Drinking Water Operator Certification Training

Module 1:
General Overview

Revised January 2006

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

Topical Outline

Unit 1 –Overview

I. Responsibilities of Water Supplier and Treatment Plant Operator
   A. Job of Public Water Supplier
   B. Job of Water Treatment Plant Operator

II. Water and Public Health
   A. Water Treatment Objectives
   B. History of Water Treatment
   C. Timeline of Water Quality Regulations

Unit 2 – Public Water Supply System Classifications

I. Purpose and Definition
   A. Purpose of Classification
   B. Definition of Public Water Supply System

II. Basis Used for Classification
   A. Non-Community vs. Community
   B. Non-Transient vs. Transient
   C. Size Classifications of Community Water Systems

Unit 1 – Overview

Learning Objectives

- Describe the responsibilities of the water supply facility and the treatment plant operator.
- List the 5 drinking water treatment objectives.
- Describe three important historical achievements in water treatment that link contaminated water to disease.

Job of Public Water Supplier

Water is essential to life. A human can only survive 5-7 days without water. However, consuming contaminated water can cause disease and death. Water can be contaminated by:

- Suspended material.
- Chemical contaminants.
- Biological contaminants.

Uncontaminated natural water sources are rare. Most water sources are contaminated by:

- **Natural impurities**
  - Dissolved naturally occurring minerals and chemicals, e.g., arsenic, radon.
  - Animal waste.
  - Algae, decaying leaves, and other organic material.
- **Man-made impurities**
  - Industrial waste discharges.
  - Human waste discharges, e.g., malfunctioning septic systems, and sewage treatment plant discharges.
  - Agricultural activities, e.g., soil erosion, chemical fertilizers, and animal wastes/manure.

The job of the public water supplier is to provide a clean, safe, and reliable supply of water at a reasonable cost.

Job of Water Treatment Plant Operator

The water treatment plant operator is ultimately responsible for the quality and safety of the treated water leaving the water treatment plant.

Operator must:

- Be aware of the type and concentration of contaminants in the raw water supply, and be aware of changing raw water conditions.
- Understand the treatment process used and be able to make adjustments to the process to compensate for changing raw water conditions.
- Monitor the quality of the water at various stages of the treatment process.
- Monitor the quality of the treated water leaving the plant to make sure it is potable, aesthetically pleasing, and meets all state and federal regulations.
- Insure water treatment plant facilities are maintained in a safe and operable condition.
- Insure reliable production and delivery of water to the distribution system.

Water Treatment Objectives

Availability of clean, safe, potable drinking water is essential to public health. In order to safeguard public health, water treatment must achieve the following objectives:

- Remove turbidity (suspended) material.
- Reduce concentrations of chemical contaminants to levels low enough that they do not pose a health risk and meet or exceed regulatory requirements.
- Remove or inactivate pathogenic protozoans, bacteria, and viruses.
- Produce water that is clear, with no objectionable colors, odors or taste.
- Produce water that is chemically stable, and is not corrosive to metal piping and fixtures.

History of Water Treatment

People were originally concerned with quantity of water, not quality. Water was used mainly for irrigation. People settled near rivers where there was a large quantity of readily available water. It was believed that taste and color determined purity.

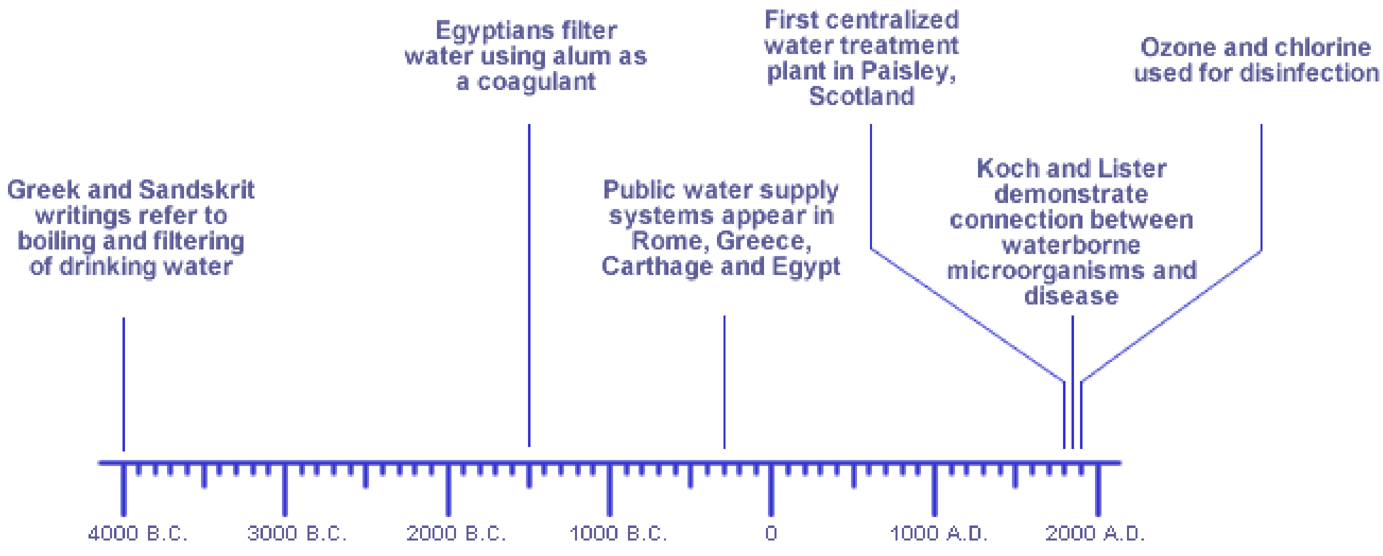


Figure 1.1 Timeline of Significant Developments in Water Treatment

Timeline of Early Water Treatment Advances

- 4,000 B.C. – Greek and Sanskrit writings reference boiling water and filtering through sand and coarse gravel.
- 2,000 B.C. – People in India filter water through charcoal.
- 1,500 B.C. – Egyptian tomb paintings show people filtering water using wick siphons. It is believed that they also used alum for treating water.
- 400 B.C. – Hippocrates makes connection between water and health. Recommends boiling and filtering rainwater through a cloth bag.
- 343 B.C. to 225 A.D. – Romans construct aqueducts.
- 300 B.C. – Public water supply systems appear in Rome, Greece, Carthage and Egypt. Cisterns constructed for storage and settling.
- 1680 - Anton Van Leeuwenhoek invents the microscope and 1685 - Lu Antonio Porzio invents a multiple sand filter.
- 1749 – Joseph Amy patents water filter for home use using sponge, charcoal and wool.
- 1804 - First centralized water treatment plant (supplying water to an entire town) constructed in Paisley Scotland. Intended to improve aesthetic quality of water. Was not concerned with health.
- 1854 - Contaminated water supplies linked with disease by Dr. John Snow in cholera outbreak in London.
- 1870's – Dr. Robert Koch and Dr. Joseph Lister demonstrate link between waterborne microorganisms and disease.
- Late 1800's – Improvements made to slow sand filtration. Rapid sand filtration developed.
- 1906 – Ozone used for disinfection in France.
- 1908 – Chlorination used for disinfection in U.S. Incidence of waterborne disease declines as more communities adopt filtration and disinfection.

In your opinion, what are the three key historical achievements in water treatment and why?

Timeline of Water Quality Regulations

Timeline of key legislation on regulating water quality is given below.

- 1893 – U.S. Public Health Service (USHPS) enacts Interstate Quarantine Act, a regulation prohibiting use of a common drinking cup by passengers on commercial transportation carriers traveling between states.
- 1914 - Federal standard for bacteriological water quality developed.
- 1925 - USPHS expanded standards to include guidelines for bacteriological sampling and maximum levels for lead, fluoride, arsenic, selenium, and chromium. Generally these were non-enforceable guidelines.
- 1962 – Guidelines are expanded to include additional constituents. Limits on many constituents made mandatory.
- 1974 – Congress passes Safe Drinking Water Act.
- 1986 and 1996 - Safe Drinking Water Act amended.

As a water treatment plant operator, you must have an understanding of all the water supply regulations that apply to your treatment plant. These regulations directly affect your day-to-day responsibilities

Key Points

The job of the public water supplier is to provide a clean, safe, and reliable supply of water at a reasonable cost.

People have been treating water to some extent since 4000 B.C. The key historical achievements in water treatment are those that link water quality to human health.

-400 B.C. – Hippocrates made a connection between water and health.

-1854 – Dr. John Snow linked contaminated water supplies with disease in 1854 cholera outbreak in London.

-1906 – Ozone used for disinfection in France and 1908 – Chlorination used for disinfection in U.S. Widespread disinfection of public water supplies finally brought many diseases under control.

Water treatment plant operators are responsible for understanding the regulations that apply to their treatment plant.

Unit 2 – Public Water Supply System Classifications

Learning Objectives

- Describe the different classifications of water systems and an example of each.

Purpose of Classification

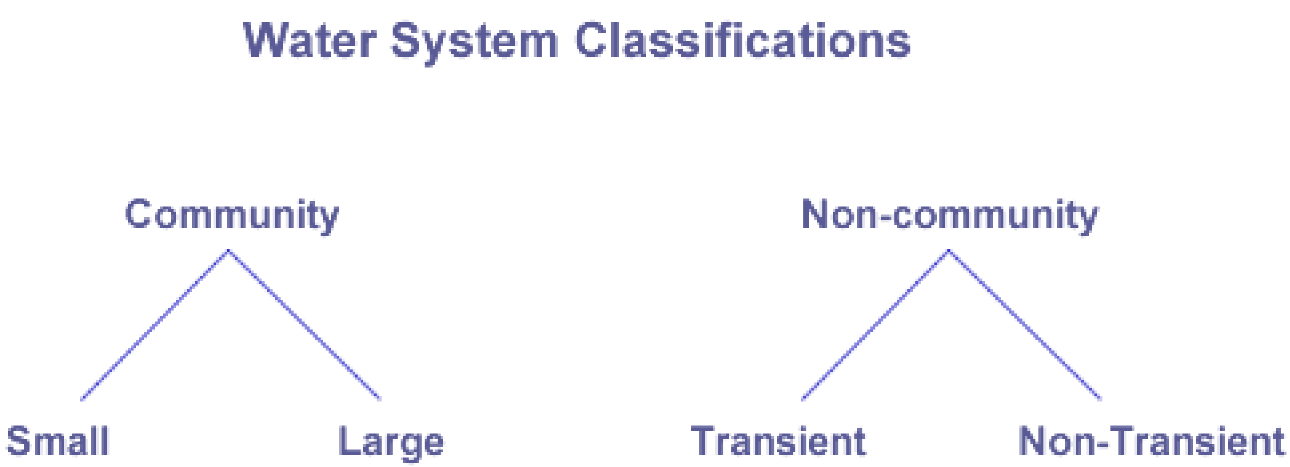
Different types of water systems have different treatment requirements. Water systems are classified on this basis. Regulatory requirements vary from one class to another, and operator certifications are specific to certain classifications of systems.

Definition of Public Water Supply System

- The United States Environmental Protection Agency (EPA) defines a **Public Water Supply System** as "a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year."[1]

Water systems are classified according to the illustration in Figure 2.1

Figure 2.1: Water system classification tree



Community or Non-Community

A **Community Water System** is defined by EPA as "a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year round residents."[2] Examples include:

- Municipally owned and operated water systems
- Systems owned and operated by authorities
- Investor owned water systems, such as Pennsylvania-American Water Company, United Water, and Philadelphia Suburban
- Privately owned systems serving residential developments or trailer parks

A **Non-Community Water System** is a public water system that serves at least 25 people, but doesn't serve them continuously year round.

Non-Transient or Transient

Non-community water systems are further broken down into Transient and Non-Transient systems.

A **Non-Transient Water System** is defined by EPA as "a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year."[3]

What are some examples of a non-transient water system?

A **Transient Water System** is defined by EPA as "a non-community water system that does not regularly serve at least 25 of the same persons over 6 months per year."[4]

What are some examples of a transient water system?

Size Classifications of Community Water Systems

Small Water Systems - water systems that serve 3,300 persons or fewer.

- Small water systems are not required to meet all the same requirements as larger systems. Most of the differences relate to frequency of sampling and testing for some contaminants.
- Small systems may also be eligible for special assistance from US-EPA and groups like the American Water Works Association (AWWA) to help them meet their needs with the limited resources generally available to small systems.

Generally, water systems that serve more than 3,300 people are classified as **Large Water Systems.** For certain specific regulations, a system must serve more than 10,000 people to be considered a "Large Water System."

- Large water systems have to meet more stringent monitoring requirements under certain regulations. Some of these are discussed in Unit 3.

Exercise

Look at the following descriptions of water systems. Identify them as Community or Non-Community. If Non-Community, further identify them as Transient or Non-Transient.

1. A hospital has its own private well and water treatment system.

2. A farmer has a good spring on his property and provides drinking water to 16 of his neighbors, free of charge.

3. A real estate developer buys bulk water from United Philadelphia American Water Company through a single metered connection and resells the water to the 17 homes in his development.

4. The same developer gets rid of the metered connection and lets UPAW Co. bill the 17 homes directly.

5. A restaurant with its own well supply has an apartment above that's connected to the restaurant's plumbing system.

6. A campground has sites with camper trailers set up permanently.

Key Points

- A community water system is defined as "a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year round residents." All other public water suppliers are considered to be non-community.

- Community water systems that serve more than 3300 people are classified as "large" while those that serve 3300 or fewer are considered to be small.

- Non-community water systems that regularly serve at least 25 of the same persons over 6 months per year are classified as "non-transient". All other non-community systems are considered "transient".

- Operators must be familiar with how treatment plants are classified because many individual plant requirements are based, in part, on the classification the water system.

[1] Definition taken from the National Primary Drinking Water Standards, which is available at the EPA Ground Water & Drinking Water website (www.epa.gov/safewater/mcl.html).

[2] Ibid.

[3] Ibid.

[4] Ibid.

Unit 3 – Federal and State Regulations

Learning Objectives

- State the roles of federal and state agencies regarding drinking water.
- Explain the requirements to becoming and maintaining operator certification
- Identify key regulations that directly affect the water treatment plant operator.
- Identify the maximum contaminant levels, and monitoring and reporting requirements for regulated contaminants.

United States Environmental Protection Agency

EPA studies health issues related to water quality and develops regulations, standards, and guidance documents related to drinking water. It legislates specific minimum requirements that the states must meet, though the states are generally permitted to enact more stringent requirements.

State of Pennsylvania Department of Environmental Protection

The Pennsylvania Department of Environmental Protection (Pa. DEP) has **primacy** , i.e. responsibility for enforcement of EPA drinking water regulations. Pa. DEP obtains primacy by meeting the minimum requirements mandated by EPA.

Other Agencies

Pennsylvania has two River Basin Commissions:

- Susquehanna River Basin Commission (SRBC)
- Delaware River Basin Commission (DRBC)

River Basin Commissions handle issues related to:

- Water allocations
- Water withdrawal limits
- Minimum stream flows and required reservoir releases
- Interbasin water transfers (i.e. water withdrawn from one river basin and discharged to another river basin either directly or as treated wastewater after consumption).

Operator Certification Act

The purpose of the operator certification (ACT 11) is to protect public health, safety and the environment. The act ensures that certified operators have appropriate skills, knowledge and abilities to make appropriate process control decisions during the operation of water systems and water distribution systems. To achieve this, the State Board of Certification of Water and Wastewater Systems Operators and the Pa. DEP sets the training, experience and examination standards for operator certification. This was done in ACT 11.

ACT 11

Every water system regulated under ACT 11 must have an **appropriately certified operator** and an appropriately certified operator must make all process control decisions of system operation.

What is an appropriately certified operator?
What is a process control decision?

An **appropriately certified operator** is ______________________________

____

____

A **process control decision** is ____

____

____

Act 11 does not require all operators that work at a water system to be certified; however only appropriately certified operators can make process control decisions. Uncertified and not appropriately certified operators can only make process control decisions when:

- Under direction of an appropriately certified operator or,
- Using Standard Operating Procedures (SOP) that were developed by an appropriately certified operator.

Additionally, an appropriately certified operator must be **available at all times** during system operations.

Available means that an appropriately certified operator is ___________________

____

____

The requirements to becoming an appropriately certified operator include:

- **Education Requirement**
  - The applicant must be at least a high school graduate, possess a GED or have been an operator before February 21, 2002.
- **Examination**
- **Criminal History Check**
  - Completed not more than 90 days before the date the operator signs the application
- **Experience Requirement**
- Final **official approval by the Board** and awarded a certificate of a class and subclass(es) commensurate with you experience. Final approval will be granted after a thorough review of the applicant's information.

Certification Requirements

Experience Requirements

Classification	High School Diploma	AS	CP	ASP	BS/BA
A	4 years	3 years	2 years	1 year	2 years
B	3 years	2 years	2 year	6 months	1 year
C	2 years	1 year	6 Months	6 Months	6 Months
D	1 year	1 year	6 Months	6 Months	6 Months
Dn	1 year	1 year	6 Months	6 Months	6 Months
Dc	6 Months	1 year	0	0	0
E	6 Months	1 year	0	0	0

AS: Associate Degree in environmental or physical sciences, engineering or engineering technology NOT approved by DEP
CP: A certificate program of a DEP-approved Certification Program in Water Treatment
ASP: An Associate Degree in a Water Treatment Program approved by DEP
BS/BA: A bachelor's or graduate degree in Biology, Chemistry, Environmental Sciences, Physical Sciences, Sanitary or Environmental Engineering or Engineering Technology from a nationally accredited college or university

Education/Experience Substitution (for High School Diploma ONLY)

Education/Experience	Total Experience Allowed
Successful completion of every 10 hours of post high school or post GED water or wastewater related training (as applicable) approved by DEP and determined by the State Board for Certification of Water and Wastewater Systems Operators (Board) to be applicable to the certification sought.	1 month experience per 10 hours of training.
Successful completion of a college course approved by DEP as being specifically applicable to the water or wastewater disciplines (Each semester college credit is equivalent to 15 hours.)	1.5 months experience for each semester college credit.

Experience can be demonstrated by participating in any of the following activities under the supervision of a certified operator or a certified operator of a higher classification than requested:

(1) Operation of mechanical equipment,

(2) Maintenance of mechanical equipment,

(3) Collection of samples,

(4) Analysis of chemical and biological samples,

(5) Performing calculations related to process control,

(6) Preparing or standardizing chemical and biological solutions,

(7) Compiling and completing monitoring data, determining appropriate process control measures

Examination Requirements

Types of Exams
Certification examinations measure the knowledge, skills and abilities necessary to successfully operate specific system sizes and technologies associated with the classification and subclassification of the water or wastewater system.

Examination for certification consists of a two (2)-part examination.

(i) Part I of the examination measures the applicant's general knowledge, skills and abilities common to all water or wastewater systems regardless of size.

(ii) Part II of the examination measures the applicant's specific knowledge, skills and abilities necessary to operate treatment technologies or system components and will parallel the water and wastewater sub-classifications.

The master examination for water systems measures the applicant's general knowledge, skills and abilities and their competency to operate all available treatment technologies and system components.

Separate and single water system examinations are prepared for both Class Dc and Class Dn water treatment plants. Also a separate and single examination for Class E water distribution systems and consecutive systems without treatment will be prepared for operator certification as well as a separate and single examination for wastewater collection systems.

Examination and experience requirements must be met before the Board can issue a certificate. On the next page are three tables that illustrate the Water system classes, subclasses and requirements for the Dc and Dn certificates.

These three illustrations below identify the Water system classes and subclasses.

Water System Classes

A >5 MGD
B >1 MGD but ≤ 5 MGD
C >0.1 MGD but ≤ 1 MGD
D ≤ 0.1 MGD
E Distribution systems and consecutive water systems without treatment

Water System Subclasses

1. Conventional filtration
2. Direct filtration
3. Diatomaceous earth filtration
4. Slow sand filtration
5. Cartridge or bag filtration
6. Membrane filtration
7. Corrosion control and sequestering
8. Chemical addition
9. Inorganic removal
10. Organic removal
11. Gaseous chlorine disinfection
12. Non-gaseous chemical disinfection
13. Ultraviolet disinfection
14. Ozone disinfection

Small Water Systems

Dc systems

1. system serves less than 500 individuals or has no more than 150 connections, whichever is less;
2. the source of water for the system is exclusively groundwater,
3. requires only disinfection, and
4. meets other applicable requirements provided by the Act and is not in violation of the Act or other PADEP rules and regulations.

Dn system

Same criteria as Dc system except for condition #3. A Dn system is one where the water requires no treatment.

- **If you have treatment you cannot be classified as an E or Dn.**
- **If you have treatment other than disinfection you cannot be classified as a Dc.**
- **In order to have an appropriate license an operator must certified in both the class and sub-classes of the treatment plant they are operating.**
- **The advantage of being classified as either Dn or Dc is that the testing process is simplified. Both the Dn and Dc classes have stand-alone tests, and no sub-classification tests are required.**

Exercise I

Answer the next three questions.

1. What certificates would be needed to run a 1 MGD water system that requires treatment for copper (due to low pH), manganese and uses gaseous chlorination as a disinfectant?
____

How much experience would be needed for a person with only a high school diploma before the board would grant a certificate to make process control decisions at this plant? ______________

2. What certificates would be needed to run a 10 MGD water system that uses conventional filtration and non-gaseous disinfection?_____________________________

____

How much experience would be needed for a person with an associates degree in environmental science before the board would grant a certificate to make process control decisions at this plant?____________________________

3. What certificates would be needed to run a groundwater system with 100 connections and 450 customers and treats with non-gaseous chemical disinfection?________________

____

How much experience would be needed for a person with only a high school diploma before the board would grant a certificate to make process control decisions at this plant? __________________

Continuing Education Requirement

Certified operators are required to obtain continuing education depending on the operator class. The continuing education requirements are different for each operator class. Continuing education must be earned in their 3-year renewal cycle and the education must be approved by DEP.

Operator Class	Contact Hours First 3-Yr Cycle	Contact Hours Subsequent 3-Yr Cycles
A	15	30
B	15	30
C	15	30
D	8	15
E (Distribution)	8	15
Dc	4	9
Dn	3	6
Grandparented	8	15

Certified Operator and Owner Responsibility

Certificate holders are required to make sound judgment and must consider the health and welfare of their customers, community and the environment. If it is found that an operator has been negligent, committed fraud, falsified an application, falsified operating records, or failed to use reasonable care or judgment in performance of duties the board may revoke suspend or modify a certificate.

Another important part of this responsibility is liability, with the new certification requirements liability of owners and operators comes to the forefront. Always use your best judgment or your system might find itself hit with a lawsuit.

Certified Operators must

- Meet all the requirements for recertification.
- Report to the system owner any know violation or system condition that may be or are causing violations of any department regulation or permit condition
- Report to the system owner any action to permit or eliminate a violation of applicable water system laws.
- Providing for the suitable O&M of a water system utilizing available resources to comply with all laws.
- Making or implementing process control decisions, or directing actions related to process control decisions for specific water systems.

Owners must:

- Employ, identify and report to the department the names of available operators required by DEP
- Require, supervise and direct certified operators to take such action so that the water system is in compliance with all laws.
- Providing a copy of permit conditions to the certified operator in responsible charge.

Owners, Operators, non-certified operators and maintenance staff can be prosecuted for failing to comply with the **Drinking Water and Wastewater Systems Operators Certification Act.**

Exercise II

Complete the following sentences by filling in the blanks.

1. Every water system regulated under ACT 11 must have ______________________.

2. Class B operators must obtain ____ hours of continuing education during their first renewal cycle and _____ hours during all subsequent renewal cycles.

3. Owners, __________, non-certified operators and maintenance staff can be prosecuted for failing to comply with the **Drinking Water and Wastewater Systems Operators Certification Act.**

4. A _________________ is a decision, which maintains or changes the quality or quantity of water or wastewater in a water system that may affect the public health or environment.

5. An __________________ is defined as an operator having a certificate containing the class and subclass(es) matching the class and subclass(es) of the system that they operate.

Safe Drinking Water Act

The **Safe Drinking Water Act** authorizes EPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. These standards are divided into:

Primary Standards – National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of specific contaminants in drinking water.

- Some contaminants are regulated by establishing a specific maximum concentration.
- Other contaminants are regulated by requiring specific treatment techniques and performance requirements that will assure their removal.
- A listing of contaminants regulated by the primary standards, their MCL's and/or treatment techniques, potential health effects, and potential sources of contamination can be found in Appendix 1.

Secondary Standards – National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

- EPA recommends secondary standards to water systems but they are not regulated.
- States with primacy, at their option, may adopt regulations that are more stringent than EPA regulations. Pa. DEP **does** require monitoring for secondary contaminants.
- A listing of contaminants regulated by the secondary standards and their MCL's can be found in Appendix 2.

Other Relevant Federal Regulations

The Safe Drinking Water Act serves as the "springboard" for all Federal drinking water regulations. This section discusses some, but not all, of the more important rules and describes the major provisions of each.

Surface Water Treatment Rule - The Surface Water Treatment Rule was implemented to overcome the shortfalls of the National Interim Primary Drinking Water Regulations (NIPDWR). This rule became effective in June, 1989. Pa. DEP has primacy for enforcement. Major components include:

- Requires disinfection of all surface supplies.
- Establishes treatment techniques to achieve at least 99.9% removal or inactivation (referred to as "3-log removal") of *Giardia lamblia* cysts and 99.99% (referred to as "4-log" removal) of viruses.
- Systems must be operated by "qualified personnel."
- Establishes criteria for operating without filtration.
  - To avoid filtration, a system must meet specific source water quality criteria and must still meet the disinfection requirements.
  - All systems that do not meet the avoidance criteria must provide filtration.
  - All surface water and GUDI sources must provide filtration
- Establishes "CT" as the basis for disinfection. "CT" is an abbreviation for "Concentration x Time." It provides a means of determining the level of disinfection being achieved under specific operating conditions.
  - In consideration of short circuiting which may occur in some basins, this rule establishes a methodology for determining effective detention time for different basin and clearwell configurations .
  - Provides a means to determine that required disinfection has been achieved, based on disinfectant used, disinfectant concentration, contact time, water temperature, pH, and required "log removal" of targeted microbes (*Giardia,* viruses).
- Establishes suitable filtration technologies and performance criteria for removal of turbidity and *Giardia*. Filtration is covered in detail in Modules 14 through 19.
- Establishes sampling requirements and MCL's for combined filter effluent turbidity to monitor performance of the filtration system.
- The Surface Water Treatment Rule includes groundwater that is "under the influence" of surface water.

Interim Enhanced Surface Water Treatment Rule: This rule builds upon the Surface Water Treatment Rule to improve control of microbial pathogens and address risk trade-offs with disinfection byproducts. This rule became effective February 16, 1999. PADEP has primacy for enforcement. This rule generally only affects systems that use surface water and serve 10,000 people or more. Some of the major provisions include:

- Systems that are required to filter under the Surface Water Treatment Rule must achieve at least 99% (2-log) removal of the protozoan *Cryptosporidium.* Systems are considered to be in compliance with this requirement if filter effluent turbidity requirements are met.

- Strengthened filter effluent turbidity requirements.
  - Combined filter effluent turbidity must be below 0.3 NTU in at least 95% of the turbidity measurements taken, and measurements must be taken at least every four hours.
  - Combined filter effluent turbidity must be below 1.0 NTU at all times.
  - Effluent turbidity of all individual filters must be monitored continuously.

- Includes disinfection CT benchmarking/profiling requirements to insure changes in disinfection practices to reduce disinfection byproducts don't result in any reduction of disinfection of pathogens.
  - The Operator must record disinfectant residual, water temperature, pH, and contact time daily during peak hourly flow for one year. This is also a beneficial monitoring practice for purposes other than simply meeting regulations.
  - Using the recorded information, the Operator must calculate *Giardia lamblia* inactivation for each day. Using the daily data, the operator must determine the average *Giardia lamblia* inactivation for each month and plot on a graph. This is the disinfection profile.
  - If any changes are made to disinfection practices, the water system operator must demonstrate that the level of *Giardia lamblia* inactivation will not be less than the lowest level shown on the system's current disinfection profile. (The lowest level on the current profile is the "benchmark").

- States are required to conduct sanitary surveys for all systems using surface water (or groundwater under direct influence of surface water).

- All new treated water storage tanks and reservoirs must be covered.

Long Term 1 Enhanced Surface Water Treatment Rule (LT1): EPA promulgated this rule on February 13, 2002. In Pennsylvania, the final version of the rule was published in the PA Bulletin on June 19, 2004 and water systems must begin compliance starting in January 2005. PADEP has primacy for enforcement. Like the Interim Enhanced Surface Water Treatment Rule, this rule was put in place to improve control of microbial pathogens, specifically the protozoan *Cryptosporidium,* and to address risk trade-offs with disinfection by-products. However, this rule applies to public water systems that serve fewer than 10,000 people. Some of the major provisions include:

- All systems covered by this rule must achieve at least 99% (2-log) removal or inactivation of *Cryptosporidium.* Systems are considered to be in compliance with this requirement if filter effluent turbidity requirements are met.
- Strengthened filter effluent turbidity monitoring requirements, as described in the Interim Enhanced Surface Water Treatment Rule.
- Disinfection benchmarking and profiling, as described in the Interim Enhanced Surface Water Treatment Rule.

Filter Backwash Recycling Rule: This rule became effective August 7, 2001. This rule was passed to regulate filter backwash recycling methods and prohibit practices that may compromise treatment. Some of the major provisions include:

- Applies to **all** systems that use surface water (or ground water under the direct influence of surface water), use conventional or direct filtration, and recycle spent filter backwash water and/or liquids from sludge thickening and dewatering processes.
- Recycled water must be reintroduced into the process upstream of any chemical treatment.
- Water system operators must submit information to their state related to their treatment process, including:
  - A treatment process schematic
  - Recycle flow streams
  - Backwash flow rates
  - Treatment provided to the waste streams before they are recycled.
- Based on this information, the state may require modifications to the water treatment plant's recycle practices.

Stage 1 Disinfectants and Disinfection Byproduct Rule: This rule became effective February 16, 1999. Pa. DEP has primacy for enforcement. This rule sets maximum contaminant levels (MCL's) for total trihalomethanes (TTHM's) and the total of five haloacetic acids (HAA5). It also sets maximum disinfectant residual concentrations for chlorine, chloramines, and chlorine dioxide. Some of the major provisions include:

- Applies to all public water systems that add a disinfectant during **any** part of the water treatment process.
- Sets MCL for TTHM's at 0.08 mg/L (80 parts per billion or ppb) and MCL for HAA5 at 0.06 mg/L (60 ppb).
- Sets MCL for chlorite (a by-product of chlorine dioxide) at 1.0 mg/L and MCL for bromate (a by-product of ozone) at 0.01 mg/L (10 ppb).
- Sets maximum residual disinfectant levels (MRDL's) of 4.0 mg/L (as Cl_2) for chlorine, 4.0 mg/L (as Cl_2) for chloramines, and 0.8 mg/L for chlorine dioxide (as ClO_2).
- Requires removal of total organic carbon (TOC) present in the raw water by enhanced coagulation (for systems using conventional treatment). Chemical disinfectants react with organic carbon in the raw water to form by-products. Removal requirements are outlined in the table below:

Table 3.1: Required Removal of Total Organic Carbon (Percent) by Enhanced Coagulation

Source Water TOC (mg/L)	Source Water Alkalinity (mg/l as $CaCO_3$)		
	0 - 60	>60 - 120	>120
	Required % Removal of TOC		
>2.0 – 4.0	35.0	25.0	15.0
>4.0 – 8.0	45.0	35.0	25.0
>8.0	50.0	40.0	30.0

TOC removal requirements apply to any system using surface water or groundwater under direct influence of surface water and that use conventional treatment (chemical coagulation, flocculation, sedimentation, and filtration) regardless of the size of the system.

Total Coliform Rule: This rule became effective December 31, 1990. Pa. DEP has primacy for enforcement. This rule sets monitoring and compliance requirements for coliform bacteria. Some of the major provisions include:

- All systems must have a written sample siting plan.
- For Community Water Systems, the number of samples is based on minimum population served, as outlined in the table below:

Table 3.2: Sampling Requirements For Coliforms

Population	Minimum Number of Samples Required per Month
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240
780,001 to 970,000	270
970,001 to 1,230,000	300
1,230,001 to 1,520,000	330
1,520,001 to 1,850,000	360
1,850,001 to 2,270,000	390
2,270,001 to 3,020,000	420
3,020,001 to 3,960,000	450
>3,960,001	480

- If any samples are positive for total coliforms, repeat samples must be taken as follows:
  - Systems that collect more than one sample per month must collect at least three repeat samples within 24 hours for each sample that tested positive for total coliforms.
  - Systems that collect only one sample per month must collect at least four repeat samples within 24 hours for each sample that tested positive for total coliforms.
  - Systems must continue to collect repeat samples until all samples are negative or it is determined that the system has violated the MCL.
  - Systems that collect less than five samples per month must collect at least five routine samples during the month immediately following the positive sample.
  - Any sample that tests positive for total coliforms must be analyzed for *E. coli* or fecal coliforms.

- Water systems that collect fewer than five routine samples per month must undergo a sanitary survey every five years.

Arsenic Rule: This rule became effective March 23, 2001. Pa. DEP has primacy for enforcement. This rule reduces the MCL for arsenic in drinking water from its previous concentration of 0.05 mg/L (50 ppb) to 0.01 mg/L (10 ppb). This rule also examines the "best available technologies" (BAT's) for arsenic removal. Some of the BAT's discussed in this rule are summarized in the table below:

Table 3.3: Best Available Technologies For Arsenic Removal

Treatment Technology	Maximum Percent Removal
Ion Exchange	95
Activated Alumina	95
Reverse Osmosis	>95
Modified Coagulation and Filtration	95
Modified Lime Softening	90

Lead and Copper Rule: This rule became effective in 1991 with revisions that became effective April 11, 2000. Pa. DEP has primacy for enforcement. This rule deals mainly with lead and copper levels in water at the customers' tap. Major provisions of this rule include:

- Requires monitoring of lead and copper levels at customer taps. Monitoring requirements vary, depending upon the size of the system.

   - Monitoring requirements are broken down by systems serving more than 50,000 persons, systems serving 3,301 to 50,000 persons, and systems serving 3,300 or fewer persons.
   - Transient non-community water systems are excluded from this rule.

- Systems where lead and copper levels at the customer tap exceed action levels (0.015 mg/L for lead and 1.3 mg/L for copper) must institute corrosion control practices. This usually involves additional chemical treatment at the water treatment plant to raise pH and make the water more stable and less corrosive.

- Follow-up monitoring is required to verify corrosion control practices are working.

- Water systems must provide educational information to their customers outlining the causes of elevated lead and copper levels, the health effects of lead and copper, and actions the customers can take on their own to reduce their risk of exposure.

Pennsylvania Water Supply Regulations

Pa. DEP publishes a Pennsylvania Water Supply Manual that describes design and operation requirements under Pennsylvania regulations. The Manual is divided into seven parts:

- Summary of Key Requirements – outlines monitoring and reporting requirements under many of the regulations discussed earlier in this workbook.

- Community System Design Standards – covers design requirements for water treatment processes, facilities, and distribution for community systems.

- Non- Community System Design Standards - covers design requirements for water treatment processes and facilities for non-community systems.

- Bottled Water, Bulk Water Hauling, Water Vending Machines, and Retail Water Facilities – covers requirements for processing and handling bottled water and bulk water hauling equipment.

- Operations and Maintenance – provides guidance on system start-up, operation, maintenance, and monitoring and reporting requirements.

- Emergency Response – describes various types of hazards, accidents, and failures that can affect water treatment plant operations and provides guidance for developing appropriate response plans.

- Cross-Connection Control/Backflow Prevention - covers acceptable means and methods for preventing cross connections and backflow between non-potable and potable water systems.

Key Monitoring and Reporting Requirements

Microbiological (Coliform)

- Must be monitored monthly. The required number of samples is based on the population served.
- Samples are taken from the distribution system.
- A system is in violation if:
    - Any sample is found to be positive for fecal coliform and at least one check sample is coliform positive, or if two or more monthly samples (for systems collecting 1 to 39 samples per month) or more than 5% of all samples collected (for systems collecting 40 or more samples per month) are coliform positive.
    - Any routine sample is fecal or *E. coli* coliform positive AND at lease one check sample is total coliform positive.
    - Any check sample is found to be fecal or *E. coli* coliform positive.

Inorganic Chemicals

- One annual sample (surface water sources) or one sample every three years (groundwater sources) is required, or quarterly samples for at least 4 consecutive quarters if initial sample is over the MCL.
- Samples are taken from each point water enters the distribution system.
- A system is in violation if average of routine and check samples exceeds the MCL for any regulated inorganic chemical contaminant.

Volatile Organic Chemicals and Synthetic Organic Chemicals

- One annual sample is required, or quarterly samples for at least 4 consecutive quarters if initial sample is over the MCL.
- Samples are taken from each point water enters the distribution system.
- A system has exceeded the MCL if average of routine and check samples exceeds the MCL.

Nitrate/Nitrite

- One annual sample is required, or quarterly samples for at least 4 consecutive quarters if initial sample is over 50% of the MCL.
- Samples are taken from each point water enters the distribution system.
- A system has exceeded the MCL if average of routine and check samples exceeds the MCL.

Disinfection Byproducts

- Sampling requirements for TTHM's and HAA5 are:
  - For large water systems (serving 10,000 persons or more), four samples per plant per quarter. One sample at point of longest residence time in distribution system and three samples at representative locations in distribution system
  - For small water systems (serving less than 10,000 persons), one sample per plant per quarter at point of longest residence time in distribution system.
- Samples are taken from the distribution system.
- A system has exceeded the MCL if the annual running average of samples collected exceeds the MCL.

Radionuclides

- Level is based on an annual composite of four consecutive quarterly samples (for surface water systems) or one sample every four years (for groundwater systems).
- Samples are taken from the distribution system.

Turbidity (Conventional or Direct Filtration)*

- Effluent turbidity of individual filters must be monitored continuously. The turbidity of the combined effluent flow from all filters must be sampled at least every 4 hours.
- The operator must also report the number of hours the filter plant was in operation each month and the number of combined effluent turbidity measurements taken.
- Combined filter effluent samples are taken immediately downstream of the confluence of all filter effluents.
- A system has exceeded the MCL if more than 5% of monthly combined filter effluent samples are over 0.3 NTU or any single sample is over 1 NTU.
- A system has exceeded the MCL if two consecutive individual filter effluent measurements taken 15 minutes apart exceed 1.0 NTU, or if two measurements taken 15 minutes apart at the end of the first four hours of operation exceed 0.5 NTU.

*Turbidity MCL's may differ for other filtration types.

Disinfectant Residual

- Disinfectant residual must be monitored continuously. The lowest value recorded each day is reported.
- Samples are taken at the point where water enters the distribution system and in the distribution system at the locations where coliform samples are taken.
- A system has not met minimum disinfectant residual requirements if residual concentration falls below 0.2 mg/l for four hours at the point where water enters the distribution system or if residual concentration in the distribution system falls below 0.02 mg/l, or if heterotrophic plate count exceeds 500.

Lead and Copper

- Samples for lead and copper must be taken every six months, unless the system is below the action levels for lead and copper for two consecutive six month periods or has optimized corrosion control. In that case samples must be taken annually.
- Small or medium sized systems (less than 10,000 persons served) that are below the action levels for lead and copper for three consecutive years may reduce sampling to once every three years. Large systems that are below the action levels for lead and copper for three consecutive years may reduce the numbers of samples taken.
- Samples are taken at the point where water enters the distribution system and at a number of locations throughout the distribution system. The number of distribution samples that must be taken depends upon the number of persons served.
- A system must implement appropriate treatment techniques if the 90^{th} percentile value of the samples collected in any monitoring period exceeds the action levels for lead or copper.
- The action levels for lead and copper are 0.015 mg/L and 1.3 mg/L

Secondary Contaminants

- MCL's for these contaminants are not enforceable; however, most water treatment plant operators still monitor and record these parameters.
- The secondary contaminants most commonly monitored by the water treatment plant operator include color, corrosivity, aluminum, chlorides, iron, manganese, odor, pH, and total dissolved solids.

The water treatment plant operator is responsible for recording, compiling, and reporting the results of water quality analysis to Pa. DEP. If certain MCL's are exceeded, Pa. DEP must be notified. Some of the key notification requirements are outlined below:

The following MCL violations must be reported to the local Pa. DEP Regional Office within **one hour** of their occurrence:

- Microbiological (Coliform) - Any single sample is positive for coliforms (requiring a check sample) or if any check sample confirms the presence of total or fecal coliform.
- Turbidity - More than 5% of monthly measurements for combined filter effluent turbidity exceed 0.3 NTU or any single measurement exceeds 1.0 NTU.
- Turbidity - Two consecutive individual filter effluent measurements taken 15 minutes apart exceed 1.0 NTU, or if two measurements taken 15 minutes apart at the end of the first four hours of operation exceed 0.5 NTU.
- Inorganic Chemicals and Nitrate/Nitrite – Any single sample exceeds the MCL or the average of the original and check samples exceed the MCL.
- Synthetic Organic Chemicals and Volatile Organic Chemicals - Any single sample exceeds the MCL or the average of the original and check samples exceed the MCL.
- Radionuclides – Any single sample exceeds the MCL.

In addition to Pa. DEP notification, public notification is required for any of the following violations and situations:

- Failure to comply with an applicable State primary maximum contaminant level (MCL) or maximum residual disinfectant level (MRDL)
- Failure to comply with a prescribed treatment technique requirement
- Failure to comply with the schedule of a variance or exemption
- Operation under a variance or an exemption
- Occurrence of a waterborne disease outbreak or other waterborne emergency
- Failure to make unregulated contaminant monitoring results available
- Exceedance of the nitrate MCL by noncommunity water systems, when permitted by the Pa. DEP in writing to operate under an Alternate Nittrate Level

Violations are organized into three tiers based on the seriousness of any potential adverse health effects. The deadlines for Tier 1, Tier 2, and Tier 3 public notice are 24 hours, 30 days, and 1 year respectively/

Impacts on Future Rulemaking and Regulations

- Risk Assessment forces regulators to look at what it will cost water suppliers to comply with the new regulation in comparison to the actual health and public safety benefits that can be achieved.

- Proponents of Risk Assessment believe this analysis will allow better prioritization of environmental hazards.

- Opponents of Risk Assessment believe the analysis will unnecessarily consume agency resources, delay new regulations, and force decisions to be made on the analytical results of the risk assessment, even if the underlying data is defective or incomplete.

How could this potentially impact your job as operators?

Regulatory Guidance - State and Federal

Many sources of information are available for additional information and guidance related to state and federal regulations. Some of these include:

- **United States Environmental Protection Agency:** EPA maintains a website which provides access to a large amount of information on federal drinking water regulations.

  Website: www.epa.gov/safewater/

- **Pennsylvania Department of Environmental Protection:** Copies of the Pennsylvania Water Supply Manual can be obtained from:

  Bureau of Water Supply Management
  P.O. Box 8467
  Harrisburg, PA 17105-8467

  Website: www.dep.state.pa.us

  Information on Pennsylvania drinking water regulations can be obtained at this website by entering the directLINK Water Management.

- **American Water Works Association:** AWWA is a national organization for water treatment professionals.

  American Water Works Association
  6666 W. Quincy Avenue
  Denver, CO 80235

  Phone: 303-794-7711 (Headquarters)
  800-926-7337 (Customer Service)
  Fax: 303-794-7310

  Website: www.awwa.org

  AWWA has many books, periodicals, and other publications available and sponsors various technical conferences throughout the year.

Key Points

- The United States Environmental Protection Agency (EPA) studies health issues related to water quality and develops regulations, standards, and guidance documents related to drinking water.

- The Pennsylvania Department of Environmental Protection (Pa. DEP) has **primacy**, i.e. responsibility for enforcement of EPA drinking water regulations.

- The Operator Certification Act ensures that certified operators have appropriate skills, knowledge and abilities to make appropriate process control decisions during the operation of water systems and water distribution systems.

- There are many regulations that dictate the various duties of a water treatment operator. It is the operator's responsibility to maintain full knowledge of not only existing water treatment requirements, but also new requirements as they are developed.

Exercise

1. **The manganese level in your treated water is 0.18 mg/l.**

   a. Are you in violation? Hint: MCL's are found in Appendices 1 and 2
   b. When do you need to report your violation?
   c. Do you need to notify the public?

2. **Your water system fluoridates the water. The fluoride feed system malfunctions and fluoride residual goes from 1.0 mg/l to 5.0 mg/l.**

   a. What is the first thing you should do?
   b. Are you in violation?
   c. When do you need to report the violation?
   d. Do you need to notify the public?

3. Look at the turbidity data in the table below. Is this system in violation of the MCL for turbidity? If so, identify which measurements constitute a violation and identify the type of each violation.

Clear Water Conventional Treatment Plant Turbidity Data			
Time	Filter 1	Filter 2	Combined Filter Effluent
0800	0.23	0.19	0.20
0815	0.25	0.19	0.22
0830	0.25	0.20	0.22
0845	0.24	0.19	0.21
0900	0.25	0.19	0.22
0915	0.26	0.18	0.23
0930	0.25	0.19	0.23
0945	0.25	0.29	0.27
1000	0.26	0.74	0.52
1015	0.25	0.76	0.53
1030	0.25	0.78	0.54
1045	0.23	0.80	0.54
1100	0.24	0.89	0.63
1115	0.23	0.97	0.72
1130	0.24	1.21	0.89
1145	0.24	2.81	1.89
1200	0.24	-Taken offline-	0.24
1215	0.23		0.23
1230	0.24		0.24
1245	0.24		0.24

4. **Your system is required to take 20 samples for lead and copper. The results of those 20 samples are given in the table below. Are you in compliance?**

Sample No.	Lead Concentration (mg/L)	Copper Concentration (mg/L)
1	0.013	1.1
2	0.009	0.7
3	0.007	0.9
4	0.002	0.6
5	0.017	0.7
6	0.016	1.2
7	0.020	1.4
8	0.004	1.2
9	0.011	1.0
10	0.009	0.7
11	0.009	0.7
12	0.005	0.5
13	0.014	0.3
14	0.013	0.9
15	0.008	1.0
16	0.012	1.2
17	0.012	1.1
18	0.003	0.6
19	0.006	0.5
20	0.011	0.8

Unit 4 – Overview of Water Treatment Processes

Learning Objectives

- Name and describe different water treatment processes and specify in what order they are used.

Overview

A water treatment plant uses a series of individual treatment processes in combination to provide an overall treatment system that takes raw source water and makes it potable.

The treatment processes provided are selected based upon the characteristics of the raw water. The overall treatment process is intended to provide “multiple barriers” against the passage of contaminants or pathogens into the drinking water supply.

Typical Water Treatment Processes	Purpose
Raw Water	
↓	
Intake-screens	removes large debris
↓	
Coagulation and Rapid Mix	coagulant chemicals are thoroughly mixed with the raw water and fine particles begin to bind together
↓	
Flocculation	slow mixing allows particles to form large masses (floc) that settle more easily
↓	
Sedimentation	large particles (floc) settle out and are removed
↓	
Filtration	remaining particles are filtered out
↓	
Post Chlorination	kills pathogenic (disease-causing) organisms and provdes a chlorine residual for the distibution system
↓	
Corrosion Control	introduces chemicals to prevent the deterioration of distribution equipment
↓	
Clear well	provides contact time for adequate disinfection
↓	
Storage and Distribution	stores finished water and conveys it to the customers

A typical Surface Water Conventional Filtration Treatment Process is shown in Figure 4.1.

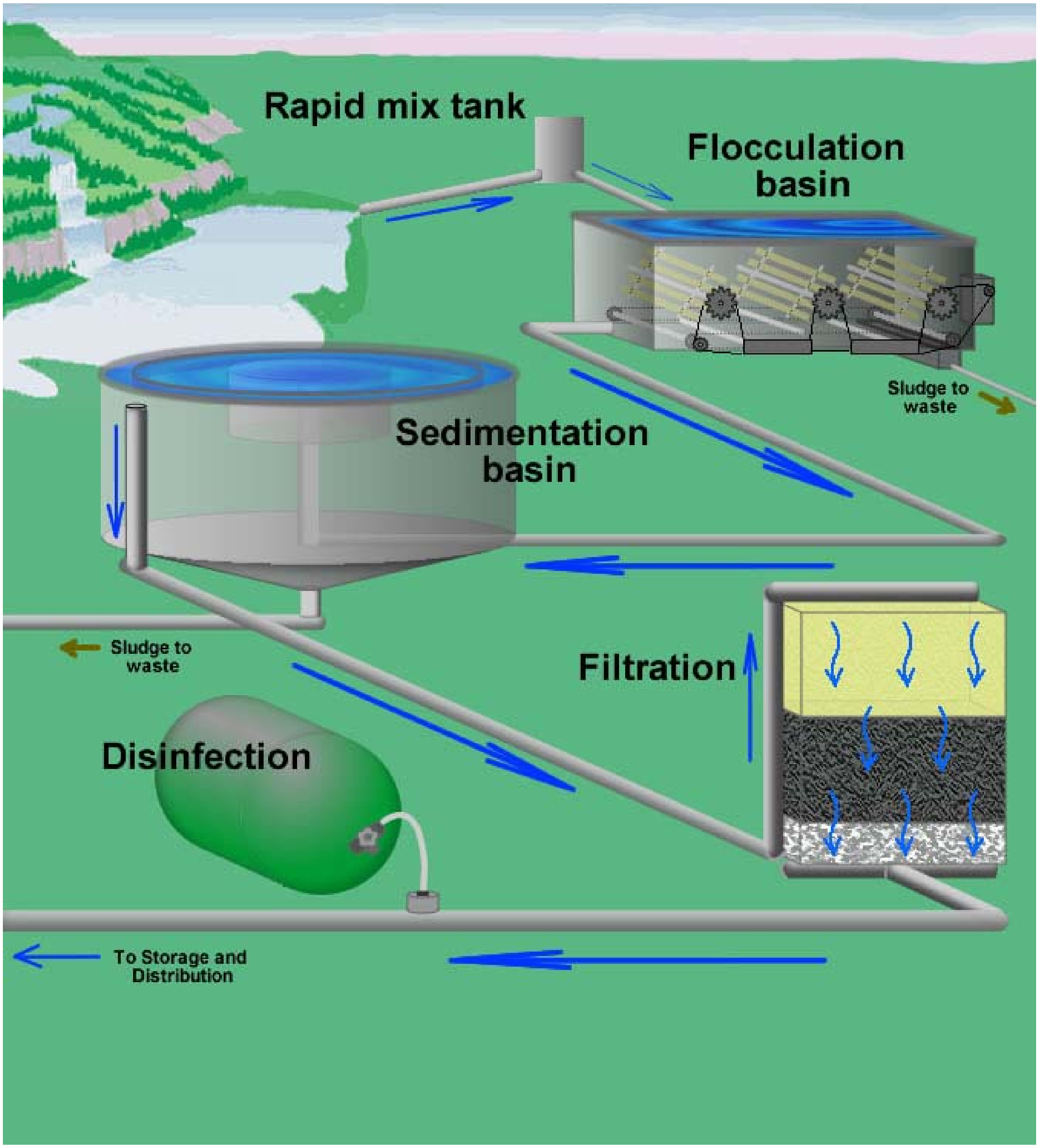


Figure 4.1 Water Treatment Process

Most of these processes apply to treatment of surface water. Processes commonly used for groundwater treatment include chemical oxidation, filtration, adsorption/ion exchange, and corrosion control. Virtually all potable water treatment plants must provide disinfection.

1. Pretreatment

Pretreatment is used to remove large debris in the water by physical removal (bar screens, racks, etc.) and by using chemical processes, to help control taste and odor causing substances. Ozone, hydrogen peroxide, potassium permanganate, powdered activated carbon (PAC) and chlorine are all commonly used in water treatment.

Adsorption

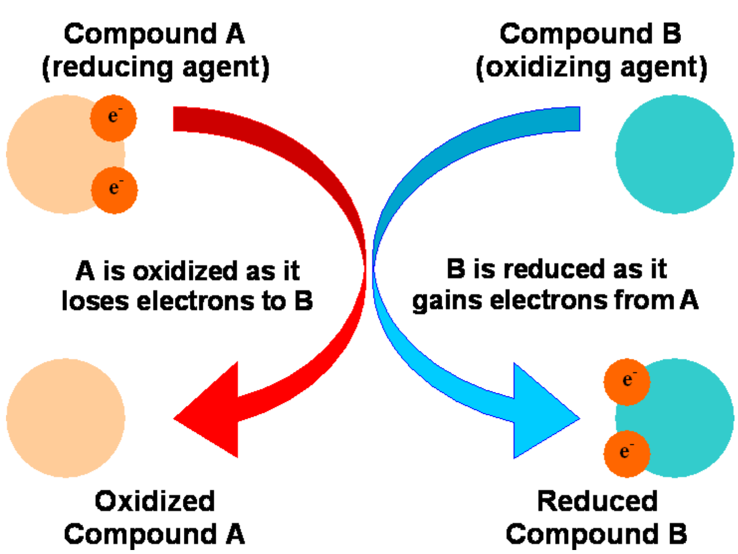
Adsorption is a process by which molecules, colloids and particles adhere to a surface by physical action and without any chemical reaction. The particles **stick to its surface**. Powdered activated carbon (PAC) is typically used when adsorption is provided as part of the pre-treatment process.

- PAC is fed into the raw water. The raw water then usually goes into a contact basin that provides detention time for the PAC to work.
- After the PAC has adsorbed the dissolved contaminants, it is removed (along with the adsorbed substances) by clarification and filtration.
- Adsorption is typically used to remove organic compounds.
  - Man-made organic compounds that pose health risks.
  - Natural organic compounds that cause tastes and odors.

Chemical Oxidation/Reduction

Chemical oxidation/reduction is a reaction where electrons are transferred from one compound to another. Soluble compounds often become insoluble when oxidized. When a dissolved substance is converted from soluble to insoluble, it forms solid, suspended particles in the water that can be removed by conventional physical processes.

Figure 4.2 – An oxidation/reduction reaction



- Typical oxidizing chemicals include: chlorine, chlorine dioxide, ozone, and potassium permanganate.

Substances typically removed by chemical oxidation include iron, manganese, and some organic compounds (from algae, dead leaves, etc.).

2. Coagulation

Coagulation uses the addition of a chemical to neutralize the charges on the small suspended (colloidal) particles and cause them to clump together into larger particles that will settle or can be filtered. Coagulant chemicals must be rapidly mixed with the source water because the reaction they generate occurs very quickly. Rapid and thorough mixing ensures that a maximum of the colloidal particles are neutralized.

- Chemicals typically used for coagulation include aluminum sulfate (alum), ferric sulfate, ferric chloride, and polyaluminum chloride.

- The coagulation process must include a short period of intense (rapid) mixing to uniformly disperse the coagulant.

Figure 4.3: A rapid mixer for coagulation

3. Flocculation

- Coagulation is followed by a longer period of gentle mixing to help the smaller particles clump together into larger particles. This process is called Flocculation.

Figure 4.4 – Horizontal Reel Flocculator

4. Sedimentation/Settling

Sedimentation processes are used to remove the larger particles (floc) formed by the coagulation processes.

Some common processes include:

- **Conventional settling** – Uses a large quiescent basin with a relatively long detention time to give particles time to settle to the bottom.

Figure 4.5 – Conventional Sedimentation Basins

- **High rate plate settling** – Uses a series of inclined plates to get more effective settling area into a smaller footprint.

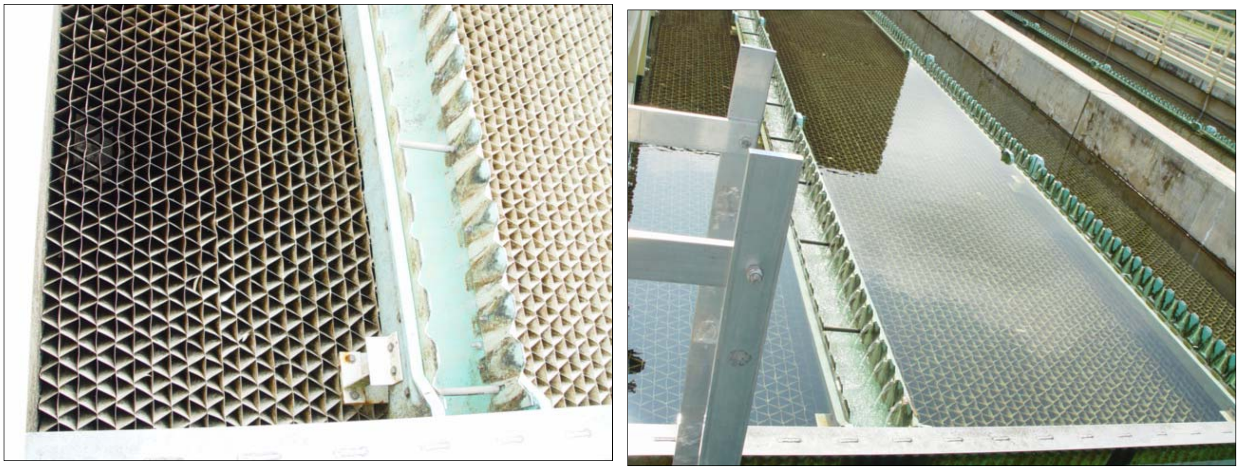


Figure 4.6 – High Rate Tube Settlers

- **Contact clarification** – Water flows upward through a bed of coarse granular media to trap larger particles. Bed is periodically flushed using a combination of air and water.

- **Solids blanket** – Flocculated water flows upward through a blanket of high concentration solids. The solids blanket traps floc particles from the water flowing through. As the blanket builds up from the trapped particles, the excess solids are discharged from the basin to waste as sludge.

- **Ballasted flocculation** – Adds very fine sand (consistency of talcum powder) to the water during flocculation to help form very dense and heavy floc particles that settle very quickly.

- **Dissolved air flotation** – A stream of water that is supersaturated with air is discharged through fine nozzles at the inlet of the basin. When the supersaturated water is discharged from the nozzles, the air in the water forms large numbers of micro-bubbles. Particles in the flocculated water fed into the basin attach themselves to the bubbles and are carried to the surface along with the bubbles as they rise. The concentrated solids are then skimmed from the surface of the basin and discharged to waste as sludge.

4. Filtration

Conventional Filtration

Conventional Filtration consists of flowing water downward through a bed of granular media to remove the smaller suspended floc that were not removed by clarification. Flow can be by gravity or under pressure.

- Typical materials used for filter media include: anthracite coal (relatively coarse and light), silica sand, garnet sand (relatively fine and dense), granular activated carbon (used for adsorption as well as filtration)
- Filtration can be designed as a high rate (high flow per square foot of filter area) or slow rate process.
- Different media can be used in combination to improve filtration.
- Trapped material is removed by flushing water upward (opposite normal flow) through the bed.

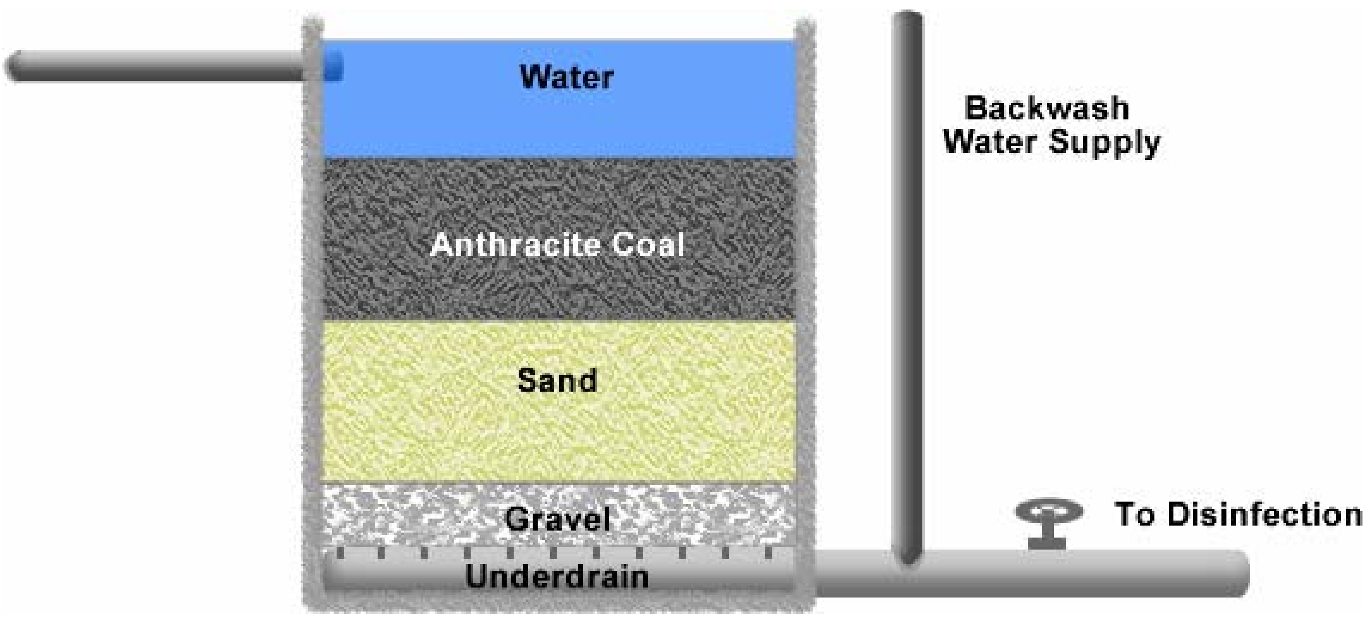


Figure 4.7– Cross Section of a Dual Media Filter

Membrane Filtration

Water is forced under pressure through polymer membranes with very small but uniform pores that strain out small particles and micro-organisms. Membranes provide an absolute barrier to these contaminants. Nanofiltration and reverse osmosis can be used to remove dissolved solids. These membranes are sometimes rated based on the range of molecular weights of particles they can remove, rather than pore size.

- **Microfiltration** – pore size = .05 to 3 microns
- **Ultrafiltration** – pore size = 0.02 to 0.1 microns
- **Nanofitration** – pore size = 0.001 to 0.005micron, can remove particles with molecular weights of 200 to 15,000
- **Reverse Osmosis** – pore size < 0.001 micron, can remove particles with molecular weights less than 200

Figure 4.8 – Reverse Osmosis Membrane Filter

Membranes must also be backflushed to remove accumulated material.

Additional Water Specific Treatment Processes

Adsorption/Ion Exchange

An additional treatment, adsorption/ion exchange removes dissolved substances and may be used after filtration, but before disinfection. Granular activated carbon (GAC) is typically used for **adsorption** when adsorption is used as a treatment process.

- GAC grains, just like PAC grains, have small pores where molecules of the substance being removed attach themselves.
- GAC is used in filter beds (see "Filtration" above). When all the pores are filled and the adsorption capacity depleted, GAC can be "regenerated" by removing it from the filter and heating to high temperatures to drive off the adsorbed substances.
- Just as in pretreatment, adsorption is typically used to remove organic compounds.
  - Man-made organic compounds that pose health risks.
  - Natural organic compounds that cause tastes and odors.

Ion exchange is used to remove dissolved minerals, nitrates and in water softening.

- Water flows through a bed of resin beads that is pre-charged with one type of ion (usually sodium).
- The resin beads adsorb the ions of the substance to be removed and release the sodium ions into the water.
- When the removal capacity of the bed is exhausted (all the sodium has been released), the bed is recharged with a concentrated salt solution.

Corrosion Control

Corrosion is the oxidation of unprotected metal surfaces leading to leaching of harmful materials such as lead into drinking water. It is usually measured by a calculation called the *Langlier Saturation Index.* **Corrosion control** uses chemicals to reduce the corrosive properties of the water. If following the filtration process water is corrosive (low pH, total dissolved solids, alkalinity and hardness) it must be stabilized by raising pH, adding sequestering agents, or other corrosion control chemicals.

- Chemicals typically used to raise pH include lime, sodium hydroxide (caustic soda), and sodium carbonate (soda ash).
- Chemicals typically used for sequestering include any of several polyphosphate chemicals. These chemicals bind certain ions such as iron and manganese into stable, water-soluble compound, thus preventing undesirable action by the ions.
- Chemicals used to minimize dissolution of pipe material into the water include zinc orthophosphate.

6. Disinfection

Disinfection is the process of inactivating or removing pathogenic microorganisms from treated water before it is delivered to the consumer. Organisms can be physically removed, killed, or rendered non-infective by several physical and/or chemical processes.

- Microorganisms are physically removed by coagulation and filtration.
- Microorganisms are killed by chemical disinfectants including chlorine, ozone, chlorine dioxide, chloramines (a chemical combination of chlorine and ammonia) and sodium hypochlorite.
  - Water leaving a treatment plant must have a "residual" concentration of some chemical disinfectant to kill any microorganisms that may find their way into the water distribution system beyond the treatment plant.
- Ultraviolet (UV) light does not necessarily kill microorganisms, but will damage their genes so that they cannot reproduce, thereby rendering them non-infective.
  - UV must be used in conjunction with a chemical disinfectant since it does not leave a "residual" to protect the water distribution system.

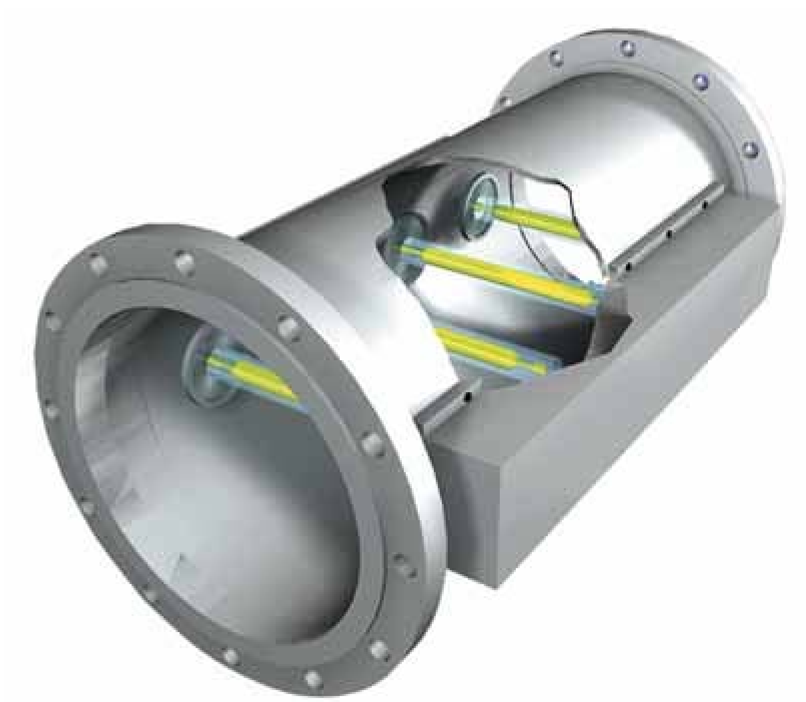


Figure 4.9 – Cutaway View of UV Disinfection Unit

Case Study

Given a raw water source with the following characteristics, what treatment processes would you recommend?

Source: Surface water reservoir in agricultural watershed. Major interstate highway crosses headwaters of reservoir.

Raw Water Quality Table

Parameter	Units	Minimum	Average	Maximum	MCL	MCLG(1)
Turbidity Notes:	NTU	3	12	97	0.3	0.1
Iron Notes:	Mg/L	0.03	0.1	0.4	0.3	None Detected
Manganese Notes:	Mg/L	0.01	0.06	0.22	0.05	0.03
Nitrates Notes:	Mg/L	9	17	33	10	8
Alkalinity Notes:	Mg/L	32	44	86	---	---
Hardness Notes:	Mg/L	40	48	103	---	100

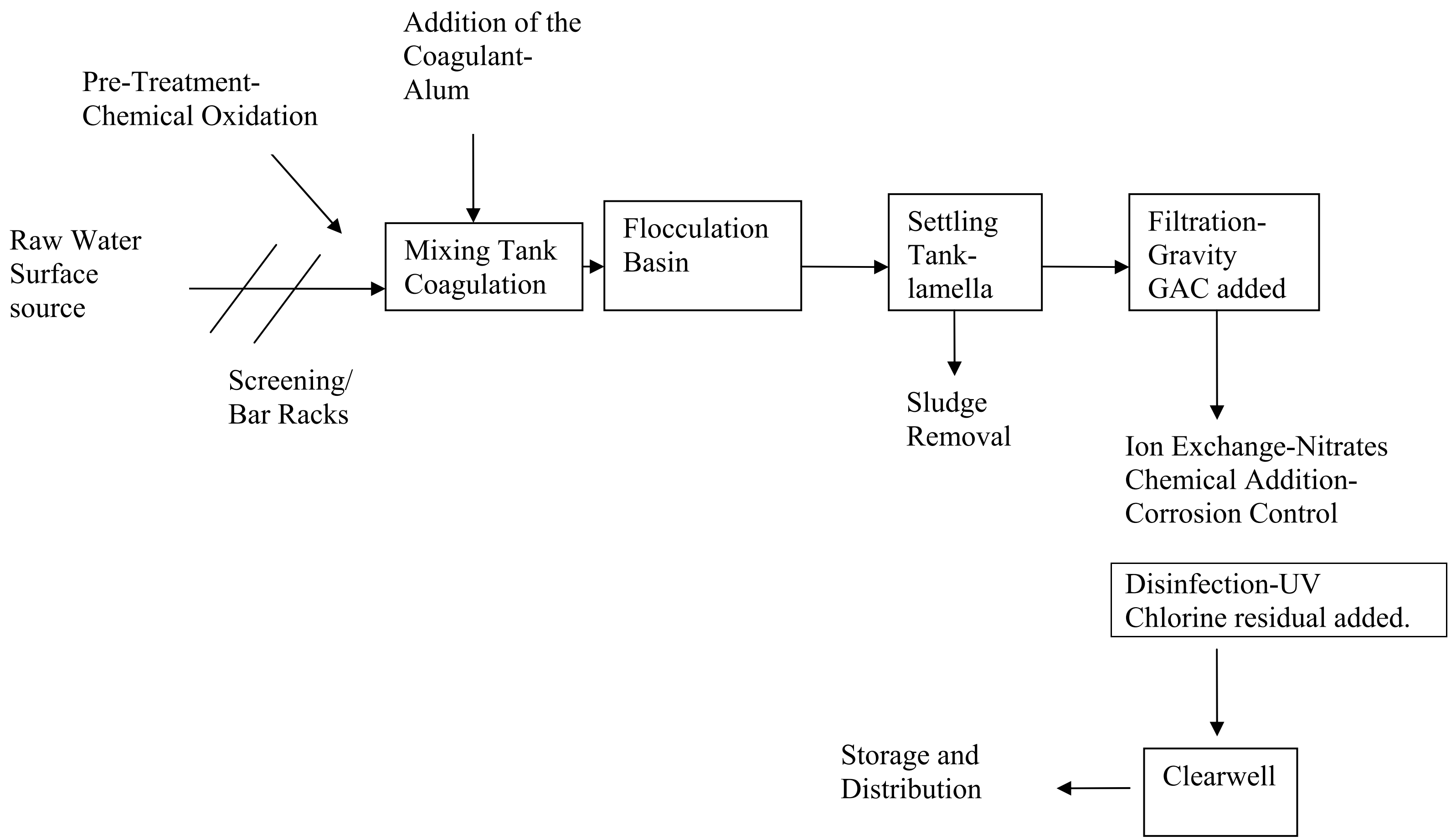
Raw Water Quality Table, cont'd

Parameter	Units	Minimum	Average	Maximum	MCL	MCLG(1)
Color Notes:	CU	4	12	32	15	0
Odor Notes:	TON	0.5	1	5	3	0
pH Notes:	---	6.9	7.1	7.7	6.5-8.5	7.0-7.5
Total Organic Carbon Notes:	Mg/L	2.0	5.3	6.2	---	<2
Total Dissolved Solids Notes:	Mg/L	280	320	400	500	----
Pathogens Notes:	Coliform Present					None Detected

Notes:

1. "MCLG" stands for Maximum Contaminant Level Goal. It is a good practice, as an operator, to set treatment goals that are more stringent than the levels set by regulation.

Water Treatment Process Schematic for Raw Water Source described in the Case Study



Key Points

- The treatment processes provided are selected based upon the characteristics of the raw water. The overall treatment process is intended to provide "multiple barriers" against the passage of contaminants or pathogens into the drinking water supply.

- Adsorption is a process by which molecules, colloids and particles adhere to a surface by physical action and without any chemical reaction.

- Chemical oxidation/reduction is a reaction where electrons are transferred from one compound to another and can be used to bring dissolved contaminants out of solution so they can be more easily removed by sedimentation and filtration.

- Coagulation uses the addition of a chemical to neutralize the charges on the small suspended (colloidal) particles and cause them to clump together into larger particles that will settle or can be filtered.

- Sedimentation processes are used to remove the larger particles (floc) formed by the coagulation processes.

- Filtration processes are used to remove the smaller particles (floc) formed by the coagulation processes that have remained in suspension following sedimentation.

- Corrosion control uses chemicals to reduce the corrosive properties of the water in order to protect the storage and distribution system.

- Disinfection is the process of inactivating or removing pathogenic microorganisms from treated water before it is delivered to the consumer.

Appendix 1
National Primary Drinking Water Regulations

Microorganisms	MCLG1 (mg/L)2	MCL or TT1 (mg/L)2	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Cryptosporidium	zero	TT 3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and fecal animal waste
Giardia lamblia	zero	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Heterotrophic plate count	n/a	TT3	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment
Legionella	zero	TT3	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%4	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.
Turbidity	n/a	TT3	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	zero	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

Disinfection Byproducts	MCLG1 (mg/L)2	MCL or TT1 (mg/L)2	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Bromate	zero	0.010	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	0.8	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection
Haloacetic acids (HAA5)	n/a6	0.060	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	none7 ---------- n/a6	0.10 ---------- 0.080	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

Disinfectants	MRDL1 (mg/L)2	MRDL1 (mg/L)2	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Chloramines (as Cl_2)	MRDLG=41	MRDL=4.01	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG=41	MRDL=4.01	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	MRDLG=0.81	MRDL=0.81	Anemia; infants & young children: nervous system effects	Water additive used to control microbes

Inorganic Chemicals	**MCLG 1 (mg/L) 2**	**MCL or TT1 (mg/L)2**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	07	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits

Copper	1.3	TT8; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	TT8; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits

Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories

Organic Chemicals	**MCLG1 (mg/L)2**	**MCL or TT1 (mg/L)2**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Acrylamide	zero	TT9	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills

Benzo(a)pyrene (PAHs)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories

1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl) adipate	0.4	0.4	Weight loss, liver problems, or possible reproductive difficulties.	Discharge from chemical factories
Di(2-ethylhexyl) phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use

Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	zero	TT9	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene	0.7	0.7	Liver or kidneys problems	Discharge from petroleum refineries
Ethylene dibromide	zero	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens

Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide

1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Radionuclides	**MCLG1 (mg/L)2**	**MCL or TT1 (mg/L)2**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Alpha particles	none7 ---------- zero	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Beta particles and photon emitters	none7 ---------- zero	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation

Radium 226 and Radium 228 (combined)	none7 ---------- zero	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	zero	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits

Notes

[1] Definitions:
Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
Treatment Technique - A required process intended to reduce the level of a contaminant in drinking water.

[2] Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

[3] EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium (as of1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- Giardia lamblia: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella:* No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.

- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

[4] more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E.coli* fecal coliforms, system has an acute MCL violation.

[5] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

[6] Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L). Chloroform is regulated with this group but has no MCLG.
- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L). Monochloroacetic acid, bromoacetic acid, and dibromoacetic acid are regulated with this group but have no MCLGs.

[7] MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

[8] Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

[9] Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

Appendix 2
National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L