

CLASS I WATER OPERATOR COURSE MANUAL



2008

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Overview/Preface

This manual is designed for operators taking the Class I water operator certification course and exam. This tool, along with your operating experience and review of the Office of Water Programs California State University Sacramento manuals, will help you prepare for the certification exam. Prior review of this manual does not eliminate the need for prospective operators to attend the required Class I training course.

Disclaimer

All reasonable precautions have been taken in the preparation of this document, including both technical and non-technical proofing. The West Virginia Bureau for Public Health and West Virginia Rural Water Association and all staff assume no responsibility for any errors or omissions. If you find any errors in this program, please inform the West Virginia Bureau for Public Health and West Virginia Rural Water Association.

Should the summarized information in this document be inconsistent with a governing rule or statute, the language of the rule or statute shall prevail.

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INTRODUCTION

Prior to 1976, water quality was regulated by individual state standards. In many cases, these standards were only recommendations rather than enforceable regulations. In December 1974, the **Federal Safe Drinking Water Act (SDWA)** (P.L. 93-523) was passed by Congress. The SDWA is a national program of regulations and standards that covers all public water systems in the United States. The **United States Environmental Protection Agency (EPA)** oversees the SDWA, although most states, including West Virginia, have taken over the responsibility of administering and enforcing the provisions of the Act in their states. In essence, the **West Virginia Bureau for Public Health (WVBPH)** is a subcontractor of the EPA. They pay WVBPH to administer the SDWA in West Virginia. EPA also audits WVBPH to make sure things are being handled correctly and in compliance with federal laws. If not, EPA can rescind their contract with WVBPH.

The SDWA sets permissible levels of substances found in water which could be hazardous to public health. These regulations include **Maximum Contaminant Levels (MCLs)** for inorganic and organic chemicals, radioactivity, turbidity and microbiological levels. Testing and monitoring requirements, reporting and record keeping schedules, and public notification are enforced by individual state agencies.

West Virginia's water quality standards are regulated and enforced by the West Virginia Bureau for Public Health. These regulations are found in the West Virginia State Code. For quick reference, these sections can be accessed online at the West Virginia Legislature web site at www.legis.state.wv.us/.

PUBLIC WATER SYSTEMS IN WEST VIRGINIA

The jurisdiction of the drinking water program at WVBPH applies only to public water systems, those that service water to the public. This includes municipal water systems as well as facilities, such as mobile home parks or factories, that have their own source of water and that serve it to the public. Whether the system is privately owned or not, if it serves water to more than 25 people, it is considered a public water supply and subject to the regulations of the SDWA.

Water System Types

Public Water Systems (PWS) provide piped water for human consumption to 15 or more service connections or an average of at least 25 individuals each day for at least 60 days each year. The system includes the source water intake (such as a well), treatment, storage, and distribution piping. This definition of a public water supply system was specified by law as part of the federal **Safe Drinking Water Act (SDWA)**. Human consumption of water includes drinking water and water used for cooking, food preparation, hand washing, bathrooms and bathing. A private home served by its own well is not a public water supply system since it serves only a single service outlet.

A **Community Water System (CWS)** is defined as a public water system which serves at least 15 service connections used by year-round residents or it regularly serves at least 25 year-round residents. A public system that is not a community water system is a **Non-Community Water System (NCWS)**.

There are two types of non-community water systems, **Non-Community Non-Transient Systems (NTNCWS)** and **(TWS) Transient Non-Community Water Systems**.

Non-Community Non-Transient Water Systems (NTNCWS) are non-community public water systems that regularly serve at least 25 of the same people over 6 months of the year. Schools with their own groundwater supply are a good example of this type of system.

Transient Non-Community Water Systems (TWS) do not serve at least 25 of the same people on a regular basis over a 6 month period in a year. This category covers bars, restaurants, rest stops and campgrounds, to name a few.

DRINKING WATER REGULATIONS

The **Safe Drinking Water Act (SDWA)**, passed in 1974 and amended in 1986 and 1996, gives the **Environmental Protection Agency (EPA)** the authority to set drinking water standards. Drinking water standards are regulations the EPA sets to control the level of contaminants in the nation's drinking water. There are two categories of water standards: the Primary Drinking Water Regulations and the Secondary Drinking Water Regulations.

A **National Primary Drinking Water Regulation** (primary standard) is a legally-enforceable standard that applies to public water systems. Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in water. They take the form of **Maximum Contaminants Levels (MCLs)** or **Treatment Techniques (TT's)**.

A **National Secondary Drinking Water Regulation** (secondary standard) is a non-enforceable guideline regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste and odor) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply.

US Environmental Protection Agency (EPA)

The federal agency responsible for establishing public drinking water standards and enforcing the requirements of the SDWA is the **EPA**. However, the EPA can delegate enforcement authority to the states if the state elects to do so. This is called "**Primacy Authority.**" Most states have primacy authority to enforce the provisions of the SDWA in their state. If they do, they must establish requirements at least as stringent as those set by EPA.

West Virginia Drinking Water Regulations

West Virginia has received approval from EPA to have primacy authority for enforcing public drinking water regulations in the state. These regulations are enforced by the **West Virginia Bureau for Public Health (WVBPH)**.

The WVBPH not only enforces drinking water standards, such as those in the SDWA, but it is also responsible for establishing and enforcing standards and regulations for water system design, construction, operation and maintenance, well construction and placement, pumps, treatment processes, chemical addition, well abandonment, lab certification, and wellhead protection. To ensure water systems meet these state requirements, water system owners are responsible for obtaining plan approvals from the WVBPH for well construction, pump installation, well rehabilitation, chemical addition to water, water treatment, and new system capacity. Plan approvals help ensure that water suppliers provide a safe and dependable supply of water to their customers.

WVBPH personnel assure compliance with all appropriate codes and regulations by performing periodic on-site inspections of each system. These inspections are called **Sanitary Surveys** and their frequency depends upon the size and classification of the water system. During the sanitary survey, the WVBPH representative will review the system's compliance and monitoring records and inspect the water system facilities. Following the inspection, the system owner will receive a written report listing any deficiencies or violations found. A PWS must respond within 45 days and establish time frames to correct the problem(s).

Maximum Contaminant Level (MCL) and Maximum Contaminant Level Goal (MCLG)

A Maximum Contaminant Level (MCL) is the highest level of a contaminant that is allowed in drinking water. Before setting a MCL for any health related drinking water contaminant, the SDWA requires EPA to set what are called **Maximum Contaminant Level Goals (MCLGs)**. The MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin or safety. MCLs are set as close to the MCLGs as feasible using the best available treatment technology. Realizing that, in some cases, it is not technologically or financially feasible to achieve the MCLG for all contaminants, EPA establishes MCLs for all regulated contaminants in drinking water. In doing so, they take into account such factors as health risk assessments, cost-benefit analysis, and **Best Available Technology (BAT)**, in establishing acceptable levels. BAT refers to the technology available to detect and treat the contaminant of concern. MCLs are the “drinking water standards” that all public water systems must meet. It is important to remember that MCLs are not set in stone. As new health effects data becomes available, MCLs are adjusted either up or down, depending on what the latest data shows.

Treatment Technique (TT) Requirement

For some contaminants, establishing a specific MCL is either not possible or too costly to mandate. For such contaminants, EPA may also choose to require a specific water treatment process intended to reduce the level of a contaminant in drinking water, called **Treatment Technique (TT)**, which, when implemented by the water system, would reasonably protect public health. Examples of TTs are corrosion control for reduction of lead and copper, and filtration for removal of particulates in surface water.

Record Keeping Requirements

Public water systems must retain copies of their records for certain lengths of time depending on the type of record. Monitoring records must contain certain information and must remain on the premises or at a convenient location near the premises.

The following is a general listing of the types of records and the length of time they must be kept:

- **Not less than 3 years:** Records of actions taken to correct violations.
- **Not less than 5 years:** Records of bacteriological analysis and records concerning a variance or conditional waiver.
- **Not less than 10 years:** Records of chemical analysis and copies of any written reports, summaries or correspondence relating to any sanitary surveys.
- **Not less than 12 years:** Records pertaining to lead & copper and corrosion control.

WVBPH Notification

In addition to monitoring requirements, the federal government realizes that an important element of public safety is keeping the customer informed about the quality of their drinking water. Two regulations that were enacted to accomplish this goal are the **Public Notification Rule** and the **Consumer Confidence Report**.

Whereas the **Consumer Confidence Report** is designed to provide information to customers on an annual basis, the **Public Notification Rule** specifies how water suppliers must inform their customers in the event of a MCL violation or emergency situation. This rule went into effect in May 2000 and established specific language, actions, time frames, and methods that must be used to notify the public in these situations. The Public Notification Rule establishes **Tiers** for each contaminant and the type of situation that resulted in the violation.

Tier 1 Violation

A **Tier 1** violation requires notification of the public **within 24 hours**. Examples include an acute violation of the MCL for total coliform, fecal or E. coli, nitrate and/or nitrite, chlorine dioxide, turbidity, TT, waterborne disease outbreak, or other waterborne emergency as determined by the WVBPH.

Tier 2 Violation

A **Tier 2** violation requires notification of the public **within 30 days**. Examples include violation of a Maximum Residual Disinfectant Level, monitoring or testing procedure, failure to comply with the conditions of a variance or conditional waiver, or MCL and TT requirement other than when a Tier 1 violation has occurred.

Tier 3 Violation

A **Tier 3** violation requires notification of the public **within 12 months**. Examples include a monitoring violation other than a Tier 1 or Tier 2; testing procedure violations other than a Tier 2; operation under a variance or conditional waiver; special notice for availability of unregulated contaminant monitoring data; or special notice for exceeding fluoride levels.

Tier Determination

In any of the above situations, the water supplier must notify the WVBPH as soon as possible for a determination of what Tier applies to a given situation. The WVBPH will make a determination and work with you to provide the appropriate language and steps you must take to notify the public. **“When in doubt, call the WVBPH and find out.”**

OPERATOR CERTIFICATION

The West Virginia Operator Certification Program was approved by EPA on February 20, 2002. West Virginia requires all public water systems to have a certified operator to effectively operate the system. Certified operators play a crucial role in protecting the health and welfare of West Virginia citizens, which can be jeopardized if persons not properly qualified are allowed to operate water supply systems. There are many disease-causing organisms and chemicals that may enter a system through the source water or through problems in the distribution system. Most contaminants cannot be seen or smelled, so proper system maintenance and monitoring is required to ensure the protection of public health. Water users expect a safe and adequate water supply and rely on the system operator to notify them if problems occur.

The need for responsible water system operators is enormous. Competent water system operations require someone with skill, knowledge and experience in operating, maintaining and troubleshooting water sources, treatment and distribution systems. Even if the operator will not be the one to repair or replace broken equipment, he/she must be able to recognize potential problems and take action to have problems corrected. Any individual making process control/system integrity decisions about water quality or quantity must be certified.

West Virginia's Operator Certification Program:

- Provides applications and study material to prospective operators;
- Administers the examination process;
- Evaluates applicant experience and education;
- Evaluates training for continuing education; and,
- Tracks continuing education obtained by each operator.

To become a certified operator, an individual must:

1. Submit an application;
2. Attend any required training courses;
3. Pass a written examination specific for the size and type of system to be operated; and,
4. Meet minimum experience and education requirements;

Maintaining certification requires:

1. Applying for new renewal by submitting an application every 2 years;
2. Documented attendance at sufficient WVBPH-approved continuing education courses (CEHs); and,
3. Continued employment as an operator in a public water system.

Continuing Education Hours

Our understanding of drinking water quality and chemical and biological contaminants in water is changing almost daily. Similarly, better laboratory methods to find small amounts of chemicals, and improvements in diagnosing and tracking disease, more clearly define water that is truly safe to consume.

Along with increased knowledge of health threats, which may be in drinking water, we have also increased our ability to prevent their occurrence, and to detect and remove them. Special sample collection methods, monitoring schedules and treatment options exist for a variety of possible contaminants.

All certified operators, as well as system owners and managers, have a responsibility to keep up with changes in monitoring and reporting requirements. Also, it is important you are aware of new information on water quality and treatment and they maintain a basic level of knowledge.

West Virginia requires all certified operators, except 1Ds, to obtain **continuing education hours (CEHs)**. Continuing education is essential to keeping up to date with water supply, treatment, maintenance, and monitoring information.

The amount of continuing education that must be obtained depends on your certification classification.

- **Operators-in-Training (OITs) and Water Distribution (WD) operators are required to obtain 6 CEHs every 2 years.**
- **Class I operators are required to obtain 12 CEHs every 2 years.**
- **Classes II-IV are required to obtain 24 CEHs every 2 years.**

Operators are required to notify the WVBPH in the event they are no longer the operator for a specific system. This is to emphasize the importance of having a certified operator at all times. A 30 day notice is required for voluntary terminations. Please complete and submit form ES-74 at least 30 days prior to quitting to stay in compliance with operator requirements and keep your certification. If you are fired, contact Certification & Training so they are aware your employment status has changed and provided them with your new or anticipated employment information.

Certification is personal. Each individual operator is responsible for keeping his/her certification current and ensuring all requirements are met. Please contact the Certification and Training Section at (304) 558-2981 or WVRWA at (304) 201-1689 if you have any questions concerning your responsibilities as a certified public water system operator.

The Certification and Training Section currently oversees information on more than 2,300 certified water operators (as of May 2007) in addition to wastewater operators, backflow prevention & assembly inspector testers, water well drillers, and monitoring well driller training in West Virginia. It is essential that we work together and openly communicate.

Public Water System Operator Responsibilities

An operator is the person who is, in whole or part, responsible for the operation of a water system. At times, he/she may be a manager, laboratory technician, mechanic, meter reader, and a public relations specialist. To become a competent operator one must have a strong interest and desire for the job. Becoming a competent operator means; being accountable, having the will to learn, and to work without supervision. Even though many aspects of a water system can be "out of sight", they should not be "out of mind" for the water treatment plant operator. By properly maintaining the system, a competent operator provides a large degree of protection for a community's great investment in infrastructure. The operator also protects the health and well being of customers by producing a safe finished product.

DRINKING WATER SOURCES

Water exists in different forms and locations. The source of drinking water refers to where it comes from. There are three main sources of drinking water: surface water, groundwater, and “groundwater under the influence” of surface water. Surface water supplies about seventy-five percent of the water consumed by people in the United States. Even though a larger number of water systems in the United States use a groundwater source, on the average, they are smaller and serve fewer people. Surface water is a more likely source for large cities.

Usually, the source of water will determine the type of treatment necessary. In most circumstances, groundwater requires little treatment. Groundwater quality problems include minerals, hardness, and dissolved gasses. Surface water and groundwater-under-the-influence quality issues are turbidity, taste, odor, and color. Surface water and “groundwater under the influence” usually require chemical treatment and filtration.

Surface Water

Surface water accumulates mainly as a result of direct runoff from precipitation (rain or snow) or recharge from groundwater. Therefore, surface waters are very susceptible to contamination. You name it - manure, gasoline, pesticides, fertilizers, industrial chemicals, bacteria, air pollution – it can enter surface waters. Because of their high susceptibility to contaminants, surface water sources must meet strict monitoring and treatment requirements for filtration and disinfection. While there are relatively few surface water systems in the world, they provide more water to more people than any other type of system. These systems are typically used by large cities that need a large volume of water to meet their needs.

In general, surface water is characterized by soft water, turbidity, suspended solids, some color and microbial contamination.

Groundwater

Groundwater occurs when water percolates down to a water table through the void spaces. Water in aquifers obtained from wells or springs is called groundwater. Groundwater is generally less susceptible to contamination than surface water. Groundwater’s susceptibility to contamination depends on the type and thickness of soil and rock layers, depth to the groundwater, and the type of contaminants. Some soils are very good at filtering out contaminants. Others are not. The central sands area and karst features are very susceptible to groundwater contamination. In contrast, areas with thick, rich soil and a good depth to groundwater are generally less susceptible to contamination. In some areas, groundwater may become contaminated with naturally occurring minerals in the soil and rock such as arsenic, lead, radium, radon gas and uranium. Groundwater systems generally have less restrictive monitoring and treatment requirements than surface water systems.

Groundwater, on the other hand is characterized by higher concentrations of dissolved solids, dissolved gases, lower levels of color, relatively high hardness, and freedom from microbial contamination.

Groundwater Under the Influence of Surface Water

Water that is obtained from an aquifer that may be intermixed with surface water is called “*groundwater under the influence of surface water*”, (GWUDI) or (GUDI). This situation may

occur when a well is placed next to a lake or river. As the well is pumped, some of the water from the lake or river enters the groundwater, which, in turn, can reach the well. In other words, the groundwater has a connection to the surface water.

This connection makes the groundwater susceptible to the same types of contaminants as the surface water. Groundwater under the influence of surface water is covered by the same regulations as surface water systems.

WATER QUALITY CHARACTERISTICS

Water acquires certain characteristics from its surroundings – from the soils, rocks, minerals, and air that the water contacts, and from animals and people that contact and influence the water. Water quality and characteristics are important to consider when choosing a water source. The quality of water is determined by the measuring the concentrations of impurities in it. Water quality characteristics are classified into four broad categories:

- Physical
- Chemical
- Biological
- Radiological

Physical Characteristics

There are a number of physical characteristics of water that consumers notice because they can be seen, smelled or tasted. Generally, these physical characteristics are important only from an aesthetic standpoint, but are typically the basis for many consumer complaints. Interestingly, complaints regarding the aesthetic quality of the water are generally the driving force behind the installation of water treatment devices. If drinking water looks, smells or tastes bad, it may be rejected in favor of an unsafe source that does look, smell or taste good.

1. Temperature

Water temperature will dictate how it tastes, how easily it dissolves things, and whether it's effective for other uses such as cooling. Generally, surface water sources are warmer than groundwater sources. Groundwater sources typically have constant temperatures, although some may be warmer than others. Temperature is a useful tool for determining if groundwater is directly influenced by surface water.

2. Turbidity

Turbidity is caused by very small particles such as clay and silt that are suspended in the water. When water is cloudy, it is said to be turbid or have a high turbidity. Consumers will object to water that is highly turbid, even though it may be perfectly safe to drink. Removal of turbidity not only makes the water more pleasing from an aesthetic standpoint, but it also has public health implications.

High turbidity in finished water is a potential health risk, because viruses and bacteria can hide, within the turbidity-causing particulates making disinfection difficult. Removal/inactivation of these particulates reduces the chance of pathogenic microorganisms in finished water.

3. Color

If water is colored, it is less pleasing to the consumer and may be rejected in favor of a drinking water source that is less safe. Color occurs most frequently in surface water due to the decay of organic material. Color can be measured in the laboratory and, generally, a measurement of 15 color units or higher is objectionable.

4. Taste and Odor

The taste and odor of water are determined by the physical and chemical characteristics of water. Taste and odors can be caused by temperature, chemicals, minerals, decaying matter, or dissolved gases. The most common cause of odor in drinking water is the presence of hydrogen

sulfide, iron, or sulfur-reducing bacteria. However, most contaminants do not impart either and cannot be detected by just smelling or looking at a glass of water.

In a distribution system, the corrosion of pipe materials can also cause taste and odor. Even though taste and odor are more of an aesthetic concern than a health related one, their presence may be indicative of other contaminants harmful to public health.

Chemical Characteristics

Although the physical characteristics exhibited by the source water are readily discernable by sight, smell and taste, the chemical composition of water can, with a few exceptions, be determined only through chemical analysis. Consequently, laboratory testing is necessary. The importance of each chemical substance depends on the kind and amount of that substance found in the water and on the use for which the water is intended. The strictest standards apply to surface water used as a public drinking water supply. Chemical characteristics are broken down into three areas: inorganics, organics and minerals.

- Inorganics chemicals (IOC) include metals such as arsenic, lead and copper.
- Organic chemicals (OC) include: volatile organics (VOC) such as trichloroethylene and benzene; and synthetic organics (SOC) such as pesticides and aldicarb.
- Mineral constituents include alkalinity, calcium, chloride, copper, foaming agents, iron, magnesium, manganese, pH, sodium, sulfate, zinc, specific conductance, total dissolved solids, and hardness (calcium and magnesium).

Some of the more troublesome naturally occurring chemical constituents found in source waters are: calcium and magnesium (hardness), iron and manganese, hydrogen sulfide, nitrate, arsenic, sulfate and radiological contaminants.

1. pH

The acidic or basic nature of a solution is expressed as the pH. The pH scale ranges from 0 to 14, with 7 being neutral. Numbers below 7 are acidic and numbers above 7 are basic.

Natural waters rarely have a pH less than 6.0 or greater than 9.0. Treated water is usually between pH 6.5 and 8.5. At values less than 6.5, water can be corrosive causing the release of toxic metals into the water from piping. Higher pH can cause scaling or reduce the efficiency of chlorine.

2. Hardness

The term hardness may be one of the oldest terms used to characterize a water supply. The term was initially used to describe the difficulty in producing soapsuds in water. Water that required a lot of soap to produce suds was termed hard water, whereas water that easily produced suds was considered soft. If you have soft water, you might notice it takes a long time to rinse the soap off your hands. Soft water reacts with soap to produce a residue that feels like it is difficult to wash off.

Hardness is caused by the presence of magnesium and calcium deposits in water. The terms soft water and hard water are relative. Water is said to be soft if it has a low concentration of calcium and magnesium, and said to be hard if it has a high concentration of calcium and magnesium.

Typically, groundwater is harder than surface water.

Hard water can lead to calcium carbonate (CaCO₃) scale in hot water heaters and boilers. Low hardness contributes to the corrosive tendencies of water.

Water hardness is expressed in **milligrams per liter (mg/L)** of CaCO₃. mg/L is equivalent to **parts per million (ppm)**. Hardness can also be expressed in **grains per gallon (gpg)**; 1 gpg = 17.1 mg/L.

Table A: Hardness Scale

Soft water	0-75 mg/L
Moderately Hard	75-150 mg/L
Hard	150-300 mg/L
Very Hard	Over 300 mg/L

Hardness is not considered a health hazard. However, at levels of 200-300 mg/L or higher, it is common practice to soften the water for household use.

3. Alkalinity

Alkalinity is defined as the capacity of water to resist pH change. The term “to buffer” is used to describe this process. So water with significant alkalinity can buffer or resist pH change. Since a stable pH is desirable for smooth and consistent performance of several treatment processes, it is desirable to have significant alkalinity. Alkalinity of about 80 mg/L will provide adequate buffering capacity.

Most of the alkalinity is provided by carbonate and bicarbonate compounds. Alkalinity is expressed as mg/L of CaCO₃. Typically, groundwater will have adequate alkalinity but surface water sources usually have very low alkalinity and the pH can easily change. Alkalinity does not pose a health risk.

4. Iron and Manganese

Iron and manganese are common metals found in the earth’s crust. Water percolating through soil and rock can dissolve minerals containing iron and manganese and hold them in solution.

Iron will cause reddish-brown staining of laundry, porcelain, dishes, utensils and even glassware. Manganese causes a brownish-black stain. Soaps and detergents do not remove these stains, and the use of chlorine bleach may intensify the stains. At elevated levels, iron and manganese deposits may build up in pipelines, pressure tanks, water heaters, and water softeners. These deposits reduce the flow and pressure in water supply lines. Iron and manganese accumulations become an economic problem when deposits become serious enough to require replacement of piping and treatment equipment.

Many groundwater supplies in West Virginia have high levels of iron and manganese. The secondary MCL for iron is 0.3 mg/L and 0.05 mg/L for manganese. These levels correspond to approximate concentrations at which iron and manganese will cause aesthetic problems such as colored water, turbidity, staining, and bad taste.

5. Hydrogen Sulfide (H₂S)

Although H₂S gas is associated with groundwater supplies more often than with surface waters, it can also occur in lakes and reservoirs under ice cover in winter. It produces the offensive rotten egg or sulfur water odor and taste found in some groundwater and can affect the taste of coffee, ice cubes, and many foods prepared with water containing it. Silverware washed in water containing H₂S can turn black. In some cases, the odor may be noticeable only when the water is initially turned on or when hot water is used. Heat forces the gas into the air and may cause the odor to be especially offensive in a shower. Occasionally, a hot water heater is a source of H₂S odor.

H₂S is a corrosive gas that forms sulfuric acid, which is corrosive to metals such as iron, steel, copper and brass.

	Range of concentrations typically found in groundwater	Range of concentrations typically found in surface water
Total Hardness	300-400 ppm	75 - 200 ppm
Alkalinity	250-350 ppm	45 - 250 ppm
Dissolved Oxygen	near 0	2 - 14 ppm
Carbon Dioxide	1 - 10ppm	Low
Calcium Hardness	High	sometimes high, usually low
Magnesium Hardness	tends to be high	sometimes high, usually low

Biological Characteristics

A variety of aquatic organisms are routinely found in raw water sources. These include tiny microorganisms, such as bacteria, protozoa, and viruses, and a variety of visible organisms, such as algae, fresh water shrimp, and snails.

Although most do not pose a health risk, the presence of some microorganisms in drinking water can be devastating. In fact, providing drinking water that is microbiologically safe is the primary goal of all water providers.

As a general rule, surface water sources are more likely to contain greater numbers and more diverse populations of microorganisms than groundwater sources. This is because surface water can easily pick up microorganisms from contaminated areas as it flows across the earth's surface. On the other hand, the filtering action of aquifer material results in fewer microorganisms in groundwater. However, shallow wells and unprotected wellheads can provide an opportunity for contaminated surface water to enter the groundwater. Consequently, groundwater cannot be assumed to be free of microorganisms. Disease-causing organisms are called **pathogens**. Water-borne pathogens include bacteria, protozoa and viruses. These pathogens can be transmitted from person to person through fecal contamination of drinking water. Consequently, disinfection is generally required for surface water sources and may be necessary for groundwater sources if they become contaminated.

1. Bacteria are single-celled organisms ranging in size from 0.5 - 2 microns in diameter and about 1-10 microns long. A micron is a metric unit of measurement equal to 1 thousandth of a

millimeter. To visualize the size of bacteria, consider that it would take approximately 1,000 bacteria lying side by side to reach across the head of a straight pin. Bacteria are among the most common microorganisms in water. Typhoid fever and cholera are examples of bacterial waterborne diseases. Most bacterial pathogens are easily controlled with normal disinfection processes.

2. Protozoa are single-celled organisms, several hundred times larger than bacteria. They range in size from 4 microns to 500 microns. Two species of protozoa, *Cryptosporidium* and *Giardia lamblia* have been found to be the cause of waterborne gastrointestinal disease outbreaks in the United States. Both have been found in Alaskan waters. Protozoan go through a life cycle, one phase of which results in an extremely resistant form that makes them very difficult to control with normal disinfection.

3. Viruses are extremely tiny microorganisms (hundreds of times smaller than bacteria) that live parasitically inside other cells. Pathogenic viruses are responsible for many waterborne diseases such as viral gastroenteritis, smallpox, poliomyelitis (polio) and infectious hepatitis. The common cold is caused by viruses, but they are not transmitted by water.

Radiological Characteristics

Although the presence of radiological elements, or **radionuclides**, in drinking water may be attributed to human activities, they are most often a result of dissolution of naturally occurring radioactive elements in rock formations such as granites. Examples of radionuclides found in drinking water include radium 226, radium 228, uranium, and radon. When consumed at high levels, these radioactive contaminants are known to cause cancer in humans.

CHEMISTRY

pH

pH is defined as the "negative log of the hydrogen ion concentration." This is actually a mathematical determination and is expressed as $\text{pH} = -\log_{10} [\text{H}^+]$. More simply, pH is a measure of the hydrogen ion concentration in water and can be considered as an "Index" of the amount of hydrogen ions present in a substance. This "Index" is important because it can be used quickly to determine if a substance is acidic, basic or neutral.

The pH scale is a numerical scale from 0 to 14, with 7 considered neutral. At a pH below 7, the water is acidic. An acidic solution is one that has a greater concentration of hydrogen ions than hydroxyl ions. At a pH above 7, the water is basic. A basic solution is one that has a greater concentration of hydroxyl ions than hydrogen ions.

Since pH is measured as a logarithm, a change of one (1) pH unit means a ten-fold increase or decrease in the hydrogen ion concentration. For example, pH 8.0 is ten times more basic than pH 7.0; pH 9.0 is ten times more basic than a pH 8.0 and pH 9.0 is 100 times more basic than pH 7.0. We see that as the pH increases, the number of hydrogen ions DECREASES.

Natural waters rarely have a pH less than 6.0 or greater than 9.0. Treated water is usually between pH 6.5 and 8.5.

The table below gives some common acids and bases and their pH values.

I. Acids	pH	Bases	pH
Hydrochloric acid	1.0	Sodium bicarbonate	8.4
Sulfuric acid	1.2	Ammonium hydroxide	9.2
Acetic acid	2.9	Sodium carbonate	11.4
Alum	3.2	Lime	12.3
		Sodium hydroxide	13.0

pH Control

There are a number of pH increase treatment options available to small systems to increase pH.

1. Lime

Lime or limestone is calcium carbonate (CaCO_3) and can be used to raise pH. As the lime is added to the water, it dissolves the CaCO_3 . Through a chemical reaction, similar to the $\text{CO}_2/\text{H}_2\text{CO}_3$ resulting in a higher pH..

A possible drawback to the use of a lime is that calcium ions are also released into the water which increases hardness and scaling.

2. Soda Ash

Soda ash (Na_2CO_3) can also be used to raise the pH. The chemistry is similar to the use of lime and causes a higher pH. Soda ash is normally fed into the water system as a solution using a liquid chemical feed pump. The feed equipment is almost the same as that used to feed hypochlorites.

3. Sodium Hydroxide

Sodium hydroxide (NaOH), commonly called caustic soda, is readily soluble in water and a very strong base. It can be used to raise pH in water systems, but it is extremely corrosive and can be very dangerous if mishandled. It is critical that workers who handle NaOH be well trained.

Diluted NaOH (30% or 50%) is normally fed into the water system using a liquid chemical feed pump similar to ones used to feed hypochlorites.

HARDNESS

The hardness of water relates to the amount of calcium, magnesium and sometimes iron in the water. The more minerals present, the harder the water. Soft water may contain sodium and other minerals or chemicals; however, it contains very little calcium, magnesium or iron.

Many people prefer soft water because it makes soap lather better, gets clothes cleaner and leaves less of a ring around the tub. Some municipalities and individuals remove calcium and magnesium, both essential nutrients, and add sodium in an ion-exchange process to soften their water.

ALKALINITY

Alkalinity is the capacity of water to neutralize acids. Alkalinity is the result of the water's content of carbonate, bicarbonate, and hydroxide. It is expressed as milligrams per liter equivalent calcium carbonate. Alkalinity is measured by titrating the sample to a pH of 4.5.

Influences of treatment

Lowers Alkalinity

Aluminum sulfate (alum)
Carbon dioxide
Chlorine gas
Ferric chloride
Ferric sulfate
Sulfuric acid

Increases Alkalinity

Calcium hypochlorite (HTH)
Caustic soda (sodium hydroxide)
Hydrated lime (calcium hydroxide)
Soda ash (sodium carbonate)

NITRATE

High levels are usually caused by concentrated sources of nitrogen such as animal feedlots, septic systems, or heavily fertilized cropland. Nitrates are the only chemical contaminant that represents an immediate health risk. High nitrate-containing water is a serious health concern for pregnant women and infants under the age of 6 months. Infants that consume water high in nitrates are susceptible to a life-threatening disease called **methemoglobinemia** or "**blue baby**" **syndrome**. Babies with this condition become oxygen starved because their red blood cells are unable to carry oxygen properly. This reduction of oxygen uptake in the bloodstream gives the skin a blue tint. Infants become less susceptible to the effects of nitrates after six months of age.

The MCL for nitrate nitrogen is 10.0 mg/L and the MCL for nitrite is 1 mg/L. Public water systems that exceed this level are required to obtain a new water source or treat their water.

HYDROGEN SULFIDE

Water containing hydrogen sulfide, commonly called sulfur water, has a distinctive "rotten egg" or swampy odor. Hydrogen sulfide is a gas formed by the decay of organic matter such as plant material. It is typically found in groundwater containing low levels of dissolved oxygen and a pH

less than 6.0. Sulfur problems occur less frequently in surface waters because flowing water is aerated naturally so that the hydrogen sulfide reacts with oxygen and escapes as a gas or settles as a solid.

Sulfur bacteria are also found in many drinking water wells and household distribution systems. These harmless bacteria use natural sulfur compounds in water as a food source, thereby producing hydrogen sulfide. Although sulfur bacteria pose no health risk to humans, their presence in drinking water may cause objectionable tastes and odors.

A water heater may also produce a sulfur odor. The magnesium rod present in many water heaters can chemically change naturally occurring sulfates in water to hydrogen sulfide. If this occurs, the magnesium rod can be replaced with an aluminum rod or simply removed, although removing the rod may nullify the warranty on the water heater.

Hydrogen sulfide is not regulated, however, because it is considered a nuisance chemical and does not pose a health risk at concentrations typically present in household water. Concentrations high enough to be a health risk also make the water unpalatable. Conversely, concentrations as low as 0.5 milligrams per liter (mg/L) can add objectionable taste and a rotten egg odor to drinking water.

Continuous chlorination is a very common and effective method for oxidizing hydrogen sulfide, especially if the water pH is 6.0-8.0. Chlorine has the secondary advantage of being lethal to bacteria so it typically follows other treatment options to maintain a chlorine residual and prevent bacterial activity. Chlorine is usually administered as sodium hypochlorite, which reacts with sulfide, hydrogen sulfide, and bisulfide to form compounds that do not cause foul taste or odors in drinking water.

Another common treatment for sulfur water is aeration. Hydrogen sulfide is physically removed by agitating the water via bubbling or cascading and then separating or "stripping" the hydrogen sulfide in a container. The undesired hydrogen sulfide is removed as a volatile gas by venting it into a waste pipe or to the outdoors. Aeration is most effective when hydrogen sulfide concentrations are lower than 2.0 mg/L. At higher concentrations, this method may not remove all of the offensive odor unless the air is used to oxidize hydrogen sulfide chemically into solid sulfur, which is then filtered.

LEAD and COPPER

Copper

Although copper is an essential micronutrient and is required by the body in very small amounts, excess copper in the human body can cause stomach and intestinal distress such as nausea, vomiting, diarrhea and stomach cramps. People with Wilson's disease, a rare genetic disorder, are more sensitive to the effects of copper.

Lead

Lead is a cumulative poison, meaning it accumulates in the body until it reaches toxic levels. Chronic exposure to low levels of lead over an extended period of time can have severe effects. Excess lead in the human body can cause serious damage to the brain, kidneys, nervous system and red blood cells. Young children, infants and fetuses are particularly vulnerable to lead poisoning. Since lead is accumulated and stored in the bones, continued exposure will allow blood lead levels to affect nerve tissue. This can then irreversibly impair a child's mental and physical development, resulting in learning disabilities or stunted growth.

Limits

The current enforceable action levels for copper is 1.3 mg/L (or 1.3 ppm) and for lead is 0.015 mg/L or 15 parts per billion (ppb).

Lead and Copper Removal Treatment

Each public water system must now target high-risk households (based on materials used in the delivery system and other factors) and analyze tap water samples from these households for lead and copper.

Lead and Copper Corrosion Control Options

EPA has identified three acceptable treatment approaches for corrosion control:

1. pH adjustment
2. Addition of calcium
3. Addition of corrosion inhibitors

FLUORIDATION

The fluoridation of water supplies has been described as one of the great advances in modern public health. Fluoridation is a process of adding a naturally occurring element, fluorine, to drinking water for the purpose of preventing tooth decay, using guidelines developed by scientific and medical research. The effectiveness of fluoridation depends on how consistently the water treatment operator maintains the optimal fluoride concentration.

FLUORIDATION AND PUBLIC HEALTH

Definition of Water Fluoridation

Water fluoridation is the deliberate upward adjustment of the natural trace element, fluorine (in the ionic form of fluoride), using guidelines developed by scientific and medical research, for the purpose of promoting the public's health through the prevention of tooth decay. Fluoride is present in small but widely varying amounts in practically all soils, water supplies, plants, and animals, and thus is a normal constituent of all diets. The highest concentrations in mammals are found in the bones and teeth. All public water supplies in this country contain at least trace amounts of natural fluoride.

Few public health measures have been accorded greater clinical and laboratory research, epidemiologic study, clinical trial, and public attention-both favorable and adverse-than the fluoridation of public water supplies.

History

The discovery of the role of waterborne fluoride in preventing tooth decay is an interesting and intriguing story. One of the most brilliant investigations ever carried out in the epidemiology of chronic disease was the series of studies that led to demonstrating that fluoridated water had caries-inhibitory properties.

It started when a young dentist, Frederick S. McKay set up his practice in Colorado Springs, Colorado. He noticed that many of his patients' teeth exhibited a condition he called "Colorado Brown Stain." Since this wasn't described in any scientific literature, he was determined to find out more about it. In 1908, he initiated a study that led to the identification of the condition we now know as fluorosis (mottled enamel); this condition was prevalent throughout the surrounding El Paso County. Dr. McKay, along with another major figure in the dental world, Dr. G. V. Black, wrote detailed descriptions of mottled enamel.

In the 1920's, Dr. McKay, along with others, concluded that something either in or missing from the drinking water was causing the mottled enamel. Also, in the late 1920's, Dr. McKay made another major discovery. Teeth with mottled enamel were essentially free of dental caries. In 1931, fluoride was identified as the element in drinking water that caused mottled enamel, but also inhibited dental caries.

In the 1930's, Dr. H. Trendley Dean, of the U.S. Public Health Service, and Dr. McKay collaborated to determine if fluoride could be added to the drinking water to prevent caries. Dr. Dean and other associates conducted several classic studies to establish a community fluorosis index. This led to further studies that predicted the cause-and-effect relationship between fluoridation and the reduction of dental caries, and determined what the optimal fluoride levels should be for a community's drinking water. Dr. G. J. Cox, a dental researcher with the Mellon

Institute in Pennsylvania, was the first person to propose adding fluoride to the drinking water for the prevention of dental caries.

The studies on fluorides were interrupted by World War II, but in 1945 and 1947, four classic studies were begun that finally proved the benefits of water fluoridation by adding fluoride to the drinking water of several communities. The most important study, under the direction of Dr. Dean, was started in 1945 in Grand Rapids, Michigan. (Fluoridation began in January 1945, in Grand Rapids; in May 1945, in Newburgh, New York; in June 1945, in Brantford, Ontario; and in February 1947, in Evanston, Illinois.) These studies firmly established fluoridation as a practical and effective public health measure that would prevent dental caries.

In the 1950's and 1960's, two more individuals emerged on the fluoridation scene. Although it had already been determined that fluoridation was safe and effective, the engineering aspects needed to be further developed and refined before more widespread community water fluoridation could be implemented. Franz J. Maier, a sanitary engineer, and Ervin Bellack, a chemist, both with the U.S. Public Health Service, made major contributions to the engineering aspects of water fluoridation.

Maier and Bellack helped determine which fluoride chemicals were the most practical to use in water fluoridation, the best mechanical equipment to use, and the best process controls. Bellack helped make major advances in testing for fluorides. In 1963, Maier published the first comprehensive book on the technical aspects of fluoridation: the "Manual of Water Fluoridation Practice." In 1972, Bellack, was with the EPA and published the "Fluoridation Engineering Manual."

Over the past 40 years continuous studies have been conducted on fluorides and fluoridation by the U.S. Public Health Service, state health departments, and nongovernmental research organizations. Many very good reference books and booklets on fluoridation are available. Please write to the Centers for Disease Control and Prevention in Atlanta, Georgia or the American Dental Association in Chicago, Illinois, for additional information.

HEALTH EFFECTS OF WATER FLUORIDATION

General

The most positive health effect of water fluoridation is the prevention of tooth decay. The diverse health effect from high levels of fluoride in the drinking water is dental fluorosis. Controversy over fluoridation continues to exist and many charges have been leveled against it; these changes are discussed in a later section.

Benefits of Fluoridation

The highest rate of tooth decay activity is found in schoolchildren. It begins in early childhood, reaches a peak in adolescence, and diminishes during adulthood. At one time nearly everyone in the United States was attacked by dental caries, the most prevalent chronic disease of man. It was truly universal. Prior to the widespread use of water fluoridation, almost 98 out of 100 Americans experienced some tooth decay by the time they reached adulthood.

Fluoride contributes substantial benefits in the prevention of tooth decay. Numerous studies, taken together, clearly establish a casual relationship between water fluoridation and the prevention of dental caries. While dental decay is reduced by fluoridated toothpastes and mouth

rinses, professional fluoride treatments, and fluoride dietary supplements, fluoridation of water is the most cost-effective method. It provides the greatest benefit to those who can least afford preventive and restorative dentistry and reduces dental disease, loss of teeth, time away from work or school, and anesthesia-related risks associated with dental treatment.

In the 1940's, children in communities with fluoridated drinking water had reductions in caries of 20 to 40 percent over a lifetime, as compared to those living in non-fluoridated communities. Recent studies still reveal that caries are lower in naturally or adjusted fluoridated areas; however, the differences in caries between fluoridated and non-fluoridated areas are not as great as those observed in the 1940s. This apparent change is likely explained by the presence, in non-fluoridated areas, of fluoride in beverages, food, dental products, and dietary supplements.

Strong evidence now exists that water fluoridation not only makes the tooth more resistant to bacterial acids, but also actually inhibits the growth of certain kinds of bacteria that produce these acids. Also, it has now been shown that fluorides actually aid in the demineralization of the tooth, thus actually reversing the decay process after it already has begun.

Fluoridation thus enhances the appearance of the teeth, makes them more impervious to bacterial acids, and substantially reduces bills for restorative dentistry. For every dollar spent on water fluoridation, up to 50 dollars in dental bills may be saved. The cost of fluoridation is about 50 cents per person per year. The benefits of fluoridation can last for a life-time if one continues to consume fluoridated water.

Systemic and Topical Effects of Fluorides in Drinking Water

Generally, when water containing fluoride is drunk, a small amount is retained by fluoride in the mouth and will be incorporated onto the tooth by surface uptake (topical effect). The other part of the fluoride utilized passes into the stomach and is rapidly absorbed by simple diffusion through the walls of the stomach and gut. It enters the blood plasma and is rapidly distributed throughout the body, including the teeth (systemic effect). Because of the systemic effect, the fluoride ion is able to pass freely through all cell walls and thus is available to all organs and tissues for the body. Distributed in this fashion, the fluoride ion is available to all the skeletal structures of the body in which it may be retained and stored in proportions which, generally speaking, increase with age and with intake.

The bone, teeth, and other parts of the skeleton tend to attract and retain fluoride. The soft tissues do not retain fluorides. It has been correctly stated that fluoride is a "bone seeker." About 96 percent of the fluoride found in the body is deposited in the skeleton.

Since the teeth are part of the skeleton, the incorporation of fluoride into the teeth is basically similar to that in other bones. Incorporation of fluoride is most rapid during the time of the child's formation and growth. This time period is roughly from the 4th month of pregnancy to the 10th year. The 8th year probably marks the end of the maximum rate of incorporation of fluoride into the teeth. Erupted teeth differ from other parts of the skeleton in that once they are formed, with the exception of the dentin (inner part of the tooth) and the root, there is little cellular activity. Thus, there is not as much change in the fluoride levels in the teeth after they are formed. It is important that children drink the proper amount of fluoridation water during the early development of the permanent teeth, starting at birth.

As is true with bones, fluoride concentrated in the teeth has a direct relationship with the level of fluoride in the drinking water and with the age of the person. But, not being subject to internal repair by the body, the teeth do not tend to lose fluoride by reabsorption except in the root structure. The amount of fluoride in the teeth varies as widely as the fluoride in the other parts of the skeleton, from several hundred to several thousand parts per million (ppm).

Note that the fluoride incorporated in the tooth is in a soluble form. Insoluble fluorides, such as calcium fluoride (CaF_2) particulates, will pass through the body and will not be utilized. Also, fluorides in the organic form are not utilized by the body. The actual mechanism for the incorporation for the fluoride ion into the tooth and bones is not well-known. But it is known that the fluoride ion replaces the hydroxyl ion (OH^-) in the crystal lattice in the enamel, resulting in a stronger tooth.

Dental Fluorosis

Dental fluorosis is defined as the whitish to brownish spots seen on teeth. It has been clearly established that high levels of fluoride in the drinking water will cause fluorosis (or “mottled enamel”, as it is sometimes called). Dental fluorosis has been recognized since the turn of the century in people with high exposure to naturally occurring fluoride in drinking water. It has always been more prevalent in fluoridated than non-fluoridated areas. Dental fluorosis occurs only during tooth formation and becomes apparent upon eruption of the teeth. It ranges from very mild symmetrical whitish areas on teeth (very mild dental fluorosis) to pitting of the enamel, frequently associated with brownish discoloration (severe dental fluorosis). The very mild form is barely detectable even by experienced dental personnel. Moderate and severe forms of dental fluorosis, considered by some investigators as presenting a cosmetic problem, do not appear to produce adverse dental health effects, such as the loss of tooth function, and represents less than six percent of the cases of fluorosis nationally.

In the 1940s, about 15 percent of the population displayed very mild and mild dental fluorosis when the concentration of fluoride found naturally in the drinking water was about 1 part per million (ppm). Over the last 40 years, in areas where fluoride is added to the drinking water to bring the total level of fluoride to about 1 ppm (optimally fluoridated areas), there may have been an increase in the total prevalence of dental fluorosis. In non-fluoridated areas, there is clear evidence that the total prevalence of dental fluorosis has increased over the last 40 years.

The greater the fluoride exposure during tooth development, the greater the likelihood of dental fluorosis. In the 1940s and 1950s, the major sources of fluoride were from drinking water and food. Since then, numerous sources of fluoride (e.g., toothpastes and mouthrinses) and fluoride dietary supplements. The inappropriate use of these products can contribute significantly to total fluoride intake.

Increases in the prevalence of dental fluorosis in a population should be taken as evidence that fluoride exposure is increasing. Because dental fluorosis does not compromise oral health or tooth function, an increase in dental fluorosis, by itself, is not as much of a dental public health concern as it is an indication that total fluoride exposure may be more than necessary; to prevent tooth decay. Prudent public health practice generally dictates using no more of a substance than the amount necessary to achieve a desired effect.

Skeletal Fluorosis

Very high concentrations of fluoride in drinking water consumed for long periods of time have been found to cause skeletal fluorosis. Crippling skeletal fluorosis is an adverse health effect of the bone resulting from a fluoride intake of 20 mg/day over periods of 20 years or more. A drinking water fluoride concentration of 10 mg/L, given at 2 liters per day consumption rate, would correspond to this value. Crippling skeletal fluorosis, as well as rheumatic attack, pain and stiffness, have been observed in individuals chronically exposed to fluoride in drinking water at levels of 10 mg/L to 40 mg/L.

Cancer

Accusations that fluoride causes cancer have existed since the 1940's. This still continues to cause controversy in some areas of the United States.

More than 50 human epidemiologic studies of the relationship between water fluoridation and cancer have been conducted. These studies usually attempt to identify statistical associations between cancer rates and county or city-wide patterns of water fluoridation. Expert panels who reviewed this international body of literature agree there is no credible evidence of an association between either natural fluoride or adjusted fluoride in drinking water and cancer in humans (IARC, 1982; Knox, 1985).

In March of 1990, the National Cancer Institute (NCI) updated and expanded an earlier analysis of cancer deaths, by county in the United States, to determine whether there is or is not an association between cancer and fluoride in drinking water. The new studies evaluated an additional 16 years of cancer mortality data, and also examined patterns of cancer incidence between 1973 and 1987 in the Surveillance, Epidemiology, and End Results (SEER) Program cancer registries. SEER, an NCI-sponsored network of population-based cancer incidence registries, started in 1973 and represents about 10 percent of the U.S. population. The SEER registries were used to obtain incidence data on all cancers, with special emphasis place on trends in osteosarcoma. Because mortality data do not contain information on tumor-specific pathology, analysis of osteosarcomas is limited to the incidence data.

The NCI study identified no trends in cancer risk which could be attributed to the introduction of fluoride into drinking water.

Bone Fractures

Findings from some epidemiologic studies suggest that the incidence of certain bone fractures may be greater in some communities with either naturally high or adjusted fluoride levels. However, there are a number of confounding factors that need resolution to determine whether or not an association exists. Additionally, other studies do not show an increase in the incidence of bone fractures; one study provided evidence of a lower incidence of bone fractures in an optimally fluoridated community as compared to a similar community with trace levels of fluoride in the water. While further research is required, there appears to be very little chance that fluoride would cause any increase in bone fractures.

Maximum Contaminant Levels

The EPA has established regulatory limits on the fluoride content of drinking water. Based on a detailed review of health effects studies on fluoride, the EPA set a primary MCL of 4 mg/L in water systems to prevent crippling skeletal fluorosis. A secondary MCL of 2 mg/L has been established by EPA as the level above which dental fluorosis is likely to occur.

Alternatives to Water Fluoridation

While there are other ways to provide the benefits of fluoride besides the fluoridation of municipal water supply systems, one point must be kept clearly in mind. Municipal water fluoridation is by far the most cost-effective and practical means available for reducing the incidence of caries in the community. This conclusion is based on the mass of evidence demonstrating the efficacy of the measure, and on the most current information on costs of implementing fluoridation. School fluoridation is another way to provide the benefits of water fluoridation, but should not be considered as an alternative to water fluoridation. This is because with both school fluoridation and community fluoridation, the fluoride level of the drinking water is being adjusted upward.

In general, there are five alternatives to water fluoridation which use either topical or systemic fluorides:

A. Topical Fluorides

1. Fluoride gels (professionally applied)
2. Fluoride mouthrinses
3. Fluoride dentifrices

B. Systemic Fluorides

1. Fluoride tablets
2. Fluoride drops

While topical fluorides can be used in conjunction with water fluoridation (optimally fluoridated water in community or school water systems or naturally fluoridated water), systemic fluorides should not. Utilization of only one type of systemic fluoride is sufficient to prevent tooth decay.

The Controversy

Although community water fluoridation has been proven to be the safest and the most cost-effective method to prevent dental caries, a small percentage of the population continues to oppose its introduction into community water systems. When fluoridation is being considered for adoption by a community, persons opposed to fluoridation often introduce charges or allegations that attempt to disprove the benefits, safety, and effectiveness of fluoridation.

The list of objections to fluoridation, whether they relate to engineering, medical, legal, or other questions, could go on indefinitely. As far as the water plant operator and the engineer are concerned, the addition of fluoride to a water supply is well within their province, and it is their duty to follow the directives of health officials and the governing body of the community in not just adding fluorides, but in doing the job right.

It is unfortunate that irrelevant, unreplicated, or refuted research is purposefully presented to the detriment of the public's health. It is also unfortunate that misinterpretation of actions in foreign countries and out-of-context statements continue to circulate and create unnecessary fears. For every report which casts doubts about fluoridation, there are innumerable reports attesting to its safety and efficacy. It is not surprising that some differences of opinion among scientist and professionals in research and medicine may occur. What is surprising, however, is their almost universal agreement on the safety and effectiveness of fluoridation. Fluoridation is not a controversy in any scientific sense. There are few public health measures which have had the scientific endorsement and board base of research which supports its use as does fluoridation.

Community fluoridation is supported by government officials, the U.S. Public Health Service, the American Dental Association, the American Medical Association, the World Health Organization, the American Water Works Association (AWWA), and virtually every scientific and professional organization in the health field. In the almost fifty years of fluoridation, there has never been any clinically substantiated evidence of harm to anyone from drinking optimally fluoridated water.

Some of the more common questions that may arise have been presented for the water treatment plant operator. There are several studies and reports on the charges against fluoridation that are very complete. If additional information is desired on any charge or information on a charge not covered in this manual, please refer to Fluoridation Facts, (a publication of the American Dental Association), or other similar publications; or contact your state regulatory agency for water supplies, the state department of health, or the Division of Oral Health in the Centers for Disease Control and Prevention, Atlanta, Ga.

Status of Water Fluoridation

As of 1989, fluoridation in the United States was being practiced in approximately 8,100 communities serving more than 126 million people. Residents of over 1,800 additional communities, serving more than 9 million people, were consuming water that contains at least 0.7 mg/L fluoride from natural sources.

One hundred cities with populations of 50,000 or more, including Washington, D.C., and Chicago, Illinois, have had adjusted fluoridation for more than 20 years. Approximately 70 percent of all cities with population of 100,000 or more have fluoridated water. More than 22 states and the District of Columbia provide fluoridated water to more than half their population. Of the 50 largest cities in the United States (from the 1989 U.S. census), 42 are fluoridated. As of 1985, eight states (Connecticut, Georgia, Illinois, Minnesota, Nebraska, Ohio, Michigan, and South Dakota) have some type of mandatory fluoridation laws.

In 1990, approximately 38 countries reported that community water fluoridation is benefiting approximately 208 million people. The United States, Canada, Brazil, Australia, Venezuela, and Chile have large populations consuming fluoridated water. The city-states of Hong Kong and Singapore are totally fluoridated. Fluoridation has been seriously hindered in Europe by the opponents of fluoridation. In fact, there may be very little progress toward fluoridation in Europe in the foreseeable future.

FLUORIDE CHEMICALS

Introduction

Fluorine, a gaseous halogen, is the thirteenth most abundant element found in earth's crust. It is a pale yellow noxious gas that is highly reactive. It is the most electronegative of all the elements. It cannot be oxidized to a positive state. Fluorine is never found in a free state in nature, but is always in combination with chemical radicals or other elements as fluoride compounds. When dissolved in water, these compounds dissociate into ions. It is the fluoride ions at the optimal levels in drinking water that are responsible for dental caries reduction. There are only three basic compounds commonly used for fluoridating drinking water supplies in the United States: Sodium fluoride, sodium fluorosilicate, and fluorosilicic acid.

Chemical Sources

Fluoride can be found in a solid form in minerals such as fluor spar, cryolite, and apatite. Fluor spar is a mineral containing from 30 to 98 percent calcium fluoride (CaF_2). Fluor spar (also called fluorite) is found in most parts of the world, with Kentucky and Illinois having the largest deposits in the United States; there are also small deposits in Nevada and Texas. Most of the U.S.-produced fluor spar comes from two mining companies in southern Illinois. In recent years, the United States has produced only about 10 percent of its fluor spar consumption. The rest has been imported, generally from Mexico (about 85 percent), because of low cost and high purity.

Cryolite (Na_3AlF_6) is a compound of aluminum, sodium, and fluoride. It is preferred for industrial use because of its low melting point. Large deposits were found in Greenland. Cryolite is not a major source of fluoride in this country.

Apatite [$\text{Ca}_{10}(\text{PO}_4, \text{CO}_3)_6, (\text{F}, \text{Cl}, \text{OH})_2$] is a deposit of a mixture of calcium compounds. (the comma in the chemical equation denotes a mixture.) These calcium compounds include primarily calcium phosphates, calcium fluorides, and calcium carbonates. Also, there are usually trace amounts of sulfates as impurities. Apatite contains from 3 to 7 percent fluoride and is the main source of fluorides used in water fluoridation at the present time. It also is the raw material used for phosphate fertilizers. Deposits of apatite are found in Tennessee, Florida, and South Carolina with small deposits also found in North Carolina, Montana, Idaho, Utah, and Wyoming. Three-fourths of the U.S. annual production of apatite comes from central Florida.

Due to the dissolving power of water and the movement of water in the hydrologic cycle, fluoride is found naturally in all waters. As water moves through the earth as groundwater, it contacts fluoride-containing minerals and carries fluoride ions away from them. Because all water eventually goes to the ocean, sea water also contains fluoride (approximately 1.2 ppm). The concentration of fluoride found in fresh waters varies according to such factors as the depth at which the water is found and the quantity of fluoride-bearing minerals in the area. Generally speaking, the deeper the groundwater, the greater the concentration of fluoride in the water.

Fluoride Compounds in General

Theoretically, any compound that forms fluoride ions in water solution can be used for adjusting the fluoride content of a water supply. However, there are several practical considerations involved in selecting compounds. First, the compound must have sufficient solubility to permit its use in routine water plant practice. Second, the cation to which the fluoride ion is attached must not have any undesirable characteristics. Third, the material should be relatively inexpensive and readily available in grades of size and purity suitable for their intended use. Fluoride chemicals, like chlorine, caustic soda, and many other chemicals used in water treatment can constitute a safety hazard for the water plant operator unless proper handling precautions are observed. It is essential that the operator be aware of the hazards associated with each individual chemical prior to its use.

Three commonly used fluoride chemicals should meet the AWWA standards for use in water fluoridation-sodium fluoride (B701-90), sodium fluorosilicate (B702-90), and fluorosilicic acid (B703-90). Imported chemicals especially should be checked for compliance with these standards.

SOLUBILITY OF FLUORIDE CHEMICALS

Chemical	Temperature	Solubility (g per 100mL of H ₂ O)
1. Sodium Fluoride (NaF)	0.0	4.00
	15.0	4.03
	20.0	4.05
	25.0	4.10
	100.0	5.00
2. Sodium Fluorosilicate (Na ₂ SiF ₆)	0.0	0.44
	25.0	0.76
	37.8	0.98
	65.6	1.52
	100.0	2.45
3. Fluorosilicic Acid (H ₂ SiF ₆)		Infinite at all temperatures

Sodium Fluoride

The first fluoride compound used in water fluoridation was sodium fluoride. It was selected on the basis of the above criteria and also because its toxicity and physiological effects had been so thoroughly studied. Sodium fluoride has become the reference standard used in measuring fluoride concentration. Other compounds came into use, but sodium fluoride is still widely used, because of its unique physical characteristics.

Sodium fluoride (NaF) is a white, odorless material available either as a powder or in the form of crystals of various sizes. It is a salt that in the past was manufactured by adding sulfuric acid to fluor spar and then neutralizing the mixture with sodium carbonate. In 1983 and 1984, the chemical industry changed the way they manufactured sodium fluoride. It is now produced by neutralizing fluorosilicic acid with caustic soda (NaOH). Its formula weight is 42.00, specific gravity 2.79, and its solubility is practically constant at 4.0 grams per 100 milliliters in water at temperatures generally encountered in water treatment practice (see Table above).

The relatively constant 4 percent solubility of sodium fluoride is the basis for the design of the saturator. The pH (hydrogen-ion concentration) of a sodium fluoride solution varies with the type and amount of impurities, but solutions prepared from the usual grades of sodium fluoride exhibit a nearly neutral pH (approximately 7.6). It is available in purities ranging from 97 to over 98 percent, with the impurities consisting of water, free acid or alkali, sodium fluorosilicate, sulfites and iron, plus traces of other substances. Approximately 19 pounds of sodium fluoride will add 1 ppm of fluoride to 1 million gallons of water.

Powdered sodium fluoride is produced in different densities, with the light grade weighing less than 65 pounds per cubic foot and the heavy grade weighing about 90 pounds per cubic foot. The average density is 85 lbs/cuft. A typical sieve analysis of powdered sodium fluoride shows 99 percent through 200 mesh and 97 percent through 325 mesh. Crystalline sodium fluoride is produced in six various ranges, usually designated roughly as course, fine and extra-fine, but some manufacturers can furnish many specific mesh sizes. The crystalline type is preferred when manual handling is involved, since the absence of fine powder results in

minimum dust. Dust constitutes the most frequently encountered hazard in handling sodium fluoride. A more thorough discussion of handling precautions is presented in later sections.

Sodium fluoride has a number of industrial uses: The manufacture of vitrified enamel and glasses; as a steel degassing agent; in electroplating; in welding fluxes; in heat treating salt compounds; in sterilizing equipment in breweries and distilleries; in paste and mucilage; as a wood preservative; and in the manufacture of coated paper. One use of the past was as a rodenticide. It is no longer used as such and is not included on the EPA list of registered rodenticides.

Sodium Fluorosilicate

Fluorosilicic acid can readily be converted into various salts, and one of these, sodium fluorosilicate (Na_2SiF_6), also known as sodium silicofluoride is widely used as a chemical for water fluoridation. As with most fluorosilicates, it is generally obtained as a by-product from the manufacture of phosphate fertilizers. Phosphate rock is ground up and treated with sulfuric acid, thus forming a gas by-product. This gas reacts with water and forms fluorosilicic acid. When neutralized with sodium carbonate, sodium fluorosilicate will precipitate out. The conversion of fluorosilicic acid (essentially a low-cost by-product, which contains too much water to permit economical shipping) to a dry material containing a high percentage of available fluoride results in a compound, which has most of the advantages of the acid, with few of its disadvantages. Once it was shown that fluorosilicates form fluoride ions in a water solution as readily as do simple fluoride compounds, and that there is no difference in the physiological effect, fluorosilicates (and fluorosilicic acid) were rapidly accepted for water fluoridation, and in many cases, have displaced the use of sodium fluoride, except in saturators.

Sodium fluorosilicate is a white, odorless crystalline powder. Its molecular weight is 188.06 and its specific gravity is 2.679. Its solubility varies from 0.44 grams per 100 milliliters of water at 0 degrees centigrade (C) to 2.45 grams per 100 milliliters at 100 degrees C. The pH's of solutions are definitely on the acid side, with saturated solutions usually exhibiting a pH between 3.0 and 4.0 (approximately 3.6). Sodium fluorosilicate is available in purities of 98 percent or greater, the principal impurities being water, chlorides, and silica. Approximately 14 pounds of sodium fluorosilicate will add 1 ppm of fluoride to 1 million gallons of water.

Sodium fluorosilicate is sold in two commercial forms-regular and fluffy. The density of sodium fluorosilicate ranges from 65 to about 95 pounds per cubic foot (lbs/cf.). The average density is approximately 75 lbs/cf. A typical sieve analysis of the regular grade shows more than 99 percent through a 200-mesh sieve and more than 10 percent through a 325-mesh sieve.

Sodium fluorosilicate has some other industrial uses: Laundry scouring agent (neutralizing industrial caustic soaps); the manufacture of opal glass; and moth-proofing woolens. It has been used in the past as a rodenticide, but like sodium fluoride, it no longer is used in this way. The EPA does not list it as a registered rodenticide.

As in the case of sodium fluoride, the principal hazard associated with handling sodium fluorosilicate is dust. Precautions for dealing with this material are discussed in later sections.

Fluorosilicic Acid

Fluorosilicic acid (H_2SiF_6), also known as hydrofluosilicic, hexafluosilicic, or silicofluoric acid is a 20 to 35 percent aqueous solution with a formula weight of 144.08. It is a straw-colored,

transparent, fuming, corrosive liquid having a pungent odor and an irritating action on the skin. Solutions of 20 to 35 percent fluorosilicic acid exhibit a low pH (1.2), and at a concentration of 1 ppm can slightly depress the pH of poorly buffered potable waters. It must be handled with great care because it will cause a “delayed burn” on skin tissue. The specific gravity and density of fluorosilicic acid are given in Table 2-2 on page 39. The average density of 23 percent acid is 10.1 lbs/gal. Fluorosilicic acid (23 percent) will freeze at approximately 4 degrees F or -15.5 degrees C. It takes approximately 46 pounds (4.4 gallons) of 23 percent acid to add 1 ppm of fluoride to 1 million gallons of water.

Fluorosilicic acid is manufactured by two different processes, resulting in products with differing characteristics. The largest production of the acid is a by-product of phosphate fertilizer manufacture. Phosphate rock is ground up and treated with sulfuric acid, forming a gas by-product. This gas is reacted with water, forming a weak fluorosilicic acid. The acid is then concentrated from 23 percent to 25 percent. This type of acid seldom exceeds 30 percent strength. A smaller amount of acid is prepared from fluorosilicic acid (HF) and silica, resulting in a purer product at a slightly higher strength. Acid prepared from phosphate rock contains colloidal silica in varying amounts, and while this is a little consequence when the acid is used as received, dilution results in the formation of a visible precipitate of the silica. Some suppliers of fluorosilicic acid sell a “fortified” acid, which has had a small amount of hydrofluoric acid added to it to prevent the formation of the precipitate. Acid prepared from hydrofluoric acid and silica does not normally form a precipitate when diluted.

Hydrofluoric acid (HF) is an extremely corrosive material. Its presence in fluorosilicic acid, whether from intentional addition, i.e., “fortified” acid or from normal production processes demands careful handling. The HF fumes from fluorosilicic acid are lighter than air, unlike chlorine fumes, which are heavier than air. Thus, the acid fumes will rise instead of settling to the floor. (The silicon tetrafluoride (SiF₆) is a gas that is heavier than air but is not toxic.)

Since fluorosilicic acid contains a high proportion of water, shipping large quantities can be quite expensive. Larger users can purchase the acid directly from the manufacturers in bulk (tank car or truck) lots, but smaller users must obtain the acid from distributors who usually pack it in drums or polyethylene carboys. Rather than attempt to adjust the acid strength to some uniform figure, producers sell the acid as it comes, and the price is adjusted to compensate for acid strength above or below the quoted figure. Note that the “23 percent basis” type of pricing applies only to bulk quantities. It is the usual practice for the supplier to furnish assay reports of the acid strength of each tank truck lot.

Attempts to dilute the acid are subject to errors in measuring both the acid and the diluting water. It is much better to use the acid undiluted as it comes from the containers in which it is shipped. If the acid is too concentrated for the solution feeder to handle, then weaker solutions of other compounds are generally indicated—for instance, saturated solutions of sodium fluoride. CDC strongly recommends against the dilution of acid. If the acid must be diluted, care should be taken to avoid the formation of a precipitate of silica, which will appear despite the quality (hardness) of the water used for dilution. Dilutions between 10:1 and 20:1 (water: acid) are where insoluble silica precipitates are most likely to occur. Softening the water will not prevent this precipitation.

Like all other fluoride compounds, fluorosilicic acid has a number of industrial uses, including the sterilization of equipment in the brewery and bottling industries; electroplating; tanning of

animal hides; etching of glass; refining of lead; hardening of cement; and preservation of wood. As with all other mineral acids, fluorosilicic acid should be handled with care to prevent injury to operators and damage to equipment from acid splatter or fumes. A more thorough discussion of handling precautions is presented in following sections.

PROPERTIES OF FLUOROSILICIC ACID

Acid* (%)	Specific gravity (s.g.)	Density (lbs/gallon)
0 (water)	1.0000	8.345
10	1.0831	9.041
21	1.167	9.739
23	1.191	9.938
25	1.208	10.080
30	1.250	10.431
35	1.291	10.773

*Based on the other percentage being distilled water.

Note: Actual densities and specific gravities will be slightly higher when distilled water is not used.

Add approximately 0.2 lb/gal to density depending on impurities.

Optimal Fluoride Levels

The recommended optimal fluoride concentrations for fluoridated water supply systems are given in the Table below.

RECOMMENDED OPTIMAL FLUORIDE LEVEL

Annual Average of Maximum Daily Air Temperatures ¹ (°F)	Recommended Fluoride Concentrations		Recommended Control Range			
			Community Systems		School Systems	
	Community (ppm)	School ² (ppm)	0.1 Below	0.5 Above	20% Low	20% High
40.0-53.7	1.2	5.4	1.1	1.7	4.3	6.5
53.8-58.3	1.1	5.0	1.0	1.6	4.0	6.0
58.4-63.8	1.0	4.5	0.9	1.5	3.6	5.4
63.9-70.6	0.9	4.1	0.8	1.4	3.3	4.9
70.7-79.2	0.8	3.6	0.7	1.3	2.9	4.3
79.3-90.5	0.7	3.2	0.6	1.2	2.6	3.8

¹Based on temperature data obtained for a minimum of five years.

²Based on 4.5 times the optimal fluoride level for communities.

These levels are based on the annual average of the maximum daily air temperature in the area of the involved school or community. In areas where the mean temperature is not shown on the chart, the optimal fluoride level can be determined by the following formula.

$$\text{ppm} = \frac{0.34}{E}$$

E is the estimated average daily water consumption of children through 10 years of age in ounces of water per pound of body weight. E is obtained from the formula:

$$E = 0.038 + 0.0062 \times \text{average maximum daily air temperature} \\ \text{(degrees Fahrenheit)}$$

The recommended control range is shifted to the high side of the optimal fluoride level for two reasons. First, it has become obvious that many water plant operators try to maintain the fluoride level in their community at the lowest level possible. The result is that the actual fluoride level in the water will vary around the lowest value in the range instead of around the optimal level. Setting a higher level for the bottom of the recommended fluoride control limits will help overcome this problem. Second, some studies have shown that sub-optimal fluorides are relatively ineffective in actually preventing dental caries. Even a drop of 0.2 ppm below optimal levels can reduce dental benefits significantly. Skewing the control limits of the optimal fluoride level will help assure that the benefits of fluoridation are being maintained even if the fluoride level in the water varies slightly. In water fluoridation, underfeeding is a much more serious problem than overfeeding.

FLUORIDATION SYSTEMS

General

Methods of Feeding Fluorides

Fluoride must be fed into the water supply system in liquid form or as a solution. This is true for both dry chemical feeders and solution feeders.

Fluorides can be fed into a water supply in the following ways:

1. Dry Chemical Feeds

The amount of dry chemical compound (usually sodium fluorosilicate) can be measured with a machine, then added to a mixing tank (solution tank) where it is thoroughly mixed and then delivered to the main flow of water, either by gravity or using a solution pump.

2. Acid Feed

A small pump can be used to add solutions of fluorosilicic acid directly to the water supply system. This method can utilize the acid as delivered.

3. Saturated Solution Feed

Saturated solutions of sodium fluoride in constant strengths of four percent can be produced in a saturator tank at almost any temperature of water encountered in the usual water plant. This saturated solution can be pumped with a small solution feeder directly into the main flow of water of a water supply system. This use of these devices eliminates the need for weighting sodium fluoride and stirring to ensure dissolving.

4. Unsaturated Solution Feed

Unsaturated solutions of sodium fluorosilicate or sodium fluoride may be prepared by weighing amounts of the compounds, measuring quantities of water, and thoroughly mixing them together. This method of feeding fluorides is not very desirable and should be avoided.

Types of Equipment

Devices for feeding fluorides accurately have generally been adapted from those machines originally designed for feeding a variety of liquid or solid chemicals in water treatment and industrial plants. In many cases, the equipment is the same.

Fluoride chemicals are always added to a water supply as liquids, but they may be measured in either liquid or solid form. The solid form of fluorides must be dissolved into a solution before entering the water supply system. Chemical feeders can therefore be broadly divided into two types: (1) Metering pumps, which are essentially small pumps used to feed a measured quantity of liquid fluoride solution during a specific time; and (2) dry feeders, which deliver a predetermined quantity of the solid material during a given time interval. The term "metering pump" is used in this manual for the terms "solution pump," "feed pump," and "solution feeder."

The choice of a feeder depends on the fluoride chemical used and the amount to be fed. The rate of feed will depend on the desired fluoride content of the treated water, the amount of water to be treated after passing a given point, and the fluoride content of the untreated water. In general, metering pumps (with acid or with saturators) are used for smaller water supply systems and dry feeders for larger systems. There is a wide range within which either type would be equally successful.

Metering Pumps

For feeding fluoride solutions, almost any type of metering pump that is used for feeding other water treatment chemicals can be used with, at most, only minor modification in construction details. If there is, indeed, any requirements for a fluoride metering pump that distinguishes it from metering pumps for other purposes, it is the accuracy and constancy of delivery. The optimal fluoride level has been prescribed between very narrow limits and thus requires that fluoride be added in precise proportion to the quantity of water being treated. This requirement favors the positive displacement type of metering pump.

Most metering come equipped with plastic heads and resilient check valves, which are generally satisfactory for discharge pressures up to 150 psi. For higher pressures, corrosion-resistant alloys such as 316 stainless steel or Carpenter 20 alloy are required for metering pump head construction. The type of plastic the metering pump heads should be made of depends upon the fluoride chemical used. Acrylic, polypropylene, and PVC heads can be used for fluorosilicic acid as well as for sodium fluoride and sodium fluorosilicate. In addition, Kynar, Ryton, and Tril heads can be used with sodium fluoride and sodium fluorosilicate. Metering pump heads of stainless steel (SS) 316, as well as 20 series SS alloys, can be used with all three fluoride chemicals.

The check valves can be made of ceramic, Teflon, or 316 stainless steel. If fluorosilicic acid is used, then the check balls and spring must be coated with Teflon or its equivalent. Note, do not use ceramic check balls, if fluorosilicic acid is used! The acrylic head is one of the most popular heads on metering pumps used in water fluoridation.

Diaphragm Metering Pumps

The diaphragm pump is by far the most common type of metering pump used in fluoridation. A flexible diaphragm is driven to alternately force solution out of a chamber, and on the return stroke, the diaphragm refills the chamber by pulling solution from a reservoir. In a typical diaphragm pump there is no chemical packing that would result in leaking through a packing gland. Typically, a diaphragm is made of hypalon, Teflon, polyurethane, or viton.

Diaphragm pumps are ideally suited for medium-pressure service-up to about 150 (pounds per square inch [psi]). They should not be used against pressure less than about 15 psi and never against a vacuum, such as that obtained in the suction side of a well pump. A constant positive pressure on the discharge is a guarantee of their continued accuracy. Some metering pumps are equipped with spring-or rubber-loaded discharge valves that assure the maintenance of such positive pressures. Negative suction heads should not exceed 4 feet. In other words, the metering pumps should be no more than 4 feet above the solution container.

Diaphragm pumps are driven by almost any source of power such as: electric motors of various speeds, hydraulic pressure, solenoid, etc. The principal characteristic of such sources of power is that they are operated at a constant speed proportional to the quantity of water to be treated.

Three common types of diaphragm metering pumps are used in fluoridation: Mechanically-driven, hydraulically actuated, and electronic. Other types are available, such as water-powered, pneumatic-drive, etc., but they are rarely used in water fluoridation. The electronic diaphragm metering pump is the newest and most popular fluoride metering pump in the field today. The pump has gained rapidly in acceptance because it is ideal for smaller flow rate-thus, it predominates in small fluoridated water systems and in school fluoridation systems.

The electronic metering pump is a special version of a diaphragm pump. Most diaphragm pumps used for fluoridation have a flexible diaphragm driven by a mechanical linkage. In the electronic metering pump, a solenoid armature that is periodically energized moves the flexible diaphragm. It has solid state electronics, circuit breakers, and built-in potentiometers. The stroke is extremely short with a maximum stroke length of 1.25 mm. Thus, diaphragm has a low amount of wear even during continuous prolonged operation-but must be replaced periodically.

Saturators

The saturator is a type of chemical feed equipment unique to fluoridation. The principle of a saturator is that a saturated fluoride solution will result if water is allowed to trickle through a bed containing a large amount of sodium fluoride. A small pump then delivers the solution of sodium fluoride into the water supply system. Saturated solutions of sodium fluoride can be manually prepared and is sometimes preferred.

There are two kinds of saturators: upflow and downflow. The downflow saturator was developed in the late 1940's by Proportioners Incorporated and engineers in the U.S. Public Health Service. It did not receive wide application until the late 1950's and early 1960's. In the mid-1970's, the upflow saturator was developed, and by the late 1970's, was becoming more popular than the downflow. After 1980, the downflow saturator was no longer being manufactured and has been replaced in most states by the upflow saturator.

Upflow Saturators

In an upflow saturator, the layer of sand and gravel is eliminated, and the bed of undissolved sodium fluoride is placed on the bottom of the tank. A spider type water distributor located at the bottom of the tank contains hundreds of very small slits. Water, forced under pressure through these slits, flows upward through the sodium fluoride bed at a controlled rate to assure the desired 4 percent solution. The metering pump intake line floats on top of the solution in order to avoid withdrawal of undissolved sodium fluoride. The water pressure requirements are 20 psi minimum to 125 psi maximum, and the upward flow must not exceed 2 gpm. Since introduction of water to the bottom of the saturator constitutes a definite cross-connection, a mechanical siphon-breaker must be incorporated into the water line. Also, a minimum of 12 inches of sodium fluoride must be kept in the bottom of the tank.

Liquid Level Switches

Liquid level switches, or controllers, are used to automatically maintain preset (fluoride) liquid levels in sodium fluoride saturators. In rare instances, they are used with fluorosilicic acid tanks when these are filled from a bulk storage tank or used with dry feeder solution tanks. The switches keep the tanks from going dry or overflowing, and may also be used to prevent a metering pump from running dry. The switch may be of the manual (lower cost) or electrical (higher cost) type.

Several different types of switches are on the market today and work on different principles: mercury, air pressure, electrode, conductivity, and encapsulated reed. Most newer models today are electrical (12 or 115 volt) and are wired to control a solenoid valve (electronically operated open-close valve), on a water line to a saturator. The manual type requires no electricity and uses water pressure or a float valve to activate a type of ball cock, similar to the common float valve in a water closet. Liquid level switches are adjustable and the high and low levels may be changed as necessary; however, the high liquid level must be set below the overflow pipe.

Softeners

When fluoridation system uses a sodium fluoride solution (primarily a saturator), remember that while sodium fluoride is quite soluble, the fluorides of calcium and magnesium are not. Thus, the fluoride ions in solution will combine with calcium and magnesium ions in the make-up water and form a precipitate, which can clog the metering pump, the injection point, the metering pumps suction line, the saturator bed, etc. For this reason, water used for sodium fluoride saturators should be softened whenever the total hardness exceeds 5-0 ppm, or even less if the amount of labor involved in clearing stoppages or removing scale is objectionable. Remember- the entire water supply need not be softened-only the water used for solution preparation (the make-up water).

Two types of softening treatment are available: ion exchange and the use of polyphosphates (calgon, micromet, etc.). The ion exchange method removes all hardness. Polyphosphates are used for sequestering (keeping in solution) calcium and magnesium and other hardness elements. The amount required usually ranges from 5 to 12 mg/L, although new more efficient types of polyphosphates are now available. They are fed at a rate of 1½-2 mg/L. The polyphosphate may be added directly into the solution tank, or in some cases, a metering pump will be required.

The ion exchange method removes all hardness by using zeolite medium or synthetic resins. Since the volume of water to be softened is usually quite small, a household type of zeolite softener is usually more than adequate. This type of softener can be installed directly in the pipeline used for solution make-up water. When the softening capacity is exhausted, the zeolite (or synthetic resin) can be regenerated with brine made from common salt.

When the softener is in service, it is strongly recommended that a complete recharge program be performed before the water softener runs out of capacity. This is important in order to protect the conditioning media from injury and to maintain its capacity. For example, water containing corrosive hydrogen sulfide can strip and permanently damage the media if the capacity of the filters is allowed to exhaust. Iron bearing waters, too, can cause an exhausted media bed to become impacted and fouled with chunks of rust. IF these conditions are allowed to develop, there will be poor performance and a noticeable reduction in capacity.

The pH of the water supply is an important consideration and should be checked closely before the equipment is installed. Water having a pH value below 6.5, for example, can be corrosive to the conditioning media.

A bypass system is a necessary part of the installation and is used to divert the flow of water around the conditioner during recharge and/or service. A drain line is also essential. It is used during recharge to direct the flow of regeneration water to a suitable waste outlet. Sodium chloride (table salt) is used as the regeneration material.

The water pressure to the softener should be checked. Most manufacturers recommend operation between 20 psi and 100 psi.

Dry Feeders

Dry chemical feeders deliver a predetermined quantity of fluoride chemical in a given time interval. The two types of dry feeders are volumetric and gravimetric. The volumetric dry

feeder delivers a measured volume of dry fluoride chemical per unit of time and the gravimetric dry feeders deliver a measured weight of chemical per unit of time.

Many water treatment plants that treat surface waters (rivers, lakes, reservoirs, etc.) will utilize dry feeders to add other chemicals to the water. Thus, many surface water plants will consider using dry feeders in order for fluorides to be consistent with their other equipment. IN fluoridation, dry feeders are used to feed sodium fluorosilicate almost exclusively. Very few water supply systems use sodium fluoride with dry feeders because the high cost of this chemical usually dictates the use of sodium fluorosilicate.

Volumetric Feeders

Volumetric feeders essentially consist of a combination of a driving mechanism for delivering a constant volume of dry compound, a hopper for holding the compounds, and a chamber for dissolving the compound before discharge into the water supply.

The chemical delivery mechanism distinguishes one type of volumetric feeder from another. Almost every manufacturer has a different design for feeding chemicals volumetrically and can be classified according to several types: rotating disk, oscillating pan, vibratory pan, rotating screw, rotating roller, star wheel, and combination of these types.

The roll-type feeder with a feed slide adjustment was one of the most widely used feeders, particularly in smaller plants. They are not as popular today as the screw-type feeders. In the roll-type feeder, the fluoride chemical is placed in the hopper through a top opening. From the hopper, it flows by gravity to the feed rolls.

Stainless steel feed rollers, which are driven in opposite directions form the material into a smooth ribbon of uniform thickness. The feed rate is adjusted externally on a graduated feed slide by varying the width of this ribbon. If the feeder is equipped with a variable speed drive, it has no feed slide. The feed rate is then adjusted by changing input rpm to the three-speed gearbox. Material leaves the rolls at a uniform rate, falls into a solution tank, and is discharged to the main water system.

The roll-type volumetric feeder feeds powdery or granular dry, free-flowing materials at rates from 6 lbs/hr to 2,100 lbs/hr, although the very fine powder will tend to run freely through the rollers.

The oscillating-pan type of feeder consists essentially of a flat, narrow pan or trough into which the fluoride compound falls from a hopper above. Either the pan or the lower part of the hopper slowly oscillates along the axis of the pan, forcing the removal along the two open edges of the pan of a portion of the chemical in the pan. Delivery rates are controlled by both the speed of oscillation and the length of the stroke or the thickness of the chemical on the pan.

The vibratory-pan dry feeder is a device for discharging a volume of chemical from a pan, chute, or trough made to vibrate electronically. A magnet is energized by means of a pulsating current (either ordinary alternating current or rectified, pulsating direct current). The trough is mounted on springs and connected directly to the magnet. The action of the tray is downward and backward on the power stroke, and upward and forward on the next stroke and appears to flow like water because of the high stroking frequency (3,600 strokes per minute on 60-cycle current).

The rate of delivery is controlled by a rheostat, which determines the voltage and consequently, the degree of movement of the trough.

The most popular type of volumetric feeder is the rotating screw feeder. The fluoride chemical is placed in the hopper through the top. It settles to the bottom by gravity. An arrangement with vibrating plates in the hopper walls provides constant agitation. The agitation extends to the feed screw (hopper bottom) and is designed to prevent arching and packing. It also helps maintain uniform delivery to the feed screw. An eccentric on the feed screw shaft drives a rocker arm connected to vibrating plates in the hopper walls. The feed screw gives single-ended delivery of fluoride to the solution tank at a uniform rate via the discharge line. There is a range of feed rates between 0.02 and 5,000 lbs. per hour.

Gravimetric Feeders

Gravimetric feeders discharge chemicals at a constant weight rather than at a constant volume during a given period of time. There are two general types of gravimetric dry feeders—those based on loss-in-weight of the feeder and those which are based on the weight of material on a section of a moving belt. Many gravimetric dry feeders also incorporate some of the features of volumetric feeders, in that they have rotary feed mechanism between the hopper and the weighing section, or use a mechanical vibrator to move chemicals out of the hopper. Since, ultimately, it is the weight of material per unit of time that is measured and regulated, such variables as material density or consistency have no effect on feed rate. This accounts for the extreme accuracy of which these feeders are capable.

The first type (loss in weight) consists of a hopper suspended from a scale system, an electrical-mechanical system for moving the poise on the scale beam, a mechanical means for moving the compound from the hopper in an amount depending on the position of the scale beam, and a solution tank. The lead screw drive (a synchronous motor) moves the poise along the beam at a pre-set rate of speed. If more material is fed momentarily than indicated by the position of the poise, then the beam will lower. This action moves the control wedge (near the oscillator) downward, permitting a decrease in the amplitude of the stroke driving the star wheel or vibrating feeder mechanism. Less material will then be delivered until the weight of the compound remaining in the hopper is again balanced by the weight of the scale beam. The margin of error in feeding for this type of feeder is generally less than 1 percent. The minimum delivery is 1.6 pounds per hour with range of feed in the order of 100 to 1, while some models can deliver more than 2 tons per hour.

The other type of gravimetric feeder is one in which a section of a loaded, moving belt is continuously weighed. The weight of the belt is balanced by a scale beam. The position of the beam controls delivery of the compound onto the belt. Any deviation from this weight on the belt causes the vertical gate to go up or down, thus causing more or less material to fall onto the belt. Vibrations imparted to a diaphragm on the hopper are generated by an eccentric and transmitted through a wedge that varies the amplitude of the vibrations, depending on the position of the scale beam. Accuracy in these feeders is in the order of 99 percent or more. Range of feed is as much as 100 to 1, and adjustments are readily made merely by moving the poise on the scale beam.

Calibration of Dry Feeders

The rate of feed of a dry chemical feeder can be varied by adjusting the controls according to a scale. The numbers on the scale have no particular units and cannot be converted to ppm or

mg/L until a calibration chart or curve has been prepared. A separate calibration chart is required for each machine and for each chemical fed by the machine. If it is possible to operate your water plant at more than one rate, then you must also have different calibration charts for each plant rate.

To calibrate a dry feeder, fill the hopper to the normal depth with the chemical to be fed. Be sure the chemical is dry, free-flowing, and contains no lumps.

Set the machine adjustment on a low number-certainly lower than the normal operation. Allow the machine to run for a few minutes so that it is feeding uniformly. Use a pan or cardboard box (which has been weighed empty), to catch the total discharge of chemical from the feeder for several minutes (say 5 minutes). Weigh the chemical on the laboratory balance (in grams) and record on a chart.

Repeat the same operation for other scale settings on the machine-usually four or five different settings. Be sure to cover the full range at which the feeder will be operated. Post the calibration curves near the machine (be sure to label each curve for the right machine) so that they can be used without mistakes or loss of time.

The feed rate of a given machine, when operating at a given setting, will vary depending on machine wear, humidity, variation in texture of the chemical being fed, etc.; therefore, **a calibration curve should not be used over an extended period without verifying the accuracy of the curve.**

Fluoride Injection Point

The first consideration in selecting the fluoride injection point is that it must be a point through which all the water to be treated passes. In a water plant, this can be in a channel where the other water treatment chemicals are added, in a main coming from the filter, or in the clear well. If there is a combination of facilities, such as a treatment plant for surface water plus supplemental wells, it must be at a point where all water from all sources passes. If there is no such common point, it means that separate fluoride feeding installations will have to be made for each water facility.

Another consideration in selecting a fluoride injection point is the question of fluoride losses in filters. Whenever possible, fluoride should be added after filtration to avoid the substantial losses that can occur, particularly with heavy alum doses or when magnesium is present and the lime-soda ash softening process is being used. There can be up to a 30 percent loss if the alum dosage rate is 100 ppm of alum. On rare occasions, it may be necessary to add fluoride before filtration, such as in the case where the clearwell is inaccessible or so far away from the plant that moving chemicals would not be economical, or to avoid a second separate injection point.

When other chemicals are being fed, the question of chemical compatibility must be considered. If any of these other chemicals contain calcium, the fluoride injection point should be as far away as possible in order to minimize loss of fluoride by precipitation. For example, lime (for pH control) is being added to the main leading from the filters, fluoride can be added to the same main but at another point, or it can be added to the clearwell. If the lime is being added to the clearwell, the fluoride should be added to the opposite side. If it is not possible to separate injection points, an in-line mixer must be used. If post-lime is added in treatment, it is preferable to use a sodium fluoride make-up water line before the lime is added.

In a single well system, the fluoride injection point will be in the discharge line of a pump. If there is more than one pump, it can be in the line leading to the elevated tank or other storage facility. In the surface water treatment plant and the water softening plant, the ideal location of the fluoride injection point is in the line from the rapid sand filters to the clearwell. This will provide maximum mixing. Sometimes the clearwell is located directly below the rapid sand filter, and discharging any chemicals directly to the clearwell is difficult.

At the fluoride injection point, the location of the chemical line should be 45 degrees from the bottom of the pipe and protrude 1/3 of the pipe diameter into the pipe. This will allow better mixing without sediments collecting around the injection point. The fluoride injection point should never be located at the top of the line because of the air binding problems. A valve, injection nozzle, or corporation stop should be part of the installation. It is strongly recommended that an anti-siphon device always be included.

Equipment Installation

Fluoridation installation should be considered during the design stage. The decisions made during the design phase will greatly affect the installation. The best installation is one that incorporates as many of these factors as possible:

1. Simple, accurate feeding equipment
2. Minimum chemical handling
3. Consistent with the above two factors, the lowest overall cost based on amortization of equipment and cost of chemical
4. Ease in collecting reliable records
5. Minimum maintenance of feeder, piping, and injector equipment

A thorough knowledge of the types of equipment available is a must in order to determine the best installation.

Before a type of feeder can be selected, sufficient and appropriate space for its installation must be provided. If there is an existing water plant where other water treatment chemicals are being fed, usually space for an additional feeder is no problem. If there is no treatment plant, as is often the case with well systems, then there may be a well house, or perhaps even some type of shelter, near an elevated storage tank. The feeder must be placed in a dry, sheltered area, near the point of fluoride injection, and preferably in a place that has storage space for chemicals. Electrical power (in most cases) and a water line for solution preparation must be available. The location must be accessible for chemical replenishment and maintenance. Other than these basic requirements, consideration should be given to the desirability of isolation of chemical storage from other materials, for adequate ventilation, and for general convenience.

When the fluoridation system is tied electrically to the well pump, it should be physically impossible to plug the fluoride metering pump into any "hot" electrical outlet. The pump should be plugged only into the circuit containing the overfeed protection. One method of ensuring this is to provide a special plug on the metering pump which is compatible only with a special outlet on the appropriate electrical outlet. This special plug should be clearly labeled. This recommendation is true for both acid feed and saturator systems.

Fluorosilicic Acid Installation

The simplest and easiest fluoridation installation is an acid feed system with a single well. The typical installation would include a carboy of acid (or drum), small metering pump, and scales. The carboy (or drum) should be vented to the outside and sealed around the pump intake line and vent line. If the room where the fluoride equipment is located is exposed to strong direct sunlight, the tubing pigment should be black. The black color screens out the ultraviolet rays, which can cause cracking of the translucent tubing.

The metering pump should be located on a shelf not more than 4 feet above the carboy or solution container, if possible. Note: Many manufacturers recommend that the pump be located so that it has a flooded suction line (low). This is not recommended in fluoridation. The suction line should be as short and straight as possible, there should be a foot-valve and strainer at the bottom and, if necessary, a weight to hold it down.

The discharge line from the metering pump should be as short and straight as possible. Avoid sharp curves or loops in the line. Injecting solution into the top of a pipe should be avoided, since air collects there and can work its way into the metering pump check valve or the discharge line and cause air-binding. It is recommended that an anti-siphon valve be installed at the injection point.

Many metering pumps come equipped with, or have available as an accessory, an anti-siphon discharge valve. This may be mounted directly on the pump head. If solution is to be fed into an open channel or a low-pressure pipeline, a "loaded" discharge valve should be used. This is a spring-loaded check or diaphragm valve, which will not open until the pump discharge pressure exceeds a certain fixed valve. A common setting is about 15 psi.

As mentioned above, the carboy of acid should be completely sealed. This is a major problem at many fluoridation sites. Several kinds of carboys are used as containers for acid. The most common (and the latest style) is a flat top.

Many states are concerned about the possibility of a fluoride overfeed not only because of the risk to health involved but also because of the adverse publicity. IF this becomes a major consideration, a physical break box can be used. The break box reduces the chance for an overfeed from siphoning, with only a marginal increase in cost. Only the amount of acid in the break box can be siphoned into the main water line. Even in very small installations, this amount would be relatively insignificant. This rather ingenious installation was developed by the state of Minnesota. The major difference in cost is the dual head metering pump instead of a single head metering pump.

The installation of an acid feed system in a larger water plant that uses bulk storage is similar to the simple well installation with some exceptions. A day tank is necessary instead of a carboy. Under normal operating conditions, the day tank should not contain over a 2 days' supply of acid. The day tank must also be sealed around the outer lip of the container, the vent hole, the pump suction line opening, and the fill pipe entrance.

There should be flexible connections in the bulk storage line and in the pump suction line (if it is not flexible tubing). This is to prevent inaccurate reading on the scales. The vent line should go from the day tank to the bulk storage tank (near the top), instead of just to an outside wall. The

metering pump should discharge the acid into the line going into a clearwell. If the discharge is directly into the clearwell, the anti-siphon device is still needed at this discharge point.

The bulk storage tank must be vented on top and should be surrounded by a berm to contain any spills. The acid will freeze if exposed to sustained temperatures at or below 4 degrees F. Therefore, in northern climates, the bulk storage tank must be protected from freezing.

Sodium Fluoride Installation (Saturators)

The sodium fluoride saturator is a very simple fluoridation system. It requires only a little more space and piping than the straight acid feed. Many of the same comments made on the acid feed installations apply to the saturator installations. The metering pump should be located not more than 4 feet over the low saturated water line in the saturator. The suction line should be as short as possible. The metering pump should be equipped with an anti-siphon valve. There also should be an anti-siphon valve at the fluoride injection point if the fluoride solution is injected into the water main.

The fluoride saturator does not need to be sealed as tightly as the acid carboy. Saturator systems should have a water meter and, if necessary, a water softener. The feed water line should contain a Y-strainer and sufficient unions to allow easy removal of piping.

When mounting a metering pump on a shelf or platform above the saturator, it is advisable to offset it sufficiently to permit access to the container for filling and cleaning. Mounting the metering pump on the lid of the saturator is not recommended.

A saturator should never be pushed to its design capacity limit for any length of time. When a saturator's capacity is approached, then another method of fluoridation should be considered, such as the use of fluorosilicic acid. The upflow saturator installation is very similar to the downflow saturator installation, with some exceptions. If a liquid switch is used, CDC recommends that there be a solenoid valve and a vacuum breaker be installed. The vacuum breaker must be between the solenoid valve and the water inlet. Also, CDC recommends that a flow restrictor with a maximum flow of 2 gallons per minute be installed to allow adequate contact time. (Note: Many states allow flow restrictors of up to 4 gpm.) There must be a minimum water pressure in the inlet line of 20 psi.

The recommendation for a different kind of metering pump plug, with sign, to prevent connecting the metering pump into a "hot" electrical outlet is especially important with an upflow saturator installation. This is because a solenoid valve requires the "hot" electrical connection, and, it thus becomes easy to make a mistake.

Sodium Fluorosilicate Installation (Dry Feeders)

Only the installation on the volumetric dry feeder will be discussed because it is the most typical one used. The gravimetric feeder installation would be, in essence, the same. When installing a dry feeder, placement should be so that the solution from the solution tank can fall directly into the chemical feed channel, if possible. If other considerations dictate that the feeder be placed some distance from the point of application, the drain line should be as direct as possible, with adequate slope and sufficient size to preclude precipitation build-ups and subsequent stoppages.

Obviously, the dry feeder installation must be on a firm, level foundation if the scales are expected to perform satisfactorily. If there is a small hopper on the feeder, it must be readily

accessible for filling, and if an extension hopper is used, it should extend vertically upward to the filling area, without angles that could trap material. For the water supply line to a volumetric feeder, there must be a section of flexible hose between the solution tank and the water pipe to permit free movement of the feeder and scald platform.

The water supply line to a dry feeder must be equipped with an air-gap or mechanical vacuum-breaker, or some other type of anti-siphon device. The air gap is the most positive protection against the dangers of a cross-connection. If water pressure is too high to permit the use of an air gap, one of the other devices may be used, but in any case, the vacuum breaker must be placed between the point of entry to the solution tank and any restrictive device in the pipeline, and must be installed in an elevated location.

Chemical Storage and Handling

A number of criteria govern the selection of a storage site for fluoridation chemicals: Dry chemicals must be kept dry and convenient to the hopper; preferably they should be isolated from other water treatment chemicals to preclude accidental intermixing; the storage area must be clean and well ventilated, and should be equipped with running water and a floor drain for ease in cleaning up spills.

Dry fluoride compounds, i.e., sodium fluoride and sodium fluorosilicate, have a tendency to compact or cake when exposed to moisture or when bags are stacked too high. Similar conditions can result from long periods of storage, so an oversupply of chemicals should be avoided. Store dry fluorides on pallets, in stacks preferably not more than six bags high. If fiber drums are used, keep the tops closed to prevent moisture absorption. Do not allow unauthorized personnel, especially small children, in areas where fluoride chemicals are fed or stored.

When fluoride sacks are handled carelessly, or if the bags are emptied too quickly, airborne fluoride dust levels may become dangerously high. Do not toss the bags. When opening the bags, cut an even slit across the top to avoid tearing the sides. Pour the contents of the bags gently into the feed hopper. Do not bellows the empty bag. Good ventilation is absolutely necessary in work areas, even if there is no visible dust production.

The disposal of empty fluoride containers has always been a problem. Do not re-use empty fluoride containers! The temptation to re-use fiber drums is strong, since the drums are convenient and sturdy. Paper bags are dusty and could cause a hazard if they are burned. The best approach is to rinse all empty containers with plenty of water—even the paper bags are strong enough to withstand repeated rinses. After all traces of fluoride are removed, the bags should be disposed of in a proper manner. Check with the solid waste division of your state's Environmental Protection Program for correct advice. Even supposedly well-rinsed drums should never be used where traces of fluoride could present a hazard. If possible, the storage area should be kept locked and not be used for any other purpose. Workers should particularly be warned against eating in a fluoride storage area.

Fluorosilicic acid presents particular storage problems, for the vapors are corrosive and will even etch glass. Containers must be kept tightly closed and vented to the outdoors. Large quantities of acid can be stored in underground or enclosed tanks equipped with outside vents. The 30 percent acid has a freezing point at 4 degrees F. The 100 percent acid will freeze at -4 degrees F. Do not store fluorosilicic acid containers in the hot sun where the containers can build hydrostatic pressure, or in open areas subject to winter freezing.

Fluorosilicic acid should be stored in well ventilated areas, well away from switches, contacts, and control panels. Although the acid is available in all-polyethylene drums, some suppliers continue to ship it in lined steel drums that may suffer leakage problems. Wash down all spills immediately.

When fluorosilicic acid is purchased in bulk, tanks are necessary for storage. Bulk storage tanks can be made of fiberglass (coated with epoxy resin), polyethylene, or rubber-lined steel. The polyethylene should be manufactured from high density cross-linked material (cross-linked provides strength). The plastic should contain a minimum of 0.25 percent ultraviolet stabilizer to protect against sun light. The polyethylene storage tanks are still relatively new-so the longevity of the tank is yet to be determined. Fiberglass and rubber-lined steel tanks are used about equally for bulk storage of fluorosilicic acid. Fiberglass tanks usually will last about 7-10 years. Several years ago, fiberglass tanks were the most popular; then, the steel tanks became the most popular; now, the polyethylene bulk storage tanks are the most frequently purchased. The steel tanks are always lined with rubber. Most linings are made of natural rubber but can be made of neoprene or butyl rubber. Butyl rubber is best, however, it's the most expensive. The steel-rubber-lined tanks will last about 20 years.

Chemistry of Fluoride Analysis

The analysis of fluoride in water involves the determination of the quantity of fluoride present in solution, irrespective of the source of that ion. There is no method capable of distinguishing natural fluoride from added fluoride, thus the fluoride test results will be in terms of total fluoride. (But remember that the test for total fluoride does not include insoluble fluorides or the organic fluorides.)

Because the recommended concentrations of fluoride in potable water are so small, the analytical method must be precise and highly selective. Methods based on classic gravimetric or volumetric techniques are generally not applicable.

Years ago, only the colorimetric methods were suited to the measurement of minute quantities of fluoride. Today the analyst may elect to use the fluoride specific ion electrode test rather than the traditional colorimetric fluoride test (SPADNS). Either method has the required sensitivity-the electrode method, however, has far fewer interferences.

Under the Safe Drinking Water Act, rigorous analytical requirements must be met for fluoride analysis. These tests are for measuring the natural fluoride in the drinking water to determine long-term health effects. However, daily testing of adjusted fluoride levels are operational or monitoring tests and do not need to be as precise. For example, under the Safe Drinking Water Act, samples to be analyzed via colorimetric analyses must be distilled prior to color development. Daily operational tests need not be distilled.

Interferences with Fluoride Analysis

Some substances interfere with the analysis of the fluoride ion. (See Table below). As can be seen, some of the interferences for the colorimetric (SPADNS) method occur at quite low concentrations. These low concentrations are definitely within the range that occurs in water plants during normal operation. However, most of the interfering substances will be fairly constant in ground water systems, so it is quite easy to account for this interference in the daily monitoring results. It's only when the interfering substance fluctuates widely, as in surface water

systems, that either the distillation step or the use of the specific ion electrode method needs to be considered for daily monitoring of the fluoride level.

INTERFERING SUBSTANCES*

Concentration of substance, in mg/L, required to cause error of plus or minus 0.1 mg at 1.0 mg/L fluoride		
Interfering Substances	SPADNS	Electrode
Alkalinity (CaCO ₃)	5,000 (-)	7,000 (+)
Aluminum (Al)	0.1 (-)**	3.0 (-)
Chloride (Cl)	7,000 (+)	20,000 (-)
Iron (Fe)	10 (-)	200 (-)
Hexametaphosphate (NaPO ₃)	1.0 (+)	50,000
Phosphate (PO ₄)	16 (+)	50,000
Sulfate (SO ₄)	200 (+)	50000 (-)
Chlorine	Must be completely removed with arsenite	5,000
Color & Turbidity	Must be removed or compensated for	---

* American Public Health Association, AWWA, Water Pollution Control Federation

Standard Methods for the Examination of Water and Wastewater, 18th Ed, 1992 pp4-59 to 4-64

** Above figure is for immediate reading.

Fluoride Sampling Collection

The reliability of an analysis of the concentration in a water sample depends upon the sampling method. The water samples must be representative of the water to be examined. In other words, water samples must be collected at a point where the fluoride has become completely mixed with the entire volume of water entering the distribution system. Otherwise, the results will have no significance.

If a sample is collected from a tap, the water should first be run long enough to empty the service pipe and thus obtain a sample representative of the water in the main.

It is not possible to specify the sampling points in general that would be applicable to a particular water supply. The important point is that the samples for analysis show the fluoride content of the water delivered to the consumer. A possible sampling point could be from a water tap in the home of the plant operator, if the operator's house is served by the distribution system being tested.

Water samples should be taken and tested for fluoride at least daily by the plant operator. In some locations the operator may be required to test more than once a day. Consult the state drinking water program to determine how often samples should be collected for testing.

The state may require a certain number of water samples to be submitted each month for fluoride analysis. These are called check samples. (At least one check sample should be taken per month.)

SPADNS Method for Fluoride Analysis

The colorimetric method, or SPADNS photometric method, is based on a reaction in which a dye lake (a deep color) is formed with zirconium and SPADNS dye.² (SPADNS is sodium 2-(parasulfophenylazo)-1,8-dihydroxy-3,6-naphthalene disulfonate.) Any fluoride present in the

water sample removes zirconium from the reaction, thus decreasing the intensity of color present. The color of the reaction mixture (water sample plus reagent) varies from very deep red in the absence of fluoride to light red when the concentration of fluoride is high.

The colors produced by different concentrations of fluoride ions are all shades of red, and it is almost impossible to detect the difference in these colors by eye. It is necessary to use a photometer to detect the color differences and therefore determine the concentration of fluoride in a water supply. A photometer is an instrument of detecting differences in color, and consists of a light source, a filter for producing monochromatic light, and a photocell for measuring the intensity of the light transmitted through the sample.

The procedures for using a photometer for analysis of the fluoride concentration in a sample of water consist of adding a measured volume of reagent to a measured volume of the water sample, placing a portion of the mixture in a cell or curvette, placing the cell in the instrument, and determining the fluoride concentration in parts per million (ppm) from the instrument scale.

The fluoride analysis of water is a comparatively delicate operation, as the quantities involved are minute, and the greatest possible accuracy is desired. For these reasons, the following special precautions should be taken with any of the SPADNS procedures.

- Ensure that the temperature of the standard sample and the water sample is the same, preferably approximately 20 degrees (± 1 degree) C (68° F). If the temperature of the standard and the unknown are different, then the results will not give a correct reading of the fluoride content.
- Ensure that glassware is clean and free from scratches and chips. In the fluoride test, the concentration of fluoride being determined is extremely small. Any fluoride test is very sensitive to small residues of various chemicals that can interfere. Therefore, **it is absolutely necessary that the colorimeter bottles and all other glassware be clean.** To make sure of the accuracy of the test, it is strongly recommended that the fluoride test be repeated as a check, using the same graduated cylinders and colorimeter bottles. Repeating the test will ensure that the glassware is free of interfering chemicals.
- Measure the reagent accurately (use pipette for SPADNS).
- If chlorine is present, it should be eliminated, using arsenite solution.
- To standardize the test equipment, use a standard fluoride solution that has a fluoride content close to what the fluoride contents should be for the sample being test. For example, if the routine test samples have about 1.5 ppm fluoride, it is recommended that a 1.5 ppm standard fluoride solution be bought and used rather than the 1.0 ppm solution.
- Perhaps the most important source of error is the presence of interfering ions in the water sample. None of the colorimetric methods are entirely specific for fluoride, and, to varying degrees, many of the other ions found in water affect the fluoride analysis. The reagents are designed to eliminate the effects of these interfering ions, or to minimize the effects as much as possible. However, if the water supply contains a large quantity of interfering ions, the reagent may not be able to minimize the effects of the interfering ions enough to get an accurate determination of the quantity of fluoride in the water. If the interferences become a problem, the ion electrode method should be considered.

The SPADNS method of fluoride analysis is directly applicable to fluoride samples in the range of 0.1 to 2.0 ppm. Beyond this range, dilutions must be made using deionized water to obtain accurate measure of the fluoride concentration. Dilutions must be carefully made.

Electrode Method for Fluoride Analysis

The electrode method is capable of measuring fluoride concentrations for 0.1 to 10 ppm. A major advantage of the electrode method is that samples generally do not require distillation to eliminate the interferences.

The basis for this method is in the fluoride electrode itself. Most electrodes contain a fluoride solution; at the tip of the electrode is a crystal doped with fluoride ions. The crystal acts as an ionic conductor, so that when the fluoride concentration outside of the electrode is higher than that inside, ions move toward the inside, setting up a voltage potential proportional to the difference in fluoride concentration. Conversely, when the fluoride concentration on the outside is lower than that on the inside, a proportional potential of opposite sign is set up. IN most fluoride electrodes, the internal solution is about 10^{-3} molar in fluoride, so concentrations below 19 ppm result in positive voltage readings. Some electrodes contain no internal solution, but the principle of operation is similar.

Maintenance

To realize the full benefits of fluoridation, it is very important that the optimal fluoride content be consistently maintained in the drinking water supply. To ensure constant fluoride feed, proper maintenance of the fluoridation equipment is essential. This includes maintaining not only the fluoride feeder, but also all the appurtenances, feed lines, and laboratory testing equipment. Experience has shown that the basic reason for low or erratic fluoride levels is due to poor operation and maintenance.

Preventive Maintenance

Breakdowns of your fluoridation system may be prevented by following a good maintenance program. In a preventive maintenance program each job-such as cleaning the equipment or replacing worn parts-is scheduled to be done periodically; then a job is done when its time comes even though the equipment may be working well. The instructions that came with the equipment will explain proper maintenance. The information can be used to make a simple plan for maintaining all the fluoridation equipment.

An example of a preventive maintenance plan is shown below.

Equipment	Maintenance Work	Time
Metering Pump	1. Disassemble pump and replace worn parts	1. Once a year
	2. Change gear oil (except electronic).	2. After first 2 to 4 weeks then every 6 months.
Saturator	1. Drain, disassemble, and clean.	1. Every 12 months (or more often with heavy use.
	2. Disassemble and clean precipitates from foot valve or suction strainer, discharge and injection lines, injection nozzle.	2. Every 6 months
	3. Disassemble and replace worn parts of the siphon breaker.	3. Every 6 months.
Dry Feeders	1. Thoroughly clean.	1. Once per year.
	2. Check for worn gears, parts, etc.	2. Once per year.
	3. Lubricate and change oil gear.	3. Once per year.
Anti-siphon	Disassemble and replace worn parts.	Once per year.
Injection Nozzle	Disassemble and clean.	Once per year.

Troubleshooting

Incredible as it may seem, even under a good maintenance program, a fluoridation system can break down. When a system breaks down, children in the community are deprived of the benefits of fluoridation. Protect your community by watching for signs of trouble and correcting malfunctions early. Trouble in the system can show up as a change in the equipment, a change in the amount of chemical fed, and/or a change in the fluoride content of the fluoridated water.

If possible, inspect the equipment in the fluoridation system at least once a day. In the daily inspection, the equipment may be tested to ensure that it cuts on an off properly. At the same time look for signs that the equipment is not operating normally.

A sign that fluoridation equipment is not operating normally may be that there is an unusual sound or a change in a normal sound; an unusual odor or a normal odor that is stronger than usual; more heat than normal given off by any part of the equipment; and/or unusual vibrations, leaks, drips, or puddles.

To recognize these signs of trouble, the operator must know what the equipment is like when it is operating normally. Once the operator knows this, he/she will probably be quick to notice a change in it. Whenever anything seems different-no matter how small a change it may be-pay attention. Don't think that it will go away. Look for the cause. It may be a sign that something is wrong with the equipment.

Examine the metering pump while the pump is well pump is operation. Listen to the pump. Is the motor operating? Are the sounds normal? If there is an unusual sound, find out what is making it. Feel the pump, the motor casing (if not normally too hot to touch) and its mounting. Is anything warmer than normal? Is it vibrating more than normal? Look for leaks. Look around the body of the pump, at the suction and discharge lines, and on the floor beneath them, at the injection point, and at all connections.

If the system has a saturator, test its liquid level control (float switch, liquid level probe) while the well pump is operating. Push the float down. The solenoid valve should open and admit water. Lift the float. The solenoid valve should close and shut off the water. Lift the liquid level probe. The solenoid valve should open and admit water. Lower the liquid level probe. The solenoid valve should close and shut off the water. Some manufacturers have a 5 minute time delay in their liquid level controls. Test the metering pump. Turn off the well pump-does the metering pump cut off as it should? Look for leaks in other parts of the fluoridation system.

The instructions that come with the fluoridation equipment may give information on troubleshooting, that is, finding out what has gone wrong. Some manufacturers have excellent troubleshooting charts, but they may not cover an entire fluoridation system. Also, the state water supply program is a good source for additional information on troubleshooting. The state engineers know a lot about what is likely to go wrong in a system like yours. They should be able to give good practical advice on how to find the cause of malfunctions.

The problems commonly encountered in the operation of a fluoridation system are related to low, high, or variable fluoride readings. Although slight over- or under- feeding fluoride for short periods actually is of no serious consequences, such variations should be investigated, since they may be indications of potential problems of a more serious nature.

When the fluoride concentration determined by analysis is consistently lower than that determined by calculation, a number of problems may be interference in the laboratory test procedure. If alum is used for flocculation, traces of aluminum in the finished water can interfere with colorimetric analysis by influencing the readings negatively. A high iron content can also cause low readings if the SPADNS method is used. In rare cases, chloride and alkalinity can also interfere, but their concentrations have to be extremely high.

A common cause of low readings is underdosing due to inadequate chemical depth in a saturator or incomplete mixing in a dissolving tank. Deposits of undissolved chemical in the dissolving tank of a dry feeder indicate incomplete mixing. This can be due to inadequate baffling or inadequate makeup-water flow rate. As the fluoride is dissolved, a high reading may result. Also, adding 100 pounds of sodium fluoride to a saturator at one time will result in a temporary higher fluoride concentration. Thus, it is better to add 50 pounds at a time.

Low chemical purity is another possible cause of low fluoride readings. Fluorosilicic acid has the most available purity and can be anywhere from 20 to 30 percent pure. The manufacturer usually specifies the purity of a given batch, but if there is some doubt, the acid should be analyzed according to directions given in the AWWA Standards. Sodium fluoride and sodium fluorosilicate usually exhibit less variation in purity, but occasionally a relatively impure lot is produced.

If the fluoride level is low in a sample taken from the distribution system, it may be advisable to check for unfluoridated water entering at some point in the distribution system and diluting the water fluoridated at the plant.

If laboratory testing indicates a fluoride concentration consistently higher than that determined by calculation, several problems may be indicated.

Polyphosphates can cause analytical error in the positive direction when using the SPADNS method. This type of error can be checked by using the electrode method or comparing results with the local or state health departments. Failure to eliminate chlorine from the water sample can also lead to high results in colorimetric analysis.

Failure to take into account the natural fluoride content of the raw water can result in adding more fluoride than is needed; surface supplies, which can show considerable variability, should be analyzed daily so that the correct dosage can be calculated. If the water supply comes from wells, the variability is much less, but in the case of a higher-than-calculated fluoride concentration, the possibility of a contribution from a high-fluoride well should be investigated.

The most difficult type of problem to solve is that of variable fluoride concentration when calculations show that the fluoride feed rate is of the required proportion. One possibility, however, that can be checked is the fluoride feeder. Verifications of the delivery rate with weight measurements at short intervals will reveal whether the feeder delivery rate is constant.

Almost all of the factors that can produce consistently low or high fluoride analyses can also produce variable errors if the analytical interference, chemical purity, raw water fluoride, or completeness of chemical solution is variable. In the last case, undissolved sodium fluorosilicate can eventually go into solution after a quantity of undissolved material accumulates at some point, and a solution feeder can begin drawing from a concentrated stratum after feeding from a dilute stratum in an improperly mixed solution tank.

One of the causes of varying fluoride content in a treated water system is the intermittent intrusion of unfluoridated water into the system. This situation usually occurs when fluoridation measures are instituted and no attempt has been made to fluoridate the reservoir separately. When no water is being pumped or the pumping rate is less than the demand, water flows into the system from the reservoir and, since this water has not yet been fluoridated, low fluoride readings will result, particularly at the sampling points nearest the reservoir. Eventually, with flow pattern reversals as the pumps operate intermittently, the reservoir contents will become displaced by fluoridated water. However, there have been cases involving large reservoirs, located at the end of a water system, where it has taken years before there was a complete turnover of the reservoir contents. The obvious solution to this type of problem is to fluoridate the reservoir separately at the time fluoridation of the system begins, if possible.

A similar situation occurs when an elevated tank or other storage facility merely rides on the system, and its contents rarely enter the system or at best there is only a slight intermixing. Sampling points near the tank will have varying fluoride concentrations-normal during pumping and low when water is being drawn from the tank. The solution is to allow the tank contents to drain into the system before fluoridation begins and then not refill the tank until the entire system is up to the optimal fluoride level.

Cyclic fluoride levels can result when the feeder is operated intermittently, such as when capacity is reduced by the use of a cycle timer and when there is insufficient storage capacity between the feeder and the consumers. Detention time in mains or a storage facility between the feed point and the first consumer are important factors in providing homogeneous fluoridated water.

There are undoubtedly many other possible causes for fluoride levels below optimum, but it is certain that fluoride does not disappear in the pipelines, nor is it likely that fluoride will concentrate at points or become leached out of incrustations in the mains. Unlike chlorine, fluoride does not have the ability to dissipate and, even though trace amounts are incorporated into tubercles in pipelines, the extreme insolubility of these formations prevents subsequent dissolution. When there is an unexplained difference between the calculated and observed fluoride concentrations, the calculations are usually at fault. If calculations prove to be accurate and none of the previous possibilities apply or can be eliminated, common sense and knowledge of the individual system should enable the operator to locate and correct the cause of the trouble.

Safety

While fluoride is an extremely safe compound at the 1 ppm level found in water supplies, the operator may be exposed to much higher levels by handling the chemicals. Therefore the use of safety equipment is strongly recommended when handling fluoride compounds or performing maintenance.

Always wear protective safety gear when handling fluoride chemicals. The following is a list of protective clothing and equipment, which is the minimum recommended for each fluoride chemical.

Sodium fluoride/Sodium fluorosilicate

1. Wear protective clothing.
 - a. NIOSH/MSHA approved high efficiency dust respirator (chemical mask) with soft rubber face-to-mask seal and replaceable cartridges*
 - b. Goggles
 - c. Gauntlet neoprene gloves (12" minimum length)
 - d. Heavy duty neoprene aprons
 - e. High top boots

Protective clothing should always be worn whenever sodium fluoride/sodium fluorosilicate is handled and should be stored near the entrance to the area where the sodium fluoride is stored and used. This clothing should not be worn into other parts of the water plant to avoid spreading sodium fluoride dust. Handle bags of sodium fluoride/sodium fluorosilicate carefully.

2. Don't tear or puncture bags when they are moved; use a knife to open the bags and make a clean cut.
3. Pour the sodium fluoride into the saturator gently, so as to raise as little as dust as possible; empty opened bags completely.
4. Do not store partially filled bags of sodium fluoride for later use.
5. Dispose of empty bags as required by your state.

Wash your hands immediately after handling sodium fluoride, the fluoridation equipment, or your protective clothing. Never eat, drink, or smoke in areas where sodium fluoride is stored or used.

Fluorosilicic acid

1. Wear protective clothing.
 - a. Gauntlet neoprene gloved (12" glove minimum length)
 - b. Full 8" face shield and/or acid type safety glasses

- c. Heavy duty acid type neoprene aprons
 - d. Safety shower/eye washer in easily accessible location (or pint bottle of eyewash solution)
 - e. Boots
2. Keep the acid off clothes and skin and don't breathe in its fumes when handling the acid.
 3. Use a transfer pup to move acid from one container to another.
 4. Mop up any spilled acid immediately and wash the area with water
 5. Dispose of empty acid containers as required by your state.
 6. Wash your hands after handling fluorosilicic acid, the fluoridation equipment, or your protective clothing. Do this immediately, before you do anything else.
 7. Never eat, drink, or smoke in areas where the acid is stored or used.

Chemical respirators with cartridges for acid fumes should be worn if the concentration is sufficient to cause irritation to the nose.

Spill control pillows can be used to clean up small fluorosilicic acid spills. The liquid is absorbed and contained within the pillow by a highly efficient "foamed-sand" type of absorbent, which is chemically inert and can absorb up to 10 times its weight. The pillows are commercially available in various sizes ranging from 1 to 4 liters.

Water plant personnel should regularly receive safety training on all chemicals, including fluoride. Hazards and first aid measures should be reviewed and explained. Emergency spill procedures should be established and personnel trained in the execution of those procedures.

Safety records show that the water treatment plant personnel have one of the highest accident/injuries rate in the United States. Until water plant managers/supervisors insist on proper safety training and utilization of safety equipment, this poor record shall continue.

Fluoride Exposure

Toxic Exposure

While potable water with fluoride levels at the recommended concentration of 1.0 ppm has been exhaustively studied and firmly established as safe beyond question, the fluoride levels to which the water plant operator can be exposed are potentially much higher. To prevent overexposure, the best safety measure is proper handling of fluoride chemicals. Proper handling implies adequate knowledge of the material, the practice of correct procedures, and the use of indicated safety equipment.

There are times, however, that the operator may be overexposed to the fluoride chemicals, especially the dusts. These overexposures, whether they occur in water or air, are called toxic exposures. The two kinds of toxic exposures are chronic toxic exposure and acute toxic exposure. A clear distinction must be made between chronic toxic exposure to large doses of fluoride over a number of years and acute toxic exposure, which results from a single massive dose.

Chronic Toxic Exposure

The only toxic effect of low levels of fluoride over a prolonged period (2 to 8 times that of the optimal level) is mottled enamel of the teeth. At higher levels of fluoride intake, osteosclerosis, calcification of ligaments and tendons, and/or vertebrae consolidation can occur. With chronic

toxic exposure from fluoride chemical dusts, there may be a general lack of appetite, slight nausea, some shortness of breath, constipation, pain in the liver region, and anemia.

Probably the greatest chance for chronic exposure to fluoride chemicals comes from the inhalation of dust generated when the feeder hoppers are being filled. To prevent overexposure during the filling operation, the operator should wear an effective NIOSH approved respirator, an apron, and rubber gloves. The respirator should have a rubber face-to-mask seal, with replaceable cartridges. Cartridges are available for either dust or acid vapor application. The maximum allowable concentration of fluoride dust in the area (TLV) should be 2.5 mg/m³ of air.

Acute Toxic Exposure

Acute fluoride poisoning may result from ingestion or bodily contact with concentrated fluoride compounds. Not a lot is known about acute fluoride poisoning caused by ingestion or inhalation because it is a very rare occurrence. Accidental ingestion is quite unlikely, but might occur by the compound being mistaken for sugar or salt or through carelessness, or allowing areas where food is consumed to become grossly contaminated by dust or spillage.

The symptoms of acute poisoning by inhalation of dust or vapor include sharp biting pains in the nose followed by nasal discharge or nosebleed, and perhaps coughing or respiratory distress. These symptoms generally start at approximately 20 mg per cubic meter of air. Acid spill or splash may cause a tingling or burning sensation of the skin, or if the eyes are involved, severe eye irritation.

Ingested toxic overdoses generally cause vomiting, stomach cramps, and diarrhea. If the poisoning involves ingestion of large amounts of fluorides, the vomitus may be white (or colored if the fluoride contains dye), and the victim may experience muscular weakness, articulation difficulty, disturbed color vision, and thirst. The final stages of fluoride intoxication would include weak pulse, unconsciousness, and convulsions. Ingestion of 5 to 10 grams of fluoride (as sodium fluoride) per 154 pounds of bodyweight may be fatal.

Several bodily functions help prevent an acute dose of fluoride from being fatal. First, there are the initial symptoms of severe nausea and vomiting when high levels of fluoride are ingested. Second, at lower levels of ingestion, individuals in a stable fluoride balance (equilibrium) will excrete fluoride at a level approximately equal to the water concentrations.

First Aid for Acute Toxic Exposure

Once fluoride poisoning has been established, first aid treatment should be started while waiting for medical help. Recommended first aid for ingested toxic fluoride overdose is given in the Table below.

EMERGENCY TREATMENT FOR INGESTED FLUORIDE OVERDOSE

Milligrams fluoride ion	Treatment
Less than 5.0 mg/kg (226 mg/100 lb)	<ol style="list-style-type: none"> 1. Give calcium orally (milk) to relieve gastrointestinal symptoms. Observe for a few hours. (Note: A can of evaporated milk can be kept on hand for a long period of time.) 2. Induced vomiting not necessary.
Over 5.0 mg/kg	<ol style="list-style-type: none"> 1. Move the victim away from any contact with fluoride and keep him warm. 2. If the victim is conscious, induce vomiting by rubbing back of the throat with a spoon or your finger; or use syrup of Ipecac. While vomiting, the patient should be placed face-down with the head lower than the body to prevent inhalation of vomitus. (For patients with depressed gag reflex caused by age (6 months old), Down's syndrome, or severe mental retardation, induced vomiting is contraindicated and endotracheal intubation should be performed before gastric lavage.) 3. Give the victim a glass of milk or any source of soluble calcium. (5% calcium gluconate, or calcium lactate solution.) 4. Take the victim to the hospital as quickly as possible.

*Average weight/age 1-2 years = 15 kg; 4-5 years = 20 kg; 6-8 years = 23 kg.

The recommended first aid for air-borne fluorides (nose bleed) is as follows:

1. Move the victim from the exposed area;
2. Keep the victim quiet;
3. Place the victim in a sitting position, leaning forward, if possible; if that is not possible, place the victim in a reclining position with the head and shoulders raised;
4. Apply pressure directly by pressing the bleeding nostril toward the midline;
5. Apply cold compresses to the victim's nose and face;
6. If bleeding cannot be controlled by the preceding measures, insert a small, clean pad of gauze (not absorbent cotton) into one or both nostrils and apply pressure externally with the thumb and index finger; A free end of the pad must extend outside the nostril so that the pad can be removed later; and
7. If bleeding continues, obtain medical assistance.

The recommended first aid for an acid splash is as follows:

1. Wash away the chemical with large amounts of water as quickly as possible. Remove the victim's clothing from the affected areas and continue washing for at least 5 minutes;
2. Where skin damage has occurred, cover the burn with a dressing bandage and seek medical attention;
3. If the eye is involved, immediately begin to wash the eye, eyelid, and face. Hold the eyelid open and wash the eye for at least 15 minutes;

4. After a thorough washing, cover the eye with a clean, dry, protective dressing and hold bandage in place, then transport the victim to a doctor; and
5. All instances of eye injury require medical attention. Even seemingly minor eye injuries can leave the eye vulnerable to infections that can lead to blindness.

Keep in mind that fluorosilicic acid can be neutralized with sodium bicarbonate (baking soda). Thus, spills that can't be washed away can be neutralized.

Emergency Procedures for Fluoride Overfeed

When a community is fluoridating its drinking water, there is always a potential for overfeeding. Most overfeeds are of no serious consequence (but should be corrected). For example, if the optimal level of fluoride for a community is 1.0 ppm, and an overfeed resulted from 2.0 ppm in the drinking water for several years, very mild fluorosis would appear in a few persons. Higher levels of fluoride for shorter periods can be accepted with no adverse effects. (See Table below). As stated previously, at a rural school in Seabrook, North Carolina, the fluoride level had been adjusted to seven times the optimal level for 12 years with no unacceptable fluorosis. Thus, the danger of overfeed, while always present, should not be over-emphasized.

RECOMMENDED ACTIONS FOR FLUORIDE OVERFEED

IF THE FLUORIDE CONTENT (mg/L) IS:	THEN, PERFORM THE FOLLOWING RECOMMENDED ACTIONS:
0.5 above the optimum to 2.0	1. Leave the fluoridation system on.
2.0 to 4.0	2. Determine what has malfunctioned and repair it.
	1. Leave the fluoridation system on. 2. Determine what has malfunctioned and repair it. 3. Notify your supervisor Name/Phone _____ / _____ and report the incident to the appropriate county or state agencies. Name/Phone _____ / _____
4.0 to 10.0	1. Determine what has malfunctioned and repair it.
	2. If the problem is not found and corrected quickly, turn off the fluoridation system.
	3. Notify your supervisor Name/Phone _____ / _____ and report the incident to the appropriate county or state agencies. Name/Phone _____ / _____
	4. Take water samples at several points in the distribution system and test the fluoride content. (Save the part of the water samples not used.)
	5. Determine what has malfunctioned and repair it. Then, with supervisor's permission, restart the fluoridation system.
10.0 or higher	1. Turn off the fluoridation system immediately.
	2. Notify your supervisor Name/Phone _____ / _____ and report the incident to the appropriate county or state agencies. Name/Phone _____ / _____ and follow their instructions.
	3. Take water samples at several points in the distribution system and test the fluoride content. Save the part of the sample for the state lab to test.
	4. Determine what has malfunctioned and repair it. Then, with supervisor's permission, restart the fluoridation system.

DISINFECTION & MICROBIOLOGY

Disinfection is used to kill disease-causing (**pathogenic**) microorganisms in the water system; therefore, it should not be confused with sterilization, which is the destruction of all living microorganisms.

The operator also needs to be aware that changes in the pH may affect the ability of the chlorine to disinfect the water. The operator needs to understand:

1. **Injection point** – whether the injection point and the method of mixing is designed so that the disinfectant can get into contact with all of the water to be disinfected.
2. **Contact time** – expressed as CT value, the residual disinfectant “C” concentration in mg/L multiplied by the corresponding disinfectant contact “T”ime in minutes. The “C” concentration of the chemical and the “T” length of contact time needed to adequately kill or inactivate pathogens vary with different types of disinfectant.
3. **Effectiveness of upstream treatment processes** – the lower the turbidity (cloudiness) of the water, the more effective the disinfection.
4. **Temperature** – at higher temperatures, the rate of disinfection is more rapid.
5. **Dosage and type of chemical** – usually the higher the dose, the quicker the disinfection rate. The form of disinfectant (chloramines vs. free chlorine) and the type of chemical (gas vs. liquid) used influence the disinfection rate.
6. **pH** – the lower the pH, the better the disinfection action.

When chlorine is initially added to water, the following may occur:

1. If the water contains iron, manganese, organic matter, or ammonia, the chlorine reacts with these materials and no residual is formed, meaning that no disinfection has taken place.
2. If additional chlorine is added at this point, it will react with the ammonia to form chloramines. The chloramines are considered a “combined” chlorine residual. As the chlorine is combined with other substances, it loses some of its disinfection strength. Combined residuals have less disinfection power than free (non-combined) residuals and may be the cause of taste and odor problems.
3. Some systems intentionally add ammonia to extend the life of the chlorine so residuals are carried to end-points in large distribution systems. The resulting combined chlorine is not as strong as free, but lasts longer.
4. With a little more chlorine added, the chloramines and some of the chlororganics are destroyed.
5. With still more chlorine added, free chlorine residual is formed, free in the sense that it can react quickly. Free also dissipates more quickly than combined.

Most chlorine analyses are performed with the DPD method. DPD reagent will change color in the presence of chlorine when added to a water sample. A manual color comparator (color wheel held up to the light) or a colorimeter (digital readout) that automatically measures the intensity of the color is used to determine the concentration of chlorine residual in the water sample.

Disinfection Requirements

West Virginia requires some form of chlorine to be used during disinfection, in order, to maintain the required 0.2 mg/L of chlorine residual in the distribution system.

West Virginia requires a minimum of 30-minute contact time (groundwater) and a free chlorine residual minimum after the contact time, based on pH. West Virginia requires a minimum of 0.4 – 1.0 mg/L free chlorine residual, depending on the pH for groundwater sources.

Breakpoint Chlorination

When chlorine is added to water that contains no ammonia, the residual that is obtained will be free available chlorine. If ammonia is present, and the demand has been satisfied, some of the free chlorine will react with the ammonia to form chloramines or combined chlorine residual. As more chlorine is added, it will breakdown the chloramines that have been formed and the combined residual will begin to drop. A point will be reached where the residual will begin to rise again after all of the chloramines, that can be, are destroyed. There may be some combined residual left in the water at this point. From this point, any additional chlorine dosage will result in the formation of only free chlorine residual. This is known as the “**breakpoint**”. All water systems that chlorinate their water will, in fact, practice breakpoint chlorination. They will add enough chlorine to the water to achieve a free chlorine residual of at least 0.2-0.5 mg/L.

Chlorine Treatment Terms

Several terms are used to identify the various stages and reactions that occur when chlorine is used as a disinfectant. The basic unit of measurement for chlorination, or any other chemical treatment is milligrams per liter (mg/L) or parts per million (ppm). These are very small units reflecting concentrations that are essentially one part chemical for every million parts of water. To get some idea of how small a concentration this really is it should be pointed out that 1% is equal to 10,000 mg/L or ppm.

Chlorine Dosage

The chlorine dosage is the amount of chlorine that is added to the water. The dosage can be determined from the number of pounds of chlorine used and the number of millions of pounds of water treated.

Chlorine Demand

Chlorine is a very reactive oxidizing agent. It will react with a certain substances that may be found in water. This list includes; iron, manganese, hydrogen sulfide, ammonia and other inorganic or organic materials in the water. When chlorine reacts with these substances, it loses its disinfecting properties. This is referred to as the chlorine demand. For chlorine to be effective as a disinfectant, the dosage must always exceed the demand that is present in the water. The chlorine demand may vary from day to day in a surface water supply. It is usually fairly constant in a ground water supply.

Chlorine Residual

The chlorine that remains in the water, after it has finished reacting with those substances that represent the demand, is known as the chlorine residual.

There are two types of residuals that result from the chlorination of water. They are free chlorine residual and combined chlorine residual.

Free Chlorine Residual

Chlorine in this form has the highest disinfection ability. After the demand has been satisfied, any chlorine that is left will react with water to form hydrochloric acid and hypochlorous acid.

Combined Chlorine Residual

Chlorine reacts with water to form hypochlorous acid. If ammonia is present, the hypochlorous acid will react with it to form compounds known as chloramines. Chloramines are weak disinfectants. They require longer contact times and higher concentrations to achieve disinfection than free chlorine residual. However, they do not breakdown as quickly as free chlorine and remain in the system longer.

Total Available Chlorine

The total available chlorine is the sum of free available chlorine and combined available chlorine.

Testing for Chlorine Residuals

Chlorine residual determinations and reporting are an important responsibility of the operator. Chlorine residual is most commonly measured using a **DPD** (Diethyl-p-Phenylene-Diamine) colorimeter test kit. This kit indicates the chlorine residual level by comparing the color produced with the DPD chemical addition to the water with a standardized color residual indicator. Not all test kits use a “color wheel”. Some kits consist of colorimeters or spectrophotometers for measuring the color intensity.

Forms of Chlorine

Chlorine is applied in one of three forms; chlorine gas, chlorine powder, or an aqueous solution like chlorine bleach.

Chlorine Gas

Chlorine gas is a greenish-yellow material with a penetrating and distinctive odor. It is more than two and a half times as heavy as air so will settle in low areas if it is released into the atmosphere. It is a poisonous gas and must be handled with care. Chlorine gas is not corrosive unless it is in a moist atmosphere or in contact with any moisture. It then becomes highly corrosive and is especially destructive to electrical equipment.

Chlorine gas (Cl_2) is compressed into a liquid for storage. It can be purchased in steel cylinders containing 100, 150 or 2000 pounds of the liquefied gas.

Chlorine Powder

Chlorine in its dry form is calcium hypochlorite, $\text{Ca}(\text{OCl})_2$, is a white solid which is available in powder, granular or tablet form. Only about 65 – 70% of $\text{Ca}(\text{OCl})_2$ is available as chlorine. The rest is calcium, which is not a disinfectant. It is normally dissolved in water and then injected into the drinking water using a solution feeder.

It is also most commonly known by the trade name **HTH** (High Test Hypochlorite), Perchloron or Pitclor.

Calcium hypochlorite is a powerful oxidizing agent and must be handled with care, kept dry and away from combustible materials. It may start a fire if the white solid material comes into contact with organic materials, such as an oily rag.

Chlorine Bleach

Chlorine bleach is a aqueous solution of sodium hypochlorite, NaOCl, containing 5 percent to 15 percent available chlorine. The 5.25 percent solution is sold in grocery stores under trade names such as Clorox, Purex, etc. This form can be used for emergency disinfection and then flushed away, but is not usually used for continuous chlorination. Sodium hypochlorite can be conveniently added to water using a small solution feed pump.

FULL-TIME CHLORINATION

Public water supply systems must demonstrate that continuous disinfection is being practiced. The public water supply system operator must monitor daily the amount of chlorine being added and the total chlorine residual obtained in the distribution system.

Chlorine Gas

When gas chlorine is used for continuous disinfection it is typically fed by use of a vacuum operated, solution feed chlorinator. For safety reasons, the chlorine is handled under vacuum so any leaks will leak air into the chlorinator instead of allowing chlorine to leak into the air. The vacuum is produced in an ejector in which a small stream of water is pressured through a nozzle orifice. The vacuum produced opens a check valve and an internal valve in the chlorinator allowing chlorine to feed from the tank into the ejector where it is mixed with the water stream from the nozzle. The resulting chlorine solution is mixed with the main stream of water to be disinfected. A variable orifice flow meter (rotometer) mounted on the chlorine gas cylinder indicates the chlorine flow rate with a small black ball suspended in a glass tube. When using a gas chlorinator, the ejector water is usually controlled either by a solenoid valve or by starting and stopping a booster pump so the chlorination system operates while the well pump is pumping and shuts down when the well pump is off.

Calcium or Sodium Hypochlorite

Hypochlorination, using either calcium hypochlorite or sodium hypochlorite, is often the most practical method of disinfection for small water systems.

Calcium hypochlorite is usually the least expensive of the two and is often selected for that reason. Typically, the hypochlorite is dissolved into a water solution and metered into the flowing water stream using a small diaphragm or plunger-type pump.

Calcium hypochlorite tablets will not dissolve readily in water colder than 41°F, so the availability and temperature of the mixing water must be considered. In hard water, calcium hypochlorite may form a calcium carbonate precipitate, which will interfere with the solution feed pump unless the chlorine solution is prepared in a separate tank and allowed to settle. The clear liquid is then siphoned to a storage tank for use.

Sodium hypochlorite may also form some precipitate but may not need to be settled and siphoned. Sodium hypochlorite is often fed at full strength from the container, allowing for fewer problems in handling.

Hypochlorination requires close attention by the operator as the pump and injection point often build scale. The scale will prevent the pump poppet valves from sealing and the pump will not move the solution into the water to be disinfected. Maintenance of the pump, and especially cleaning the pump valves, should be on a regular weekly schedule, or as often as experience indicates.

CHLORINE SAFETY

Although it is used as a disinfectant, it is a dangerous and potentially fatal chemical if used improperly. Chlorine, in any form, can be a difficult and hazardous chemical to handle in the concentrations used in water treatment.

Chlorine gas can be especially hazardous to handle and all personnel should be thoroughly aware of its hazardous properties. All personnel handling chlorine should know the location and use of the various pieces of personal protective equipment and be instructed in safety procedures. In a moist atmosphere, or in contact with any moisture, chlorine is highly corrosive and is especially destructive to electrical equipment. When combined with the moisture in mucous membranes of the nose and throat, and with the fluids in the eyes and lungs, a very small amount of chlorine gas in the air can be very irritating and can cause severe coughing. Heavy exposure can be fatal.

Chlorine gas leaks may be detected by passing an ammonia-soaked cotton swab near the suspected area. If chlorine gas is leaking and comes in contact with ammonia, a white smoke appears. Do not spray ammonia on the leak, because too much white smoke will be formed to see the leak area and may fill the room so that even the exit is difficult to find. If a chlorine cylinder is leaking, it should only be handled by a person equipped with and trained to use a proper self-contained breathing apparatus (SCBA) in good operating condition.

Chlorine gas storage rooms and rooms where chlorine gas is used are required to have mechanical exhaust systems that draw air from the room at a point no higher than 12 inches above the floor. This low height is necessary so the exhaust fan will remove the settling chlorine gas from the room.

Empty tanks, tanks in use and back-up tanks must be restrained using a chain or other means so that they cannot be knocked over.

Sodium and calcium hypochlorite are not as hazardous as gaseous chlorine and therefore are easier and safer to handle. This certainly should be one of the major considerations for a small system when determining which form of chlorine to use. Personal protective equipment (mask, apron, gloves) should be used when handling hypochlorite since it can cause damage to eyes and skin upon contact. If spilled on skin, the affected area should be washed quickly with large amounts of water. Hypochlorite solutions are very corrosive. Large volumes of water should be used to wash-down spills. Hypochlorite compounds are non-flammable; however, they can cause fires when they come in contact with organics (oily rags) or other easily oxidizable substances.

General Chlorine Safety

Chlorine is a greenish-yellow gas. It is 2.5 times heavier than air. Chlorine gas is very corrosive. It turns into hydrochloric acid when it comes in contact with moisture (in the water, in the chlorine lines, or in your eyes or lungs). It does not support combustion but can be harmful if inhaled in small quantities and fatal in larger doses. Chlorine leaks can be located using ammonia vapors.

Chlorinator Room

The chlorinator room should have a window in the door so that the operator in the room can be seen from the outside. The light and vent switches should also be located outside the room. The room should have ventilation located at floor level since chlorine gas is heavier than air and will

settle in the lowest spot in the room. The room should be kept between 60° F and 120° F. Below 60° F, chlorine gas forms chlorine hydrate, also known as “green ice,” when it comes in contact with water. This green ice can clog the injector and gas piping, creating a serious maintenance problem.

When a chlorine cylinder is full and at room temperature, it is about 85% full of liquefied chlorine. As the temperature rises, the liquid expands and takes up more space in the cylinder. At 157° F the liquid will expand to occupy 100% of the cylinder. If the liquid expands any further the cylinder will rupture, causing a massive chlorine leak.

Chlorine Storage

The room where chlorine cylinders or HTH drums are stored must be kept dry and well ventilated. Chlorine should always be stored in a room separate from other chemicals. Chlorine cylinders that are empty should be separated from those that are full. All cylinders should be chained to the wall.

Chlorine Cylinders

NEVER remove the valve hood from a chlorine cylinder unless it is chained to the scales and ready to be put on the system. All cylinders should be chained to the wall or the scales unless they are being moved. Every system that operates a gas chlorine system should have an emergency kit or be able to get access to one on very short notice. To prevent the cylinder from rupturing when it gets too hot, every gas cylinder will have a “fusible plug” that is designed to melt at 157° F. There is one in the valve assembly of every 150 lb. cylinder and six (three on each end) in the body of every 1-ton cylinder. As one of these fusible plugs melts, it will allow the release of chlorine gas from the cylinder. This still represents a serious problem, but the release will be more gradual than it would if the tank ruptured.

Respiratory Protection

Anyone involved in handling chlorine should have access to respiratory protection equipment. There are two basic types of respiratory protection. One is the gas mask that uses a filtering device to remove chlorine. These are either a full-face mask or a mouth/nose type respirator. The other type of respirator is the self-contained breathing apparatus (**SCBA**). The SCBA unit is full-face mask with an air tank to provide the operator with fresh air to breathe when in hazardous atmospheres. Both of these devices may be rendered ineffective if the wearer has facial hair that interferes with the face-to-mask seal.

FORMS OF CHLORINE

Chlorine Gas

Chlorine gas is a hazardous substance and should be handled with care. The following list gives some general safety precautions that should be taken when handling 100-or 150-lb chlorine cylinders:

- Chlorine cylinders should be moved on properly balanced hand trucks, preferably with rubbers tires. A clamp or chain support two-thirds of the way up the cylinder should be used to secure the container.
- Chlorine cylinders should be transported and stored in an upright position.
- Chlorine cylinders must be secured so that they cannot be tipped over
- Chlorine cylinders should not be dropped, allowed to strike forcefully against anything, or struck forcefully by other objects.
- Chlorine cylinders should be stored so that they can be moved in the event of a leak or fire.
- Chlorine cylinders should not be stored or used in an area below ground level, because chlorine gas is heavier than air and will settle into and remain in such areas.
- When receiving a shipment of chlorine cylinders, inspect the shipment before accepting it.
 - Check each cylinder for serious dents, cuts, or gouges that might decrease the wall thickness of the container.
 - Look for signs of corrosion or pitting that might be serious enough to weaken the cylinder.
 - Check for obvious bulges
 - Put your hand on each cylinder to see if it is hot to the touch. This could indicate internal moisture contamination. If there appears to be internal moisture, return the cylinder to the manufacturer or supplier
 - Visually inspect the valves and fusible plugs.
- If any the chlorine cylinders appear of questionable status, return the cylinder to the manufacturer or supplier.
- Whenever there is any indication of a leak or other problem with the chlorine cylinders, take safety precautions immediately. Only authorized, trained personnel with suitable self-contained breathing apparatus should investigate; all other persons should be kept away from the affected area. When you suspect problems with a chlorine cylinder, the chlorine supplier should be contacted for emergency assistance.

Calcium Hypochlorite

While calcium hypochlorite is not as dangerous as chlorine gas, it should be handled according to the recommended procedures. The following is a short list of precautions than should be taken when working with this solid form of chlorine.

- Calcium hypochlorite should be stored only in the original container and away from moisture.
- Calcium hypochlorite is relatively stable but will decompose in storage. It can ignite or explode on contact with organic materials (oil, rags, or alcohol), and it should not be exposed to fire or elevated temperatures.

- When handling calcium hypochlorite, the operator should wear a protective apron, rubber gloves, eye protection, and a dust-protection respirator.

Sodium Hypochlorite

The following is a list of precautions to take when working with this liquid form of chlorine:

- Sodium hypochlorite should be stored in a cool, dark place to minimize decomposition.
- Always store sodium hypochlorite in a container made of a proper material, such as plastic, because the chemical is corrosive to many types of materials. The containers should be kept closed. Fumes escaping from the containers are corrosive.
- When working with this product, wear protective gloves, apron, and eye protection.

THE WATER CYCLE

The Earth's water is always in movement, and the water cycle, also known as the **hydrologic cycle**, describes the continuous movement of water on, above, and below the surface of the Earth. Since the water cycle is truly a "cycle," there is no beginning or end. Water is not gained or lost. Water changes states among liquid, vapor, and solid at various places in the water cycle continuously.

A drop of water:

- Evaporates as water vapor from the heat of the sun or other sources
- Condenses in the atmosphere
- Falls to the earth in the form of precipitation
- Leaches or infiltrates into the ground entering aquifers
- Recharges surface water
- Evaporates again beginning the cycle all over

This means all the water we have now is all we've ever had, and all we're ever going to have. When we look at all the water on earth, most of it (~97%) is in oceans and salty. Icecaps and glaciers make up 2% of earth's water supply. Therefore, there is only 1% or less fresh water available on the surface and in the ground to use.

As rain and snow fall to the earth, some of the water runs off the surface into lakes, rivers, streams and the oceans; some evaporates; and some is absorbed by plant roots. The rest of the water soaks through the ground's surface and moves downward through the unsaturated zone, where the open spaces in rocks and soil are filled with a mixture of air and water, until it reaches the water table. The water table is the top of the saturated zone, or the area in which all interconnected spaces in rocks, and soil are filled with water. The water in the saturated zone is called groundwater. In areas where the water table occurs at the ground's surface, the groundwater discharges into marshes, lakes, springs, or streams and evaporates into the atmosphere to form clouds, eventually falling back to earth again as precipitation.

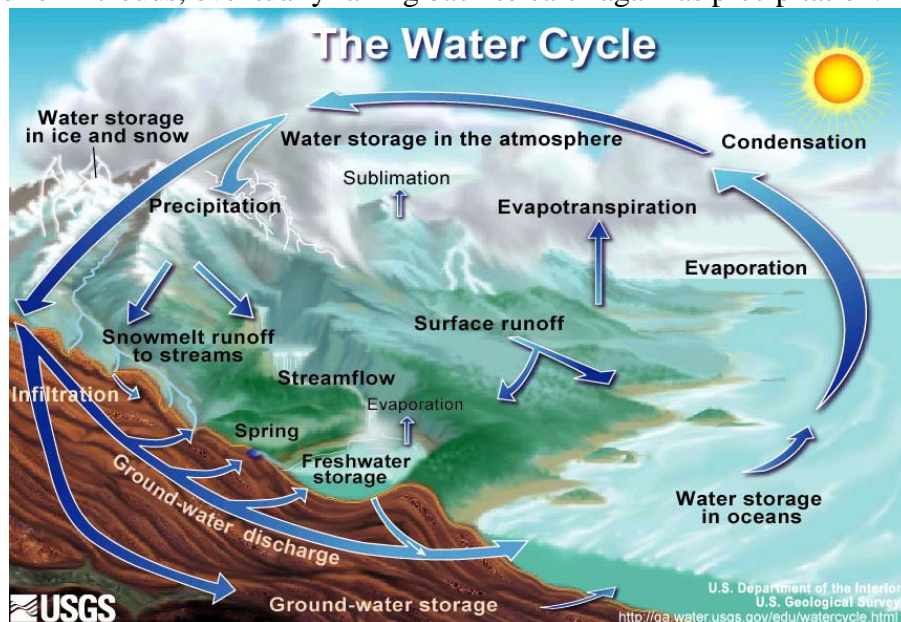


Illustration courtesy of the U.S. Geological Survey

GROUNDWATER

Water beneath the land surface occurs in 2 different zones- the unsaturated zone and the saturated zone. The **unsaturated zone** is the area immediately beneath the surface that contains both water and air. Any water in the unsaturated zone is not officially considered groundwater. The **saturated zone** is the area beneath the unsaturated zone where all interconnected openings contain water. The top of the saturated zone is referred to as the water table and any water beneath is officially considered groundwater. The water table:

- Marks the zone of saturation, when rock openings are completely saturated with water and officially called groundwater
- Is the depth at which an aquifer is first found
- Is capable of varying from place to place, and with time
- Is one sign of how surface water and groundwater flow into (or recharge) each other

Groundwater is stored under many types of geologic conditions. Areas where groundwater exists in sufficient quantities to supply wells or springs are called **aquifers**, a term that literally means “water bearer”.

Aquifers store water in the spaces between particles of sand, gravel, soil and rock as well as cracks, pores, and channels in relatively solid rocks. An aquifer’s storage capacity is controlled largely by its **porosity**, or the relative amount of open space present to hold water. Its ability to transmit water or **permeability** is based in part on the size of these spaces and the extent to which they are connected.

Basically, there are two kinds of aquifers; confined and unconfined. If the aquifer is sandwiched between layers of less permeable materials (e.g. clay), it is called a **confined aquifer**. Confined aquifers are frequently found at greater depth than unconfined aquifers. Artesian wells originate from groundwater that is trapped between two impervious strata. As the water flows between these strata it becomes confined as recharge continues, the water backs up, creating pressurized conditions in the aquifer. Water in a well located in an artesian aquifer will rise above the point at which it is first located. If the water rises to the surface, it is a free-flowing artesian well. If not, it is called a non-flowing artesian well.

In contrast, **unconfined aquifers** are not sandwiched between these layers of relatively impermeable materials, and their upper boundaries are generally closer to the surface of the land. The water table is the upper most unconfined aquifer that is free to rise and fall with seasonal changes of recharge rate. The water level in a well located in an unconfined aquifer will not rise above the initial point of encounter because it is not under pressure. A **perched aquifer** is a very small, unconfined aquifer that doesn’t contain much water and is only recharged by local precipitation.

WELLS

The purpose of design standards and proper well development is to improve water quality and quantity and protect public health. WV Water Well Design Standards (Title 64-Series 46) are available from the Secretary of State's website at <http://www.wvsos.com/csr/verify.asp?TitleSeries=64-46>. All water well drillers in West Virginia must be certified by the West Virginia Department of Health and Human Resources, Bureau for Public Health, Office of Environmental Health Services. As an operator, it is important to understand some basic water well terms instrumental in protecting ground water sources. The following section is only a brief overview.

All wells in WV, public and private, must be cased and grouted to prevent surface water contamination from entering the aquifer and to exclude undesirable ground water zones. Casing must be made of steel, concrete or a safe plastic such as PVC. The casing should extend from the aquifer to at least 18 inches above the ground surface. The hole should be at least 4 inches larger in diameter than the casing to allow for cement grout. The space between the casing and the wall of the hole is known as the annular space. The annular space is grouted with cement, neat cement, bentonite or a bentonite/cement mix to seal the casing against the borehole. Grout also protects the steel casing from contact with corrosive soils and waters, which would cause it to rust out. Although the depth of grout is determined on a case-by-case basis, it must be pumped into the well from the bottom to the top to prevent air from being trapped and ensure proper sealing of the cavity.

Well Screens

Many rock wells are not equipped with screens. Where water is obtained from water-bearing sands, some type screen must be provided. The selection and construction of this section of the well is most important. The life of the well depends to a large degree on the proper screen. The screen is just what the name implies—a device to hold back sand or any other foreign matter and let water through to the pump. The screen is placed in the well where it is not available for inspection and repair, but the life and performance of the well is dependent upon it. Therefore, serious consideration should be given to its selection.

Perhaps the two most important items for consideration in selecting the screen are the size of the sand encountered and the chemical characteristics of the water. The screen openings must be small enough to hold back the larger sand grains or gravel and at the same time be large enough so that resistance to the flow of water is reduced. The screen openings are determined after the particular sand size is measured. If the screen is improperly sized or ruptures and permits sand to pass, the pump, valves, and meters in the distribution system will be damaged and/or last only a short time. Meters will become plugged and inoperable or complaints of sand in the water will result.

Well Cap

Weatherproof and insect-proof water supply well covers are required. Electrical connections for the pump and any treatment installations also require weatherproof and insect-proof covers to prevent contamination of the well. Ground fault protectors would also be desirable.

Well Pad

The casing should extend at least 6 to 12 inches above the well pad, depending on whether the well is located in a well house or out in the open, to prevent standing water from entering the

well. The **well pad** should be sloped away from the casing. Well housings should never be located in a pit.

Well Ventilation

Well casing and discharge column pipe vents should extend at least 18 inches above ground. An air vent is needed for most wells. This vent is usually part of the well cap. The outlets should be turned down to prevent rainwater from entering and screened to prevent contamination by insects, dust, debris, etc.

Sanitary Well Seal

A sanitary well seal is used instead of a well cap on wells that have piping exiting at the top of the casing. It consists of a rubber gasket that is sandwiched between an upper and lower metal plate and all fits inside the top of the casing. The sanitary well seal has openings on the top for piping. Two-piece top plate sanitary seals are only acceptable for wells located in an approved well house. One-piece top plate sanitary seals are acceptable for outdoor use. Well seals are usually made of rubber or neoprene. A welded seal is also approved and used in some cases.

Pitless Units and Pitless Adapters

A pitless adaptor or pitless unit is used to create a frost-proof connection between the well and the water service line. The water service line is attached to the fittings on the well underground – below the frost line, typically 18 to 36 inches below the surface. This is to prevent freezing during cold weather. A water service line connects the well to the water distribution system. Pitless adapters are fittings that can be installed using a hole through the well casing. Pitless units are more complex assemblies, which completely replace the well casing between the frost line and the top of the well.

Last but not least, it is very important to properly abandon water wells no longer in use in accordance with 64CSR46 to prevent future aquifer contamination.

Well Terms

The top of the water table or natural water level in the well while the pump is not running is called the **static water level or static head**. In most cases, the static water level rarely fluctuates much over time as the aquifer is recharged through the hydrologic water cycle. But in some cases, due to excess pumpage from the aquifer over time or drought, the static water level lowers as the aquifer becomes depleted.

The top of the water level in the well while the pump is running is called the **pumping water level**. This level is important because it is an indicator of the ability of the aquifer to supply water to the well.

The difference between the static water level and the pumping water level is known as the **drawdown** of the well. Drawdown is determined by the ability of the aquifer to replace the amount of water that is being pumped from the well. If there is an abundance of water in an aquifer and the water can move freely to the well, the drawdown will be fairly low, typical of sand and gravel formations. Conversely, if the water cannot move through the formation quickly enough to replace the water being pumped, the drawdown can be quite high.

Well yield and **specific capacity** are two terms that refer to the measurement of the amount of water a well can produce. Well yield is generally expressed in gallons per minute (gpm). Specific

capacity is the rate of water that discharges from a well per unit of drawdown (usually feet). It is determined by dividing the well yield by the drawdown and is usually expressed in gallons per minute per foot (gpm/ft). For example, if a well pumps 100 gpm and it has a drawdown of 30 feet, its specific capacity at that flow rate is 3.33 gpm/ft. By tracking the specific capacity of a well over time, an operator can identify well and aquifer performance problems.

As water is pumped from the well, a depression in the water table forms in the shape of an inverted cone called the **cone of depression**. If the drawdown is low, the cone of depression may only extend for a short distance away from the well. Conversely, if the drawdown is high, the cone of depression can extend for quite a ways out from the well, in some cases for hundreds of feet. The cone will continue to enlarge until the rate of groundwater flow or recharge equals the pumping rate, or sufficient leakage occurs between formations to equal the pumping rate, or the cone intercepts a surface water body (lake, stream, etc), or some combination of these occur.

Well Pumps

Most well pumps that are installed in public water systems are vertical turbine centrifugal pumps. The main difference between vertical turbines and other types of centrifugal pumps is that the vertical turbine impeller discharges water out of the top of the impeller. This water flows upward along the pump shaft, instead of at a right angle to the shaft. These pumps can generate the high discharge pressures needed to pump water several hundred feet out of the ground.

“Staging” or stacking several impellers on the shaft is how the high pressures are generated. As the water passes from the discharge of one impeller to the suction of the impeller above it, the pressure that the pump develops is increased. If five impellers that each generates 100 feet of head are staged in a pump, the pump will generate 500 feet of head pressure. Anytime pumps are operated in series, where one pump or impeller discharges to the suction of another pump; the pressure will increase while the flow remains constant.

In some very small, shallow wells airlift pumps may be used. These are normally not suitable for wells supplying most public water systems.

There are two kinds of vertical turbine pumps installed in wells. One of these is known as a submersible pump. A submersible pump will have the motor located beneath the pump. In a small well, it is the least expensive centrifugal well pump to purchase and install. Because there is no pump shaft running to the surface, the submersible is also the ideal pump installation in wells where vertical casing alignment problems exist.

PUMPS AND MAINTENANCE

Pumps are the heart of a water system. Pumps provide the means for moving water through the system at usable working pressures. In almost all cases, the source is at a lower elevation than the user so the water must be raised to a higher level. Some type of pumping equipment must be used to generate the pressure for raising the water to the higher elevation. Pumps of one type or another accomplish a major part of the work accomplished and energy expended in a water system. There are two basic types of pumps used in water. The most common type of pump is the centrifugal pump. The other type is the positive displacement pump.

Many different types of pumps can be used with the selection depending on the work that needs to be done. One type would be used for transferring water from a well to a tower; another would be better suited for pumping sludge containing a lime byproduct from a softening plant; still another would be used for feeding a chemical into the water for treatment. Among the considerations in selecting a pump are the maximum flow needed in gallons per minute (gpm), the head it needs to pump against, and the accuracy needed for flow control.

Positive Displacement Pump

The positive displacement pump is commonly used to feed chemicals into the water or to move heavy suspension, such as sludge.

Piston Pump

One type of positive displacement pump consists of a piston that moves in a back and forth motion within a cylinder. It is used primarily to move material that has large amounts of suspended material, such as sludges, in wastewater or for trash pumps for pumping mud. The cylinder will have check valves that operate opposite to each other, depending on the motion of the piston. One check will be located on the suction side of the piston and will open as the piston moves back, creating a larger cylinder area. After the piston has reached the longest stroke position, the motion of the piston will reverse. This action will open the discharge check valve and close the suction check. The contents of the piston are then discharged to discharge piping. After the discharge, the motion of the piston will reverse and the suction stroke will begin. This action will take place as long as power is applied to the pump.

Diaphragm Pump

Another type of positive displacement pump used in the water industry is the diaphragm pump. This pump operates the same way as the piston pump except that, in place of a piston that moves in a cylinder, a flexible diaphragm moves back and forth in a closed area. The check valves operate in the same fashion as they feed or move liquid in the pump. This type of pump is used when high accuracy is required. Most of these pumps are operated by the use of a solenoid that will pulse a set number of times per minute. This pulsing, which is termed frequency, is variable and can be set by the operator or by a control signal. The length of the stroke can also be adjusted in order to vary the size of chamber that fills with liquid.

Peristaltic Metering Pump

A peristaltic metering pump is a positive displacement pump that uses the alternating waves of contraction and dilation of a plastic tubing to move liquid through the tubing into the water line. (This is the peristaltic principle similar to the action of the large intestines in the human body). A rotary gear rolls over the plastic tubing creating a suction on the solution side of the feeder. Thus, fluoride solution is drawn in one end of the tube and is forced out the other end.

The peristaltic pump is adjusted by means of a dial ring and the size of the tubing. At full setting of the dial, the rotor turns continuously. At lower settings of the dial, the rotor starts and stops, moving at slower intervals. At the lowest setting, the rotor moves in very small jerks. The tubing size ranges from 1/8 inch to 1/4 inch with the standard size tubing being 3/16 inches. The tubing also comes in low pressure (up to 20 psi) and high pressure (up to 100 psi) types. The high pressure type tubing is used for most pumps designed for fluoridation.

The peristaltic metering pump is self-priming and will not be damaged by the freezing of the solution being pumped. The range of feed is from 0.5 gallons per day up to 85 gallons per day. The tubing is designed to last from one to 2 years, depending upon usage. Proper installation of the correct type of tubing is very important.

Centrifugal Pumps

Because it delivers a constant flow of water at a constant pressure for any given set of conditions, the centrifugal pump is ideal for delivering water to customers. Most well pumps are centrifugal pumps. They are ideal for use in the distribution system since they do not produce pulsating surges of flow and pressure.

This pump operates on the theory of centrifugal force. As the impeller rotates in the pump case, it tends to push water away from the center of the rotation. As the water is pushed away from the center of the impeller, additional water is pulled into the eye, or center, of the impeller. The water that has been pushed to the outside of the impeller is removed from the pump through the discharge piping. This water will have a pressure that is determined by the pitch of the impeller and the speed at which the impeller is turning.

Priming

Never start a centrifugal pump unless it is primed. Priming a pump means that the volute is completely filled with water and all air removed.

Vibration

Centrifugal pumps should operate smoothly. Excessive vibration caused by loose foundation bolts, a broken impeller, worn bearings, misaligned shafts, or similar mechanical failure can damage the pump. If a centrifugal pump vibrates, it should be shut down and checked.

Water Hammer

Water hammer results when the closing of a valve suddenly stops such as a moving column of water. A pressure wave develops at the valve and travels back upstream to the water source. Pressures developed by water hammer can be very high for a brief instant before the pressure wave is reflected back upstream. Pressure dissipates in an oscillating manner as the wave travels back and forth in the closed pipe, causing a loud banging or hammering sound. Although brief, the pressures can be high enough to damage the system piping. Installation of a pump control valve and slow operation of downstream valves may prevent water hammer.

Cavitation

A noisy pump should be checked to see if the problem is cavitation. Modifications to the system may be necessary, such as reducing suction lift to decrease net positive suction head (NPSH) at the pump, modifying suction piping, or selecting a different pump with a lower required NPSH. Such changes often require the assistance of an experienced engineer.

BASIC ELECTRICITY

Electricity is the flow of invisible particles called electrons, through a **conductor**. That flow is controlled in an electric circuit. The knowledge that electricity is created by the flow of electrons, and the knowledge of how to capture electrons, makes electricity a convenient and convertible form of energy.

Electrons flow better in some things than in others. Conductors are substances in which electrons flow freely. Metals are excellent conductors. Water is a fair conductor. Since the human body is mostly water, it can conduct electricity fairly well, too. This is why it is important to be very careful when working around electricity.

Insulators are substances in which electrons cannot flow freely. Glass, plastic, and rubber are good insulators. Electrical wiring is always enclosed in a protective covering of plastic or rubber that serve as insulators.

In order to make electrons do useful work, the electrons must have a source of pressure to push on them and cause them to move. Also, the electrons must have a complete path or **circuit** to follow. The basic components of an electric circuit include the following:

- **Source**-The part that provides the electric force or pressure to move the electrons; such as a battery or generator
- **Load**-The part that does the work or uses the electricity; such as a light bulb, heater or motor
- **Conductor**-The part that carries the electricity around the circuit such as wire, cable, or power line.

Current Flow: Amperes

Current is the flow of electrons. To understand current, imagine an electric circuit as a chain. When all three components (source, load, conductor) exist in the circuit, the electrical force causes the electrons to move down the chain. This forced movement of electrons is called current and is measured in **amperes**. Current is measured with a test instrument called an **ammeter**. Two types of current flow are: **Direct Current (DC)** -The electrons flow in one direction; and **Alternating Current (AC)** -The electrons flow back-and-forth

The AC you use at home changes direction 60 times per second. This means the electrons move back-and-forth 60 times per second. This flow in one direction, reversing, and flowing in the other direction is called a **cycle**. The term 60 cycles AC or 60 Hertz means 60 of these cycles occur each second.

Electrical Pressure: Volts

Electrical pressure is the force that causes electrons to move in a closed electric circuit. It is also referred to as **voltage**. The pressure or force is measured in **volts** by a test instrument called a **voltmeter**. In a DC circuit, a battery produces voltage and in AC circuit a generator produces voltage.

A car battery is typically 12 volts DC. That means that the difference in electron pressure between the two terminals is 12 volts. The electric outlets in your well house are 120 volts or 240 volts AC. The voltage difference between the two prongs of the outlet is 120 V or 240 V.

Resistance: Ohms

Electrons do not flow freely in a conductor. There is a certain amount of **resistance** or friction to oppose the electron flow. This resistance is called **ohms** and is measured by a test instrument called an **ohmmeter**.

Water Flow Analogy of Electrical Circuit

The flow of electrons in an electric circuit can be compared to the flow of water through a closed loop piping system. Volts, amps, and watts measure electricity. Volts measure the pressure under which electricity flows. Amps measure the amount of electric current. Watts measure the amount of work done by a certain amount of current at a certain pressure or voltage.

To simplify the relationship, think of water in a hose. Turning on the faucet supplies the force, which is like the voltage. The amount of water flowing (gallons per minute) through the hose is like the amperage. You would use a lot of water that comes out fast (more watts) to wash off a muddy car. You would use less water that comes out more slowly (less watts) to fill a glass.

Water circuit vs. Electric circuit Source

- Water circuit - water pump produces water pressures (psi) to cause water to flow (gpm)
- Electric circuit - generator produces electrical force (volts) to cause electrons to flow (amps)

Flow measurement

- Water circuit - flow meter measures water flow in gpm
- Electric circuit - ammeter measures current in amperes (amps)

Load

- Water circuit - water wheel does work by rotating
- Electric circuit - light bulb does work by producing light and heat

Pressure loss

- To determine the loss of energy, pressure gauges installed before and after the water wheel can measure the loss of water pressure.
- A voltmeter measures voltage drop as the current goes through the light bulb (conversion of electrical energy to light and heat energy).

Conductor

- Water circuit - pipe that carries the flow of water
- Electric circuit - wire that carries the electrons

DISTRIBUTION SYSTEM

STORAGE

The distribution system is a network of storage tanks, pipes, valves, hydrants, service connections, and meters that are needed to get water from the point of production to the customer. The distribution system begins at the point where water enters the system at usable pressure. It ends at the customer's side of the meter installation.

Each water system has its own unique requirements for water storage. These depend on such factors as the system's pressure, normal water usage, low and peak demand, and fire protection requirements. Ground elevations in the area should be surveyed and the storage tanks located at the highest possible elevation to the area served. Ample storage capacity in a water distribution system will mean lower operating costs and fewer pressure problems for the operator.

Storage Tanks

The two primary purposes for the use of storage tanks within a water distribution system are to provide for:

1. Volume: Providing sufficient storage volume is generally the function of a water storage tank. A typical operating day in any public water system involves varying demands for the water.
2. Pressure: The other function of storage tanks is to provide pressure. The most common method of creating system pressure is through the use of an elevated water storage tank to develop the necessary feet of head to force water through the system.

The operation of storage tanks is also critical to maintaining a continued flow of water to a distribution system for domestic, commercial, or industrial use and for fire protection.

Types of Storage Tanks

Water storage facilities come in a variety of tank types or configurations including:

- **Gravity storage: ground storage, elevated tanks, standpipes, and**
- **Pressure storage: hydropneumatic or diaphragm (bladder) tanks.**

Depending on their type, they are usually constructed of either steel or concrete. Their primary purpose is to store water during periods of low demand for distribution during periods of high demand.

Gravity Storage Tanks

Adequate ground and elevated storage tanks are essential for the proper operation of a water system. These tanks are necessary in order to provide an ample supply of water during peak demands, dependable fire protection, adequate water pressure to outlying areas, and lower pumping costs.

A gravity storage system offers several advantages over other (e.g., hydropneumatic) systems and should be considered where topographic conditions are favorable. The larger water systems have greater advantages. However, even smaller systems will have these advantages:

- Less variation in pressure

- Storage for fire fighting use
- One to two days storage to meet water requirements
- Greater flexibility to meet peak demands
- Use of lower capacity wells (pumping not necessary to meet peak system demand)
- Sizing of pumps to take better advantage of electric load factors
- Reduced on and off cycling of pumps
- Tie-in of several wells, each pumping at its optimal rate

Ground Storage Tanks

The purpose of ground storage is to hold enough water in reserve to compensate for fluctuation of the water demand in the system.

Ground storage tanks are constructed of reinforced concrete, pre-stressed concrete, and steel and are circular or rectangular. Reinforced or pre-stressed concrete is the preferred material since it is more resistant to deterioration when in contact with water. Some ground storage tanks are built above ground while others may be partial or completely underground. Underground storage should be located above the local ground water table. All tanks should be located so that surface and underground drainage is away from the structure. Tanks should never be located within the 100-year flood plain. Sewers, drains, standing water, and similar sources of possible contamination must be kept at least 50 feet from the tank.

The most common location of ground storage tanks is near the treatment plant. These storage tanks are usually referred to as clear wells. Ground storage tanks are also used to store additional water, which can be pumped into the system for fire fighting purposes. A ground storage tank should provide storage equivalent to 2 times average daily demand or 150 gallons per customer per day. This amount will usually permit a uniform pumping rate throughout the day. Ground storage tanks should contain additional storage for filter backwash water.

Ground storage tanks can provide system pressure if they are located on hills within or near the distribution system area. Such situations are ideal since ground storage tanks are usually less expensive to construct than elevated storage tanks.

Standpipe Tanks

Standpipes are essentially ground storage tanks constructed to a height that is greater than their diameter. Their diameter is constant from the ground to the top, and they are completely filled with water. In most installations, only the water in the upper portion of the tank will furnish usable system pressure. When the water level falls to less than 70 feet from the ground surface, there will be less than 30 psi of pressure. For this reason most standpipes are constructed with an adjacent pumping station that can be used to boost the pressure of water from the lower section of the standpipe when needed.

Elevated Storage Tanks

Elevated storage tanks are generally located where the land is flat. These water tanks are supported by towers (or legs) and are said to "float" on the system. This means that they are directly connected to a system main and hold large volumes of water high enough in the air to supply the system with an adequate and fairly uniform pressure during peak demands. In this type of storage tank the system pressure is provided by the height of the water above the ground. The overflow point of the tank is the maximum system pressure. One limitation of elevated storage tanks is that the pressure in the distribution system may vary with the water level in the

tank. In order to maintain a static pressure of 50 psi, water must be stored 115 feet above the customer.

General Operation of Ground and Elevated Storage Tanks

Water contained in a vessel or pipe 100 feet high will exert a pressure of 43.33 pounds per square inch at the bottom of the pipe. The pressure is constant no matter the diameter of the pipe. It could be one inch or ten feet in diameter, but the pressure at the bottom of this vessel will still be 43.33 pounds per square inch.

Pressure Storage

Pneumatic storage tanks are pressurized by a surcharge of air that forms a bubble in the tank. Pneumatic systems are very common for use in storing and distributing small quantities of water. They combine the energy from a pump with the principle of air pressure to force water into the distribution system. The compressed air maintains water pressure when use exceeds the pump capacity and keeps the pump from cycling off and on every time a faucet opens. Pneumatic tanks are also used in large systems as surge protection systems. As the pressure from water hammer surge enters the tank, the force is exerted against the air pocket. The air pocket is compressed and absorbs the energy to dampen the shock wave.

Understanding how a pneumatic system works requires understanding basic system operation and the role of system components.

- The pump starts up when the pressure inside the tank falls to a certain pressure (cut-in pressure), and it pumps water into the tank. The pocket of air in the tank gets smaller and the pressure inside the tank increases as more water is pumped into the tank.
- When the pressure builds to a certain point (cut-out pressure), the pump stops and the air forces the water into the distribution system, as it is needed.
- When the pressure becomes too low, the pump starts up again, and the cycle is repeated. The cycle rate is the number of times the pump starts and stops in 1 hour.

Pneumatic systems are a good, reliable source for providing water to a small number of customers. In West Virginia, they cannot serve more than 75 living units. The gross volume of the pneumatic tank (in gallons) shall be at least 10 times the capacity of the largest pump (rated in gallons per minute). For example, a 250 gallon per minute pump must have a 2,500 gallon pressure tank. They are not a good storage vessel for fire protection purposes due to the small volume of water within the vessel.

Disinfection of Water Storage Facilities

New storage facilities and ones that have been repaired or cleaned must be disinfected before being placed in service. The storage facilities must be disinfected in accordance with current AWWA Standard C652. The following forms of chlorine may be used: gaseous chlorine, sodium hypochlorite or calcium hypochlorite.

There are several methods used for disinfection. Below is a brief description, the complete procedure can be found in Section 4: Alternative Methods of Chlorination of the AWWA Standard for Disinfection of Water-Storage Facilities (C652).

The three methods are:

1. Chlorination of the full storage facility such that, at the end of the appropriate retention period, the water will have a free chlorine residual of not less than 10 mg/L
2. Spraying or painting of all storage facility water-contact surfaces with a solution of 200 mg/L available chlorine
3. Chlorination of the full storage facility with water having a free chlorine residual of 2 mg/L after 24 hours.

The disinfection procedure (AWWA C652 chlorination method 3, section 4.3) that allows use of the chlorinated water held in the storage tank for disinfection purposes is not recommended. When this procedure is used, it is recommended that the initial heavily chlorinated water be properly disposed in order to prevent the release of water that may contain various chlorinated organic compounds into the distribution system.

After the chlorination procedure is completed and before the tank is placed in service, water from the full tank must be tested for bacteriological safety. Three (3) or more successive sets of samples, taken at twenty-four (24) hour intervals, must be microbiologically satisfactory before the facility is placed into operation. If the test results are unsatisfactory, the process must be repeated.

The chlorine level must be reduced to acceptable levels before the water is used or discharged. Disposal of heavily chlorinated water from the tank disinfection process must be in accordance with the requirements of the WVDEP.

WATER MAINS

Water mains are the pipes that carry water from the source to the storage facilities and throughout the distribution system. The size of the main is an important factor. It will determine how well the main transmits water through the system. This is due to the fact that smaller pipes allow less water flow due to the size restriction and the **friction loss**. This is the friction created between the water and the inside of the pipe.

There are three general types of piping systems used by water utilities in the distribution system.

1. Transmission Mains

Transmission mains are designed to carry large quantities of water from the source of supply to the distribution mains. They usually run in a nearly straight line and have only a few side connections.

2. Distribution Mains

Distribution mains are the pipelines that carry water from the transmission mains and distribute it throughout the system. They have many side connections and are frequently tapped for customer connections and fire hydrants.

3. Service Lines

Service lines or “services” are small diameter pipe that run from the distribution mains to the customers homes.

WATER MAIN DESIGN

Pressure

All water mains, including those not designed to provide fire protection, must be sized after a hydraulic analysis based on peak flow demands and pressure requirements. The system must be designed to maintain a minimum pressure of 20 pounds per square inch (psi) at ground level at all points in the distribution system under all conditions of flow and 30 psi under static conditions. The normal working pressure in the distribution system must be designed based upon the pipe manufacturer's recommendations and the applicable AWWA standards for the type of pipe.

Fire Protection

The minimum size of a water main for providing fire protection and serving fire hydrants must be of 6-inch diameter. Larger size mains will be required if necessary to allow the withdrawal of the required fire flow while maintaining the minimum residual pressures. Any departure from minimum 6 inch diameter requirements must be justified by hydraulic analysis and future water use, and can be considered only in special circumstances; however, no mains less than 2 inches are permitted.

When fire protection is to be provided, system design must be such that fire flows and facilities are in accordance with the requirements of the ISO. Under no circumstances must fire flows be less than 250 gallons per minute.

Dead Ends

In order to provide increased reliability of service and reduce head loss, dead ends must be minimized by making appropriate tie-ins whenever practical. Where dead-end mains occur, they must be provided with a fire hydrant if flow and pressure are sufficient, or with a flushing hydrant or blow-off, approved by the Environmental Engineering Division, for flushing purposes. Flushing devices must be sized to provide flows that will give a velocity of at least 2.5 feet per second in the water main being flushed.

INSTALLATION OF WATER MAINS

Specifications must incorporate the provisions of the AWWA standards and manufacturer's recommended installation procedures.

Bedding

A continuous and uniform bedding must be provided in the trench for all buried pipe. Backfill material must be tamped in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Stones found in the trench must be removed for a depth of at least 6 inches below the bottom of the pipe.

Depth

All water mains must be covered with sufficient earth or other insulation to prevent freezing. All distribution mains must be provided with a minimum of 36 inches of earth covering; 42 inches are recommended. All mains of less than 8 inches in diameter within 5 feet of a heavily traveled highway must be provided with at least 42 inches of cover.

Blocking

Water in motion can exert a tremendous pressure if it is suddenly stopped or there is a change in direction of flow. Wherever tees, bends, plugs and hydrants exists in a pipeline having flexible joints, the force (**thrust**) created by the water motion is likely to open the joints nearest the

fittings, unless there is a backing block to resist the thrust. The purpose of the backing (thrust) block is to spread the thrust over an area large enough to absorb or restrain it. It is important for the block to be centered on the thrust force and to cradle the fitting to distribute the force. The magnitude of the thrust varies with the amount of bend, diameter of pipe, and the pressure inside the pipe. Pipelines should not be pressure tested until the thrust block has been set.

Pressure and Leakage Testing

All types of installed pipe must be pressure tested and leakage tested in accordance with AWWA Standard C600. This testing will determine if the pipe has been installed correctly and if it is ready for service. Hydrostatic testing is by far the most common and logical. Pressures for testing are normally at least 50 psi above normal operating pressure for operating pressures that do not exceed 200 psi. Where the operating pressure is greater than 200 psi, the test pressure should be 1.5 times the operating pressure, but no more than the design rating of the pipe and valves. This will disclose faulty pipes, bad joints, breaks, and other major defects. The duration of the test should be no less than 2 hours and no more than 24 hours.

When pressure tests reveal an excessive water loss, the source of the leakage must be found and corrected and additional tests made.

Disinfection

Disinfection will ensure that the water delivered to the customer is safe. The problems encountered with main disinfection will be lessened, if proper precautions are taken during pipe installation to prevent dirt, trench water, and other foreign material from entering the pipe.

All new, cleaned or repaired water mains must be disinfected in accordance with AWWA Standard C651. The following forms of chlorine may be used: gaseous chlorine, sodium hypochlorite or calcium hypochlorite. The disinfection procedure consists of three operations.

Below is a brief description:

- 1) Preliminary flushing. Mains must be flushed, prior to disinfection, by running a sufficient amount of water through them.
- 2) Disinfection. The chlorine dosage should be 50 mg/L for 24 hours.
- 3) Final flushing and testing. Mains should be flushed until there is a normal, operating chlorine residual (usually 1 mg/L). Bacteriological samples must be collected, 24 hours apart. Results must be negative for 2 consecutive days.

Disposal of heavily chlorinated water from the tank disinfection process must be in accordance with the requirements of the WVDEP.

Separation of Water and Sewer Lines

Adequate separation should always be maintained between water mains and sewer lines. The theory is that sewers are likely to leak and contaminate the soil with wastes. If at the same time the adjoining water main depressurizes, the wastes can be drawn into the water main. Water mains must be laid at least 10 feet horizontally from any existing or proposed sewer. The distance must be measured edge to edge. Water mains must cross above sewers and must be laid to provide a minimum vertical distance of 18 inches between the bottom of the water main and the top of the sewer.

Flushing

West Virginia recommends flushing of water mains twice a year from the source out to the dead ends with a minimum velocity of 5 feet per second (fps).

PIPING

Of the many types of pipe in use today, no one type fits all conditions of service. Knowledge of the different types of pipe will allow the operator to select the one that best fits the installation. Pipe is classified based on its composition: **Cast Iron Pipe; Ductile Iron Pipe; Steel Pipe; Asbestos Cement Pipe; and Plastic Pipe.**

Pipe Size and Location

Water mains should be placed in the public right of way or easements must be obtained if it becomes necessary to cross private property. The overall pattern of the system should provide for as many closed loops as possible. Long isolated lines terminating in dead ends without interconnections should be avoided.

The separation required to avoid contamination of the water main must be laid 10 feet from a sanitary sewer when they are running parallel. The distance must be measured edge to edge. Water mains must cross above sewers and must be laid to provide a minimum vertical distance of 18 inches between the bottom of the water main and the top of the sewer. At crossings, one full length (20 feet) of water pipe must be located so both joints will be as far from the sewer as possible. Special structural support for the water and sewer pipes may be required.

The size of the water main will depend on what services it will supply and the flow expected. When determining the water demand, pressure losses have to be taken into consideration. If fire protection is required, the minimum size of a water main must be six inches in diameter. Some utilities have adopted an eight-inch minimum size for the main network.

Service Line Design

The condition of the service lines is often an overlooked part of the water system. In most systems, the total length of service lines may nearly equal and sometimes even exceed the total length of the mains.

Service lines consist of two parts: the service connection that extends from the main in the street to the property line or curb stop; and the portion of the pipe that runs from the curb stop to the building. In most cities, the water operator needs to be concerned only with size, selection of pipe materials, and installation of the service connection.

VALVES

Valves are mechanical devices used to stop flow, regulate water flows, reduce pressure, provide air and vacuum relief, blow off or drain water from the system, to prevent backflow and to isolate sections of the piping system for repair and maintenance.

Valve placement depends on the layout of the system, location of the customers, location of points susceptible to damage, and cost factors. The WVBPH requires valve spacing of every 500 feet in commercial districts and at not more than 800 foot intervals in other districts. Where

systems serve widely scattered customers and where future development is not expected, the valve spacing must not exceed 2,500 feet.

Valves are installed at enough points on a water system to minimize loss of water service during repairs. It is common to place valves at street intersections or at the extension of property lines. Valves are supplied with valve boxes or pits for maintenance.

Valves come in a variety of styles, shapes and sizes, but their main purpose is to regulate or stop the flow of water. Most of the valves in a distribution system are installed for isolation of sections of piping for maintenance and repair. Control valves are designed to control pressures and throttle flows to prevent damage to the system.

ISOLATION VALVES

Isolation valves are used throughout the system to stop the flow of water. They are usually gate valves or butterfly valves. Each branch line should have an isolation valve at the point of connection to the main line. The proper location of these valves is important in order to isolate small sections of line for repair in an effort to minimize the number of customers that are out of water.

Gate Valves

The most common type of valve used in a water distribution system is the gate valve. It receives its name because of its gate-like operation. When fully open, gate valves provide almost unrestricted flow. A gate valve is not well adapted for throttling flow or for frequent operation. Either will cause excessive wear on the seating edges of the discs and guides.

The number of turns needed to open or close a gate valve that is not gear reduced is equal to 3 times the diameter plus 1-3 turns to seat properly. So a 6" valve will take $3 \times 6 = 18 + 1-2$ or about 19-20 turns to close. Larger valves will take 2-3 extra turns.

Butterfly Valves

The butterfly valve consists of a shaft-mounted disc that rotates in a 90° arc from fully open to fully closed. Although butterfly valves are frequently used in place of gate valves to shut off services, the butterfly is also used in throttling or in automatic control of the flow of water. The valve will open, close, or throttle on command from a controller.

Ball Valves

Ball valves are similar to butterfly valves. They are the second most common type of valve used in most systems. Ball valves offer little or no resistance to the flow of liquids. One of its features is that a 90° turn quickly opens or closes the valve completely. The handle position also indicates whether or not the valve is in the opened or closed position. Its simple design allows the valve to operate easily and offers ease of repair. They are used as corporation stops on service lines and curb stops on meter setters.

Globe Valves

Globe valves are installed where there is to be a frequent change of operation and can be used as an isolation or control valve. It receives its name because the main body is globelike in shape. Because of its design, this type of valve offers a significant resistance to the flow of liquids but does provide a more positive shutoff. Except for some special service applications, the globe valves used in water systems are generally three inches or smaller. The high-pressure loss in this

valve limits it to smaller sizes. Globe valves are commonly used for water faucets and other household plumbing.

CONTROL VALVES

Control valves are designed to control flows or pressures in the system. Control valves are usually one of the least understood components of a water system. They are designed to control the flow of water by reacting to changes in the system and automatically opening or closing the valve to compensate. They are globe valves. There are a number of different applications for the control valves that may be used in the system.

Check Valves

A check valve is designed to allow flow in only one direction. These types of valves are most commonly used on the discharge side of the pumps to prevent backflow when the power is turned off. Foot valves are a special type of check valve installed on the bottom of pump suction to prevent loss of prime when the pump is turned off.

Air Release Valves

Air release valves are used to allow air that may be trapped in the line to escape. The trapped air can create pressure and pumping problems, milky-water complaints, and pressure spikes that resemble water hammer. They are very useful in systems that are in hilly country. They should be located at the top of hills where the trapped air will collect.

Altitude Valves

An altitude valve is a control valve that is designed to close when an elevated storage tank is full. They are needed when there are several storage tanks at different elevations in a system. Altitude valves will be used on the lower tanks to prevent them from overflowing. Each valve will isolate its tank so that the top tank can be filled and not drain out through the lower tanks. This is one of the most common uses of control valves in water systems.

Pressure Reducing Valves

Another common use of a control valve is found in areas where the differences in elevation in the system create unacceptably high water pressures in the lower elevations. A control valve can reduce and maintain a steady pressure on the downstream side of the valve. There is a maximum and minimum flow that a PRV can handle. When the low drops too low the valve will chatter or start slamming open and closed. This will create severe water hammer problems. To avoid this problem, PRV's are sometimes installed in pairs with a small valve in parallel with the larger valve. The small valve is set at a higher pressure. This will allow it to handle the low flows and keep the large valve shut so it doesn't chatter.

Pressure Relief Valves

Pressure relief valves are similar to globe valves, but their disks are normally maintained by a spring. Pressure relief valves are used to provide protection against high pressures that may develop in the system. They should be located in any part of the system where pressure is controlled by a pressure-reducing valve. They are also used at booster pump stations. When the valve senses a high pressure upstream, it will open to pass enough water to drop the pressure back down to set point. The water is discharged to a storm sewer or ditch. If the pressure upstream drops, it will close automatically. The set point should be about 10-15 psi higher than the normal system pressure at that location.

Valve Operation and Maintenance

Valves normally suffer from a lack of operation, not wear. Valves four inches and larger should be exercised annually. Exercising valves means completely opening and closing the valve manually to assure they operate properly and easily. If not, they may become frozen and inoperative when isolation is necessary. Where the water carries small amounts of sand or silt, the valve seats may fill with deposited material unless operated at regular intervals to keep the valve seat clear.

When operating valves, they must be opened and closed slowly. If they are opened or closed rapidly a quick rise and fall of water pressure throughout the distribution piping system takes place. Also called a **water hammer** because it sounds like someone hammering on the pipe. Water hammer can cause serious damage to the distribution pipes and components. Water hammer results when a moving column of water is suddenly stopped by the closing of a valve.

FIRE HYDRANTS

Fire hydrants have a number of uses in the distribution system. Although fire protection is the most important, there are several other uses that are equally important in operating and maintaining the distribution system.

Types of Fire Hydrants

There are two types of fire hydrants used in water systems; wet barrel and dry barrel. A wet barrel hydrant is always pressurized and the main valve is at the top of the hydrant barrel. A dry barrel hydrant has the valve at the bottom of the barrel and a drain hole that drains the barrel when the hydrant is closed. These hydrants are used in areas where freezing occurs in the winter. An additional advantage to the dry barrel hydrant: it comes with special breakaway unions on the stem and flanges on the upper barrel that allow it to break cleanly if hit by vehicle and that there is no flow of water from a broken hydrant because the main valve is underground.

Fire Hydrant Requirements

The size of the hydrant refers to the size of the opening in the valve. For example, a four-inch hydrant has a four-inch valve. Hydrants can be furnished with one to four 2.5-inch nozzles and one to two 4-inch steamer nozzles. The length of the hydrant is referred to as the depth of buries and is the distance from the surface of the ground to the bottom of the inlet pipe. It is also recommended that fire hydrants be installed with the nozzles at least 18 inches above grade. This is the clearance needed to operate a hydrant wrench when removing the nozzle. In West Virginia, fire hydrants must have a bottom valve size of at least 5 inches, on 4½-inch pumper nozzle and two 2½-inch nozzles.

Hydrant Operation and Maintenance

Regular flushing of hydrants is important to ensure that they work and are in operational condition at all times. In addition, flushing can reveal information about the condition of the water system. When the system is flushed, the velocity has to be high enough (at least 2.5 ft/sec) to clear out any material that has accumulated in the system.

Hydrants should not be used to regularly fill tanks and should never be operated with the valve partially opened for throttling. A fire hydrant should be opened slowly and fully and then closed fully, in order to prevent water hammer.

METERS

Displacement Meters

The common small diameter service meter is of the displacement type. Displacement meters are capable of measuring small flows with relatively high accuracy. Water flowing through the meter is measured by counting the number of times the chamber is filled and emptied.

Velocity or Current Meters

A velocity meter, or current meter as it is more commonly called, registers the volume of water passing through it by measuring the velocity of the flow within a known cross-section area. The two basic current-meter types in use are the turbine and the propeller meters.

Compound Meters

In situations in which a customer's water use fluctuates regularly over a wide range, compound meters are used to accurately measure the water consumption. A compound meter is a combination meter with a turbine section for high flows and a displacement section for low flows. In normal operation, the low flows pass through the displacement section until the friction loss is so great that the valve opens, allowing the water to flow through the turbine section of the meter. A compound meter in good repair is capable of measuring flow with 98 percent accuracy over a wide range of flow conditions.

Meter Maintenance

Having meters installed at the customers' locations provides the only fair and equitable method of charging for water. This is one of the most economical means of reducing water waste. Meters are the "cash registers" of the water system and should be maintained in proper working order.

The maintenance of positive displacement meters consists of temporarily removing them from the customer's service, taking them apart, and thoroughly cleaning and inspecting all parts. Meters should be inspected and tested every 10 years.

Meter Records

A suitable meter record provides full and complete information about the installation repair and testing of each meter. Any record system should provide such basic data as the date of purchase, size, make, type, location of meter, and the data on all tests and repairs.

CROSS-CONNECTIONS AND BACKFLOW

Cross-connections are points in a piping system where it is possible for a nonpotable substance to come into contact with the potable drinking water supply. They can provide a pathway for backflow of nonpotable water into potable water. Backflow occurs from negative pressure in the distribution system (termed backsiphonage) or from increased pressure from a nonpotable source (termed backpressure). Backflow from a cross-connection can affect water quality and create health problems. Cross-connections can result in serious illness and even death.

Backflow

Backflow is defined as unwanted, reversed flow of liquid in a piping system. Backflow can be caused by back-siphonage, backpressure, or a combination of the two.

Backsiphonage

Backsiphonage is backflow caused by negative (sub-atmospheric pressure) in the distribution system or supply piping. When the system pressure becomes negative, atmospheric pressure on the distribution system, water columns (from buildings or other elevated piping), or other pressure sources will cause the direction of flow within portions of the system to reverse. If a cross-connection exists in the area where flow reverses direction, contaminants can be siphoned into the distribution system. The effect is similar to sipping a soda by inhaling through a straw.

Backpressure

Backpressure is backflow caused when the distribution system is connected to a nonpotable supply operating under a pressure higher than the distribution system, the direction of flow will reverse if there is no mechanism to stop the flow. A pump, boiler, elevation difference, or other means can create the higher pressure.

METHODS USED TO PROTECT AGAINST CROSS-CONNECTIONS

There are five basic assemblies/devices which are used to prevent or reduce the possibility of backflow in cross-connections: air gaps, atmospheric vacuum breakers, pressure-type vacuum breakers, double check valve assemblies, and reduced pressure backflow preventers.

Air Gap

Of the five assemblies/devices listed, the air gap (physical separation of the potable and nonpotable systems by an air space) is most reliable backflow prevention measure to use when there is potential for a cross connection to an extreme hazard. The vertical distance between the supply pipe and the flood-level rim should be two times the diameter of the supply pipe, but never less than one inch. This type of backflow prevention can be used in situations in which potable water runs into a tank or a source, which is under atmospheric pressure. Obviously, this type of backflow prevention method cannot be used for a direct connection to a pressurized system.

Atmospheric Vacuum Breakers

Atmospheric Vacuum Breakers (AVB) do not prevent backflow due to backpressure. They must be installed on the discharge side of the last control valve. They must be installed six inches

above the rim of the fixture they serve. In addition, they cannot be used under continuous pressure for a period of eight hours or more. Atmospheric vacuum breakers are usually used with hose bibs or sillcocks in situations in which a hose is attached to a sprinkler system or is draining into a tank. Atmospheric vacuum breakers cannot be tested at any time.

Pressure Vacuum Breakers

Pressure vacuum breakers (PVB) are similar to atmospheric vacuum breakers except that these devices can be used under continuous pressure. They cannot prevent backflow due to backpressure and must be installed above the usage point to prevent backsiphonage. They must be installed at least 12 inches above the rim of the device that they are protecting.

Double Check Valve Assemblies

Double check valve assemblies (DCVA) are used for a direct connection between two potable water systems. These assemblies may be used to protect against both backsiphonage and backpressure. They can be used under continuous pressure but cannot be used to connect to a contaminated or high-hazard system. The assembly consists of two ordinary spring-loaded or balance-weight-assisted swing check valves mounted in series. They offer only a partial degree of protection because particles can prevent proper seating of the valves causing them to leak. Double check valves protect against backpressure and back-siphonage conditions. Once installed, they can be tested.

Reduced Pressure Principal Backflow Preventers

The reduced pressure principal (reduced pressure zone) backflow preventer (RPZ) provides the greatest protection against backflow-caused by backpressure and backsiphonage. The RPZ can be used under continuous pressure and in high-hazard conditions. The RPZ is designed so it will operate even if both the check valves become fouled. A reduced pressure backflow preventer consists of two check valves with a zone of reduced pressure between the check valves. The reduced pressure chamber also has a spring-differential pressure relief valve.

Such a backflow preventer can be put on each water line that is used to fill tank trucks. Many private facilities in communities allow farmers or others needing water to fill their tanks. These facilities should be inspected for approved backflow prevention assemblies/devices. In addition, the city must not allow tanks to fill from hydrants, which are not protected by backflow prevention equipment.

Thermal Expansion

When water is heated it expands in volume. Water in a residential water heater may expand about one-half gallon during each recovery period. In an open system this water will be easily absorbed. However, if a backflow preventer is placed in the service line to a residence it will create a closed system with no room for expansion. Since water is not compressible, it has to go someplace and that is generally out the water heater pressure relief valve. This is a dangerous situation since these relief valves are not designed for frequent operation. In addition, the pressures generated may cause an explosion.

Operators need to recognize the implication of placing a backflow preventer or a check valve upstream of a water heater. If this must be done, installation of a small thermal expansion tank

between the water heater and backflow preventer is the simple solution.

Inspection and Testing

All backflow prevention assemblies must be tested by a Certified Backflow Assembly Tester at the time of installation, repair, or relocation, and at least on an annual schedule thereafter.

For more information, please refer to the

- [Cross-Connection Fact Sheet](#) included.
- Cross-Connection and Backflow Prevention Manual – online at http://www.wvdhhr.org/oehs/eed/swap/training&certification/cross-connection&backflow/documents/Cross_Connection_Backflow_Prevention.pdf
- Cross-Connection and Backflow Control Manual – EPA online at <http://www.epa.gov/safewater/pdfs/crossconnection/crossconnection.pdf>
- Website <http://www.wvdhhr.org/oehs/backflow/default.aspx> to [Search for Certified Backflow Prevention & Assembly Inspector Testers in West Virginia](#)
- Website <http://www.wvdhhr.org/oehs/eed/swap/training&certification/cross-connection&backflow/>

SAFETY

The 2002 Keller's Official OSHA Safety Handbook, 5th Edition, is provided for safety information.

BASIC SAMPLING PROCEDURES

Basic Sampling Procedures

The way you collect, store and transport your drinking water test sample affects the accuracy of your test results. Improper handling may show signs of drinking water contamination where it may not truly exist. The certified laboratory you have hired will give you detailed instructions for handling a drinking water test sample, including:

- Collection procedures;
- Containers to use, including those supplied by the laboratory;
- Labeling of samples;
- Completion and chain of custody forms;
- Transportation of samples; and
- Time periods for delivery of samples.

Carefully follow the instructions from the laboratory to ensure accurate results.

Location of sampling points

One objective of sampling is to assess the quality of the water supplied by the water purveyor and the point of use, so that samples of both should be taken. Any significant difference between the two has important implications for remedial strategies.

Samples must be taken from locations that are representative of the water source, treatment plant, storage facilities, distribution network, points at which water is delivered to the consumer, and points of use. In selecting sampling points, each locality should be considered individually; however, the following general criteria are usually applicable:

- Sampling points should be selected such that the samples taken are representative of the different sources from which water is obtained by the public or enters the system.
- These points should include those that yield samples representative of the conditions at the most unfavorable sources or places in the supply system, particularly points of possible contamination such as unprotected sources, loops, reservoirs, low-pressure zones, ends of the system, etc.
- Sampling points should be uniformly distributed throughout a piped distribution system, taking population distribution into account; the number of sampling points should be proportional to the number of links or branches.
- The points chosen should generally yield samples that are representative of the system as a whole and of its main components.
- Sampling points should be located in such a way that water can be sampled from reserve tanks and reservoirs, etc.
- In systems with more than one water source, the locations of the sampling points should take into account the number of inhabitants served by each source.
- There should be at least one sampling point directly after the clean-water outlet from each treatment plant.

Analytical quality assurance and quality control

Standard methods for drinking-water analysis should be tested under local conditions for accuracy and precision, agreed at national level, and applied universally by both water-supply

and regulatory agencies. However, the use of standard methods does not in itself ensure that reliable and accurate results will be obtained.

In the context of analytical work, the terms quality assurance and quality control are often treated as synonymous. In fact, they are different concepts. Analytical quality control is the generation of data for the purpose of assessing and monitoring how good an analytical method is and how well it is operating. This is normally described in terms of within-day and day-to-day precision.

Analytical quality assurance, by contrast, comprises all the steps taken by a laboratory to assure those who receive the data that the laboratory is producing valid results. Quality assurance thus encompasses analytical quality control but also includes many other aspects such as proving that the individuals who carried out an analysis were competent to do so, and ensuring that the laboratory has established and documented analytical methods, equipment calibration procedures, management lines of responsibility, systems for data retrieval, sample handling procedures, certification, and so on.

Field Analysis and Field Instruments

All field instruments should be calibrated according to the manufacturer's instructions prior to field use and documented in a calibration notebook to be kept with the instrument. Operation of field equipment varies depending on the manufacturer. Care must be taken to assure that each instrument is functioning properly and calibrated according to any calibration schedule.

Field measurements should be made in accordance with equipment manufacturer's instructions and at appropriate times and locations so that valid information is obtained.

Chain of Custody Procedure

Procedures for Chain of Custody (COC) require maintenance of permanent records for all sample handling and shipment. COC procedures must be used to ensure sample integrity as well as legal and technically defensible data.

Any samples collected must be submitted with a COC form and a signed affidavit. The lab has stated that one COC form per shipping container (ice chest) is sufficient. The COC form must have each analysis request checked and show a range of collection times.

The sample should be kept in view or in locked storage until custody is relinquished to the shipper and formal documentation of the transfer is completed. The person collecting a sample will start the COC procedure.

In completing the tag, care should be taken to insure that all necessary information is correct and legibly written on the tag with a black waterproof ink pen. The use of a fine point pen is discouraged because of possible problems in making legible photostatic copies.

Shipping of Samples

The water system is responsible for shipment of all routine samples to the laboratories so that analyses can be conducted in accordance with EPA methods. Each sample must be accompanied by a COC form.

When a sample is shipped to the laboratory, it must be packaged in a proper shipping container to avoid leakage and/or breakage. The laboratory must be able to associate each container in the ice chest with a COC form.

COC forms or other documents should be shipped inside the ice chest and must be placed in a plastic bag to prevent water damage. A good method is to use a zip-lock bag taped to the inside of the ice chest lid. All shipping boxes must be taped closed with shipping tape, strapping tape or fiber plastic tape, etc.

The complete address of the sender and the receiving laboratory must legibly appear on each container. When sent by U.S. Mail, register the package with a return receipt requested. When sent by a shipping service, obtain a copy of the bill of lading. Post office receipts and bills of lading may be used as part of the COC documentation.

Certified laboratories must conduct analyses within the prescribed holding times in order to produce valid compliance results. An even flow of samples must be maintained into the labs throughout each sampling period so as to assure that the laboratory capacity is not exceeded. This will require that the Contractor and each shipper carefully plan and coordinate the collection and shipment of samples. Samples must be shipped on a routine daily basis.

It is far better to spend extra funds on ice and shipping costs than to have an entire shipment of samples rejected at the lab because of the failure to meet temperature requirements due to ice melt.

How to store your sample and send it to the laboratory

- **Submit your drinking water test sample to the certified laboratory as quickly as possible after collection.** To give the most accurate results, testing for bacteria must begin within 30 hours of collecting the drinking water sample. Be sure to obtain clear instructions from the laboratory regarding sample submission drop-off time.
- **Refrigerate samples until ready for shipping.**
- **Ship your sample bottles or containers to the laboratory in coolers, or in foam pack containers, with ice or ice packs.** Don't pack the bottles with loose ice as this may contaminate the sample. If you only have loose ice, encase the sample/container in waterproof packaging or a sealed container. Be sure it is well protected from other samples that you may be sending to the laboratory at the same time (e.g. sewage samples).
- **Don't allow samples to freeze.** In winter, you may want to take advantage of heated shipping offered by some courier companies.
- **Package the completed *Chain-of-Custody* form, provided by the certified laboratory, with the collected sample.** If sending it inside the cooler containing the sample, ensure that the form is enclosed inside a waterproof package (e.g., a new zip-lock bag).

Safety for Laboratory Personnel

The safety of staff undertaking analytical procedures, both in the field and in the laboratory, is of the greatest importance. All staff should be trained in safety procedures relevant to their work. In the laboratory, individual staff members should be authorized to undertake procedures involving risk of any type only after appropriate training; unauthorized staff should not be allowed to undertake analyses.

All laboratories should formulate and implement a safety policy that should cover cleaning, disinfection, and the containment of hazardous substances. Safety equipment such as fire extinguishers, safety glasses, and first-aid kits should be suitably located, and readily available; they should be routinely checked and all staff should be trained in their use.

Sampling Safety - Preservation Chemicals

Acids of various types are the most common sample preservation materials that may pose a risk or hazard. Preservation chemicals must be handled with care and all appropriate safety procedures followed. You may feel that safety precautions are a burden; however, no amount of compensation can replace an eye or other body part damaged by acid. Material Safety Data Sheets are available wherever chemicals are stored.

It is your responsibility to use appropriate eye, hand, and clothing protection.

Also, if you are shipping samples that you know or suspect as a health hazard, include a warning note or letter in an appropriate location on the shipping container to minimize laboratory personnel exposure to an unknown health hazard.

Procedure for Testing Free Chlorine Residual (using DPD Method)

The method recommended for the analysis of chlorine residual in drinking water employs *N,N*-diethyl-*p*-phenylenediamine, more commonly referred to as DPD. This is an indicator test, using a comparator. This test is the quickest and simplest method for testing chlorine residual. With this test, the reagent is added to a sample of water, coloring it red. The strength of color is measured against standard colors to determine the chlorine concentration. The stronger the color, the higher the concentration of chlorine in the water. Several kits for analyzing the chlorine residual in water are available commercially. The kits are small and portable.

Sample Collection, Storage and Preservation

1. Analyze samples for chlorine immediately after collection.
2. Free chlorine is a strong oxidizing agent and it is unstable in natural waters. It reacts rapidly with various inorganic compounds and more slowly oxidizes organic compounds.
3. Many factors, including reactant concentrations, sunlight, pH, temperature, and salinity influence decomposition of free chlorine in water.
4. Avoid plastic containers since these may have a large chlorine demand.
5. Pretreat glass sample containers to remove any chlorine demand by soaking in a dilute bleach solution (1 mL commercial bleach to 1 liter of deionized water) for at least 1 hour. Rinse thoroughly with deionized or distilled water.
6. If sample containers are rinsed thoroughly with deionized or distilled water after use, only occasional pre-treatment is necessary.
7. Do not use the same sample cells for free and total chlorine. If trace iodide from the total chlorine reagent is carried over into the free chlorine determination, monochloramine will interfere.
8. It is best to use separate, dedicated sample cells for free and total chlorine determinations.
9. A common error in testing for chlorine is not obtaining a representative sample.
10. If sampling from a tap, let the water flow for at least 5 minutes to ensure a representative sample.
11. Let the container overflow with the sample several times, then cap the sample containers so there is no headspace (air) above the sample.
12. If sampling with a sample cell, rinse the cell several times with the sample, then carefully fill to the 10-mL mark.
13. Perform the chlorine analysis immediately.
14. After adding reagent to the sample cell, a pink color will develop if free chlorine is present.
15. If the test overranges, dilute the sample with a known volume of high quality, chlorine demand-free water and repeat the test. Some loss of chlorine may occur due to the dilution. Multiply the result by the dilution factor.
16. Wipe the outside of sample cells before each insertion into the instrument cell holder. Use a damp towel followed by a dry one to remove fingerprints or other marks.
17. Place the sample cell into the cell holder.
18. Fill a second round cell with 10 mL of sample.
19. Add the contents of one DPD Free Chlorine Powder Pillow to the sample cell. (This is the prepared sample).
20. Swirl the sample cell for 20 seconds to mix.
21. **Within one minute** of adding the reagent, place the prepared sample into the cell holder.
22. Compare results.

Reference: HACH, Water Analysis Handbook

Procedure for Testing Total Chlorine Residual (using DPD Method)

The method recommended for the analysis of chlorine residual in drinking water employs *N,N*-diethyl-*p*-phenylenediamine, more commonly referred to as DPD. This is an indicator test, using a comparator. This test is the quickest and simplest method for testing chlorine residual. With this test, the reagent is added to a sample of water, coloring it red. The strength of color is measured against standard colors to determine the chlorine concentration. The stronger the color, the higher the concentration of chlorine in the water. Several kits for analyzing the chlorine residual in water are available commercially. The kits are small and portable.

Sample Collection, Storage and Preservation

1. Analyze samples for chlorine immediately after collection.
2. Free chlorine is a strong oxidizing agent and it is unstable in natural waters. It reacts rapidly with various inorganic compounds and more slowly oxidizes organic compounds.
3. Many factors, including reactant concentrations, sunlight, pH, temperature, and salinity influence decomposition of free chlorine in water.
4. Avoid plastic containers since these may have a large chlorine demand.
5. Pretreat glass sample containers to remove any chlorine demand by soaking in a dilute bleach solution (1 mL commercial bleach to 1 liter of deionized water) for at least 1 hour. Rinse thoroughly with deionized or distilled water.
6. If sample containers are rinsed thoroughly with deionized or distilled water after use, only occasional pre-treatment is necessary.
7. Do not use the same sample cells for free and total chlorine. If trace iodide from the total chlorine reagent is carried over into the free chlorine determination, monochloramine will interfere.
8. It is best to use separate, dedicated sample cells for free and total chlorine determinations.
9. A common error in testing for chlorine is not obtaining a representative sample.
10. If sampling from a tap, let the water flow for at least 5 minutes to ensure a representative sample.
11. Let the container overflow with the sample several times, then cap the sample containers so there is no headspace (air) above the sample.
12. If sampling with a sample cell, rinse the cell several times with the sample, then carefully fill to the 10-mL mark.
13. Perform the chlorine analysis immediately.
14. After adding reagent to the sample cell, a pink color will develop if free chlorine is present.
15. If the test overranges, dilute the sample with a known volume of high quality, chlorine demand-free water and repeat the test. Some loss of chlorine may occur due to the dilution. Multiply the result by the dilution factor.
16. Wipe the outside of sample cells before each insertion into the instrument cell holder. Use a damp towel followed by a dry one to remove fingerprints or other marks.
17. Place the sample cell into the cell holder.
18. Fill a second round cell with 10 mL of sample.
19. Add the contents of one DPD Total Chlorine Powder Pillow to the sample cell. (This is the prepared sample).
20. Swirl the sample cell for 20 seconds to mix.
21. **Wait three minutes** after adding the reagent and place the prepared sample into the cell holder.
22. Compare results.

Reference: HACH, Water Analysis Handbook

WATER BACTERIOLOGICAL SAMPLING SUGGESTIONS

General Procedures –

1. Use only sterile bottles furnished by the State or County Health Department. These sample bottles have shelf life of six (6) months, after which they must be returned to the Office of Laboratory Services for reprocessing.
2. **Do Not Touch** the inside of the sample bottle or cap.
3. Do not collect samples from a storage tank, leaky faucet, aerators, or “purifiers”.
4. Allow cold water to run five (5) minutes to clean service line before sampling.
5. **Do Not Rinse Out The Bottle.**
6. Reduce water flow and fill bottle to the shoulder, leaving about one inch (1”) air space at the top to facilitate mixing. Samples can be rejected at the laboratory for insufficient air space.
7. Replace the sample bottle cap securely.

If tap cleanliness is questionable –

1. Apply a solution of sodium hypochlorite (100 mg NaOCl/L) to faucet before sampling.
2. Let water run an additional 2-3 minutes.

Sampling from a mixing faucet –

1. Remove faucet attachments, such as a screen or splashguard.
2. Run hot water for 2 minutes.
3. Run cold water for 2-3 minutes.

Sampling from a river, stream, lake or reservoir –

1. Hold bottle near its base in the hand and plunging it, neck downward, below the surface.
2. Turn bottle until neck points slightly upward and mouth is directed toward the current. If there is not current, as in the case of a reservoir, create a current artificially by pushing bottle forward horizontally in a direction away from the hand.

DIRECTIONS FOR BACTERIOLOGICAL SAMPLING

Collecting the Sample

1. Use only sterile sample bottle furnished by State or County Health Departments. These sample bottles have six-month shelf life after which they must be returned to the Office of Laboratory Services for reprocessing.
2. Do not touch the inside of the sample bottle or cap or otherwise contaminate outfit.
3. Do not collect from a storage tank, leaky faucet, aerators, or “purifiers”.
4. Allow water to run 5 minutes to clean service line before sampling.
5. Do not overflow or rinse sample bottle.
6. Fill sample bottle to the shoulder leaving about a 1-inch air space at the top.
7. Replace the sample bottle cap securely.

Completing the Sample History – Report Form

1. Complete all of the following information **IN INK** – make sure that all copies are legible.
2. Provide the following information:
 - a. County of water sample origin.
 - b. Public Supply (PWS) ID Number and name of water supply.
 - c. Who is to be charged for the sample examination?
 - d. Collector’s name, title, certification number, organization, and telephone number.
 - e. To whom the final report of examination is to be mailed? (DO NOT WRITE “SAME AS ABOVE” – This information appears in a window envelope.)
3. Complete the following sample collection data:
 - a. Sample type – Repeat samples and replacement samples must have the complete lab number of the previous sample that they are a repeat/replacement for. (Repeat samples are for samples that were previously positive, replacements samples are for samples that were previously unsatisfactory, laboratory accident or invalid.
 - b. Date and Time of sample collection. **COLLECTOR MUST INITIAL THE FORM.**
 - c. Give a specific description or location of the sampling point.
 - d. Is the water supply chlorinated? Chlorine residual.
 - e. pH
 - f. How the sample is to be transported to the laboratory and the transportation condition.

Mailing – Delivery to Laboratory

Samples must be sent or brought for receipt to the laboratory in time for examination during the following hours (South Charleston Laboratory: 8:00 am to 4:30 pm, Monday thru Friday. Kearneysville Laboratory: 8:00 am to 4:00 pm, Monday thru Wednesday and 8:00 am to 12:00 pm, Thursday) and **within 30 hours of collection.**

Check departure schedule of mail or delivery service from your area and plan for collections to be readied for shipment at that time.

Make sure postage is affixed to outer mailer.

ALL FIVE COPIES OF THE COMPLETED HISTORY FORM MUST BE ENCLOSED WITH THE SAMPLE.

SAMPLING CONTAINERS ARE THE PROPERTY OF THE STATE AND THEIR USE IS RESTRICTED ONLY FOR THE COLLECTIONS BY STATE AGENCIES OR THOSE DULY AUTHORIZED BY THE STATE.

Fluoride Sampling Procedures

Water system personnel must monitor daily fluoride levels in the water distribution system daily (including weekend days). Samples that reflect the actual level of fluoride in the water system should be taken at points throughout the distribution. The sites where samples are taken should be rotated daily.

At least once a month, the public water system must submit a sample of drinking water to the commissioner or to a certified laboratory for fluoride analysis. The plant's and the state laboratory split sample results and the plant's self monitoring form averages must also correlate.

Sampling Procedure

1. Collect sample at a representative sample point in the distribution system.
2. Remove any screen, hoses and aerators from end of faucet.
3. Run COLD water for 3 to 5 minutes to make sure water has not been sitting for a long time in pipes or tanks and is fresh from the well.
4. Turn water down so it does not splash.
5. Uncap bottle and fill to shoulder with water. Screw the cap on tightly.
6. Fill out the required information on Chain of Custody form. **SIGN THE FORM!** The sample will not be processed unless the form has a signature! Also, it is always a good idea to include your printed name next to your signature. In most cases, signature alone cannot identify an individual.
7. Return bottle with completed paperwork to lab.
8. **SAMPLE MUST ARRIVE AT LAB WITHIN 28 DAYS OF COLLECTION!**

Water Fluoridation Report

Public Water Supply Information

Supply: _____ County: _____

P.W.S. Number: _____ Water Plant Phone Number: _____

Sampling Point: _____

Date Collected: _____

Collected by: _____ Title: _____

Water System Results (PPM): _____

Check Method: Specific Ion Method SPADNS

Mail Report to: *(address must be legible on all copies of report form for return)*

LABORATORY RESULTS

Fluoride Level (PPM): _____

Date Analyzed: _____

Analyst: _____

Comments: _____

Exceeds maximum recommended level of 1.3.

Below minimum recommended level of 0.8.

Satisfactory

Optimum level of fluoridation is 1.0.

West Virginia Department of Health and Human Resources
Office of Laboratory Services – Environmental Chemistry Laboratory – Water Fluoridation Section
4710 Chimney Drive, Suite G, Charleston, WV 25302
Phone: (304) 558-0197 Fax: (304) 558-4143

Total Nitrates Sampling Procedures

Total Nitrate Sampling Supplies

Before you begin sampling, it is important to have all of your supplies on hand. Here is a list of the suggested supplies you may need:

- Cooler for shipping and storage of your sample while in transit between collection point and lab.
- Bagged Ice for your shipping cooler.
- PVC or unsupported Neoprene gloves which are necessary to keep your hands safe from sample container preservative chemicals.
- Safety Goggles which are necessary to keep your hands and eyes safe from sample container preservative chemicals.
- Sample Container
- Lab slips, labels, and markers for sample container identification

Additional Recommended Items

- Paper towels for drying off the outside of your sample container after sampling.
- Plastic storage baggies for ice and sample container
- Sampling Containers
 - Although different sizes and types of sample containers can be used for Nitrate sampling, most laboratories supply 80mL sample bottles with concentrated Sulfuric Acid as a preservative
- As a general rule, proper washing of hands is highly recommended for the sample collector.
- Also, food, drink, and even 2nd hand cigarette smoke should never come into contact with the sample or its containers. These foreign objects have been suspected of causing false results in samples, so be sure to practice good clean sample collection procedures.
- Do not sample with any containers that appear to have been tampered with since this may cause an undesirable sample result.
- The laboratory that supplies the sampling containers may provide instruction with the kit for the type of monitoring being performed. Be sure to refer to those instructions when provided.

Important Safety Precautions

Safety goggles and gloves must be worn.

Wash hands before and after sampling.

Sampling Procedures

Sample containers may contain liquid preservatives. Liquid preservatives will cause burns. If it comes into contact with the skin or eyes, flush with liberal amounts of water and seek immediate medical attention.

1. Select a state approved sampling location if any have been designated. If none have been designated, contact your state or tribal drinking water program office. For a surface water system, the plant effluent tap might be an appropriate sampling location. For a well discharging directly into a distribution system (entry point to the distribution system or EPTDS), a tap on the well's discharge piping after any treatment may be appropriate.

2. If possible, use a non-swivel faucet and remove all attachments, including any aerators, strainers and hoses. It is normally recommended not to take a sample at that location if all attachments cannot be removed because they may alter the sample results.
3. Turn on the water tap and run the water until the temperature has stabilized (use a thermometer if possible). This typically takes 2 to 3 minutes. Then reduce the flow so that the stream is approximately ¼ inch in diameter. Do not change the flow rate until after sampling is completed.
4. While the water is running for those 2-3 minutes, completely fill out the labels and lab slip. Be sure to clearly identify the system information, like the public water system identification number, exact sample location, date and time of collection, and the sampler's name.
5. If the sample collection point has a specific coded identification, include it on the label and sample submission form. Be sure to attach the label prior to sampling. A wet sample container may not allow the label to properly adhere.
6. Hold bottle at an angle and carefully fill it to its shoulder. Do not touch the interior of the bottle or the underside of the cap. Do not allow the bottle to touch the faucet, or allow water to splash up onto the faucet.
7. The sample container should be tightly capped.
8. Blot the sample container with a paper towel to dry it off.
9. It is recommended that you place the sample in a sealable plastic bag before shipping in a closed chest or box.
10. Since Ice is sometimes recommended for use in shipping, it is recommended that it be bagged separately to eliminate any contamination of the sample.
11. Samples must be delivered to the analytical laboratory within 3 days for proper testing

RECOMMENDED:

Taping of the chest prior to shipping is also recommended since the container could be mistakenly opened during shipment.

Also be sure to tape the sample forms and any other sample documentation either inside or the outside of the lid.

If the laboratory has any additional recommendations or requirements, they should be read and followed closely.

If you have any additional questions, please contact your state or tribal drinking water program office for assistance.

Following the proper drinking water sample collection procedures can lead to peace of mind, knowing that the test results truly represent the quality of water your customers are drinking.

Lead and Copper Sampling Procedures

1. **Sample must be first-draw after water has been motionless in the plumbing for a minimum of 6 hours.** An exception to the first-draw requirement can be granted to non-transient non-community systems that operate 24 hours per day. They must document that they are 24-hour operations and indicate the approximate length of time the water was motionless before sample was collected.
2. Samples must be from cold, untreated water taps in the kitchen or bathroom of residential buildings. Non-residential building samples must be collected from taps where water is typically drawn for consumption. Taps connected to a softener or other point-of-use device may not be used
3. Sample must be acidified immediately after collection. If not, the sample has to stand in the original bottle for 28 hours after acidification.
4. Label bottles and fill out laboratory request forms completely.
5. Be sure to take the required number of samples for your system. Refer to the included, *EPA Lead and Copper Rule: A Quick Reference Guide* to determine your system's sampling requirements and the 90th percentile. In general, the Lead and Copper Rule (LCR) established an action level of 0.015 mg/L (15 ppb) for lead and 1.3 mg/L (1300 ppb) for copper based on the 90th percentile level of tap water samples. Therefore, no more than 10 percent of samples can be above either action level.

To calculate the 90th percentile for a system that must only collect 5 samples:

- List the sample results ranking in order from the lowest to the highest value, numbering each from 1 up to the number of samples taken.
- Find the average of the values in the 4th and 5th positions.

To calculate the 90th percentile for a system that must collect > 5 samples:

- List the sample results ranking in order from the lowest to the highest value, numbering each from 1 up to the number of samples taken.
- The number of samples taken is multiplied by 0.9 to find the location of the value that is the 90th percentile. (Example: If a system collects from 20 sites, it sorts its results from the lowest to the highest concentration and reports the concentration it observed in the 90th sample (20 x 0.9) which is the value in the 18th position.

Example calculations:

1. A system collected 5 samples with the following results: 0.023 mg/L, 0.004 mg/L, 0.014 mg/L, 0.008 mg/L, and 0.019 mg/L. What is the 90th percentile?

Answer: 0.021 mg/L

2. If a system collected 50 samples, the 90th percentile would be in the _____ value place.

Answer: 45th

3. What is the 90th percentile for a system with the following sample results: 0.013 mg/L, 0.012mg/L, 0.019 mg/L, 0.02 mg/L, 0.013 mg/L, 0.007 mg/L, 0.011 mg/L, 0.022 mg/L, 0.017 mg/L, 0.015 mg/L?

Answer: 0.02 mg/L

Disinfection Byproducts Sampling Procedures

TTHM/HAA5 Sampling Supplies

Before you begin sampling, it is important to have all of your supplies on hand. Here is a list of the suggested supplies you may need:

- Cooler for shipping and storage of your sample while in transit between collection point and lab.
- Bagged Ice for your shipping cooler.
- PVC or unsupported Neoprene gloves which are necessary to keep your hands safe from sample container preservative chemicals.
- Safety Goggles which are necessary to keep your hands and eyes safe from sample container preservative chemicals.
- Sample Container
- Lab slips, labels, and markers for sample container
- identification

Additional Recommended Items are:

- Paper towels for drying off the outside of your sample container after sampling.
- Plastic storage baggies for ice and sample container
- For this sampling Method, The laboratory normally sends either 2- 40 or 2- 60 milliliter glass vial containers. Some labs may provide ampules with acid for pH adjustment which is not covered in this presentation.
- Obtain specific instructions from the laboratory at the time empty containers are received.

As a general rule, proper washing of hands is highly recommended for the sample collector.

Also, food, drink, and even 2nd hand cigarette smoke should never come into contact with the sample or its containers. These foreign objects have been suspected of causing false results in samples, so be sure to practice good clean sample collection procedures.

Do not sample with any containers that appear to have been tampered with since this may cause an undesirable sample result.

Procedures

The laboratory that supplies the sampling containers may provide instruction with the kit for the type of monitoring being performed. Be sure to refer to those instructions when provided.

IMPORTANT: The laboratory supplying the sample containers may send trip blanks, sometimes called field reagent blanks, along with the sample containers. Trip blanks consist of sample containers filled at the laboratory, that must remain sealed and must be shipped back to the lab . This is done to check if samples were contaminated during shipment.

Important Safety Precautions

Safety goggles and gloves must be worn.

Wash hands before and after sampling.

Caution-Hazard

Sample containers may contain liquid preservatives. Liquid preservatives will cause burns. If it comes into contact with the skin or eyes, flush with liberal amounts of water and seek immediate medical attention.

Sampling Procedure

1. Select a state approved sampling location. Normally, this type of sample is collected at various locations throughout the distribution system.
2. If possible, use a non-swivel faucet and remove all attachments, including any aerators, strainers and hoses. It is normally recommended not to take a sample at that location if all attachments cannot be removed because they may alter the sample results.
3. Turn on the water tap and run the water until the temperature has stabilized (use a thermometer if possible). This typically takes 2 to 3 minutes. Then reduce the flow so that the stream is approximately ¼ inch in diameter. Do not change the flow rate until after sampling is completed.
4. While the water is running for those 2-3 minutes, completely fill out the labels and lab slip. Be sure to clearly identify the system information, like the public water system identification number, exact sample location, date and time of collection, and the sampler's name.
5. If the sample collection point has a specific coded identification, include it on the label and sample submission form. Be sure to attach the label prior to sampling. A wet sample container may not allow the label to properly adhere.
6. Remove the cap from the vial, keeping the vial upright to prevent spilling any preservatives. Do not put the cap face down or put it in your pocket. Do not allow the inside of the cap or the bottle threads to be touched by any object.
7. Hold the vial at an angle pointing away from your face and carefully fill it until it is completely full. Be careful not to rinse out the preservatives. If acid has been added to the vial by the laboratory, it will mix rapidly with the water and may splatter a bit.
8. Carefully complete filling the vial by putting water inside the cap and transferring it one drop at a time to the vial until completely full.
9. Screw the cap on the bottle being sure not to overtighten the cap.
10. Invert the bottle 2 or 3 times and check for air bubbles. If any are present, add additional water- just a drop or 2- seal and check again.
11. Remember that each "sample" consists of 2 to 3 filled vials. Repeat the previous steps to fill additional vials for each sample.
12. Complete all necessary forms supplied by the laboratory with the appropriate information. In many states, the same form that is filled out here will be used to report the analytical results. Also, you may need to complete a chain of custody form, if required.

13. Place the samples in a cooler. The trip blanks should still be in the cooler. Keep the samples at 2 degrees to 6 degrees Celsius (36 degrees to 43 degrees Fahrenheit) and keep them away from direct light or gasoline and solvent vapors. Pack the samples in a cooler with Ice. As a tip, it might be a good idea to bag up the sample and the ice separately in the cooler. This will help prevent leakage or contamination of the sample from the ice.
14. Deliver the samples to the laboratory or ship the samples by an overnight courier. This will ensure prompt testing for the most accurate results. It is recommended that all samples be received by the laboratory within 7 days.
15. If the laboratory has any additional recommendations or requirements, they should be read and followed closely.

If you have any additional questions, please contact your state drinking water program office at 304-558-2981 for assistance.

Following the proper drinking water sample collection procedures can lead to peace of mind, knowing that the test results truly represent the quality of water your customers are drinking.

Sample Containers, Preservation and Holding Times for Regulated Parameters

Parameter/ Method	Preservative	Sample Holding Time	Extract Holding Time and Storage Conditions	Suggested Sample Size	Type of Container
Metals (except Hg)	HNO ₃ pH<2	6 months		1 L	Plastic or Glass
Mercury	HNO ₃ pH<2	28 days		100 mL	Plastic or Glass
Alkalinity	Cool, 4C	14 days		100 mL	Plastic or Glass
Asbestos	Cool, 4C	48 hours		1 L	Plastic or Glass
Chloride	none	28 days		100 mL	Plastic or Glass
Residual Disinfectant	none	immediately		200 mL	Plastic or Glass
Color	Cool, 4C	48 hours		100 mL	Plastic or Glass
Conductivity	Cool, 4C	28 days		100 mL	Plastic or Glass
Cyanide	Cool, 4C, Ascorbic acid (if chlorinated), NaOH pH>12	14 days		1 L	Plastic or Glass
Fluoride	none	1 month		100 mL	Plastic or Glass
Foaming Agents	Cool, 4C	48 hours			
Nitrate (chlorinated)	Cool, 4C non-acidified	14 days		100 mL	Plastic or Glass
Nitrate (non chlorinated)	Cool, 4C, non-acidified	48 hours		100 mL	Plastic or Glass
Nitrite	Cool, 4C	48 hours		100 mL	Plastic or Glass
Nitrate+ Nitrite	H ₂ SO ₄ pH<2	28 days		100 mL	Plastic or Glass
Odor	Cool, 4C	24 hours		200 mL	Glass
pH	none	immediately		25 mL	Plastic or Glass
o-Phosphate	Cool, 4C	48 hours		100mL	Plastic or Glass

Parameter/ Method	Preservative	Sample Holding Time	Extract Holding Time and Storage Conditions	Suggested Sample Size	Type of Container
Silica	Cool, 4C	28 days		100 mL	Plastic
Solids (TDS)	Cool, 4C	7 days		100 mL	Plastic or Glass
Sulfate	Cool, 4C	28 days		100 mL	Plastic or Glass
Temperature	none	immediately		1 L	Plastic or Glass
Turbidity	Cool, 4C	48 hours		100 mL	Plastic or Glass
302.2	Sodium Thiosulfate or Ascorbic Acid, 4C, HCl pH<2	14 days		40-120 mL	Glass with PTFE Lined Septum
304.1	Sodium Thiosulfate Cool, 4C,	14 days	4C, 24 hours	40 mL	Glass with PTFE Lined Septum
305	Sodium Thiosulfate Cool, 4C	14 days (7 days for Heptachlor)	4C, 24 hours	40 mL	Glass with PTFE Lined Septum
306	Sodium Thiosulfate Cool, 4C, Dark	14 days	4C, dark 14 days	1 L	Amber Glass with PTFE Lined Cap
307	Sodium Thiosulfate Cool, 4C, Dark	14 days(see method for exceptions)	4C, dark 14 days	1 L	Amber Glass with PTFE Lined Cap
308	Sodium Thiosulfate Cool, 4C, Dark	7 days (see method for exceptions)	4C, dark 14 days	1 L	Glass with PTFE Lined Cap
308A	Cool, 4C	14 days	30 days	1 L	Amber Glass with PTFE Lined Cap
308.1	Sodium Sulfite HCl pH<2 Cool, 4C	14 days (see method for exceptions)	30 days	1 L	Glass with PTFE Lined Cap
315.1	Sodium Thiosulfate Cool, 4C, Dark	14 days	4C, dark 28 days	1 L	Amber Glass with PTFE Lined Cap

Parameter/ Method	Preservative	Sample Holding Time	Extract Holding Time and Storage Conditions	Suggested Sample Size	Type of Container
S15.2	Sodium Thiosulfate or Sodium Sulfite HCl pH<2 Cool, 4C, Dark	14 days	≤4C, dark 14 days	1 L.	Amber Glass with PTFE Lined Cap
S15.3	Sodium Thiosulfate Cool, 4C, Dark	14 days	≤4C, dark 14 days	50 mL.	Amber Glass with PTFE Lined Cap
S15.4	Sodium Sulfite, dark, cool ≤10C for first 48 hr. ≤6C thereafter	14 days	≤0C 21 days	40 mL.	Amber glass with PTFE lined septum
S24.2	Ascorbic Acid or Sodium Thiosulfate HCl pH<2, Cool 4C	14 days		40-120 mL.	Glass with PTFE Lined Septum
S25.2	Sodium Sulfite, Dark, Cool, 4C, HCl pH<2	14 days (see method for exceptions)	≤4C 30 days	1 L.	Amber Glass with PTFE Lined Cap
S31.1, 6610	Sodium Thiosulfate, Monochloroacetic acid, pH<3, Cool, 4C	Cool 4C 28 days		60 mL.	Glass with PTFE Lined Septum
S31.2	Sodium Thiosulfate, Potassium Dihydrogen Citrate buffer to pH 4, dark, ≤10C for first 48 hr, ≤6C thereafter	28 days		40 mL.	Glass with PTFE Lined Septum
S47	Sodium Thiosulfate Cool, 4C	14 days(18 mo. frozen)		60 mL.	Glass with PTFE Lined Septum

Parameter/ Method	Preservative	Sample Holding Time	Extract Holding Time and Storage Conditions	Suggested Sample Size	Type of Container
548.1	Sodium Thiosulfate (HCl pH 1.5-2 if high biological activity) Cool, 4C, Dark	7 days	≤4C 14 days	≥ 250 mL	Amber Glass with PTFE Lined Septum
549.2	Sodium Thiosulfate, (H ₂ SO ₄ pH<2 if biologically active) Cool, 4C, Dark	7 days	21 days	≥ 250mL	High Density Amber Plastic or Silanized Amber Glass
550, 550.1	Sodium Thiosulfate Cool, 4C, HCl pH<2	7 days	4C, Dark 550, 30 days 550.1, 40 days	1 L	Amber Glass with PTFE Lined Cap
551.1	Sodium Sulfite, Ammonium Chloride, pH 4.5-5.0 with phosphate buffer Cool, 4C	14 days		≥ 40 mL	Glass with PTFE Lined Septum
552.1	Ammonium chloride Cool, 4C, Dark	28 days	≤4C, dark 48 hours	250 mL	Amber Glass with PTFE Lined Cap
552.2	Ammonium chloride Cool, 4C, Dark	14 days	≤4C, dark 7 days ≤-10C 14 days	50mL	Amber Glass with PTFE Lined Cap
555	Sodium Sulfite HCl, pH ≤2 Dark, Cool 4C	14 days		≥ 100 mL	Glass with PTFE Lined cap
1613	Sodium Thiosulfate Cool, 0-4C, Dark		Recommend 40 days	1 L	Amber Glass with PTFE Lined Cap

Reference: Manual for the Certification of Laboratories Analyzing Drinking Water Criteria and Procedures Quality Assurance, Fifth Edition: US Environmental Protection Agency Office of Water Office of Ground Water and Drinking Water, EPA 815-R-05-004, January 2005.

MATH

One difficulty in operator certification exams appears to be solving math problems. The 2007 BASIC MATH HANDBOOK was developed to assist operators with the math required to accomplish his or her everyday work and is provided as part of this manual.

CLASS I WATER OPERATOR EXAM FORMULA SHEET

9/2007

CONVERSION FACTORS

1 foot = 12 inches	1 minute = 60 seconds	cfs = cubic feet per second
1 inch = 2.54 centimeters	1 hour = 60 minutes	gpm = gallons per minute
1 gallon = 8 pints	1 day = 86,400 seconds	gpd = gallon per day
1 gallon = 8.34 pounds	1 day = 1,440 minutes	MGD = million gallons per day
1 gallon = 3.785 liters	1 day = 24 hours	mg/L = milligrams per liter
1 liter = 1,000 milliliters	1 % = 10,000 ppm	ppm = parts per million
1 cubic foot = 7.48 gallons	1 mg/L = 1 ppm	psi = pounds per square inch
1 cfs = 448 gpm	1 cubic foot = 62.38 pounds	fps = feet per second
1 gpm = 1,440 gpd	1 cubic yard = 27 cubic feet	cu ft = ft ³ = cubic feet
1 MGD = 1.55 cfs	1 gallon = 8 pints	sq ft = ft ² = square feet
1 psi = 2.31 feet	1 MGD = 694.4 gpm	gpg = grains per gallon
1 foot = 0.433 psi	1 grain per gallon = 17.12 mg/L	
π (pi) = 3.14		

TEMPERATURE

Fahrenheit (°F) = (1.8 x °C) + 32

Celsius (°C) = 0.56 x (°F - 32)

CIRCUMFERENCE, AREA & VOLUME

Circumference (C, ft) = π x diameter (D, ft)

Area of a rectangle (A, sq ft) = (length, ft) x (width, ft)

Area of a circle (A, sq ft) = 0.785 x (diameter, ft)²

Area of a circle (A, sq ft) = π x (radius, ft)²

Volume of a rectangle (V, cu ft) = (length, ft) x (width, ft) x (height, ft)

Volume of a rectangle (V, gal) = (length, ft) x (width, ft) x (height, ft) x 7.48 gal/cu ft

Volume of a cylinder (V, cu ft) = 0.785 x (diameter, ft)² x (height, ft)

Volume of a cylinder (V, gal) = 0.785 x (diameter, ft)² x (height, ft) x 7.48 gal/cu ft

CHLORINATION

Chlorine dose (mg/L) = chlorine demand (mg/L) + chlorine residual (mg/L)

Total chlorine residual (mg/L) = free chlorine residual (mg/L) + combined chlorine residual (mg/L)

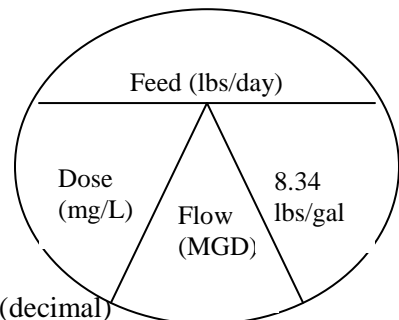
POUNDS, DOSAGE & FLOW

Dose (mg/L) = Feed (lbs/day) ÷ flow (MGD) ÷ (8.34 lbs/gal)

Flow (MGD) = Feed (lbs/day) ÷ dose (mg/L) ÷ (8.34 lbs/gal)

Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal)

Feed (lbs/day) = dose (mg/L) x flow (MGD) x (8.34 lbs/gal) ÷ % purity (decimal)



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FLOW

Flow (Q, gpm) = volume (V, gal) ÷ time (t, min.)

Flow (Q, gps) = velocity (v, fps) x area (A, sq ft) x (7.48 gal/cu ft)

Flow (Q, cfs) = velocity (v, fps) x area (A, sq ft)

DETENTION TIME

Detention time (DT, min) = volume (V, gal) ÷ flow (Q, gpm)

PERCENT

Percent (%) = part ÷ whole x 100

Part = whole x percent ÷ 100

FLUORIDATION

Fluoride Feed Rate (lbs/day) =
$$\frac{\text{Dose (mg/L)} \times \text{Capacity (MGD)} \times (8.34 \text{ lbs/gal})}{\text{Available Fluoride Ion (AFI)} \times \text{chemical purity (decimal)}}$$

Fluoride Feed Rate (gpd) =
$$\frac{\text{Dose (mg/L)} \times \text{Capacity (gpd)}}{18,000 \text{ mg/L}}$$

Dose (mg/L) =
$$\frac{\text{Fluoride Feed rate (lbs/day)} \times \text{Available Fluoride Ion (AFI)} \times \text{chemical purity (decimal)}}{\text{Capacity (MGD)} \times (8.34 \text{ lbs/gal})}$$

Dose (mg/L) =
$$\frac{\text{Solution fed (gal)} \times 18,000 \text{ mg/L}}{\text{Capacity (gpd)}}$$

Chemical	Formula	Available Fluoride Ion (AFI) Concentration	Chemical Purity
Sodium Fluoride	NaF	0.453	98%
Sodium Fluorosilicate	Na ₂ SiF ₆	0.607	98%
Fluorosilicic Acid	H ₂ SiF ₆	0.792	23%

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CHEMICAL DOSES

$$\text{Chemical Feed Setting (mL/min)} = \frac{(\text{Flow, MDG})(\text{Alum Dose, mg/L})(3.785\text{L/gal})(1,000,000 \text{ gal/MG})}{(\text{Liquid Alum, mg/mL})(24 \text{ hr/day})(60 \text{ min/hr})}$$

$$\text{Calibration of a Dry Chemical Feeder (lbs/day)} = \frac{\text{Chemical Applied, lbs}}{\text{Length of Application, day}}$$

Calibration of Solution

$$\text{Chemical Feeder (lbs/day)} = \frac{(\text{Chem Conc, mg/L})(\text{Vol pumped, mL})(1,440 \text{ min/day})}{(\text{Time pumped, min})(1,000 \text{ mL/L})(1,000 \text{ mg/g})(454 \text{ g/lb})}$$

FILTRATION

$$\text{Filtration Rate (gpm/sq ft)} = \frac{\text{Flow, gpm}}{\text{Surface area, sq ft}}$$

$$\text{Unit Filter Rate Volume (UFRV)} = (\text{Filtration Rate, gpm/sq ft})(\text{Filter Run, hr})(60 \text{ min/hr})$$

$$\text{Backwash Water, gal} = (\text{Backwash Flow, gpm})(\text{Backwash Time, min})$$

$$\text{Backwash, \%} = \frac{(\text{Backwash Water, gal})(100\%)}{(\text{Water Filtered, gal})}$$

CORROSION CONTROL

$$\text{pH}_s = A + B + \log(\text{Ca}^{2+}) + \log(\text{Alk})$$

$$\text{Langlier Index} = \text{pH} - \text{pH}_s$$

COAGULATION AND FLOCCULATION

$$\text{Polymer, lbs} = \frac{(\text{Polymer Solution, gal})(8.34 \text{ lbs/gal})(\text{Polymer, \%})(\text{Sp Gr})}{100\%}$$

DISINFECTION

$$\text{Hypochlorite Flow, gpd} = \frac{(\text{Container area, sq ft})(\text{Drop, ft})(7.48 \text{ gal/cu ft})(24 \text{ hr/day})}{(\text{Time, hr})}$$

$$\text{Feed Rate, gal/day} = \frac{(\text{Feed Rate, lbs/day})(\text{Feed Dose, mg/L})}{\text{Feed Solution, mg/L}}$$

$$\text{Feed Rate, lbs/day} = \frac{\text{Feeder Setting, lbs/day}}{24 \text{ hr/day}}$$

$$\text{CT, mg/L-min} = \frac{(\text{Vol, gal})(T_{10})(\text{Free Chlorine Residual, mg/L})}{\text{Flow, gpm}}$$

$$\text{Free Chlorine Residual, mg/L} = \frac{(\text{CT, mg/L-min})}{T_{10, \text{ min}}}$$

EXAM PREPARATION

The following is some information about the exam that may make you a little less apprehensive. Use common sense when studying for the exam. The WV Bureau for Public Health does not write the exams to try and fail people. Exams are developed and revised by an Exam Review Committee based on what currently certified operators indicate they “Need to know” for the job. A validated exam is an important step in preparing operators for job duties and responsibilities associated with the treatment and distribution of drinking water.

If a person is familiar with how the exam is conducted, he/she will be more comfortable with the exam process and more likely to pass the exam. This list will help you familiarize yourself with the certification exam.

1. Most exams have 100 questions, with each question worth one point. A score of 70 or above is passing.
2. All questions are multiple-choice. You will receive partial credit on the math problems, so make sure you **show all of your work**. It could mean the difference between passing and not passing.
3. You will be given three hours to complete the exam. This has proven to be plenty of time for people to complete the exam.
4. The exam is a closed-book exam. All equations and conversions needed for math problems will be given on a exam formula sheet with each exam so there is no need to memorize equations.
5. The percentage of people passing a given exam is good.
6. All applicants must complete and submit form EW-102C at least thirty (30) days prior to the requested exam date.
7. If you have any special learning needs, please notify the Certification and Training section so appropriate accommodations can be arranged in advance.
8. WVBPH is required to notify applicants before the exam date with a confirmation letter by mail. Bring this confirmation letter, a photo ID, a pencil, and a calculator to the exam with you.
9. Exam scores are valid for two (2) years, so you must fulfill the experience requirement to upgrade to a Class I within that timeframe or reapply and retake the exam.
10. If you do not make a passing grade on the exam, you must wait at least 60 days before reapplying for reexamination.
11. Once certified, a Class I operator must acquire at least 12 hours of continuing education credits (CEHs) every two years to maintain certification.
12. CEHs are training classes pre-approved by the WVBPH based on their relevancy to the drinking water industry. Operators must provide copies of class certificates with their renewal application (EW-102D).

**HERE'S A QUICK SUMMARY OF TEST-TAKING STRATEGIES
YOU NEED TO KNOW!**

- ◆ Be on time and try to relax.
- ◆ Pace yourself, so you have time to answer all of the questions.
- ◆ Read the instructions carefully and look at both side of each page.
- ◆ Consider doing easier questions first and coming back to harder, more time-consuming questions such as those with calculations.
- ◆ Read each question carefully.
- ◆ Read all of the answers so that you can pick the best one.
- ◆ There's no penalty for wrong answers, so answer every question, even if you have to guess.
- ◆ If you have to guess, improve your odds by eliminating obviously wrong answers.
- ◆ Take a break if you need one.
- ◆ Recheck your answers after you've finished the exam.
- ◆ Watch out for distracting information in the questions and answers. Some of the information you're given may be irrelevant or may even lead you to the wrong answer. Make it a point to determine what the question is really asking.
- ◆ Beware of extreme modifiers (like "all" or "never"). There are exceptions to most rules, so be careful about any statement that expresses an absolute truth.
- ◆ Some answers may be partially correct, so be sure that you read every answer and then pick the best one.
- ◆ Make a drawing or sketch if it will help you understand the question.
- ◆ Be aware that another question may contain the answer to a question you are not sure of.
- ◆ Underline key points in a question such as variables in a math problem.

PRACTICE QUESTIONS

All questions for Class I examination are multiple choice. These sample questions are not necessarily on the examination, but are used as examples only.

1. Chlorine gas is about _____ times heavier than air:
 - a. 1/4
 - b. 1/2
 - c. 2
 - d. 2 1/2
 - e. 3

2. A hypochlorinator is a device for injecting into water:
 - a. Gaseous chlorine
 - b. Dry hypochlorites
 - c. Hypochlorite solutions
 - d. Fluoride Solutions
 - e. Potassium Permanganate

3. A full 150 lb chlorine cylinder weighs:
 - a. 150 lbs
 - b. 200 lbs
 - c. 240 lbs
 - d. 300 lbs
 - e. 380 lbs

4. Water mains should be disinfected by using a chlorine solution containing no less than:
 - a. 25 mg/L
 - b. 50 mg/L
 - c. 75 mg/L
 - d. 100mg/L
 - e. 150mg/L

5. You are chlorinating a well supply and the chlorine demand increases from 2 mg/L to 10 mg/L. This is indicative of:
 - a. Pollution
 - b. Weak chlorine
 - c. More water being pumped
 - d. Piezometric distance
 - e. Circle of Influence

6. Temporary cloudiness in a freshly drawn sample of tap water may be caused by:
 - a. Hardness
 - b. Alkalinity
 - c. Air
 - d. Chlorine
 - e. Arsenic

7. A waterborne disease that can be transferred to humans if proper disinfection is not provided is:
 - a. Malaria
 - b. Measles
 - c. Typhoid
 - d. Trichinosis
 - e. Psittacosis

8. A water seal on a pump serves a dual purpose. It acts as a lubricant and it also:
 - a. Acts as a coolant to keep pump bearing from over-heating.
 - b. Keeps gritty materials from entering the packing box
 - c. Keeps the pump primed
 - d. Is a reserve water supply
 - e. Is the impeller

9. An example of a chemical compound is:
 - a. Copper
 - b. Mercury
 - c. Table salt
 - d. Calcium
 - e. Potassium

10. According to EPA, which of the following is used to determine the number of water samples examined bacteriologically per month?
- a. Treatment applied
 - b. Source of raw water
 - c. Population served
 - d. Capacity of plant
 - e. Number of operators

ANSWERS

1. D 2. C 3. C 4. B 5. A 6. C 7. C 8. B 9. C 10. C

GLOSSARY

ABSORPTION - Taking in or soaking up of one substance into the body of another by molecular or chemical action (as tree roots absorb dissolved nutrients in the soil).

ACIDIC - The condition of water or soil which contains a sufficient amount of acid substances to lower the pH below 7.0.

ADSORPTION - The collection of a gas, liquid, or dissolved substance on the surface or interface zone of another material.

AERATION - The process of adding air to water. Air can be added to water by either passing air through water or passing water through air.

AEROBIC - A condition in which “free” (atmospheric) or dissolved oxygen is present in the water.

AIR GAP - An open vertical drop of vertical empty space that separates a drinking (potable) water supply to be protected from another water system in a water treatment plant or other location. This open gap prevents the contamination of drinking water by backsiphonage or backflow because there is no way raw water or any other water can reach the drinking water.

ALGAE - Microscopic plants which contain chlorophyll and live floating or suspended in water. They also may be attached to structures, rocks or other submerged surfaces. Excess algal growths can impart tastes and odors to potable water. Algae produce oxygen during sunlight hours and use oxygen during the night hours. Their biological activities appreciable affect the pH and dissolved oxygen of the water.

ALKALINE - The condition of water or soil which contains a sufficient amount of alkali substances to raise the pH about 7.0

ALKALINITY - The capacity of water to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strangely basic (high pH) to have a high alkalinity. Alkalinity is a measure of how much acid can be added to a liquid without causing a great change in pH.

ALTERNATING CURRENT - An electric current that reverses its direction (positive/negative values) at regular intervals.

AMBIENT TEMPERATURE - Temperature of the surrounding air (or other medium). For example, temperature of the room where a gas chlorinator is installed.

AMPERE - The unit used to measure current strength. The current produced by electromotive force of one volt acting through a resistance of one ohm.

ANAEROBIC - A condition in which “free” (atmospheric) or dissolved oxygen is NOT present in water.

ANALYZER - A device which conducts periodic or continuous measurement of some factor such as chlorine, fluoride turbidity. Analyzers operate by any of several methods including photocells, conductivity or complex instrumentation.

ANNULAR SPACE - A ring-shaped space located between two circular objects, such as two pipes.

AQUIFER - A natural underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water.

AUDIT, WATER - A thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system.

AVERAGE DEMAND - The total demand for water during a period of time divided by the number of days in that time period. This is also called the **AVERAGE DAILY DEMAND**.

AWWA - American Water Works Association.

BACK PRESSURE - A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

BACKFLOW - A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than an intended source. Also see **BACKSIPHONAGE**.

BACKSIPHONAGE - A form of backflow caused by a negative or below atmospheric pressure within a water system. Also see **BACKFLOW**.

BACTERIA - Bacteria are living organisms, microscopic in size, which usually consist of a single cell. Most bacteria use organic matter for their food and produce waste products as a result of their life processes.

BASE - Any substance which contains hydroxyl (OH) groups and furnishes hydroxide ions in solution; a molecular or ionic substance capable of combining with a proton to form a new substance; a substance that provides a pair of electrons for a covalent bond with an acid; a solution with a pH of greater than 7.

BATCH PROCESS - A treatment process in which a tank or reactor is filled, the water is treated or a chemical solution is prepared, and the tank is emptied. The tank may then be filled and the process repeated.

BIOLOGICAL GROWTH - The activity and growth of any and all living organisms.

BLOWOFF - A controlled outlet on a pipeline, tank, or conduit which is used to discharge water or accumulations of material carried by the water.

BREAKPOINT CHLORINATION - Addition of chlorine to water until the chlorine demand

has been satisfied. At this point, further addition of chlorine will result in a free residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.

C FACTOR - A factor or value used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses from water flowing in the pipe. To calculate the C Factor, measure the flow, pipe diameter, distance between two pressure gages, and the friction or energy loss of the water between the gages.

CALCIUM CARBONATE (CaCO₃) EQUIVALENT - An expression of the concentration of specified constituents in water in terms of their equivalent value to calcium carbonate. For example, the hardness in water which is caused by calcium, magnesium and other ions is usually described as calcium carbonate equivalent.

CALIBRATION - A procedure which checks or adjusts an instrument's accuracy by comparison with a standard or reference.

CARCINOGEN - Any substance which tends to produce cancer in an organism.

CAVITATION - The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.

CENTRIFUGAL PUMP - A pump consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having an inlet and discharge connection. As the rotating impeller whirls the water around, centrifugal force builds up enough pressure to force the water through the discharge outlet.

CHECK VALVE - A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flow.

CHLORAMINES - Compounds formed by the reaction of hypochlorous acid (or aqueous chlorine) with ammonia.

CHLORINATION - The application of chlorine to water, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results (aiding coagulation and controlling tastes and odors).

CHLORINATOR - A metering device which is used to add chlorine to water.

CHLORINE DEMAND - The difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, pH, and nature and amount of the impurities in the water.

COMBINED AVAILABLE RESIDUAL CHLORINE - That portion of the total residual chlorine remaining in water, sewage or industrial waste at the end of a specified contact period, which will react chemically and biologically as chloramines or organic chloramines.

CHRONIC - Effects of an exposure which causes symptoms to continue for a long time.

CIRCLE OF INFLUENCE - The circular outer edge of a depression produced in the water table by the pumping of water from a well. Also see **CONE OF INFLUENCE AND CONE OF DEPRESSION**.

CIRCUIT - A path through which an electrical current can flow when the path is complete.

CLEAR WELL - A reservoir for the storage of filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand. Also used to provide chlorine contact time for disinfection.

COLIFORM - A group of bacteria found in the intestines of warm-blooded animals (including humans) and also in plants, soil, air and water. Fecal coliforms are a specific class of bacteria which only inhabit the intestines of warm-blooded animals. The presence of coliform bacteria is an indication that the water is polluted and may contain pathogenic organisms.

COLORIMETRIC MEASUREMENT - A means of measuring unknown chemical concentrations in water by measuring a sample's color intensity. The specific color of the sample, developed by addition of chemical reagents, is measured with a photoelectric colorimeter or is compared with "color standards" using, or corresponding with, known concentrations of the chemical.

COMPOUND - A substance composed of two or more elements whose composition is constant. For example, table salt (sodium chloride -NaCl) is a compound.

CONDUCTANCE - A measure of the conducting power of a solution equal to the reciprocal of the resistance. The resistance is expressed in ohms.

CONDUCTIVITY - The ability of a material to carry current or heat.

CONE OF DEPRESSION - The depression, roughly conical in shape, produced in the water table by pumping of water from a well. Also see **CIRCLE OF INFLUENCE** and **CONE OF DEPRESSION**.

CONTAMINATION - The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in concentration that makes the water unfit for its next intended use.

CORPORATION STOP - A water service shutoff valve located at a street water main. This valve cannot be operated from the ground surface because it is buried and there is not valve box. Also called a **CORPORATION COCK**.

CORROSION - The gradual decomposition or destruction of a material by chemical reaction. Corrosion may be caused by (1) stray current electrolysis, (2) galvanic corrosion caused by

dissimilar metals, or (3) differential-concentration cells. Corrosion starts at the surface of a material and moves inward.

CORROSION INHIBITORS - Substances that slow the rate of corrosion.

CORROSIVITY - An indication of the corrosiveness of water. The corrosiveness of water is described by the water's pH, alkalinity, hardness, temperature, total dissolved solids, dissolved oxygen concentration, and the Langelier Index.

CROSS-CONNECTION - A connection between a drinking (potable) water system and an unapproved water supply. For example, if you have a pump moving nonpotable water and hooking into the drinking water system to supply water for pump seal, a cross-connection or mixing between the two water systems can occur. This mixing may lead to contamination of the drinking water.

CURRENT - A movement of electrons through a conductor. Measured in amperes.

DAY TANK - A tank used to store a chemical solution of known concentration for feed to a chemical feeder. A day tank usually stores sufficient chemical solution to properly treat the water being treated for at least one day. Also called an AGE TANK.

DECOMPOSITION - The conversion of chemically unstable materials to more stable forms by chemical or biological action. If organic matter decays when there is no oxygen present (anaerobic conditions or putrefaction), undesirable tastes and odors are produced. Decay of organic matter when oxygen is present (aerobic conditions) tends to produce much less objectionable tastes and odors.

DENTAL FLUOROSIS – The whitish to brownish spots seen to appear on teeth caused by high levels of fluoride in the drinking water. Also known as “mottled enamel”

DETENTION TIME - The time allowed for water to collect in a settling tank. Theoretically detention time is equal to the volume of the tank divided by the flow rate.

DIRECT CURRENT - Electrical current flowing in one direction only and essentially free from pulsation.

DISINFECTION - The process designed to kill most microorganisms in water, including essentially all pathogenic (disease-causing bacteria). There are several ways to disinfect, with chlorine being most frequently used in water treatment. Compare with STERILIZATION.

DISSOLVED SOLIDS - The total amount of dissolved material, organic and inorganic, contained in water. Excessive dissolved solids make water unpalatable for drinking and unsuitable for industrial use. Measurements are expressed as ppm or mg/L.

DPD - A method of measuring the chlorine residual in water. The residual may be determined by either titrating or comparing a developed color with color standards. DPD stands for N,N-diethyl-p-phenylene-diamine.

DRAWDOWN - The drop in the water table or level of water in the ground when water is being

pumped from a well. The amount of water used from a tank or reservoir. The drop in the water level of a tank or reservoir.

EFFLUENT - Water or other liquid - raw, partially or completely treated - flowing FROM a reservoir, basin, treatment process or treatment plant.

ELEMENT - A substance which cannot be separated into its constituent parts and still retain chemical identity. For example, sodium (Na) is an element.

EPA - U. S. Environmental Protection Agency.

EPIDEMIC - A disease that occurs in a large number people in a locality at the same time and spreads from person to person.

EPIDEMIOLOGY - A branch of medicine which studies epidemics (diseases which affect significant numbers of people during the same time period in the same locality). The objective of epidemiology is to determine the factors that cause epidemic diseases and how to prevent them.

EVAPORATION - The process by which water or other liquid becomes a gas (water vapor or ammonia vapor)

EVAPOTRANSPIRATION - The process by which water vapor passes into the atmosphere from living plants. Also called TRANSPIRATION.

FINISHED WATER - Water that has passed through a water treatment plant, and when all the treatment processes are completed or “finished”. This water is ready to be delivered to consumers. Also call PRODUCT WATER.

FLUORIDATION - The addition of a chemical to increase the concentration of fluoride ions in drinking water to a predetermined optimum limit to reduce the incidence (number) of dental caries (tooth decay) in children. Defluoridation is the removal of excess fluoride in drinking water to prevent the mottling (brown stains) of teeth.

FLUSHING - A method used to clean water distribution lines. Hydrants are opened and water with a high velocity flows through the pipes, removes deposits form the pipes, and flows out the hydrants.

FOOT VALVE - A special type of check valve located at the bottom end of the suction pipe on a pump. This valve opens when the pump operates to allow water to enter the suction pipe but closes when the pump shuts off to prevent water from flowing out of the suction pipe.

FREE AVAILABLE RESIDUAL CHLORINE - That portion of the total available residual chlorine composed of dissolved chlorine gas (Cl_2), hypochlorous acid (HOCl), and/or hypochlorite ion (OCI^-) remaining in water after chlorination. This does not include chlorine that has combined with ammonia, nitrogen, or other compounds.

GIARDIASIS - Intestinal disease caused by an infestation of Giardia flagellates.

GRAB SAMPLE - A single sample collected at a particular time and place which represents the composition of the water only at that time and place.

GRADE - (1) The elevation of the invert (lowest point) of the bottom of a pipeline, canal, culvert, or similar conduit. (2) The inclination or slope of a pipeline, conduit, stream channel, or natural ground surface; usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance. A 0.5 percent grade would be a drop of one-half per hundred feet of pipe.

HARD WATER - Water having a high concentration of calcium and magnesium ions. A water may be considered hard if it has hardness greater than the typical hardness of water from the region. Some textbooks define hard water with a hardness of more than 100 mg/L as calcium carbonate.

HARDNESS, WATER - A characteristic of water caused mainly by the salts of calcium and magnesium, such as bicarbonate, carbonate, sulfate, chlorine, and nitrate. Excessive hardness in water is undesirable because it causes the formation of soap curds, increased use of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes causes objectionable tastes in drinking water.

HEAD - The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.

HOSE BIB - Faucet. A location in a water line where a hose is connected.

HYDROLOGIC CYCLE - The process of evaporation of water into the air and its return to Earth by precipitation (rain or snow). This process also includes transpiration from plants, groundwater movement, and runoff into rivers, streams and the ocean. Also called the WATER CYCLE.

HYDROSTATIC PRESSURE - The pressure at a specific elevation exerted by a body of water at rest, or in the case of groundwater, the pressure at a specific elevation due to the weight of water at higher levels in the same zone of saturation.

IMPELLER - A rotating set of vanes in a pump designed to pump or lift water.

INDICATOR - A substance that gives a visible change, usually of color, at a desired point in a chemical reaction, generally at a specified end point.

INFLUENT - Water or other liquid - raw or partially treated - flowing INTO a reservoir, basin, or treatment process of treatment plant.

INORGANIC - Material such as sand, salt, iron, calcium salts and other mineral materials. Inorganic substances are of mineral origin, whereas organic substances are usually of animal or plant origin. Also see ORGANIC.

INSECTICIDE - Any substance or chemical formulated to kill or control insects.

LANGELIER INDEX - An index reflecting the equilibrium pH of water with respect to

calcium and alkalinity. This index is used in stabilizing water to control both corrosion and the deposition of scale.

MACROSCOPIC - Organisms big enough to be seen by the eye without the aid of a microscope.

MATERIAL SAFETY DATA SHEET - A document which provides pertinent information and a profile of a particular hazardous substance or mixture. An MSDS is required to be made available to employers and operators whenever there is the likelihood of the hazardous substance or mixture being introduced into a workplace.

MCL - Maximum Contaminant Level. The largest allowable amount. MCLs for various water quality indicators are specified in the National Interim Primary Drinking Water Regulations (NIPDWR).

MENISCUS - The curved top of a column of liquid (water, oil, mercury) in a small tube. When the liquid wets the sides of the container (as with water), the curve forms a valley. When the confining sides are not wetted (as with mercury), the curve forms a hill or upward bulge.

MICROBIAL GROWTH - The activity and growth of microorganisms such as bacteria, algae, diatoms, plankton and fungi.

MICROORGANISMS - Living organisms that can be seen individually only with the aid of a microscope.

MILLIGRAMS PER LITER, mg/L - A measure of the concentration by weight of a substance per unit volume. For practical purposes, one mg/L of a substance in fresh water is equal to one part per million parts (ppm).

NIOSH - The *National Institute of Occupational Safety and Health* is an organization that tests and approves safety equipment for particular applications. NIOSH is the primary Federal agency engaged in research in the national effort to eliminate on-the-job hazards to the health and safety of working place. The NIOSH Publications Catalog contains a listing of NIOSH publications mainly on industrial hygiene and occupational health. To obtain a copy of the catalog, write to NIOSH Publications, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

NONPOINT SOURCE - A runoff or discharge from a field or similar source. A point source refers to a discharge that comes out the end of a pipe.

NPDES PERMIT - *National Pollutant Discharge Elimination System* permit is the regulatory agency document designed to control all discharges of pollutant from point sources in US waterways. NPDES permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal treatment plants, large agricultural feed lots and return irrigation flows.

OHMS - A unit of electrical resistance equal to that of a conductor in which a current of one ampere is produced by a potential of one volt across its terminals.

OLFACTORY FATIGUE - A condition in which a person's nose, after exposure to certain

odors, so no longer able to detect the odor.

ORGANIC - Substances that come from animal or plant sources. Organic substances always contain carbon. (Inorganic materials are chemical of mineral origin.) Also see INORGANIC.

ORGANISM - Any form of animal or plant life. See also BACTERIA.

PALATABLE - Water at a desirable temperature that is free from objectionable tastes, odors, colors, and turbidity. Pleasing to the senses.

PARTS PER MILLION (PPM) - Parts per million parts, measurement of concentration on a weight or volume basis. This term is equivalent to milligrams per liter (mg/L) which is the preferred term.

PATHOGENIC ORGANISMS - Organisms, including bacteria, viruses or cysts, capable of causing diseases (typhoid, cholera, dysentery) in a host (such as a person). There are many type of organisms which do NOT cause disease. These organisms are called non-pathogenic.

PATHOGENS - Pathogenic or disease-causing organisms.

PEAK DEMAND - The maximum momentary load placed on a water treatment plant, pumping station or distribution system. This demand is usually the maximum average load in one hour or less, but may be specified as the instantaneous or with some other short time period.

PERISTALTIC METERING PUMP - A positive displacement pump that uses the alternating waves of contraction and dilation of a plastic tubing to move liquid through the tubing into the water line.

PERMEABILITY - The property of a material or soil that permits considerable movement of water through it when it is saturated.

pH - pH is an expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion activity.

PITLESS ADAPTER - A fitting which allows the well casing to be extended above the ground while having a discharge connection located below the frost line. Advantages of using a pitless adapter include the elimination of the need for a pit or pump house and it is a water-tight design, which helps maintain a sanitary water supply.

POSITIVE DISPLACEMENT PUMP - A type of piston, diaphragm, gear or screw pump that delivers a constant volume with each stroke. Positive displacement pumps are used as chemical solution feeders.

POROSITY - A measure of the spaces or voids in a material or aquifer. The ratio of the volume of spaces in a rock or soil to the total volume. This ratio is usually expressed as a percentage.

POSTCHLORINATION - The addition of chlorine to the plant effluent, FOLLOWING plant treatment, for disinfection purposes.

POTABLE WATER - Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for drinking.

PRESSURE HEAD - The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.

PUMPING WATER LEVEL - The vertical distance in feet from the centerline of the pump discharge to the level of the free pool while water is being drawn from the pool.

RANNEY COLLECTOR - This water collector is constructed as a dug well from 12 to 16 feet (3.5 to 5 m) in diameter that has been sunk as a caisson near the bank of a river or lake. Screens are driven radially and approximately horizontally from this well into the sand and the gravel deposits underlying the river.

RAW WATER - Water in its natural state, prior to any treatment. Usually the water entering the first treatment process of a water treatment plant.

REAGENT - A pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances.

RESIDUAL CHLORINE - The amount of free and/or available chlorine remaining after a given contact time under specified conditions.

SAFE DRINKING WATER ACT - Commonly referred to as SDWA. An Act passed by the US Congress in 1974. The Act establishes a cooperative program among local, state, and federal agencies to insure safe drinking water for consumers.

SAFE YIELD - The annual quantity of water that can be taken from a source of supply over a period of years without depleting the source permanently (beyond its ability to be replenished naturally in “wet years”).

SANITARY SURVEY - A detailed evaluation and/or inspection of a source of water supply and all conveyances, storage, treatment and distribution facilities to insure its protection from all pollution sources.

SATURATOR - A device which produces fluoride solution for the fluoridation process. The device is usually a cylindrical container with granular sodium fluoride on the bottom. Water flows either upward or downward through the sodium fluoride to produce the fluoride solution.

SOFT WATER - Water having a low concentration of calcium and magnesium ions. According to US Geological Survey guidelines, soft water is water having a hardness of 60 milligrams per liter or less.

SOLUTION - A liquid mixture of dissolved substances. In a solution it is impossible to see all the separate parts.

SPECIFIC YIELD - The quantity of water that a unit volume of saturated permeable rock or soil will yield when drained by gravity. Specific yield may be expressed as a ratio or as a percentage by volume.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER - A joint publication of the *American Public Health Association*, *American Water Works Association*, and the *Water Pollution Control Federation* which outlines the procedures used to analyze the impurities in water and wastewater.

STATIC HEAD - When water is not moving, the vertical distance (in feet) from a specific point to the water surface. The static pressure in psi is the static head in feet times 0.433 psi/ft. Also see **DYNAMIC PRESSURE** and **STATIC PRESSURE**.

STATIC WATER LEVEL - The elevation or level of the water table in a well when the pump is not operating. The level or elevation to which water would rise in a tube connected to an artesian aquifer, or basin, or conduit under pressure.

THRUST BLOCK - A mass of concrete or similar material appropriately placed around a pipe to prevent movement when the pipe is carrying water. Usually placed at bends and valve structures.

TITRATE - To **TITRATE** a sample, a chemical solution of known strength is added on a drop-by-drop basis until a certain color change, precipitate, or pH change in the sample is observed (end point). Titration is the process of adding the chemical reagent in increments until completion of the reaction, as signaled by the end point.

TOTAL DISSOLVED SOLIDS (TDS) - All of the dissolved solids in a water. TDS is measured on a sample of water that has passed through a very fine mesh filter to remove suspended solids. The water passing through the filter is evaporated and the residue represents the dissolved solids.

TOTAL DYNAMIC HEAD (TDH) - When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.

TOTAL RESIDUAL CHLORINE - The amount of available chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine. Also see **RESIDUAL CHLORINE**.

TOXIC - A substance which is poisonous to an organism.

TURBIDITY - The cloudy appearance of water caused by the presence of suspended and colloidal matter. In the waterworks field, a turbidity measurement is used to indicate the clarity of the water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended solids. Turbidity cannot be directly equated to suspended solids because white particles reflect more light than dark-colored particles and many small particles will reflect more light than an equivalent large particle.

VELOCITY - A measure of how fast water flows, usually expressed in feet/second or (distance/time).

VENTURI METER - A flow measuring device placed in a pipe. The device of a tube whose diameter gradually decreases to a throat and then gradually expands to the diameter of the pipe.

The flow is determined on the bases of the differences in pressure (caused by different velocity heads) between the entrance and throat of the Venturi meter.

VOLTAGE - The electrical pressure available to cause a flow of current (amperage) when an electrical circuit is closed. Also called ELECTROMOTIVE FORCE (E.M.F.)

VOLATILE - A substance that is capable of being evaporated or easily changed to a vapor at relatively low temperatures. For example, gasoline is a highly volatile liquid.

WATER AUDIT - A thorough examination of the accuracy of water agency records or accounts (volumes of water) and system control equipment. Water managers can use audits to determine their water distribution system efficiency. The overall goal is to identify and verify water and revenue losses in a water system.

WATER CYCLE - Also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. Processes include precipitation, condensation, interception, runoff, infiltration/percolation, transpiration and evaporation.

WATER HAMMER - The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressure can do serious damage to the system.

WATER TABLE - The upper surface of the zone of saturation of groundwater in an unconfined aquifer.

WELL LOG - A record of the thickness and characteristics of the soil, rock and water-bearing formations encountered during the drilling (sinking) of a well.

YIELD - The quantity of water (expressed as a rate of flow - GPM, GPH, GPD, or total quantity per year) that can be collected for a given use from surface or groundwater sources. The yield may vary with the use proposed, with the plan of development, and also with economic consideration. Also see SAFE YIELD.

ZONE OF SATURATION - The soil or rock located below the top of the groundwater table. By definition, the zone of saturation is saturated with water. Also see WATER TABLE.

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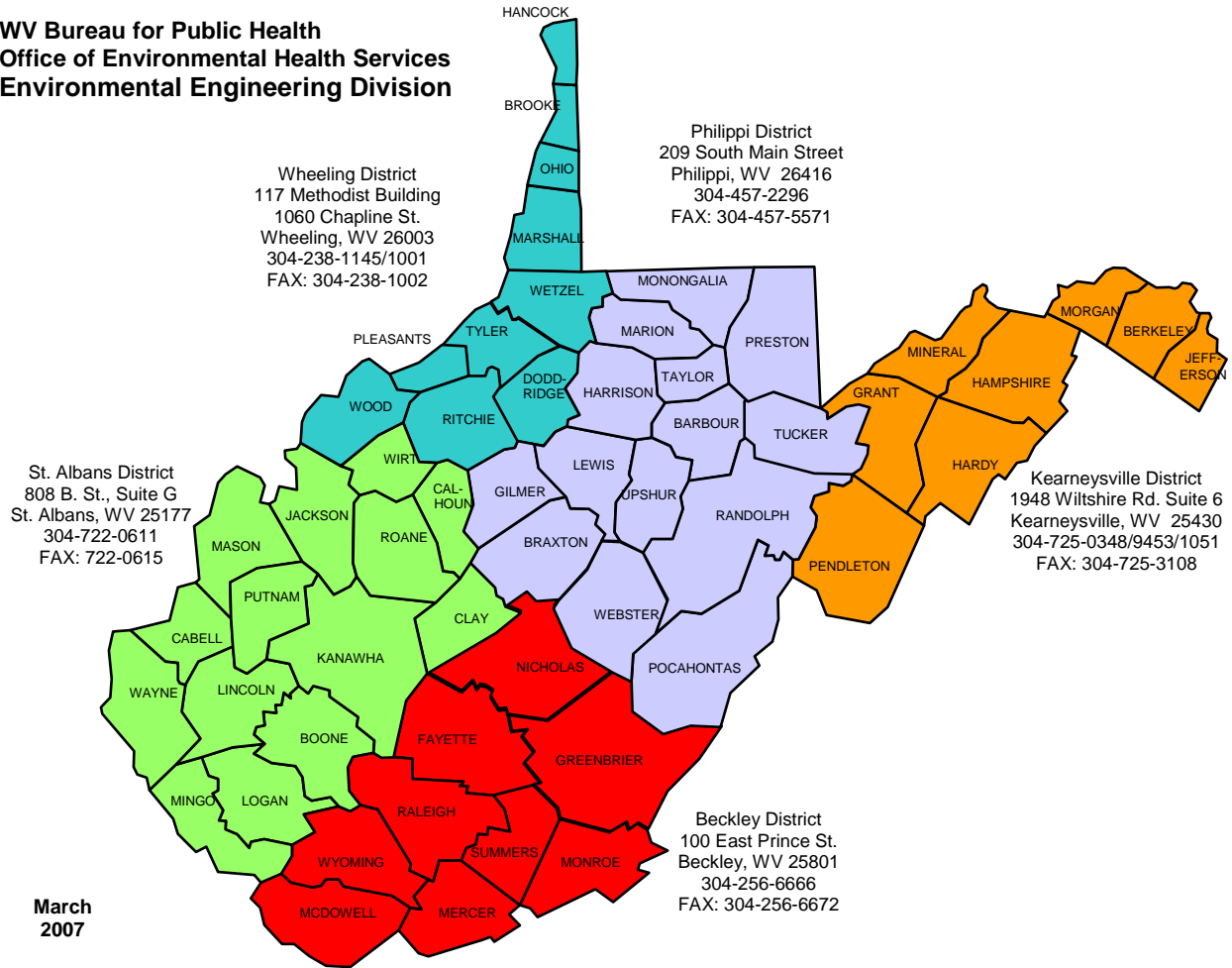
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**WV Bureau for Public Health
Office of Environmental Health Services
Environmental Engineering Division**



CLASS I REFERENCE LIST

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7. Water Fluoridation A Manual for Water Plant Operators, Center for Disease Control and Prevention, April 1994.
8. Safe Drinking Water Act and all current Rules and Regulations from www.epa.gov/safewater
9. EPA's Interactive Sampling Guide for Drinking Water System Operators CDROM, Office of Water (4606M), EPA816-C-06-001, April 2006.
10. www.wvdhhr.org/oehs/eed
11. www.wvetc.org
12. www.wvrwa.org
13. www.owp.csus.edu

FORMS

Certification & Training

Operator Forms

- Form EW-102C (Application for Certification and Examination of WD & Class I-IV)
- Form EW-102D (Application for Renewal of WD & Class I-IV)
- Form EW-102E (Application for Certification as an OIT)
- Form EW-102F (Application for 1D Certification, Examination, and Renewal)
- Form EW-74 (Resignation)
- Form EW-75 (Application for Certification as a Backflow Prevention Assembly Inspector/Tester)
- Form EW-108 (Application for Certification Through Reciprocity)

System Forms

- Form EW-104 (Annual Personnel Status Change)
- Form EW-111 (Employment Status Change)
- Form EW-107 (Certified Operator Requirement Waiver Application)

Data Management

Monthly Operational Reports

- EW-103 Groundwater Systems Form
- EW-210 Purchase Systems Form
- EW-90 Surface Water Series Form
- EW-80 Fluoride Form

Monitoring Guidance Form

- EW-141-A Monitoring Guidance for Public Water Systems Form (for lead and copper)

Regulation Public Notice Forms

- TIER 1 - 24 HOUR NOTIFICATION Form
- TIER 2/3 - PUBLIC NOTICE CERTIFICATION & "IMPORTANT INFORMATION"

Public Notice Forms

- BOIL WATER NOTICE Form
- HEALTH DEPARTMENT BOIL WATER NOTICE Form
- HEALTH DEPARTMENT PUBLIC SERVICE ANNOUNCEMENT Form