined to be connected to your water system. As a public water purveyor, you can strictly adhere to the regulations, or allow for devices that provide less protection. What devices will you require or approve? Using the device abbreviation, indicate next to each customer what device it should use.

Device abbreviation	Device
AG	Air gap
AVB	Atmospheric vacuum breaker
DCV	Double check valve
RPP	Reduced pressure principal
NA	None

Customer	What type will you require?
Agricultural spraying service that uses pesticides, herbicides and fertilizers	
Customer with a private well for lawn sprinkling that is connected to the public water system	
Customer with fire-suppression system that can connect to an unapproved auxiliary water supply	
RV park with freeze hydrants used to supply water for campers	
Residential customer with a hot tub that is not directly connected to the public water supply	
A wastewater treatment plant with direct connection to the public water system	
A customer that handles hazardous substances that may enter the public water system (mortuary)	
A customer that uses reclaimed water with no direct connection to the public water system (city park)	

How do you educate the public on the need for a BPD on their connection?

See page 62 for answers.

What to do in case of a backflow event:

1. Stop the pressure differential that caused the backflow of contaminants, if possible.
2. Identify and remove the cross connections.
3. Contact your primacy agency.
4. If harmful contaminants are suspected, provide immediate notice to the affected customers.
5. Develop and carry out a plan for systematic flushing of the system.
6. Continue to sample within and outside the suspected contaminated area.

Resources

EPA's Cross-Connection Control Manual at *www.epa.gov/safewater/crossconnectioncontrol/pdfs/crossconnection.pdf*

EPA's Cross-Connection Control: A Best Practices Guide at *www.epa.gov/safewater/smallsystems/pdfs/guide_smallsystems_crossconnectioncontrol.pdf*

Chapter 11
Pressure

Learning objectives:

- Be able to identify the causes of high or low pressure
- Be able to describe performance indicators of proper pressure
- Be able to describe the procedures in the event of a pressure loss
- Prepare a generic outline for reacting to pressure loss

Pressure should be maintained at a minimum of 20 psi at any point in the distribution system during all flow conditions. Pressures of less than 20 psi may lead to contamination entering the distribution system through cracks in pipes or cross connections as well as customer complaints due to low flow. Between 40 and 60 psi is a good target range. Avoid pressures above 70 psi to prevent breaks and leaks. Pressure at any point in the distribution system will vary due to main breaks, fire flow, seasonal uses, and high or low demand.

Here are some useful performance indicators of proper pressure in your system

- above 35 psi under normal conditions
- less than 100 psi under normal conditions
- above 20 psi under maximum day-demand and fire-flow conditions
- Above 0 psi during emergencies such as main breaks and power outages
- Maintain pressures within ± 10 psi of average pressures greater than 95 percent of the time.

A pressure-grading system can be used to track the performance of your system. It may be impossible to limit pressures within ± 10 psi at all locations in all pressure zones, especially for large systems. The following "grade scale" is proposed:

A	System able to maintain pressures within ± 10 psi of average pressures greater than 95 percent of the time
B	System able to maintain pressures within ± 15 psi of average pressures greater than 95 percent of the time
C	System able to maintain pressures within ± 20 psi of average pressures greater than 95 percent of the time
D	System able to maintain pressures within ± 25 psi of average pressures greater than 95 percent of the time
F	System has sustained pressure fluctuations of greater than 25 psi of average pressures more than 5 percent of the time

The pressures in your system should be measured at two key locations in each pressure zone. These locations should be representative of areas of high and low pressure in each zone and located as far away from pump stations and elevated storage tanks as possible. Ideally, utilities would permanently install pressure loggers at critical locations, but an adequate characterization can be made by collecting hourly data for a minimum of four days.

Water-main breaks are a common cause of pressure loss. Low pressures can also result from a loss of power or pump failure, closing a valve for pipe repair, high demand in one area of the system, or water demands for fire fighting.

Activity

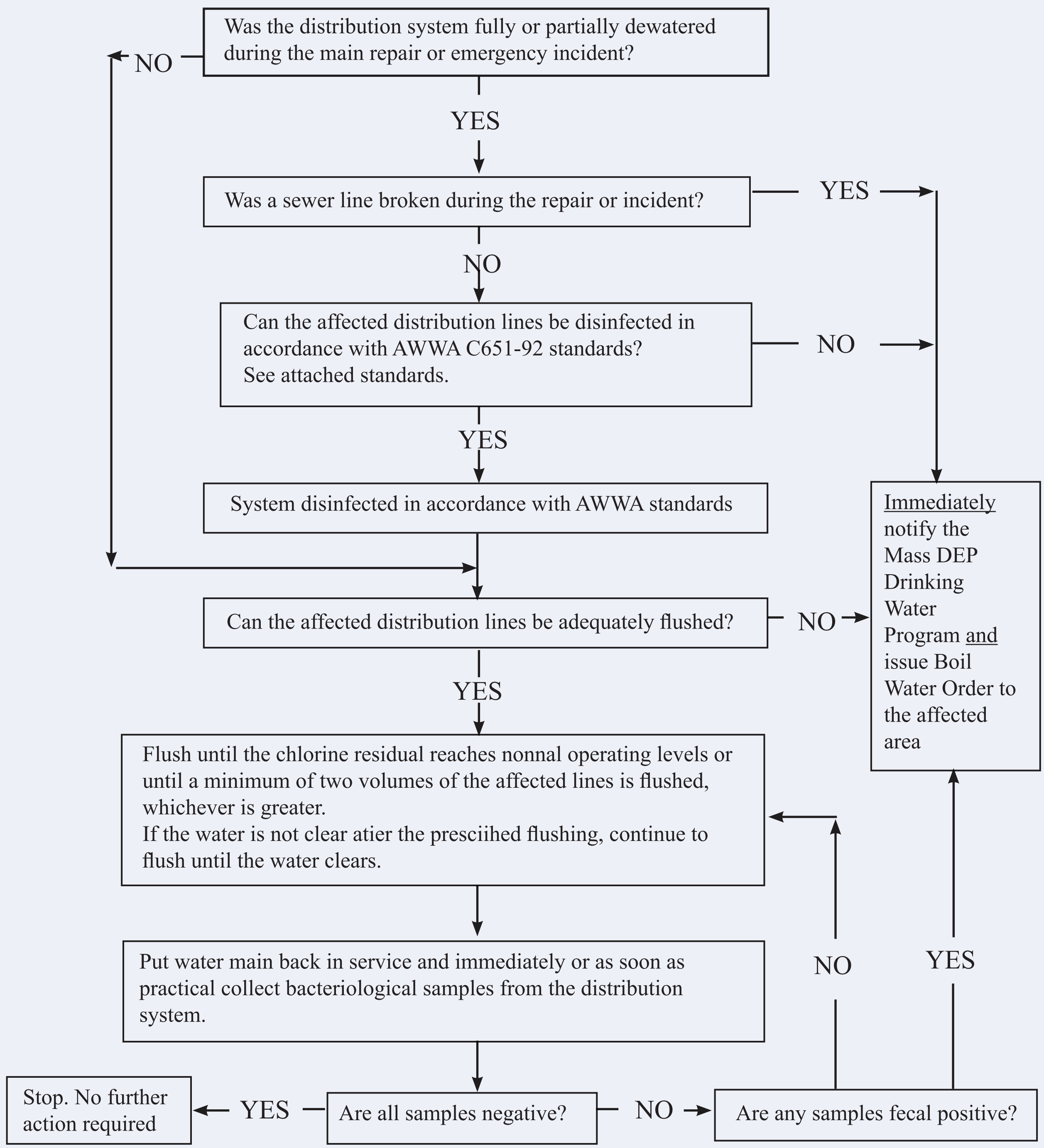
Develop an emergency-response plan for reacting to water loss

- Write down the steps that you would take after noticing a pressure loss
- Review the following handouts from Massachusetts and Washington (starting on following page)

MASSDEP DRINKING WATER PROGRAM

Sometimes a public water system may lose pressure as a result of a main repair or accident. The following flow chart may be useful in determining the appropriate steps.

PUBLIC WATER SYSTEM RESPONSE TO LOSS OF PRESSURE TO ALL OR PART OF THE DISTRIBUTION SYSTEM



MASSDEP DRINKING WATER PROGRAM

Excerpt from AWWA Standard ANSI/AWWA C651-92
for
Disinfecting Water Mains

Section 10: disinfection procedures when cutting into or repairing existing mains

---

The following procedures apply primarily when existing mains are wholly or partially dewatered. After the appropriate procedures have been completed, the existing main may be returned to service prior to completion of bacteriological testing in order to minimize the time customers are out of water. Leaks or breaks that are repaired with clamping devices while the mains remain full of pressurized water presents little danger of contamination and require no disinfection.

SEC. 10.1 TRENCH TREATMENT

When an existing main is opened, either by accident or by design, the excavation will likely be wet and may be badly contaminated from nearby sewers. Liberal quantities of hypochlorite applied to open trench areas will lessen the danger from such pollution. Tablets have the advantage in such a situation because they dissolve slowly and continue to release hypochlorite as water is pumped from the excavation.

SEC. 10.2 SWABBING WITH HYPOCHLORITE SOLUTION

The interior of all pipe and fittings (particularly couplings and sleeves) used in making the repair shall be swabbed or sprayed with a 1 percent hypochlorite solution before they are installed.

SEC. 10.3 FLUSHING

Thorough flushing is the most practical means of removing contamination introduced during repairs. If valve and hydrant locations permit, flushing toward the work location from both directions is recommended. Flushing shall be started as soon as the repairs are completed and shall be continued until discolored water is eliminated.

SEC. 10.4 SLUG CHLORINATION

When practical, in addition to the procedures above, the section of main in which the break is located shall be isolated, all service connections shut off, and the section flushed and chlorinated as described in Sec. 5.3, except that the dose may be increased to as much as 300 mg/l and the contact time reduced to as little as 15 min. After chlorination, flushing shall be resumed and continued until discolored water is eliminated, and the water is free of noticeable chlorine odor.

SEC. 10.5 SAMPLING

Bacteriological samples shall be taken after repairs are completed to provide a record for determining the procedure's effectiveness. If the direction of flow is unknown, then samples shall be taken on each side of the main break. If positive bacteriological samples are recorded, then the situation shall be evaluated by the public water supplier (or public water supplier's representative) who can determine corrective action, and daily sampling shall be continued until two consecutive negative samples are recorded.

April 2006
DOH PUB. #331-338

Questions & Answers

Responding to Pressure-Loss Events

What is a pressure-loss event and what causes it?

A pressure-loss event occurs when pressure in the water distribution system drops significantly below normal. These events may be planned or unplanned. For example, system operators may plan to reduce pressure when they install, replace or repair water lines. Unplanned pressure loss can be caused by broken water mains, a failed pumping system, power outages, leaking storage reservoirs and excessive demand.

Should I be concerned about pressure loss events in my water system?

Yes. Pressure loss can be a serious threat to public health. A reduction or loss of pressure in the distribution system can result in backflow, allowing contaminants to enter drinking water through unprotected cross-connections. Backflow is a reverse of normal water flow due to back pressure or back siphonage that occurs when the pressure of a polluted source exceeds the pressure in the distribution system. Backflow incidents have caused illness, injury and, in some cases, death.

How can I prevent backflow?

The best way to prevent backflow is by developing and implementing a cross-connection control program. For guidance see Department of Health Office of Drinking Water's (ODW) ***Cross Connection Control for Small Water Systems*** (331-234).*

What should I do if a pressure loss event occurs?

Immediately take the following steps to ensure the safety of your customers:

1. **Find the cause of the problem and restore pressure.** Your first priority is restoring water pressure and maintaining the ability to fight fires.
2. **Call your ODW regional office.** Phone numbers are on page 2. We will help you determine if a health advisory is needed. For guidance on health advisories see ODW's ***Coliform Public Health Advisory Packet*** (331-260) or ***Nitrate Public Health Advisory Packet*** (331-259).*
3. **Flush the lines.** Customers face greater risk of consuming contaminated drinking water after a pressure-loss event. Flush the lines to reduce the risk and cleanse the system of contaminants. Follow general industry standards for flushing the system.
4. **Disinfect the system.** Disinfection is a preventive measure to protect the water system. However, you must notify your customers first. For guidance see ODW's ***Emergency Disinfection of Small Systems*** (331-242).*
5. **Collect Samples.** After you restore normal operating pressure, check the quality of the water.

Washington State Department of Health
Division of Environmental Health
Office of Drinking Water
HELPING TO ENSURE SAFE AND RELIABLE DRINKING WATER

How do I know if backflow occurred?

Most pressure-loss events are obvious; however, there are times when you may not know an event occurred. These events can be a serious threat to public health because of the ever-present link to possible contamination through a cross-connection.

Indications of a backflow incident include:

- **Discolored or unusual looking water.** Investigate any abnormal appearances of water, such as an unusual color, or soapy, foamy or oily water. Discolored water can also be caused by increased flows in pipes or changes in normal pipe flows that disturb sediments in the distribution system. Investigate all reports of colored water.
- **Inconsistent chlorine residuals throughout the distribution system.** Chlorine in the distribution system reacts with many different substances, including possible backflow contaminants. Low or zero chlorine residuals in the distribution system following a loss of pressure event could be a sign that chlorine is reacting with substances not normally found.
- **Taste and odor complaints.** If there are taste and odor complaints after a low pressure event, evaluate the nature of the complaints and call ODW for technical assistance. Detectable differences in taste and odor could indicate a backflow incident occurred. The human nose and taste buds are extremely sensitive and can detect some contaminants in water at extremely low concentrations.

For more information

Call the nearest ODW regional office:

Eastern Region (509) 456-3115
Northwest Region (253) 395-6750
Southwest Region (360) 664-0768

* ODW publications are online at http://www4.doh.wa.gov/dw/publications/publications.cfm

DRINKING WATER WARNING

(System name) ____

BOIL YOUR WATER BEFORE USING

We had a line break on (date) ________________ which resulted in a significant loss of pressure in the drinking water system.

What does this mean? What should I do?

- ✓ **DO NOT DRINK THE WATER WITHOUT BOILING IT FIRST.** Bring all water to a boil, let it boil for three (3) minutes, and let it cool before using, or use bottled water. Boiled or bottled water should be used for drinking, making ice, brushing teeth, washing dishes, and food preparation until further notice. Boiling kills bacteria and other organisms in the water.
- ✓ Water main breaks resulting in a loss of system pressure can introduce disease-causing organisms into the water system. These organisms include bacteria, viruses, and parasites, which can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. The symptoms above are not caused only by organisms in drinking water. If you experience any of these symptoms and they persist, you may want to seek medical advice.
- ✓ People with severely compromised immune systems, infants, and some elderly may be at increased risk. These people should seek advice from their health care providers about drinking water.

What happened? What is being done?

(Describe corrective action)

____

____

____

We will inform you when tests show no bacteria and you no longer need to boil your water. We anticipate resolving the problem within (estimated time frame) ____________________. For more information, please contact (name of contact) _______________________________________ at (phone number) __________________ or (mailing address) ________________________________. General guidelines on ways to lessen the risk of infection by microbes are available from the EPA Safe Drinking Water Hotline at 1(800) 426-4791.

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

This notice is being sent to you by (system name) ____
Colorado Public Water System ID#: ____________ Date distributed: __________________________

DRINKING WATER WARNING

(system name) ______________________________

USE BOTTLED WATER

What should I do?

- ✓ **DO NOT DRINK THE WATER FROM THE TAP.** Bottled water should be used for drinking, making ice, washing dishes, brushing teeth and food preparation until further notice.

- ✓ **DO NOT BOIL THE WATER.** The water may contain high levels of nitrate. Boiling, freezing, filtering or letting water stand does not reduce the nitrate level. Excessive boiling can make the nitrate more concentrated. DO NOT GIVE THE WATER TO INFANTS. Infants below the age of six months who drink water containing too much nitrate could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome (blueness of the skin). If symptoms occur, seek medical attention immediately.

- ✓ The water may contain bacteria or other disease-causing organisms such as viruses and parasites, which can cause short-term effects, such as nausea, cramps, diarrhea and associated headaches. People with severely compromised immune systems, infants, and some elderly may be at increased risk. The symptoms above are not caused only by organisms in drinking water. If you experience any of these symptoms and they persist, you may want to seek medical advice.

What happened? What is being done?

(Describe what happened and corrective action)

____

____

____

We anticipate resolving the problem within (estimated time frame) ______________. For more information, please contact (contact name) ________________________ at (phone number) __________ or (address) ________________________. General guidelines on ways to lessen the risk of infection by microbes are available from the EPA Safe Drinking Water Hotline at 1(800) 426-4791.

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

This notice is being sent to you by (system name) ______________________________
Colorado Public Water System ID#: _________ Date distributed: ____________________

Chapter 12
How to implement an effective flushing program

Learning objectives:

- Be able to describe the importance of flushing
- Prepare a simple checklist for flushing a hydrant
- Identify the components in developing a flushing program

Flushing has generally been established as a corrective measure for removing contamination from the piping in a distribution system. However, it can be implemented as a proactive method to maintain high-quality water. Flushing is considered a best management practice by AWWA.

The main reasons to flush are to respond to customer complaints, expel contaminants following a backflow episode, remove sediment and loose deposits, and decrease water age in dead-end mains.

Activity

Flushing programs

- Do you have an active flushing program?
- What are your triggers for flushing?

A four-step program for flushing

STEP 1

Determine the appropriateness of flushing as part of a utility-maintenance program.

Questions to ask:

- Do you use unfiltered surface water?
- Do you use an undisinfected groundwater supply?
- Do you use a source of supply with elevated iron and/or manganese?
- Do you experience positive coliform or elevated levels of HPCs?
- Do you use chloramination?
- Have you implemented a treatment change that could affect water quality?
- Do you experience frequent customer complaints?
- Do you have difficulty maintaining a disinfectant residual in parts of the distribution system?
- Does your system lack an aggressive valve/hydrant exercise program?
- Is the water entering the distribution system considered to be corrosive?
- Does sediment accumulate in your storage facilities?

CHAPTER 12

If you answered yes to any of these questions, then a flushing program will provide water-quality improvements. If you did not answer yes to any of the questions, other maintenance procedures may be more advantageous for your system.

Source AwwaRF: Guidance Manual for Maintaining Distribution System Water Quality

STEP 2

Plan and manage a flushing program.

- Determine the plan's objectives
  - Planning is critical for attaining water-quality objectives and minimizing costs.
  - Need to consider both water-quality considerations and hydraulic/ maintenance considerations.
- Determine flushing approach
  - unidirectional
  - conventional
  - continuous blow-off

Unidirectional flushing consists of isolating a particular pipe section or loop by closing valves and exercising hydrants in an organized and sequential manner. It is performed by isolating sections of the distribution system. It can be implemented system-wide or on a "where-needed" basis. The results are dependent on velocity.

- $\geq$ 3 ft/sec – remove silt, sediment, and reduce disinfectant demand
- $\geq$ 5 ft/sec – promote scouring, remove biofilm, loosen deposits and reduce disinfectant demand
- ~ 12 ft/sec – remove sand from inverted siphons

Unidirectional flushing can be proactive. It allows for simultaneous implementation of preventive maintenance procedures of valves and hydrants. It uses less water than conventional flushing, provides a performance baseline for comparison with future events, and reduces trouble-shooting efforts. Elements of unidirectional flushing include:

- Flushes from source to end of distribution system
- Provides a clean source for flushing.
- Water should be flushed from larger-sized pipes to smaller.
- Dechlorinate, if necessary.
- Be sure to include public outreach and communication using newspaper, website, signage, door-to-door notifications, mailers, etc.
- Conventional flushing is reactive.
- Unidirectional is proactive. You can use water quality (heterotrophic plate count) as a trigger for flushing.
- Flushing forces preventive maintenance of valves and identifies problems, which can then be prioritized for repair.

Conventional flushing is the most commonly used technique. It is implemented with minimal pre-design. Conventional flushing consists of opening hydrants in the distribution system until specific criteria are met. These criteria include disinfectant residual, reduction of color, and turbidity reduction. Since the use of isolation valves is not optimized, velocities are not maximized.

Conventional flushing can be reactive. In reactive flushing, the primary water-quality improvement objectives are restoration of disinfectant residual and expulsion of some of the poor-quality water in specified areas of the distribution system. Conventional flushing drawbacks include customer complaints during and immediately after flushing events, excessive water waste, minimal improvements to overall water quality, short-lived water-quality benefits, and the potential for increased coliform occurrences.

Continuous blow-off flushing can be used in parts of the distribution system

RCAP

that have known stagnation or circulation issues. Typically, velocities are < 1 ft/sec. This type of flushing can help restore or maintain disinfection residuals and reduce water age. However, it can result in significant water loss and does not address the source of water-quality issues.

There are costs associated with any type of flushing, including loss of water, staff time, equipment, and dechlorination chemicals.

STEP 3

Implement a flushing program and collect data.

- **Identify loops:** Flushing should be conducted from the source to the periphery of the distribution system, and from larger pipes to smaller. A loop should be able to be flushed during one work shift.
- **Determine flushing velocities:** For thorough scouring, pipe velocities should be targeted at 6 ft/sec.
- **Develop step-by-step procedures:** Include detailed instructions for sequencing of valve and hydrant opening and closing.
- **Complete a trial run**
  - Verify the crew is prepared and can respond to unforeseen challenges.
- **Conduct flushing program**
  - Ideally, the flushing program is conducted during off-peak hours to minimize service disruptions.
  - Your program should have a safety protocol in place.
  - Data should be collected before flushing for baseline conditions, during flushing, and post-flushing.

STEP 4

Evaluate and revise the program.

Ask the following questions after flushing is complete:

- Were water-quality objectives met?
- What are the estimated costs/savings of the program?
- Were there any positive secondary impacts of the program?
- Were there any negative secondary impacts of the flushing program?

Positive secondary impacts can include a reduction in operating costs, improved customer perception, and higher-quality water. Negative secondary impacts include negative public perception due to wasted water, poor water appearance in the short-term, and poor water quality during flushing.

How to flush a hydrant – opening and closing

Open and close hydrants (and valves) *slowly* to prevent surges

- For a velocity change of 1 ft/sec, a 50 to 60 psi pressure rise can be expected.
- Open hydrant valves completely to prevent water from discharging through the barrel drain, which could undermine the hydrant support.

Managing flow

- Restrain flow dissipaters to limit damage to property.
- Discharge water directly to the sewer when possible to prevent flooding (if not possible, redirect traffic and use signage as necessary).
    - ➢ Dechlorinate when required.

How long a segment of the distribution system should be flushed depends on the objective of flushing. You should sample water frequently until the objective is reached. Measure turbidity reduction, color reduction, or chlorine-residual increase. Record the time of flushing to estimate the amount of water used, and set a baseline for that segment of the distribution system.

Hydrant safety

Use caution! Damage or injury can result from the force of the water, and objects may be in the pipes (rocks, bolts, construction debris, etc.). Make sure all attachments are on tight, and do not stand in front of the attachments. Be aware of traffic and use traffic control. Use special care in freezing conditions. If diverting the water to the sewer with a hose, watch out for a cross connection. Open and close valves slowly to avoid water hammer.

You should always notify the public about any flushing event. Flushing is seen by some as a waste of water. It is important to let the public know why flushing is conducted:

- to improve water quality
- part of maintenance of the distribution system
- to lessen reliance on chemical treatment and chemical use within the distribution system
- to improve system hydraulics

Resources

- AWWA video: "Unidirectional Flushing"
- AWWA *Water Distribution Operator Training Handbook*
- AWWA *Water Distribution Systems Handbook*

All of the above are available for purchase from the American Water Works Association bookstore at *http://apps.awwa.org/ebusmain/OnlineStore.aspx.*

Chapter 13
Emergency Planning

Learning objectives:

- Be able to list actions that show responsible operations and housekeeping
- Be able to identify the components in an emergency response plan
- Be able to find resources online and from the primacy agency

Planning for the unexpected includes consideration of storm events (flooding, tornadoes, snow, hurricanes), equipment failure (treatment failure, main break, power outage), terrorism and vandalism, unintentional human error (chemical spill), and other impacts to operations (workforce issues, pandemic flu, interruption to chemical supply). Although planning for an emergency is always beneficial, each emergency is unique and may require customized responses.

What would happen if:

- You had a major system failure?
- You had no access to your office (including your computer and/or paper records)?
- You or your chief operator could not come to work for a week; a month; ever again?

You will need to ask the questions:

- What do I need to do in response to the emergency?
- How can I minimize the impact to public health?
- How can I protect my water system and people from further damage?
- Whom should I call for help?
- What are my reporting requirements?

The steps to develop an emergency-response plan are:

1. Consider and list all possible events or threats.
2. Perform an initial assessment of the impacts.
3. Develop a communications plan that includes communication with:
   - ➢ employees
   - ➢ primacy agency
   - ➢ consumers and media
4. Develop a plan to correct the damage.
5. Initiate closure actions when remediation efforts have been completed.

Preparation begins with good housekeeping practices. You should have the following in place:

- Record keeping and reporting systems:
  - ➢ water-quality and operations data
  - ➢ records of line breaks, pump failures, etc.
  - ➢ pipe maps, as-built drawings, specifications
  - ➢ inventory of repair materials
- A system to implement maintenance and surveillance:
  - ➢ Detect and correct any problems that pose a sanitary hazard.

- Detect and correct any significant deterioration of equipment, facilities, and infrastructure.
- Detect any encroachment of other utilities.

Be familiar with the emergency-response plan, keep it updated, and keep it accessible.

A useful source of information and resources is your state Water and Wastewater Agency Response Network (WARN). WARNs are utilities helping fellow utilities in times of emergency.

Activity

Develop an emergency-response plan for each of the following scenarios:

Scenario A

A water main along a major street breaks around lunchtime.

What are the appropriate responses?

- operational, repair, and monitoring
- to the state and local municipality
- to the public
- to the media

Scenario B

Pandemic flu strikes your community. Your chief operator is sick for more than a week as well as 50 percent of your work force.

Scenario C

Your chlorine pump breaks down. Water entering the distribution system is essentially without any residual.

What are the appropriate responses?

- operational, repair, and monitoring
- to the state and local municipality
- to the public
- to the media

Online resources

- Your state WARN
  - Usually *www.XXwarn.org*, where XX is your state postal abbreviation
  - Also available at *www.awwa.org/warn*
- Utilities Helping Utilities
  - *www.awwa.org/files/Advocacy/Govtaff/Documents/Utilities_Helping_Utilities.pdf#Whitepaper*
  - *In Spanish: www.awwa.org/files/WARN/9131%20WARN%20Spanish.pdf*
- Emergency-Response Planning Overview for Small Non-community Public Water Systems in Colorado
  - *www.cdphe.state.co.us/wq/drinkingwater/pdf/Security/EmergencyResponsePlanning_SmallSystems.pdf*
- EPA's Response Protocol Toolbox
  - *www.epa.gov/safewater/watersecurity/pubs/rptb_response_guidelines.pdf*
- EPA's Vulnerability Assessment Factsheet
  - *www.epa.gov/watersecurity/pubs/va_fact_sheet_12-19.pdf*
- RCAP's Security Toolbox
  www.rcap.org/toolbox

Chapter 14
Asset Management

Learning objectives:

- Understand the process of asset management, what an asset-management plan is, and how it is used in preparing the annual budget
- Understand the basics of preparing an asset-management plan and know where to find tools and resources to prepare one

Asset management is a planning process that ensures you get the most value from each asset and have the financial resources to rehabilitate and replace assets when necessary. The resulting asset-management plan is used to determine reserve requirements that should be included in your system's annual operating budget. The plan provides an estimated schedule of repairs and replacement for facilities and equipment. Conditions change, and short-term forecasting is better than long-term forecasting, so the plan should be updated annually.

When properly implemented, asset management saves customers money over time by reducing costly repairs (fewer emergency repairs) and improves customer service by having fewer service interruptions. As you work your way through an asset-management plan, you will increase your knowledge of the system, thereby reducing your dependence on consultants. You will prioritize projects and give yourself time to explore funding sources (rate adjustments, grants, and loans). It also shows lenders you are a good risk (a worthy borrower). In addition to these benefits, a plan assures that you continue to protect public health and maintain compliance with drinking water regulations.

The EPA's *STEP Guide for Asset Management* provides step-by-step instructions for simple planning.

- Call 800-426-4791 and request EPA 816-R-03-016
- Go to *www.epa.gov/safewater/smallsys/ssinfo.htm*

The five steps of asset management are listed and explained below. The EPA guide referred to above includes worksheets for carrying out these on paper. At the end of this section, you will find resources for computer-based asset-management planning.

STEP 1

Take an inventory

Before assets can be managed, you need to know what you have. The inventory information that you will need to compile is:

- the item/asset name and description
- expected useful life
- current condition
- service history
- adjusted useful life
- age
- remaining useful life

The process of taking an inventory will organize the available information. You will put the operators' knowledge on paper. You can use your system's existing files, records, inventories, CAD drawings, and blue prints. Discussions with longtime board members might also be useful. Existing capital-improvement plans and reports,and GIS programs may have information. You should also explore outside sources of information, such as professional engineers, sanitary surveys, enforcement agreements, consumer confidence reports, and source water assessment program reports.

For the expected useful life of an asset, use the manufacturer's recommendation, past experience, or use the list on page 9 of the STEP guide.

To record the condition of the assets, briefly describe the condition of each asset (new, excellent, minor defects, maintenance required, major renewal required, or almost unserviceable). Also note conditions that may influence the useful life (for example, rust or broken parts, poor installation). Be sure to note items that are obsolete.

For the service history, briefly describe the service history of each asset, including routine maintenance, repairs, rehabilitations, and frequency of these activities.

To estimate the adjusted useful life, consider the current condition and the service history.

To record the age of the assets, list how long each asset has been in use since its date of manufacture.

STEP 2

Prioritize your assets:

Prioritize the assets based on their remaining useful lives, redundancy, importance to protect public health, importance to safety and security, and importance to customer service.

STEP 3

Develop an asset-management plan

In other words, calculate what needs to be set aside annually to pay for rehabilitation and replacement of the assets, and create a plan/schedule to do the work. Determine replacement costs by including all costs, such as purchase price, installation costs, pilot tests, clean up, and disposal. Operators should always be consulted. You may want to look at past engineering reports or ask an engineer who has experience with your system or similar systems. Contact other systems that have done similar work, and call local contractors to benefit from their experience. You can receive quotes from equipment manufacturers and consult the *BNI Public Works Cost Book*, RS Means or other cost data books that are updated annually. Advice is also available from technical assistance providers like those with the Rural Community Assistance Partnership (RCAP).

In most cases, it is not realistic to expect the system to be able to fund replacement of capital fully from reserves. You should identify which items will be funded fully from reserves and which items will be funded in part using other sources (primarily loans). The useful life of any items that are funded using other sources (loans, bonds) should meet or exceed their terms (for example, a 20-year loan should not fund equipment with a useful life of only 15 years).

After identifying the items that will be paid fully from reserves, for the remaining items it is recommended that 10 to 15 percent of the funds for a capital project should come from reserves. This provides critical funds for part or all of the preliminary engineering and design, other project development costs, and/or to help mitigate the first debt-service payments.

So far we have focused only on refurbishing and replacing existing assets. It is important to plan for capital improvements as well. Using the capital-improvements worksheet in the STEP guide, list three improvements on your wish list.

STEP 4

Implement the plan

STEP 5

Review and revise the plan

Do this on an annual basis because unanticipated changes may impact assets, pricing changes may occur (inflation, market changes), and priorities change.

Resources

Software:

- CAP Finance – Asset Management Software for Water and Wastewater Utilities

  http://efc.boisestate.edu/Tools/AssetManagementwithCapFinance/tabid/90/Default.aspx

  (you must register to download the free software)
- CUPSS – Check-Up Program for Small Systems – Asset Management Tool for Small Utilities
  - Free, CD-based, stand-alone asset-management tool
  - For utilities serving up to 3,300 population
  - Based on successful STEP Guides
  - *www.epa.gov/cupss*

Chapter 15
The operator's role in providing high-quality drinking water

Some common distribution-system problems include:

- not maintaining a disinfectant residual at the entry point or in the distribution system
- raw-water bypass
- domestic water taps on untreated raw water lines
- system pressure less than 20 psi
- no flushing programs
- cross connections
- no emergency action plan

Do you have any of these problems? Remember, regulations are the minimum. It is too late if you exceed or fail a regulatory requirement. Routine activities keep you out of trouble, but just barely. A proactive approach helps you maintain reliability and prevent problems before they happen. Proactive activities can include water-quality monitoring beyond the minimum, a regular flushing program, a valve-exercise program, a leak-detection program, and an effective cross-connection control plan. A proactive monitoring program will allow you to obtain water-quality information regularly and identify localized areas where water quality has deteriorated. It will also provide early detection of emergency situations, which will allow you to respond promptly and effectively.

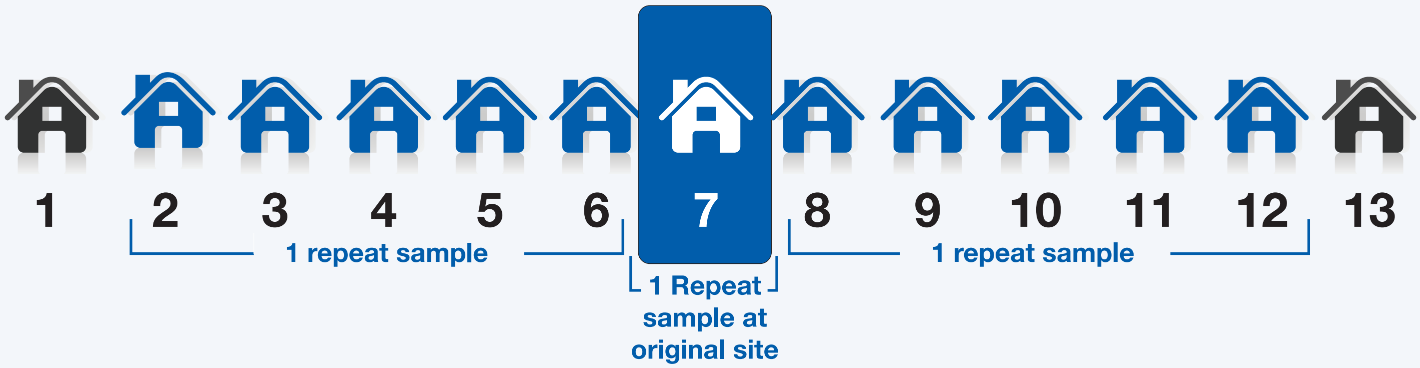
Setting tangible and measurable goals will help you achieve your water-quality objectives. For example:

- **Goal:** Maintain detectable chlorine residual in a certain location
- **Action:** Change chlorination practices and evaluate if residual is present in that location

Activity
Looking forward

Based on the materials in Section 1, identify two actions you will take in the near future.

Suggested Answers for Activity from page 8



The response to a total coliform positive (TC+) sample result depends on the number of routine samples that a system is required to collect per month.

For systems that collect 1 sample per month or less:

- Notify the primacy agency.
- Collect 4 repeats:
  - one from the original TC+ location
  - one from upstream within 5 service connections
  - one from downstream within 5 service connections
  - one from anywhere in the distribution system
- Conduct an investigation into the reason for the TC+.
- Collect 5 samples the month following the TC+.

For systems that collect more than 1 sample per month:

- Notify the primacy agency.
- Collect 3 repeats:
  - one from the original TC+ location
  - one from upstream within 5 service connections
  - one from downstream within 5 service connections
- Conduct an investigation into the reason for the TC+.

For systems that collect fewer than 5 samples per month, collect 5 samples the month following the TC+.

What would you do if the positive was at house #9? Collect 1 repeat sample from house 9, 1 repeat sample from houses 4, 5, 6, 7, or 8, and 1 repeat sample from houses 10, 11, 12, or 13.

You should not take a routine sample from house #13 because there are no places to sample downstream if you need to take a repeat.

Answers for Example problem on page 14

Q1: • Calculate system-wide average of each quarter (Qtr 1: 67.75; Qtr 2: 82.25; Qtr 3: 94; Qtr 4: 61
• The running annual average is the average of those four quarters = 76.25 µg/L

Q2: Calculate 4-quarter average for each location (#1 - 74, #2 - 82.5, #3 - 76, #4 - 72.5)

Q1: Drop the data from the first Qtr 1.
Q2: Calculate 4-quarter average for each location (#1: 71; #2: 76.5; #3: 70.5; #4: 69)

	SS #1	SS #2	SS #3	SS #4
~~Qtr 1~~	~~55~~	~~75~~	~~76~~	~~65~~
Qtr 2	80	83	85	81
Qtr 3	95	102	93	86
Qtr 4	66	70	50	58
Qtr 1	42	51	54	51

Suggested Answers for Activity from page 22

What was the issue(s) that lead to the outbreak in Alamosa?

- Lack of disinfection
- Physical deficiencies
- nferior construction quality

As an operator, what could have been done to prevent the outbreak?

- Install disinfection and maintain a disinfectant residual
- Maintain facilities
- Enforce construction standards

Answers for page 26

CHLORINE DOSE CALCULATION 1

- If stock chlorine solution is 10%
- Flow rate is 200 gpm

Useful conversion factors

- 10% NaOCl = 100,000 ppm = 100,000 mg/L
- 1 gallon = 3.78 liters

Determine

1) What is the necessary chlorine stock solution feed rate (in gal/hour, gal/day, and gal/week) if you wanted an initial chlorine dose of 3 mg/L?

Using the dosing equation:

(mg/L) x (MGD) x (8.34) = pounds/day

You need to convert gpm to MGD

200 gal	1 MGD	1440 min	= 0.288 MGD
min	1,000,000 gal	day	

(3 mg/L) x (0.288 MGD) x (8.34) = 7.21 lbs chlorine/day

Answers from page 26 (continued)

Convert lbs per day of chlorine to gal/day of stock solution:

7.21 lbs chlorine	100 lbs stock solution	gal stock solution	= 8.65 gal stock solution/day
day	10 lbs chlorine	8.34 lbs stock solution	

8.65 gal stock solution	day	= 0.360 gal/hr
day	24 hours	

8.65 gal stock solution	7 days	= 60.6 gal/wk
day	week	

Or, using dimensional analysis:

3 mg chlorine	200 gal water	3.78 L water	L solution	gal soln	1440 min	= 8.64 gal stock solution/day
L water	min	gal water	100,000 mg chlorine	3.78 L soln	day	

CHLORINE DOSE CALCULATION 2

Using the diagram below:

1. What is the Cl_2 stock strength (in ppm)?

12% w/w = 120,000mg/L = 120,000 ppm

2. What should Cl_2 target be immediately after chlorine boosting (in ppm)?

The demand between points A and B is 0.2 mg/L and the target at point B is 0.8 mg/L. Therefore, the target at point A should be (0.2 mg/L) + (0.8 mg/L) = 1.0 mg/L

3. What should the Cl_2 stock flow rate be (in gpd)?

Dose = Demand + Residual – Background

Dose = (0.2 mg/L) + (0.8 mg/L) – (0.5 mg/L) = 0.5 mg/L

(mg/L) x (MGD) x (8.34) = pounds/day

50 gal	1 MGD	1440 min	= 0.072 MGD
min	1,000,000 gal	day	

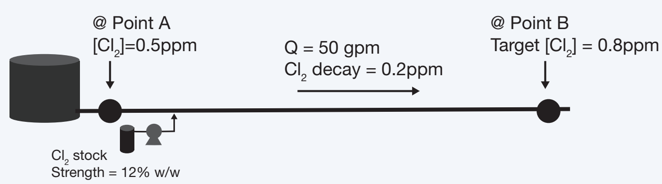
(0.5 mg/L) x (0.072 MGD) x (8.34) = 0.300 lbs chlorine/day

Convert lbs per day of chlorine to gal/day of stock solution:

0.300 lbs chlorine	100 lbs stock solution	gal stock solution	= 0.300 gal stock solution/ day
day	12 lbs chlorine	8.34 lbs stock solution	

Or, using dimensional analysis:

0.5 mg chlorine	50 gal water	3.78 L water	L solution	gal soln	1440 min	= 0.300 gal stock solution/day
L water	min	gal water	120,000 mg chlorine	3.78 L soln	day	



Answers from page 29

In a 12-inch diameter pipe, what flow rate is necessary to create a flushing velocity of 2.5 fps?

- Flow rate = (Velocity) x (Area)
- You know the velocity, and you can calculate the cross-sectional area from the diameter.
- Area = (0.785) x $(\text{Diameter})^2$
  or Area = (π) x $(\text{radius})^2$
- Area = (0.785) x $(1\text{ft})^2$ = 0.785 ft^2 or
  Area = (3.14) x $(0.5\text{ ft})^2$ = 0.785 ft^2

Substitute the known values into the first equation:

- Flow rate = (2.5 ft/sec) x (0.785 ft^2) = 1.96 ft^3/sec
- Convert ft^3/sec to gpm:
- (1.96 ft^3/sec) x (60 sec/min) x (7.48 gal/ft^3) = 881 gpm

What is the volume if the pipe is 150 feet long?

- Volume = (Area) x (Length)
- From above:
- Area = 0.785 ft^2

Substitute the known values into the equation:

- Volume = (0.785 ft^2) x (150 ft) = 118 ft^3
- Convert ft^3 to gal:
- (118 ft^3) x (7.48 gal/ft^3) = 883 gal

How long should pipe be flushed to remove two full volumes?

- (2) x (118 ft^3) / (1.96 ft^3/sec) = 120 sec = 2 min

Or

- (2) x (883 gal) / (881 gal/min) = 2 min

Answers from page 38

Customer **What type will you require?**

Agricultural spraying service that uses pesticides, herbicides and fertilizers
AG or RPP

Customer with a private well for lawn sprinkling that is connected to the public water system **RPP**

Customer with fire-suppression system that can connect to an unapproved auxiliary water supply
RPP

RV park with freeze hydrants used to supply water for campers **RPP**

Residential customer with a hot tub that is not directly connected to the public water supply
AVB

A wastewater treatment plant with direct connection to the public water system
AG

A customer that handles hazardous substances that may enter the public water system (mortuary)
AG or RPP

A customer that uses reclaimed water with no direct connection to the public water system (city park) **AVB**

SECTION 2

Water Quality in Storage Facilities

This section provides information to allow you to effectively manage water quality in storage facilities and identify shortcomings and challenges in your storage facilities. It also discusses potential improvements and solutions.

Chapter 16
The operator's role in providing high-quality drinking water

Learning objectives:

- Be able to describe why managing water quality during storage is important
- Be able to describe water-quality problems that occur during storage

As discussed in Section 1, Chapter 1, the multiple-barrier approach is an effective way to protect public health by reliably providing high-quality, safe drinking water. This should be a top priority. You can ensure that customers receive safe drinking water by providing the best product possible, from source to tap. That means you must not only protect the source water, but also provide adequate treatment, properly operate and maintain the distribution system, and sufficiently monitor the entire system.

Proper operation and maintenance of your distribution system should include your treated-water storage facilities. Water quality can degrade over time in a storage tank, which can lead to a contamination risk.

The water-quality problems that can occur during storage are classified as:

- **Biological:** Contamination can come from insects, birds, or small animals. Biofilms can grow inside the tank, leading to high heterotrophic plate counts and nitrification.
- **Chemical:** Problems can result from the loss of chlorine residual and the formation of disinfection byproducts (DBPs).
- **Physical:** Problems can come from sediment and rust.

Common storage facility-related problems include:

- Finished water storage not covered
- Cracks in the walls or storage cover
- Access hatches and vents not protected with screen or other approved device
- Storage facility not structurally sound
- Vents not terminating in a downward direction
- Lack of normal maintenance and inspection schedule for storage tanks

Chapter 17
Water-storage facility components

Learning objective:

- Be able to identify and describe key storage-facility components

Purpose of water storage facilities

Water storage is included in a distribution system for these reasons:

- equalizing supply and demand
- balancing pumping requirements
- increasing operating convenience
- decreasing power costs
- emergency and fire protection
- surge protection
- increasing chlorine contact time
- blending water from different sources

Storage facilities serve the purpose of equalizing supply and demand, including fire-fighting needs. Tanks fill during times of low water demand and drain during high demand, with the water level fluctuating within predetermined limits.

Your storage tank's ability to equalize flow allows your other equipment to operate more conveniently and efficiently. Treatment facilities and other equipment can run at an optimum rate of flow and can run when your operators are available. Your pumps can also run at lower flow rates for longer periods, which will reduce peak electrical demand and reduce wear on them caused by starts and stops. Another benefit is that your pumps can run during the time of the day when the electricity rates are the lowest.

Storage tanks can be used for surge protection by pumping water into a tank and using the head in the tank to pressurize the system, rather than using the pump to pressurize the system.

If properly baffled and with the inlet and outlet correctly positioned tanks can be used to increase chlorine contact time.

Tanks can also be used for blending water from different sources.

Types of storage facilities

Water systems have different types of storage facilities for different reasons, such as size and location of treatment facilities, fire-flow needs, topography, and the configuration of the distribution system. Not all systems will have each type of storage described below. Many small systems will have only one storage tank.

Clearwell

Clearwells are located at the end of the treatment process, before distribution. They are often in-ground concrete tanks that provide disinfection contact time and can act as a wet well for pumping into the distribution system.

Elevated storage

Elevated storage is above-ground on legs or a central supporting structure. These generally float on the distribution system's pressure. The pressure depends on the height of water in the tank.

Standpipes

Standpipes typically rest on the ground with a height much greater than the diameter. They provide pressure to the system due to the water's elevation and do not provide much storage.

Ground storage

Ground storage refers to any storage tank at or below ground level. These tanks must be covered. A ground-level tank on a hill can serve as elevated storage.

Hydropneumatic storage

Hydropneumatic storage is a type of ground-level tank used most commonly by small systems. The tank contains a bladder that is pressurized with compressed air to act as surge protection and pressure storage. These tanks have minimal fire-protection capabilities.

Design of storage facilities

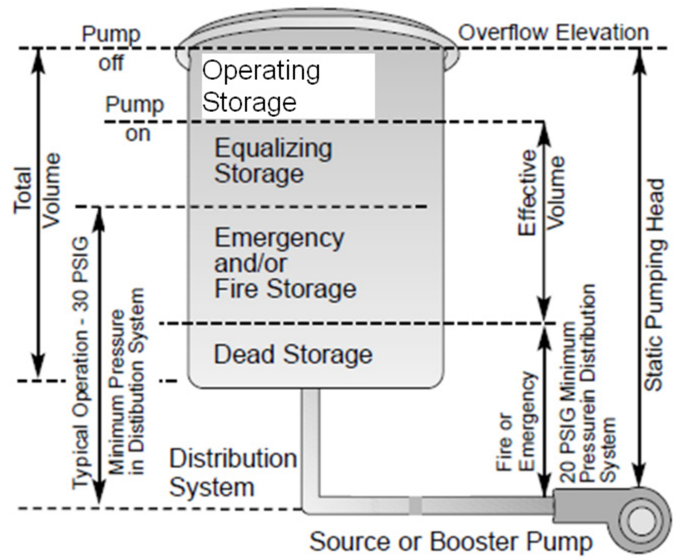
Storage can be designed and operated in two basic ways – as floating storage or as direct pumping from the storage to the distribution system.

Floating storage

In this design, the elevation of the water in the tank determines the pressure in the system. Water flows in when demand is low and out when demand exceeds supply. The tank cannot be used for disinfection contact time. Elevated tanks, standpipes, and ground storage at elevated locations can be used for floating storage.

Direct pumping from storage

This design is used when pumping is required to supply adequate pressure to the system or the pressure zone. The storage volume can be optimized for disinfectant contact time if the inlet and outlet are properly designed and baffles are included. Examples of direct pumping systems include hydropneumatic systems and ground storage with pump stations.



Storage-capacity requirements

Storage tanks must meet a variety of requirements, such as:

- **Operating storage:** Operating storage volume is the difference in tank level between the upper-level set point for the supply pump (or fill valve) and the lower-level set point. This is also called the working volume.
- **Equalizing storage:** Equalizing storage volume is the storage capacity that is used when the source capacity is less than peak demand. This allows the production flow rate to occur at a near-constant rate, even when demand flow rate varies.
- **Fire/emergency storage:** Fire storage volume is water stored specifically for the purpose of fighting fires or for use in other emergencies. Emergency storage denotes storage that is designated for other emergencies, such as system interruptions or failures.
- **Dead storage:** Dead storage volume cannot be used due to piping or elevation (pressure) constraints. Typically, standpipe tanks have a large percentage of their volume as dead storage in order to maintain

Activity
Storage-facility design

What type of storage facility do you have? Is it floating or pumped?

What are the advantages and disadvantages of your tank(s) for:

- fire protection
- water turnover and water age
- maintaining system pressure
- obtaining disinfection contact time

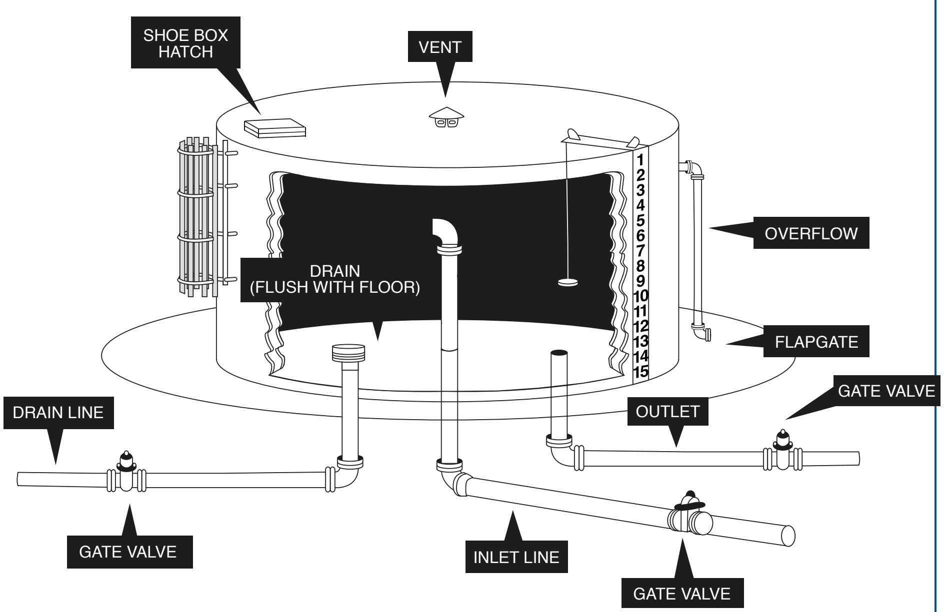
Storage-facility components

Water-storage facilities are made up of components that can have a significant impact on the water quality in the system.

adequate pressure in the system.

Tank Materials and Components

• Steel • Concrete • Wood



Inlet/outlet orientation

Inlet and outlet piping can be configured in two general ways: 1) common inlet and outlet or 2) separate inlet and outlet.

With a common inlet and outlet, one pipe enters the tank from the distribution system. Water flows into and out of the tank depending on the tank water level and distribution system pressure. A common inlet and outlet can result in poor circulation and mixing, which can lead to high water age, low disinfectant-residual concentrations, and high disinfection-byproduct concentrations. This configuration can also cause freezing problems. However, a common inlet and outlet is less costly to construct and has fewer fittings and tank penetrations to maintain.

An advantage of a separate inlet and outlet orientation is that this configuration can be designed to promote mixing and can reduce short-circuiting, thus providing more uniform water quality and lower water age. The tank should be designed so that the outlet is higher than the tank bottom, which will limit sediment from leaving the tanks. Tanks originally built with a common inlet and outlet can be redesigned and retrofitted with a separate inlet and outlet.

Vents

Vents allow air to enter or exit the tank as the water level fluctuates, thereby preventing the tank from collapsing from a vacuum or rupturing due to excess pressure.

Vents should be screened to prevent the entry of foreign objects, such as dust, insects and animals. Vent screens are required to be #24 mesh, non-corrodible material for ground tanks, and a #4 mesh, non-corrodible material for elevated tanks. Number 24 mesh screen is much finer than window screen, and so you must obtain it from a specialty supplier.

Vents should also open downward to prevent the entry of rainwater and other airborne material. By keeping the downward-turned vent openings at least 24 inches above any horizontal surface, contaminants will not splash into the vents.

If a vent screen becomes blocked with ice, it can no longer relieve pressure or vacuum in the tank, potentially causing the tank to collapse or rupture. To prevent this condition, the vent should be engineered to give way to release the pressure or vacuum.

Overflows

Overflows should be covered with #24 mesh screen. If a flapper valve is used, it can also be screened for extra protection. Remember that an air gap must be used to avoid cross connections.

The overflow should terminate between 12 and 24 inches off the ground. Higher than this can cause erosion and splashing. Lower than this allows easy access by animals and contaminants.

Drains

Drains should be screened with #24 mesh, non-corrodible material and should terminate 12 to 24 inches from the ground. Again, remember to eliminate all possible cross connections with an air gap.

Hatches

The ideal hatch is designed to keep out contamination and prevent unauthorized access. This can be accomplished by raising the hatch 24 inches above the tank roof for ground-level tanks, and 4 inches for elevated tanks. The lid should be a shoe-box style with a 2-inch overlap and a pliable gasket between the lid and frame. The lid should be solid, water tight, and locked.

Roof-to-sidewall joints

Roof-to-sidewall joints should contain no openings greater than what is afforded by a #24 mesh screen (0.0277 inches). The same constraint is true for any opening in a storage tank.

Coatings

Steel tanks need to be protected with coatings to prevent corrosion. The alternate wetting and drying of the interior of a tank makes it highly prone to corrosion. In freezing climates, tank coatings can be damaged by freezing events when ice abrades the interior surface of the walls.

Coatings should comply with AWWA D102-3, Coating Steel Water-Storage Tanks. Older coatings may still be lead-based and should be removed and the tank recoated. New coatings must be National Sanitation Foundation (NSF)-approved.

Cathodic protection

Cathodic protection is another method to protect tanks from corrosion. Cathodic protection consists of a series of anodes suspended in a tank. Direct current is applied to the anodes so that corrosion occurs at the “sacrificial” anode instead of the tank’s interior. Cathodic protection is best implemented with an appropriate interior coating. This method can be implemented in tanks without interior coating, but anodes must be replaced frequently.

Activity 1

Write down the name or identifier for each water-storage facility in your system.
What type is each storage facility?
What is the capacity (volume) of each?
What are the major components?

Activity 2

As discussed in Chapter 16, some common storage-facility issues include:

- Finished water storage not covered
- Cracks in the walls or storage cover
- Access hatches and vents not protected with screen or other approved device
- Storage facility not structurally sound
- Vents do not terminate in a downward direction
- Lack of normal maintenance and inspection schedule for storage tanks

Does your system have any of these issues? Can you identify any other major vulnerabilities of your storage facilities? What can be done to rectify them?

Chapter 18
Water-quality concerns in storage facilties

Learning objective:

- Be able to identify key factors that affect water quality in storage

Water quality deteriorates in storage facilities because of the potential for stratification, dead zones, and low velocities. Stratification and dead zones can cause problems associated with high water age, such as reduced chlorine residual and the formation of disinfection byproducts. Low velocities can result in sedimentation and biological growth.

Stratification

Stratification occurs in water-storage facilities when water in the tank is warmed by the sun or high outside air temperatures. This warm water rises and forms a stagnant upper layer in the tank. The stagnant water layer remains (or even grows) if the tank lacks mixers, the inlet and outlet configuration does not promote mixing, or if the highest and lowest water levels in the tank during the day are close together.

When stratification occurs, the water entering and leaving the tank is forced to occupy a small fraction of the tank's total volume. As the water in the stagnant layer continues to age, the water-quality problems described below can result.

Dead zones

Dead zones in storage facilities have the same result as stratification but from different causes. Dead zones, or short-circuiting, occur when inlet and outlet configurations do not promote mixing within the tank. Dead zones are more likely to occur in larger tanks.

There are three main categories of water-quality concerns in storage facilities: chemical, biological, and physical. Chemical and biological problems increase with time, so as water spends more time in storage facilities (high water age) the problems will become worse.

Chemical concerns

Decay of chlorine residual

The rate of chlorine-residual decay increases when chlorinated water is exposed to sunlight or high temperatures. Chlorine concentrations are also reduced by biological growth, nitrification, and organic and inorganic chlorine-demanding compounds.

The presence of organic compounds (such as humic and fulvic acids) and inorganic compounds (such as iron and manganese) will exert a chlorine demand. Sedimentation and contamination can increase contact with chlorine-demanding compounds.

At a minimum, chlorine residual should be monitored at the tank outlet. However, you will not be able to detect stratification and dead zones unless samples are taken from different levels and locations within the tank.

Formation of disinfection byproducts

Disinfection byproducts (DBPs) are formed when organic matter reacts with disinfectants.

The following all increase the concentration of DBPs:

- **Increased time (water age):** Water age can increase significantly in stratified layers and dead zones in tanks.
- **Chlorine concentration:** Chlorine concentrations may need to be high in storage tanks in order to maintain an adequate residual in the distribution system.
- **Temperature:** Water temperature in storage tanks is highest in the late summer, so the concentration of DBPs will likely be the highest in the late summer.
- **Organic-matter concentration:** Organic matter can come from the source water, contamination from outside the distribution system, or biological regrowth inside the system.

Taste and odor challenges

Taste and odor problems can develop in water-storage facilities from biological activity (such as anaerobic production of hydrogen sulfide gas), high disinfectant residuals, improper chloramine concentrations, and leaching of chemicals from the storage facility linings.

Increase in pH

The pH of the water in storage tanks can change in several ways:

- Carbon dioxide can off-gas, which tends to raise the pH.
- Re-chlorination can increase or decrease pH, depending on the chemical used for chlorination. If chlorine gas is used, the pH will drop. If sodium or calcium hypochlorite is used, the pH will rise.
- The pH can also increase due to interaction with concrete in storage facilities.

Changes in pH can potentially increase DBP levels. At higher pH values, more trihalomethanes are formed. When the pH is lower, more haloacetic acids are formed.

Corrosion

Steel storage tanks are susceptible to corrosion from failed coatings. The corrosion rate is dependent on water hardness, the type of disinfectant used, conductivity, dissolved oxygen, temperature, sulfides, and chlorides. Customers may complain about red water as a result of corrosion. Corrosion can be prevented by periodically inspecting and repairing the coatings. It is also important to have a properly maintained and calibrated cathodic protection system.

Hydrogen sulfide

Hydrogen sulfide (H_2S) can be naturally occurring in some ground waters. It is mainly an aesthetic problem, responsible for a "rotten-egg" odor. However, hydrogen sulfide can also cause corrosion and may be a safety hazard. Hydrogen sulfide is a dissolved gas that forms when sulfate and sulfur-reducing bacteria are present. The formation of hydrogen sulfide is a function of time that can be mitigated by aeration or ventilation systems.

Leachate from internal coatings

Tank coatings may deteriorate over time and leach into stored water. The rate of leaching is dependent on coating age, temperature, and water composition.

Volatile organic compounds (VOCs) can be emitted from new coatings if insufficient curing time is allowed.

Increases in pH can result from leaching in concrete tanks.

Biological concerns

Bacteria growth

Bacteria regrowth is generally associated with the distribution system's piping. However, storage tanks often create an environment prone to regrowth because of decreased chlorine residual, increased temperatures (temperatures above 15 degrees C/59 degrees F), and the presence of biodegradable dissolved organic carbon. Other factors that affect regrowth include seasonal temperature variations, availability of nutrients, distribution-system corrosion products, disinfection practices, and hydrodynamics (water residence time and velocity).

Bacteria regrowth tends to occur on the interior surfaces of storage tanks and in the non-circulating zones of the tank. Regrowth is a public health and compliance concern because it may contain total coliform, which can lead to Total Coliform Rule (TCR) compliance issues downstream. Bacteria regrowth can also exert a chlorine demand, resulting in a loss of chlorine residual.

Nitrification

Nitrification is a subset of bacteria regrowth.

Nitrification is the bacteriological conversion of ammonia to nitrate in a two-step process. Ammonia can be naturally occurring in the source water, or it can come from the chloramination process. Ammonia is first converted to nitrite, and nitrite is then converted to nitrate.

Nitrate and nitrite are both primary contaminants. The nitrate maximum contaminant level (MCL) is 10 mg/L-N, and the nitrite MCL is 1 mg/L-N.

Nitrification affects water quality by degrading chloramine residuals, consuming dissolved oxygen, increasing heterotrophic plate counts, decreasing the pH, and increasing the nitrate and nitrite levels.

The best way to control nitrification is through management practices of your storage facility, such as decreasing detention time and promoting mixing. Breakpoint chlorination to remove source water ammonia and changing from chloramines to chlorine will also control nitrification.

Physical concerns

Sedimentation

Sedimentation results from precipitation of solids in the tank due to low velocities. A common source of sediment is naturally occurring iron and manganese in the source water that precipitates from solution while in storage. This process is accelerated with the presence of chlorine and/or dissolved oxygen. Another source of sedimentation is when sediment is carried in from disruptions in the water mains, such as fire flow, hydrant testing, or main breaks.

Sediment can be re-suspended in the water if there are flow surges, increasing water turbidity and heterotrophic plate counts. Solids can also be released from the tank into the distribution system if there are high levels of pumping.

Tanks should be cleaned of sediment regularly to prevent adverse water-quality impacts. Sediment can affect chlorine demand, increase coliform levels, and cause taste and odor problems.

Sedimentation problems can be solved with the installation of a riser pipe on the tank outlet to raise the outlet above the tank floor. However, this solution reduces the available storage volume. Tank hydraulics can be modified in other ways to prevent sedimentation.

Regular flushing of lines entering the tank can prevent sediment from entering storage facilities. Tank cleaning to remove sediment periodically will also reduce sedimentation problems. The appropriate frequency of cleaning will be specific to each tank and needs to be based on experience with that tank.

Contaminant entry

Contaminant entry is a major problem for uncovered storage facilities. That is why uncovered treated-water storage facilities are no longer permitted. However, covered facilities are also susceptible. Airborne particulates can enter through hatches and vents. Insects, birds, and other animals can enter storage facilities through faulty screens, cracks, open joints, or poorly sealed hatches. Routine maintenance and inspections can reduce or eliminate the threat of external contaminant entry.

Activity

Water-quality problems associated with storage

In the table below, for each factor that may influence water quality, write every possible resulting water-quality problem from in the list at right:

Possible water-quality problems:

a. loss of chlorine residual
b. positive coliform sample
c. taste and odor event
d. high DBP formation
e. nitrification (for systems using chloramines)
f. other?

Factor that may influence water quality	**Possible water-quality problems (List all possible problems that apply.)**
Biofilm	
High water age	
High temperature	
Changing water pH	
Using a #4 screen on a vent	
Missing screen on vent	
Improper fitting hatch	
Build-up of sediment	
Failure of a tank coating	
New tank coating	

See page 92 for answers.

CHAPTER 18

Chapter 19
Inspections of water-storage facilities

Learning objectives:

- Be able to describe various types of inspections and what they include
- Be able to describe what to look for during an inspection of water-storage facilities

Inspection is important because it:

- leads to early detection of any anomalies and maintenance needs
- maximizes the service life and efficiency of storage facilities
- ensures system integrity, reliable water supply, and high water quality

As discussed earlier, common storage-tank problems include cracks in the walls or the storage cover, access hatches and vents not being protected with screens or another approved device, a structurally unsound storage facility, vents not terminating in a downward direction, and a lack of normal maintenance and inspection schedule for storage tanks.

Inspections are focused on the following areas:

- sanitary
- structural
- safety
- coatings
- security

Chapter 17 discussed the requirements for vents, drains, hatches, and overflows installed on storage facilities. When inspecting these items, be sure to verify that your screens are the proper mesh and are intact, that all items are designed properly, that hatch seals are in place, and that there are no openings larger than a #24 mesh screen anywhere on the tank.

When inspecting the structural condition of your tank, be sure to examine the anchor bolts, foundations, wind rods, riser/shell steel, spider rods, and roof trusses.

Pay attention to the following when inspecting the condition of your tank coatings: the generic type and general condition of the coating, the approximate percentage and type of coating failure, adhesion, coating thickness, and the extent of pitting damage.

An inspection of safety conditions should focus on compliance with OSHA regulations. This includes inspecting all safety equipment, such as ladders, handrails, fall-prevention barriers, access, confined space, and radiation.

Security conditions that should be included in an inspection relate to threats from terrorist acts, disgruntled employees, pranks, and environmental events, such as storms. You should inspect all physical deterrents, such as fences, locks, barricades, lighting, and ladder guards, as well as telemetry elements, including alarm systems, water monitors, and control systems.

Types of inspections

The following information is adapted from “Maintaining Water Quality in Finished Water Storage Facilities,” published by the AWWA Research Foundation (AwwaRF is now called the Water Research Foundation).

Routine inspections

The purpose of a routine inspection is to monitor the exterior of your storage facility and to detect signs of intrusion, vandalism, and coating failures. Routine inspections can also insure general security and operational readiness.

Routine inspections should be part of an operator’s standard daily, weekly, or monthly duties.

Routine inspection checklist

- ☐ Security fence locked?
- ☐ Signs of entry, such as:
  - ☐ litter
  - ☐ graffiti
- ☐ Encroachment of vegetation?
- ☐ Valve pit locked and dry?
- ☐ Warning lights operational?
- ☐ Overflow screen in place?
- ☐ Cathodic protection operational?
- ☐ Ladders locked and secure?
- ☐ Visible leakage?
- ☐ Roof hatches locked?
- ☐ Vent screens in place?

Periodic inspections

Periodic inspections review areas of the storage facility that are not normally accessible from the ground during routine activities. Periodic inspections usually require climbing the storage facilities. Inspectors should be comfortable with heights and aware of OSHA procedures. The recommended frequency of these inspections is monthly to quarterly.

Periodic inspection checklist

- ☐ Roof hatch locked?
- ☐ Bug screens in place on all vents?
- ☐ Level indicator accurately calibrated?
- ☐ Check operation of cathodic protection
- ☐ All tank penetrations are properly sealed
- ☐ Exterior coating:
  - ☐ Blistering?
  - ☐ Peeling?
  - ☐ Scaling?
  - ☐ Rusting?
  - ☐ Other failure?

Comprehensive

Comprehensive inspections are aimed at gaining a detailed understanding of all storage-facility components and their current condition. A consultant often is hired to perform comprehensive inspections. It is recommended that a National Association of Corrosion Engineers (NACE)-certified coating inspector be selected for coating inspection. It is also advisable to hire an engineer to review field findings and a licensed structural engineer to handle the structural evaluation.

Old facilities with previous coating and structural issues should be inspected at shorter intervals. However, new and well-maintained facilities can be inspected at longer intervals. AWWA M42 states: "The maximum interval for (comprehensive inspections) of the tank interior should normally be 3 years. It is usually advisable to wash out the tank at the time of inspection. Proper inspections cannot be conducted if sediment covers the bottom of the tank. Tanks should be washed out and inspected at least every 3 years, and where water supplies have sediment problems, annual washouts are recommended."

Comprehensive inspection checklist

- ☐ Exterior and interior coating conditions
- ☐ Foundations and visible footings
- ☐ Structural components
- ☐ Ladders, vents, and safety devices
- ☐ Cathodic protection system
- ☐ Overflow pipe, weir boxes, and bug screens
- ☐ Interior sediment depth

Inspecting the interior of tanks

Due to the difficulty of access, special methods are required to inspect the interior of tanks. Visual inspection is done as part of, or in between, comprehensive inspections.

Without completely draining the tank, viewing the interior through a roof hatch can be accomplished with the aid of a flashlight. The water level should be brought as low as possible to expose the greatest amount of interior surface.

If the tank can be taken out of service and drained completely, it can be inspected while empty. Entry is considered a confined-space entry, and proper precautions should be taken. The facility must be disinfected prior to returning to service.

Another method of inspection is a float-down inspection. In this approach, inspection is done with the inspector riding on a raft in the storage facility. The raft must be disinfected prior to use. The water level should be adjusted to the lowest level possible to maximize the exposed interior surface. This method is also considered a confined-space entry, and proper precautions should be taken.

Wet inspections are performed when the storage facility is full of water. This type of inspection requires a professionally certified diver or the use of a remotely-operated vehicle (ROV).

Recommended record retention

It is critical that you keep accurate and detailed records to properly document changes to the conditions of the storage facilities. The following table provides a list of recommended data and how long it should be retained.

Data	Suggested minimum retention period
Construction prints and information	Tank life
Routine inspection checklists	12 months
Periodic inspection forms	Between comprehensive inspections
Comprehensive inspection reports	Tank life
Cathodic protection operations tests	Tank life
Rehabilitation specifications	Tank life
Rehabilitation contracts	Tank life

Activity

Using the materials presented in this section and the reference documents provided (following six pages), develop a routine inspection checklist for your storage facilities.

MISSOURI DEPARTMENT OF NATURAL RESOURCES

Inspection of Water Storage Facilities

Technical Bulletin

3/2002

Public Drinking Water Program

A Technical Bulletin, *Microbiological Contamination of Water Storage Tanks,* was issued September 1995, because of too many occurrences of microbial contamination of water storage facilities and because of failure to inspect or inadequate inspection of water storage facilities. Today, the occurrence of microbial contamination is lower because more tanks are being inspected, but the quality of inspections varies widely. Too many inspection services look only at the condition of the paint and ignore other important issues. These inspections may fail to reveal major sanitary defects in water storage facilities while giving a false belief in the integrity of the storage facility. Currently, no certification of water storage inspectors exists and the qualifications of inspectors vary widely. The department is issuing this bulletin to aid water system officials in assuring proper inspection of their storage facilities and to secure some uniformity in the reports submitted to officials by inspecting firms. This bulletin is not intended to be a definitive reference concerning the construction, operation and maintenance of steel water storage tanks. Those wanting more information concerning these issues may wish to refer to the American Water Works Association's Manual M42, *Steel Water Storage Tanks,* or to publications of the Steel Plate Fabricators Association.

The following information is only for guidance and covers all types of finished water storage facility inspections.

General

The items on finished water storage facilities that must be inspected can be divided into five categories:
1. Sanitary conditions
2. Structural and footing conditions
3. Safety and security conditions
4. Coating system conditions
5. General details.

Sanitary conditions are those that could allow contamination of the water in storage. Structural and footing conditions are those that can affect the structural integrity of the storage facility. Safety and security conditions are those affecting the equipment that enables or protects inspectors and maintenance workers and prevents access to the tank by unauthorized people. Coating system conditions are those affecting the interior and exterior paint. General details are information on the storage facility such as overflow height, tank dimensions, overflow pipe size and other construction features. This information must be readily available, up-to-date, accurate and confirm as-built data to prevent costly mistakes when constructing additional storage facilities or major expansions to the water system, and to facilitate inspections, maintenance or emergencies.

PUB002112

Recycled Paper

Inspector Qualifications

Only organizations and individuals knowledgeable and equipped to do the work should do inspections. It is extremely important that inspectors have a thorough knowledge of water storage construction and be able to recognize improperly maintained or constructed vents, overflows, roof hatches, etc. Furthermore, inspectors must be thoroughly familiar with all the different safety equipment installed on storage facilities and with current safety standards. Any inspection service should be willing to explain the qualifications of their inspectors. Also, any firm should be willing to provide inspection checklists or copies of reports that show they can and will inspect facilities for sanitary defects and structural damage as well as paint condition.

The inspection firm or inspector shall carry adequate workman's compensation, property damage and public liability insurance and shall fully protect the owner against claims of any nature arising out of the inspection work.

Inspection Services

Ideally, the inspection firm should be a neutral third party that is not involved in storage facility maintenance, painting or repair. No inspection should be done without a written contract or agreement between the system and the inspection firm. This contract should clearly state the type and scope of the inspection to be provided and of any other services that will or will not be provided. For example, some firms do not provide repairs of steel and equipment or painting services. Also, it should state what equipment, material and services the system will provide, and what the inspection firm will provide. For example, who will provide pressure relief valves, pressure tanks and other equipment needed to isolate the storage facility during an inspection? Furthermore, the contract must state who is responsible for disinfecting the storage facility after the inspection and state the disinfection method to be used. The contract must require sufficient advance notice so that the water storage facility can be drained for the inspection.

In water systems having only one storage tank, consideration should be given to leasing a portable pressure tank to stabilize pressure, to minimize wasting water and to prevent main breaks. Some inspection firms have these tanks available as part of their service.

The inspection firm should provide all necessary personal safety equipment for its inspectors and assume the entire responsibility for accident to its employees while inspecting the structure. The inspectors must make such observations of ladders, railings, roof rods and other parts of the structure necessary to determine their safety for use while inspecting the structure.

Inspection Report

All inspection firms should provide quality videotapes or pictures of the facility and written reports describing all the inspection findings. These written reports shall be detailed and describe all conditions discovered during an inspection and not just the deficiencies. Do not assume that anything not mentioned in the report is in good condition. Furthermore, the report must provide enough information on any deficiencies found that system officials can make informed decisions as to actions that must be taken and their timing.

The report must include the inspector's professional evaluation of the general conditions and specific deficiencies found and recommend actions for correcting the deficiencies. Any sanitary defect, contamination, safety hazard or serious structural damage found should be reported at the time of the inspection so the facility owner can have them corrected immediately. Furthermore, these serious conditions shall be included in the written report.

Cleanliness and Cleaning

The inspector shall conduct all his work in a clean and sanitary manner and shall be responsible for cleaning all surfaces thoroughly before a storage facility is returned to service. Any time exterior repairs are done that could affect the quality of the water in a facility or work is done in a storage facility interior, the storage facility must be cleaned and disinfected before it is returned to service. State rule 10 CSR 60-4.080(6) requires public water systems to disinfect every newly repaired finished water storage facility by methods acceptable to the Department of Natural Resources before returning it to service. The department accepts the methods described in ANSI/AWWA Standard C652-92 for Disinfection of Water-Storage Facilities. However, the department accept only the membrane-filter technique for coliform analysis [the State Laboratory now does the membrane-filter technique only when specifically requested]. Ultimately, it is the responsibility of the tank owner to either conduct or require water quality tests to demonstrate the good sanitary condition of the tank interior.

When cleaning or disinfecting a storage facility, follow all environmental laws and rules to dispose of the chlorinated water, sludge, debris and other waste. Before the work begins, the facility owner and the inspection firm must make arrangements to properly handle and dispose of these. Frequently these wastes are dumped to sanitary sewers. However, strong chlorine residuals or heavy solids may cause sewer plugging and treatment problems. In addition, hydraulic limitations may exist in some sewer systems. Therefore, make all necessary agreements and arrangements with wastewater system operating authority before dumping anything.

What You Should Inspect

The following are lists of the minimum things that should be inspected during a water storage facility inspection. These lists are not all inclusive and the items requiring inspection depends somewhat on the design of a storage facility.

Sanitary conditions:

Birds, bats, bees, wasps and unidentifiable animals entering and contaminating storage facilities have caused water borne disease outbreaks and boil water notices on radio and TV. Water in storage facilities has also been contaminated by bird droppings and dirt washed into facilities by precipitation. Therefore, any sanitary defect found should be immediately brought to the attention of the facility owner so it can be quickly corrected.

1. The roof and side walls of all structures must be watertight with no openings except properly constructed vents, manways, overflows, cathodic protection equipment, risers, drains, pump mountings, control ports or piping for inflow and outflow. No unprotected opening between the walls and roof is permissible.

2. Any openings in a roof must be curbed (four to six inches) or sleeved with proper additional shielding to prevent precipitation and surface or floor drainage water from getting into the structure.

3. Roof access hatches must have watertight covers that overlap the framed opening and extend down around the frame at least two inches. The covers must be hinged on one side and have a locking device. All hatches should be checked to assure proper operation and fit.

4. Water storage roofs must be well drained and not tend to hold water. Low spots or structures that hold water must be corrected.

5. All finished water storage facilities must be properly vented and overflows cannot be used as vents.

6. Vent construction must prevent the entrance of surface water and rainwater and exclude birds, animals and insects. Vents must be screened with No.18 mesh, non-corroding material.
7. Vents must be designed so they do not become bird roosts and bird droppings cannot enter the storage facility through the vent by washing, falling or being inhaled. The old style ball and finial type vents do not meet these requirements.

8. Vents must be sized adequately to prevent differential pressures between the inside and outside of the storage facility.

9. Vents must be constructed to prevent frosting of the screens or provided with vacuum valves or failsafe devices.

10. Overflows on elevated tanks, standpipes and tall ground storage facilities must discharge at an elevation no higher than 12 to 24 inches above ground and discharge into or onto a drainage inlet structure or splash plate.

11. Overflows must be sized to carry more than the largest filling rate of the storage facility.

12. Overflows cannot be directly connected to sewers or drains.

13. Overflows must be screened or equipped with a flap valve to prevent the entrance of birds, animals and insects. Flap valves must be designed so they close completely and cannot high center and stick open.

14. Brackets connecting overflow piping to the structure must be checked to assure they are secure to both the structure and the overflow pipe and that they are not damaged by corrosion.

15. If water stands stagnant or silt collects in the bottom of a tank bowl, the tank must be modified to minimize this or provided with siphon drains or freeze proof direct drains. The water and deposits must be removed periodically to prevent microbial growths, to minimize corrosion and to prevent the deposits from going into the distribution system.

16. Check for evidence of contamination of the storage interior.

17. Hydrants, cleanouts or similar flushing devices must be provided on the piping of all water towers, standpipes and ground storage tanks. These devices must be located so that they can drain the storage facility while it is isolated from the system. Flushing devices on separate lines that are directly connected to the storage facility are acceptable substitutes but valves or plugs installed in wet risers or standpipes are not acceptable.

18. Taps or sampling stations suitable for collecting microbiological samples must be provided on the discharge piping of each storage facility. These must be located so that water directly from the storage facility can be sampled.

Structural conditions:

In the event that significant structural defects are identified, public water system officials should consult with a Missouri registered professional engineer to evaluate the inspection findings and recommendations. Some inspection firms will provide this service if it is specifically requested.

1. Are anchor bolts rusted enough to materially reduce their strength?
2. Are anchor bolts tight? Has dirt, grass or weeds accumulated on the anchor bolts?
3. Are column shoes clean and painted?
4. What is the condition of the grout under the column shoes and riser plate?
5. Does dirt, grass or weeds accumulate on the column shoes or riser plate?
6. Is there any indication of settlement of column or riser foundations?
7. Do areas exist where water pools or erosion has occurred around the foundations?
8. Do the foundations extend far enough above ground level to protect the column shoes and riser plates from excessive moisture and corrosion?
9. What is the physical condition of the concrete foundations?
10. Are the wind rods in good condition and properly tightened?
11. Where the wind rod connecting pins are secured with cotter pins or welded washers, check each connecting pin and report any missing cotter pins or washers.
12. Where the wind rod connecting pins are secured with nuts, check to make sure that each nut is full threaded and the thread is well battered.
13. Are the leg struts and their connections in good condition?
14. Is the riser straight and are the riser pipe stay rods in good condition?
15. Check the entire structure for water leaks including all manways, risers and tower legs.
16. Check all welds and seams for cracks.
17. Check all bolts and rivets for corrosion and leaks.
18. Older style elevated tanks with spider rods and hubs should have these removed and replaced with a stiffener ring welded around the upper perimeter of the tank wall.
19. Check to see that all cables, conduits, antennae and similar devices are properly secured to the storage structures
20. All roof trusses, rafters and their connections must be checked for ice damage, corrosion and soundness. This must include the welds connecting the roof to the rim angles and trusses.

Safety and security conditions:
Many safety requirements are set by Occupational Safety and Health Act (OSHA) and their latest requirements should be followed. While most OSHA requirements do not apply to political subdivisions, they do apply to privately owned firms hired to inspect, maintain and repair publicly

owned facilities and are used as standards of safety by many courts. Publicly owned facilities should meet OSHA requirements to avoid liability issues, and more importantly, to protect people working on the storage facilities.

1. Older elevated water tanks, that do not have leg ladders but require maintenance workers to climb a tower leg are serious safety hazards. These must have properly constructed safe ladders installed.
2. Check ladder brackets to assure that enough are provided, that they are not damaged by corrosion and that they are secure to both the structure and the ladders.
3. Check all ladder rungs to assure that they are secure and not damaged by corrosion.
4. Check to see that all ladders (interior and exterior) are constructed to OSHA requirements and that adequate room exists between the storage structure and the ladder rungs (seven inches minimum). Replace any flimsy or improperly constructed ladders.
5. Make sure safety devices that incorporate life belts, friction brakes and sliding attachments are provided on all ladders and that they are properly secured and operate safely.
6. Cables, power conduits, antenna brackets or similar devices should not be attached to any ladder because they will obstruct the ladder and prevent the safe use of the ladder or its safety devices.
7. Ladders or sections of ladders having pitches greater than 90 percent are prohibited and must be replaced with properly constructed ladders or sections.
8. All cables and wires to devices on the storage structure must be installed inside properly constructed conduits. Properly designed brackets must safely secure the conduits to the storage structure.
9. Check catwalk railings and posts to make sure they are securely attached. All catwalks must have railings that meet OSHA construction regulations. The intent of OSHA regulations is to have railings that do more than prevent people from falling. They must also prevent equipment, work material and other objects from falling. Therefore, the spacing between railings must meet standards and toe plates must be provided.
10. Check the condition of all landings and catwalks to make sure they are clean, that they drain properly and are not damaged by corrosion.
11. Large diameter wet risers in the bottom of elevated tanks are fall hazards so guardrails must be installed to protect people from falling into the riser. Grates over the riser tops do not meet OSHA standards, are easily damaged and displaced by ice and are dangerous to repair. If the wet riser pipe is extended into the tank for this purpose, it must meet the same criteria as a guard rail system (extend a minimum of 42-inches, have a top rail that can be gripped, etc.).
12. All water storage structures must have at least two access ways such that when ventilation equipment blocks one, the other is free from obstruction. Elevated water tanks must have at least two access ways in the tank portion of the structure and the manway in the riser does not count. The number of manways required depends on the size of the facility and is specified by OSHA.

13. Check to see that all manways are large enough (24-inches in diameter minimum).

14. Check all painters rings and brackets to assure they are sound, securely attached and not excessively corroded.

15. Inspect all Federal Aviation Administration warning lights to see that they are working properly.

Security Issues:

1. On elevated water tanks, standpipes and tall ground storage facilities, exterior ladders must terminate at least eight feet above ground and have their bottom sections covered with locking ladder guards.

2. Access to water storage structures must be restricted to only authorized people. Therefore, the tower site should be properly fenced. Check to see that security fences are sound and that their gates and locks work properly.

3. Check to see that all doors and access hatches are locked.

Coating system conditions:

The following things should be done when inspecting the coating systems on a storage facility and explained in the facility inspection report.

1. Determine the type and general condition of the interior and exterior paint systems. Determine lead and chromium levels on any paint that appears to be high in lead or chromium.

2. If rusting is continuous, approximate the percent of rusted area and determine the character of the areas (loose paint, blotchy, general corrosion, no paint).

3. Determine the extent, nature and depth of pitting.

4. Determine total system film thickness and run adhesion tests.

5. Check the paint for chalking and blistering.

6. Determine surface profiles.

7. Concrete structures should be inspected for signs of concrete deterioration (spalding, cracking, leaking, etc.).

8. Glass coated structures should be inspected for cracking, corrosion and other signs of coating deterioration.

Inspection Frequency

The frequency of inspection of items in each category varies. Sanitary, safety, security and some structural conditions should be inspected every year. Coating system conditions should be inspected every two to five years. In addition, storage facilities should be cleaned every two to five years depending on silt build up. The frequency that general information is physically determined depends upon the quality of a system's records on the particular water storage facility. However, this information should be physically determined before doing any major repair work on the storage structure and before designing other storage facilities or major expansions to the water distribution system. Therefore, the type of firm hired, the equipment required and how a facility is drained and disinfected all depend upon the scope of the inspection and the items inspected. Finally, every system should keep inspection records on file for each storage facility and use them to decide the frequency and scope of inspections.

For more information call or write
Missouri Department of Natural Resources
Public Drinking Water Program
P.O. Box 176, Jefferson City, MO 65102-0176
1-800-361-4827 or (573) 751-5331 office
(573) 751-3110 fax
www.dnr.state.mo.us/deq/pdwp

Drinking Water Sanitary Surveys Background & Preparation Checklist

Reference Guide: Colorado Department of Public Health and Environment - Water Quality Control Division
Engineering Section http://www.cdphe.state.co.us/wq/ 303-692-3500 April 2010

Who should attend your sanitary survey?

- Operator (s)
- Owner
- Administrative Contact

Please prepare for questions about general operations, management, security, and specific technical questions.

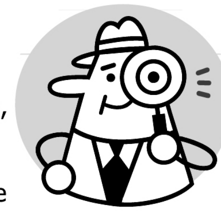
Sanitary Survey Scheduling

Typically, if your system is scheduled for a sanitary survey then an inspector will contact your facility to schedule.

How long will the sanitary survey take?

The sanitary survey can take a several hours to days depending on the complexity of the water system (e.g., a restaurant vs. metropolitan system).

What is a Sanitary Survey?



A sanitary survey is an on-site review of the eight elements of a sanitary survey including: water source, facilities, equipment, operation, and maintenance of a public water system for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The sanitary survey is required by Article 11 of the *Colorado Primary Drinking Water Regulations* (CPDWRs).

Sanitary Survey Frequency

Per Article 11 of the CPDWRs, routine sanitary survey are required by the CPDWRs for all pubic water systems (PWS) every three to five years.

- Community Water Systems (CWS) - Every Three Years
- Non-Transient, Non-Community Water Systems (NTNC) - Every Five Years
- Transient, Non-Community Water Systems (TNC) - Every Five Years

The Water Quality Control Division (division) has the authority to conduct more frequent sanitary surveys based on water quality concerns or to follow up on previous sanitary surveys. In addition, the division may conduct sanitary surveys without advance notice.

Engineering Section Sanitary Survey Goals

- Identify and address significant deficiencies and minor deficiencies
- Provide assistance
- Produce consistent, reliable reports which correctly identify the compliance and technical issues at a facility
- Facilitate continuous improvement
  - Accurately capture system inventory
  - Identify system strengths
  - Provide resources to the systems
- Establish working relationships between the systems and engineering section

The Eight Sanitary Survey Elements

Element	Description
1. Monitoring, reporting, and data verification	Review paperwork and plans to demonstrate compliance with CPDWRs (e.g., monitoring plan, sample results, maps)
2. System management and operation	Review paperwork and plans to demonstrate that maintenance and operations can maintain compliance (e.g., cross connection control, emergency plan, operations and maintenance plan)
3. Operator compliance	Review operator status to ensure the operator's certification is current and the appropriate level to meet Regulation 100
4. Water source(s)	Evaluate water supply sources to ensure proper source protection
5. Treatment facilities	Evaluate treatment processes (e.g., chemical addition, filtration), facilities, components, and techniques
6. Distribution system	Evaluate the adequacy, reliability, and safety of the system for distributing water
7. Finished water storage	Evaluate the adequacy, reliability, and safety of finished water storage
8. Pumps and pump facilities	Identify proper operation and maintenance of water system pumps and pumping facilities

Sanitary Survey Preparation Checklist

General Facility Checks — prior to sanitary survey date

- ☐ Are all facilities accessible (e.g., keys to buildings available, gates accessible, water hauling truck onsite)?
- ☐ Are all facilities safe for inspection attendees (e.g., no unexposed wiring, no un-covered pits)?
- ☐ Are all facilities operational (e.g., chemical feed pump working)?
- ☐ Are all facilities clean (e.g., floor swept, chemicals/spare equipment stored properly)?
- ☐ Are there any obvious problems with each potable water facility (e.g., holes in tanks, sanitary well seals not in place, vents not screened with 24 non-corrosive mesh)?

General Paperwork Reviews — prior to sanitary survey date

- ☐ Review previous sanitary survey reports and be prepared to discuss findings and resolution of deficiencies
- ☐ Review any recent correspondence from the division including violation letters and notifications
- ☐ Review operator status to ensure the operator's certification is current and the appropriate level to meet Regulation 100

Water System Records and Paperwork Available for Review During Sanitary Survey (for record keeping retention periods—see box below)

- ☐ Monitoring Plan, updated with all recent system modifications (Required for all PWS per CPDWR Section 1.12)
    - Bacteriological Sampling Plan (Part 5 of overall Monitoring Plan) including System Map
- ☐ Water quality analyses/laboratory records (Required for all PWS)
- ☐ Monitoring Schedule for current year (Required for all PWS)
- ☐ Correspondence to/from division staff (Required for all PWS depending on correspondence type)
- ☐ Other paperwork depending on System Type (e.g., water hauling records, consecutive system agreement)
- ☐ Consumer Confidence Reports (Required for community water systems (CWS) by CPDWR Article 9)
- ☐ Disinfection Profile and Benchmark for Surface Water and Ground Water under the Direct Influence of Surface Water (SW/GWUDI) Systems (Required per CPDWR Section 7.2.2 and 7.3.2)
- ☐ Treatment Facility Wastewater Discharge Permit (if applicable)
- ☐ Cross Connection Records to demonstrate compliance with CPDWRs Article 12 (Required for all PWS)
- ☐ Operation and Maintenance Plan (Recommended for all PWS)
- ☐ Emergency Response Plan / Security Plan (Recommended for all PWS)

Other items to have available:

- ☐ Water testing equipment (e.g., chlorine analyzer, sampling bottles)
- ☐ Safety equipment (e.g., gloves, boots, eye, head, and ear protection)
- ☐ Paper and pencil or pen for notes
- ☐ Camera (optional)

For your comfort consider bringing:

- Clothing for adverse weather
- Snack / drink
- Sunglasses / Sunscreen
- Phone or radio
- Insect repellent
- First Aid Kit

Record Keeping Retention Periods for Analyses Results and Water System Records

All Public Water Systems		**Community Water System (CWS) and Non-Transient Non-Community (NTNC)**	
Bacteriological analyses	5 years	Lead & copper records	12 years
Chemical analyses	10 years	Disinfectant/disinfection by-products records	up to 10 years
Actions to correct violations	3 years	Stage 2 disinfection by-product rule information	3 to 10 years
Sanitary survey reports and any subsequent correspondence	10 years	Consumer confidence reports (CWS only)	3 years
Monitoring plans, cross-connection control plans, emergency response plans, etc.	Indefinitely or until superseded	**Surface Water and Ground Water under the Direct Influence of Surface Water (SW/GWUDI) systems**	
Water system information (e.g., "as-built" construction drawings, water studies, well permits)	Indefinitely or until superseded	Turbidity results	5 years
Major division correspondence (e.g., current monitoring schedule, facility design approval letters)	Indefinitely or until superseded	Disinfection profile/benchmark	Indefinitely
Other records as required in CPDWR **If in doubt — keep a copy**		Long term 2 surface water treatment rule information	3 to 10 years

Page 2

Activity

Identify 2-3 items to routinely check on your water storage facilities for each category below.

Sanitary Components

____

____

____

____

Structural Components

____

____

____

____

Safety Components

____

____

____

Coatings

____

____

____

Security Components

____

____

____

Chapter 20
Monitoring water quality in storage facilities

Learning objectives:

- Be able to describe the importance of monitoring water quality in storage facilities
- Be able to identify water-quality parameters for monitoring
- Be able to describe the importance of sampling locations

Monitoring is critical when you seek to identify the origin of water-quality issues in distribution systems and storage facilities.

Developing trends in drinking-water quality and increased monitoring due to new regulations can help you to identify potential problems. Thus, you can use monitoring to ensure that your storage facilities are functioning properly.

Sampling

Sampling of water storage facilities can be divided into two types:

- **Continuous sampling:** Conducted by sensors and remote recording stations.
- **Grab sampling:** Done by the operator through access hatches and sample taps. The safety of the operator is of paramount concern when designing grab-sampling procedures and locations. A calibrated cord may be needed to ensure that samples are taken at a consistent depth within the tank.

Sample taps can also be used. Ideally, the taps should be indoors (such as in your pump room).

A single sample may not represent conditions throughout storage. For example, accumulated sediment at the bottom of the tank cannot be detected from a clear effluent sample when the outlet is above the bottom. Similarly, chlorine residual at one sampling point cannot indicate the presence of a “dead zone” in the tank. The configuration of the tank and water-flow dynamics should be considered when choosing your sampling locations.

The configuration of the inlet and outlet piping affects the circulation and mixing characteristics of the water and thus determines the location and number of samples required to obtain representative samples. Samples taken from common inlet/outlet facilities may represent inflow or outflow depending on when the sample is taken.

Water-quality monitoring

Typical water-quality parameters to monitor

Parameter	Purpose	Procedure
pH	Indicates changes from the water source and corrosion	grab sample or continuous sampling
Alkalinity	Indicates potential buffering capacity	grab sample or continuous sampling
Chlorine residual	Indicates conformance to MCL; provides early warning sign of water-quality deterioration	grab sample or continuous sampling
Total coliform	Indicates presence of indicator bacteria	grab sample
Heterotrophic bacteria	Indicates conformance to MCL; provides early warning sign of water quality deterioration	grab sample
Temperature	Temperature difference within tank may indicate stratification	grab sample or continuous sampling

Sediment monitoring

You can sample your tank for sediment after the storage facility is drained and before cleaning. You may opt to install a sediment gauge for collection of samples. A sediment gauge is fastened to the bottom of the storage facility, retrieved after it is drained, and is then inspected for sediment depth and characteristics.

The following table shows some sediment characteristics and what the presence of the sediment could indicate.

Parameter	Distribution system indicator
Iron hydroxide	Distribution system corrosion
Aluminum hydroxides	Treatment plant issue
Calcium carbonates	Minerals in hard waters
HPC	Possible taste and odor indicator Potential source of recurring bacterial counts
Depth of sediment	Rate of accumulation Cause of chlorine residual degradation
Gross microbial examination	System cross connections, poor hydraulics, faulty screening

Biofilm monitoring
You should monitor your storage tank for the formation of biofilm, which grows and accumulates on the surface of storage facilities. Biofilm is a health concern because it a can harbor pathogens. These growths are also a potential cause of disinfectant loss (chlorine demand) and taste and odor problems.

One technique for sampling biofilm is the "coupon" method. A coupon has the same materials of construction and coatings as the tank. It is attached to the interior of the storage facility. You retrieve and examine the coupon to determine the extent of biofilm formation in the rest of the tank.

Activity

- What type of samples have you collected from a storage facility?
- Is it a routine practice, or is it done only in response to an emergency?
- What are some of your experiences/issues/challenges regarding sampling and monitoring?
- What monitoring will you do in the future?

Chapter 21
Managing water age and quality in storage facilities

Learning objective:

- Be able to describe and apply key factors for managing water quality during storage

Water quality can be managed in water-storage facilities when you manipulate hydraulics by increasing turnover rate, adjusting fill and drain schedules (deep cycling), altering the inlet/outlet configuration and baffling, and by adding mixing. Water quality can also be managed when you manipulate the chemistry by increasing chlorine residual, shock chlorination, and aeration.

The turnover rate can be increased by decreasing storage volume, partially draining and refilling, and changing high and low levels based on seasonal water-usage variations. You may need to close down some facilities during low-usage seasons or operate with lower volumes. It is important to ensure a certain minimum storage at all times for emergency purposes (e.g., fire flow). Also, set a minimum water level to prevent re-suspending sediments.

Deep cycling is accomplished with large water-level fluctuations that facilitate mixing and help increase turnover rates. However, be sure to avoid rapid filling when the tank is unusually low, since this can cause scouring and sediment release. Deep cycling may not achieve mixing of the upper layers in a stratified tank.

Baffle walls can be added to the storage facility to make the interior "channel-like" to enhance a "plug-flow" condition. This will make water age more uniform and reduce short circuiting. Even in a storage facility that has a high turnover, dead zones can still occur due to thermal stratification and short circuiting. Adequate mixing can break up stagnation and promote consistent water quality.

Passive mixing systems use nozzles (water jets), separate inlets/outlets, and baffles. Active mixing uses mechanical mixers. In both cases, the goal is consistent water quality and water age throughout a tank.

You may wish to increase the chlorine residual of your water prior to storage so that the water will have more contact time and can achieve adequate disinfection. It may also be necessary to boost chlorine residual so that adequate disinfectant concentration can be maintained in all parts of the distribution system.

Chlorine is usually dosed continuously, paced by flow, or it can be added in batches. The choice of chlorine dose (concentration) and location depends on several factors, including DBP formation considerations, biological growth in the storage tank, and taste complaints.

Aeration can be used to remove volatile and semi-volatile chemicals, such as radon, TTHMs, and hydrogen sulfide. Aeration will increase pH (by removing CO_2) and it can provide some additional mixing. If you choose to incorporate aeration, your tank will require some re-engineering to facilitate the aerators.

You may consider removing a storage facility from use during low-demand seasons. Low demands can increase detention time and, therefore, water age. By reducing storage volume, water age during low-demand seasons can be reduced to normal.

Another seasonal consideration in cold climates is the formation of ice. Ice can form at the wall and water surface of tanks in the winter. Ice can degrade the tank's coating and can have an adverse impact on water quality. An ice "donut" may form inside the tank against the walls and damage internal components as it moves up and down. Continuous water movement from mixers or deep cycling can minimize the formation of ice.

Chapter 22
Cleaning, disinfecting, and returning tanks to service

Learning objectives:

- Understand the fundamentals of tank cleaning
- Be able to describe the procedures required to disinfect a storage facility
- Understand the steps required to return a tank to service after it has been cleaned

Tanks are cleaned to remove sediment, clean biofilm, address water-quality complaints, and during inspections. Tanks can be cleaned when they are out of service by draining and entering (using proper confined-space procedures), or they can be cleaned while still in service using divers or remotely-operated vehicles (ROVs).

Out-of-service cleaning

Out-of-service cleaning is the traditional method of cleaning a storage tank. It requires that you drain the tank and temporarily remove it from service. Once drained, the tank is manually cleaned, and repairs are made as necessary.

Removing sediment

Once sediment is removed from the tank (usually with a shovel or vacuum), you must locate a site to properly dispose of the sediment. If appropriate, sediment may be disposed in a storm sewer, sanitary sewer, ground discharge, or approved landfill.

Cleaning the interior of a tank

The tank interior can be cleaned using a fire hose, pressure washer, or chemical cleaning. When using high-pressure water and chemicals, take care to observe appropriate safety precautions. All equipment, including boots, should be disinfected prior to entering the tank. Remember to flush all inlet and outlet pipes to remove residual contaminants. The facility should be disinfected as per AWWA Standard C652.

In-service cleaning

Many storage facilities cannot be removed from service and must be cleaned while in service. In-service cleaning is performed by either a certified dive crew or by ROVs. All equipment must be dedicated for use in potable-water applications, and all equipment must be properly disinfected.

Dive crew

Divers enter the tanks through hatches, inspect the tank, and vacuum sediment. The dive crew can record a video of the inspection and cleaning process for your records.

ROV cleaning

ROV cleaning is accomplished with a vacuum hose attached to a remote-controlled unit. The ROV operator guides the unit while it removes the sediment and makes a video recording of the tank walls, appurtenances, and sediment buildup. ROV cleaning is typically less expensive than divers because there are no confined-space procedures, fewer worker-safety concerns, and less risk of water-quality degradation.

Benefits and limitations

Since divers and ROVs are disinfected prior to entering the tank, there is no need to disinfect the tank after the inspection and cleaning procedure. However, water-quality sampling should be performed before and after in-service cleaning. This provides a baseline for turbidity, chlorine residual, and coliform.

In-service cleaning has benefits. It minimizes water loss, there is no service interruption, and emergency-storage capacity (for things like firefighting) is maintained. However, there are limitations of in-service cleaning. Biofilm cannot be removed with the tank in service, and very dense sediment may be difficult to remove.

Comparison of benefits of tank-cleaning methods

Out-of-service	In-service divers	In-service ROV
• No turbidity upsets • Minimizes water loss • Allows for walls to be pressure washed • Allows removal of packed sediments • Achieves thorough cleaning • Allows for detailed inspection • Allows sampling of sediment	• Minimal downtime • Minor turbidity upsets • Less need for disinfection • Allows visual tank inspection	• Minimal downtime • Minor turbidity upsets • No human exposure • No worker-safety issues • Less need for disinfection

Comparison of limitations of tank-cleaning methods

Out-of-service	In-service divers	In-service ROV
• Extended downtime • Bacteria testing required • Disinfection mandated	• Cannot wash walls • Difficult to remove packed sediment • Human exposure to water • Some wasted water • Bacteria testing required	• Cannot wash walls • Difficult to remove packed sediment • Human exposure to water • Some wasted water • Bacteria testing required • Problems cleaning around anodes

Removing a tank from service

Tanks can be removed from service for inspections, cleaning, repairs, or recoating the interior surfaces. You should always consider the pre- and post-sampling and disinfection efforts prior to taking a tank out of service.

All utilities should have a tank-outage plan. This plan should cover the steps to take a tank out of service, provisions to maintain service while the tank is offline, and steps to return the tank to service.

Specifically, the plan should include:

- safety
- personnel required for each step
- disinfection procedures
- confined-space protocols
- demand management in case of peak demands, fire flow, and the impact of main breaks

Returning a tank to service

The following should be considered before returning a tank to service:

- chlorine residual
- colifrom sampling
- odor

There are three methods for disinfecting a tank before returning it to service. These methods are outlined in the AWWA Standard for Disinfection of Water-Storage Facilities, C-652-02.

Method 1

1. Add sodium hypochlorite to the influent pipe while filling, or place calcium hypochlorite tablets on the bottom of the tank before filling.
2. Target chlorine residual > 10 mg/L after the retention period.
   a. 6 hours required for sodium hypochlorite
   b. 24 hours required for calcium hypochlorite
3. Drain the high chlorine residual water, or blend it with distribution-system water.
   a. Must be certain to meet local discharge requirements, so you may need to dechlorinate.
4. Conduct bacteriological testing
   a. If sample passes and water is of acceptable aesthetic quality, the water may be delivered to the distribution system.

Method 2

1. Spray solution of 200-mg/L available chlorine onto all surfaces that would be in contact with water.
   a. Contact time for at least 30 minutes
2. Fill any drain pipes with a chlorine solution of 10 mg/L.
3. Fill storage facility with potable water.
4. Conduct bacteriological testing.
   a. If sample passes and water is of acceptable aesthetic quality, the water may be delivered to the distribution system.

Method 3

1. Add chlorine and water into the storage facility.
   a. Target initial chlorine dose 50 mg/L.
   b. Fill approximately 5 percent of total storage volume.
2. Hold for at least 6 hours.
3. Fill to overflow level and hold for at least 24 hours.
4. Water containing a high disinfectant concentration should be purged from any pipes.
5. Conduct bacteriological testing.
   a. If sample passes and water is of acceptable aesthetic quality, *and* chlorine residual is between 2 mg/L and 4 mg/L, it may be delivered to the distribution system.

Activity Answers from page 73

Water-quality problems associated with storage

In the table below, for each factor that may influence water quality, write every possible resulting water-quality problem from in the list below:

Factor that may influence water quality	Possible water-quality problems (List all possible problems that apply.)
Biofilm	a, b, c, e
High water age	a, c, d, e
High temperature	a, d, e
Changing water pH	d, f-corrosion
Using a #4 screen on a vent	f-contamination
Missing screen on vent	f-contamination
Improper fitting hatch	f-contamination
Build-up of sediment	a, b, c, e
Failure of a tank coating	f-corrosion
New tank coating	c

Note: Other answers may also be correct

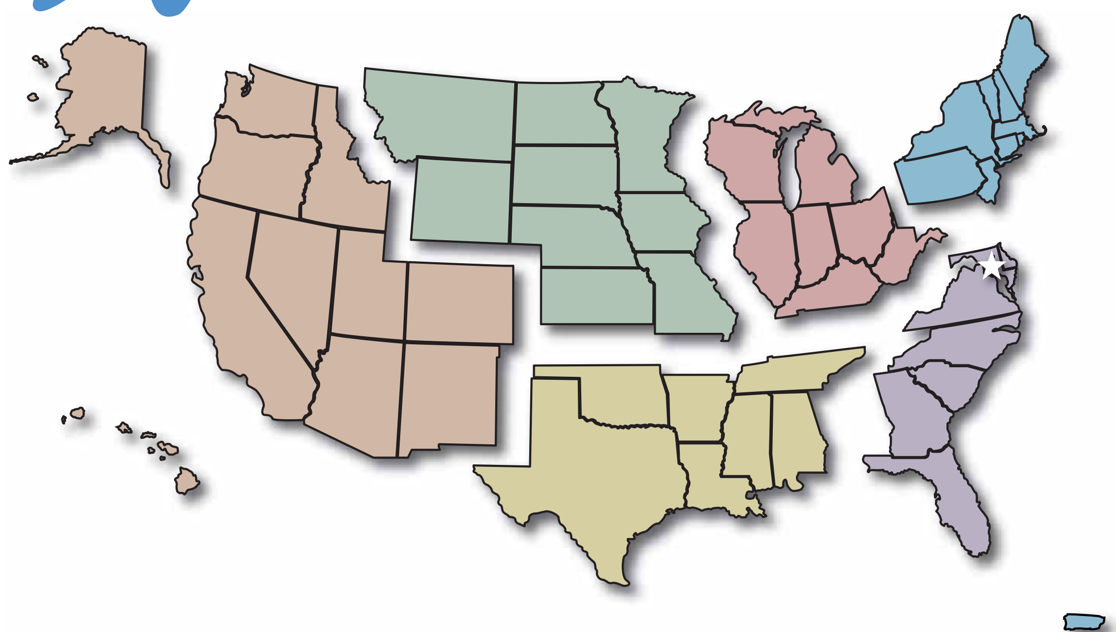
Need help with your community's water or wastewater system?

The Rural Community Assistance Partnership (RCAP) is a national network of nonprofit organizations working to ensure that rural and small communities throughout the United States have access to safe drinking water and sanitary wastewater disposal. The six regional RCAPs provide a variety of programs to accomplish this goal, such as direct training and technical assistance, leveraging millions of dollars to assist communities develop and improve their water and wastewater systems.

If you are seeking assistance in your community, contact the office for the RCAP region that your state is in, according to the map below. Work in individual communities is coordinated by these regional offices.

RCAP

Rural Community Assistance Partnership



Puerto Rico (Northeast RCAP) and U.S. Virgin Islands (RCAC)

Western RCAP
Rural Community Assistance Corporation
3120 Freeboard Drive, Suite 201
West Sacramento, CA 95691
(916) 447-2854
www.rcac.org

Midwest RCAP
Midwest Assistance Program
P.O. Box 81
212 Lady Slipper Avenue NE
New Prague, MN 56071
(952) 758-4334
www.map-inc.org

Southern RCAP
Community Resource Group
3 East Colt Square Drive
Fayetteville, AR 72703
(479) 443-2700
www.crg.org

Northeast RCAP
RCAP Solutions
P.O. Box 159
205 School Street
Gardner, MA 01440
(800) 488-1969
www.rcapsolutions.org

Great Lakes RCAP
WSOS Community Action Commission
P.O. Box 590
219 S. Front St., 2nd Floor
Fremont, OH 43420
(800) 775-9767
www.glrcap.org

Southeast RCAP
Southeast Rural Community Assistance Project
P.O. Box 2868
347 Campbell Ave. SW
Roanoke, VA 24016
(866) 928-3731
www.southeastrcap.org

★ RCAP National Office ★
1701 K Street NW, Suite 700 • Washington, DC 20006
202/408-1273 • 800/321-7227
www.rcap.org

Rural Community Assistance Partnership, Inc.
1701 K St. NW, Suite 700
Washington, DC 20006
202/408-1273
800/321-7227 (toll-free)
info@rcap.org

www.rcap.org

Visit our website for other publications, electronic and print periodicals, and ways your community can get assistance with its water and wastewater system.