WATER DISTRIBUTION SYSTEM OPERATOR MANUAL

WEST VIRGINIA
Department of
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WATER DISTRIBUTION SYSTEM OPERATOR MANUAL
Overview/Preface

This manual has been developed to provide you with some basic information to assist you in operating your water system and serving safe drinking water. The manual also gives you background information on how water systems work and the regulations applied to public water systems in West Virginia. With the great diversity and dynamics present in the water treatment industry, it is important for operators to be resourceful – at least know enough to ask the right questions to the right people.

Your water supply is critical to the operation of your facility and an uninterrupted, safe supply of water is necessary for your daily operations. Additionally, state and federal regulations require you to provide a safe and adequate supply of water. Knowing about your water system, operating it properly, and performing preventative maintenance can help avoid unsafe, costly, and inconvenient problems with your water system.

Information contained within this manual should give you a basic understanding of any water system you may work with and enable you to apply a systematic troubleshooting process to solve or correct operational problems of a small ground water system with disinfection using hypochlorination. At no time should the operator undertake troubleshooting activities for which they are not trained for or involve unsafe practices. The troubleshooting process presented in this manual begins with the simplest, and often the easiest to correct, and continues to the more complex without endangering the operator or the users of the water system. The troubleshooting steps allow the operator to assess an operational problem to the point that it can either be easily corrected or requires a technical specialist, e.g. electrician, well specialist, etc. The manual also encourages the user to contact their state drinking water office (Office of Environmental Health Services) for information, technical assistance and advice when responding to a water system problem.

Disclaimer

All reasonable precautions have been taken in the preparation of this document, including both technical and non-technical proofing. The West Virginia Department of Health and Human Resources and West Virginia Rural Water Association and all staff assume no responsibility for any errors or omissions.

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

Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the West Virginia Department of Health and Human Resources and West Virginia Rural Water Association.

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INTRODUCTION INTO BEING A CERTIFIED OPERATOR

Why should I become a certified operator?

Drinking water system operators are front-line environmental professionals who ensure the quality of West Virginia's water resources and protect the public's health. Every public water system (PWS) in West Virginia must employ a certified operator.

Working in the water industry can be extremely rewarding as you will be providing a critical service to your community. It just might be one of the most important positions in the world since no one can live without water. It takes knowledgeable, conscientious people to deliver clean, potable water.

Certification Process

Certification is obtained by meeting minimum education and experience requirements, submitting the appropriate forms and by passing the certification examination with at least a 70%. Regulations pertaining to the certification of drinking water operators are located in 64CSR04.

Operator-in-Training Certifications

Operator-in-training (OIT) certifications are available for each certification type. An OIT is an individual who holds a valid operator-in-training certificate issued by the Commissioner, and who is training under the responsibility of the Chief Operator at a PWS while completing the educational and experience requirements to become a WDS.

An OIT will become a certificated operator after he/she has:

- Attended an approved course;
- Passed the appropriate exam with a 70% or better;
- Earned the required operational experience;
- Submitted documentation form verifying his/her experience; and
- Submitted a letter of recommendation from the chief operator

Certification Renewal or Maintenance

Certification expires two years after issuance and requires continuing education hours. Certifications shall remain valid until the expiration date, unless suspended, revoked or replaced by a higher classification certificate before that date. Failure to renew before the expiration of certification will result in a suspension. If the certificate is not renewed on or before one year after the certification expired, the operator will have to retest in order to renew. **Reminder -- Continuing education hours earned prior to certification shall not count toward certificate renewal.**

Standards of Professional Conduct for Certified Operators

In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, standards of professional conduct apply to persons certified in accordance with WV 64CSR04. This regulation states that a certified operator shall:

- Be responsible for their certification in accordance with all aspects of this rule;
- Carry his or her current certification card issued by the Commissioner upon them at all times the operator is operating the PWS;

- Not work in a PWS under the certification of another person; only the person whose name appears on the operator certification is certified by that document. Certifications are not transferable;
- Notify the Commissioner at least 30 calendar days in advance of the voluntary termination of his or her employment at a PWS;
- Comply with the provisions of Bureau for Public Health legislative rule, Public Water Systems, 64CSR3; and,
- Demonstrate data integrity by providing complete, accurate, and true information for the period in which they were responsible for data collection, including but not limited to, records, reports, and lab results.

Operator Ethics

Your job as a certified operator has a direct impact on the health of the people who consume your water. Failure to obtain a bacteriological (Bac-T) sample from a problem area or worse yet, writing down false readings, ruins your reputation, puts your future credibility in jeopardy, puts your career choice at risk, and potentially could cause someone who ingests your water to become sick or die. Nationally, more and more certified operators are being prosecuted for unethical or dishonorable behavior in the workplace. Our job is to protect the consuming public and provide potable water to each and every one of them, not satisfy regulatory numbers. Take pride in your work and in your ethical behavior.

WATER DISTRIBUTION SYSTEM CERTIFICATION

US Environmental Protection Agency (EPA) guidelines require all PWS operating personnel making process control/system integrity decisions about water quality or quantity that affect public health be done under the direction of a qualified, certified operator. This potential exists in both the treatment facility and distribution system. Therefore, a Water Distribution System (WDS) operator certification was added in 2007.

Some water utilities also have “split” responsibilities, where the water treatment plant may be under the direction of a certified PWS operator but the distribution system is not. This is no longer allowable under 64CSR04. The WDS certification will allow two “chief operators” to be assigned under the above scenario and still meet the federal guidelines. Although a WDS system is defined as a PWS that obtains all of its water from another PWS (also known as a purchase system), and is not owned or operated by the supplying PWS, an individual working in the distribution portion of any PWS must hold a WDS or higher certification to ensure properly certified operator coverage.

Since WDS operators collect water quality samples at the distribution system but not provide any treatment, much of the current Class I (and higher) operator certification training is not needed for distribution only systems or related work. Development of a WDS training course and exam where only distribution activities are taught and tested, will eliminate the problem of a person having to study unneeded and unnecessary material in order to proficiently perform their job functions.

WDS certification requires:

- 18 years of age
- High school diploma or GED
- Commissioner-approved WD course
- 1,000 hours (~6 months full-time) certified experience at a WD or higher PWS documented
- EW-102 for exam
- 70 or better on WD exam
- Form EW-211 for certification

All of the requirements for WDS operator certification are based on current EPA guidelines related to operator education, examination, experience, and continued training. Any operator collecting samples at a WDS or higher system must hold a 1D or higher certification. This provision was added to give existing WDS operators a chance to upgrade without going through the Operator-in-Training (OIT) process.

A Class I-IV certified operator may choose to be WDS certified in addition to their higher classifications, however, it is not required. If both certifications are held, the requirements for the highest must be met. The Water Distribution Operator Certification Course is approved for 24 CEHs (CEH2008-052R) so it may be taken for continued learning purposes instead of certification if the individual chooses.

Keep in mind, **all operator certification requirements are based on federal and state regulations to ultimately protect public health.** Each certified PWS operator is responsible in providing adequate supply of safe, potable drinking water to consumers who are confident their water is safe to drink. It is essential these operators not only achieve these minimum requirements for certification but continue to gain knowledge and acknowledge the public health foundation of their career choice in the drinking water industry. Please contact the Certification and Training Program at any time to discuss any aspect of the operator certification program.

INTRODUCTION TO U.S. ENVIRONMENTAL PROTECTION AGENCY

The **U.S. Environmental Protection Agency** (**EPA** or sometimes **USEPA**) is federal agency charged with protecting human health and with safeguarding the natural environment: air, water, and land. On July 9, 1970, Richard Nixon transmitted Reorganization Plan No. 3 to the U.S. Congress by executive order, creating the EPA as a single, independent, agency from a number of smaller arms of different federal agencies. Prior to the establishment of the EPA, the federal government was not structured to make a coordinated attack on the pollutants which harm human health and degrade the environment. The EPA was assigned the task of repairing the damage already done to the natural environment and to establish new criteria to guide Americans in making a cleaner, safer America.

The agency conducts environmental assessment, research, and education. It has the primary responsibility for setting and enforcing national standards under a variety of environmental laws, in consultation with state, tribal, and local governments. It delegates some permitting, monitoring, and enforcement responsibility to U.S. states and Native American tribes. EPA enforcement powers include fines, sanctions, and other measures.

EPA headquarters in Washington, D.C. EPA comprises 17,000 people in headquarters program offices, 10 regional offices, and 27 laboratories across the country. More than half of its staff are engineers, scientists, and environmental protection specialists; other groups include legal, public affairs, financial, and computer specialists.

Each EPA regional office is responsible within its states for implementing the Agency's programs, except those programs that have been specifically delegated to states.

- Region 1 - responsible within the states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
- Region 2 - responsible within the states of New Jersey and New York in addition it's also responsible for the US territories of Puerto Rico, and the U.S. Virgin Islands.
- **Region 3 - responsible within the states of Delaware, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia.**
- Region 4 - responsible within the states of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.
- Region 5 - responsible within the states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.
- Region 6 - responsible within the states of Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.
- Region 7 - responsible within the states of Iowa, Kansas, Missouri, and Nebraska.
- Region 8 - responsible within the states of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.
- Region 9 - responsible within the states of Arizona, California, Hawaii, Nevada, and the territories of Guam and American Samoa.
- Region 10 - responsible within the states of Alaska, Idaho, Oregon, and Washington.

The Environmental Protection Agency's **Office of Groundwater and Drinking Water (OGWDW)**, together with states, tribes, and its many partners, protects public health by ensuring safe drinking water and protecting groundwater. OGWDW, along with EPA's ten regional drinking water programs, oversees implementation of the **Safe Drinking Water Act (SDWA),** which is the national law safeguarding tap water in America. The SDWA requires **public water systems (PWSs)** to provide drinking water that meets safety standards and protects sources of drinking water, including rivers, lakes, reservoirs, springs, or groundwater wells. Approximately 90% of Americans rely on public water systems for their drinking water at home; the other 10% have private wells, which are not federally regulated. Almost everyone drinks water from a public system at some point: while at school, at work, in a restaurant, or on vacation.

OGWDW develops and helps implement national drinking water standards; oversees, assists and helps fund state drinking water programs and source water protection programs; helps small drinking water systems; protects underground sources of drinking water through the Underground Injection Control Program; and provides information to the public. OGWDW also works in cooperation with states, tribes, and EPA's Office of Enforcement and Compliance Assurance to guarantee that water systems meet these protective standards.

OGWDW sets national standards for drinking water, which either limit the amount of a particular contaminant in drinking water or require a certain treatment to remove or inactivate a contaminant. Both types of standards protect public health. When setting these standards, OGWDW uses sound data and peer-reviewed science to focus on the contaminants which present the greatest public health risk and which appear most frequently in drinking water. OGWDW also identifies sub-populations most vulnerable to drinking water contaminants, such as infants, children, pregnant women, the elderly, and the immunocompromised, and considers the risk to these sensitive sub-populations when setting safety standards. As part of the standard-setting process, OGWDW relies on input from all interested parties, looks at whether drinking water regulations are cost effective, determines appropriate procedures for analyzing samples of drinking water, and identifies affordable ways to treat drinking water.

States and tribes work directly with water systems to implement the national drinking water program. To implement the drinking water program, each state or tribe must establish a drinking water program that is at least as stringent as the federal program (some states have stricter programs), assure that water systems meet safety standards, and adopt and implement adequate enforcement procedures (called primacy). If a state or tribe is unable to meet the requirements for primacy, or is simply unwilling, EPA's regional offices will directly implement the drinking water program in that jurisdiction. OGWDW provides grants, training, and technical assistance to help states and tribes successfully carry out the provisions of the SDWA. OGWDW also administers the drinking water state revolving loan fund, and grants funds to states, that loan money to water systems to install or upgrade facilities and to replace aging pipes and other infrastructure. The fund's policy is to support all water systems in need, including assisting small and disadvantaged communities, and protecting sources of drinking water from contamination.

The vast majority of water systems in the U.S. serve fewer than 3,300 people. Small water systems incur greater costs per household because they must spread the cost of infrastructure improvement over a smaller customer base. In fact, small systems could incur three times as much cost per household to continue to provide safe drinking water in the future as compared to that of larger systems. OGWDW assists small systems by identifying affordable and effective ways for small systems to treat water for their customers and providing technical and financial assistance.

The Partnership for Safe Water is a unique cooperative effort between OGWDW and over 100 large water systems that join the partnership to provide protection beyond what is currently required by federal law to their customers from *Cryptosporidium*, *Giardia lambia* (herein referred to as *Giardia*) and other microbial contaminants.

OGWDW is working with states so that they can determine how susceptible drinking water sources are to contamination. States and water suppliers will share this information (compiled into source water assessments) with the public so that communities can protect their drinking water sources. OGWDW also oversees programs that protect aquifers which serve as the primary source of drinking water for one or more communities (sole source aquifers), and works with states to implement wellhead protection programs, under which states protect the land around wells from contaminants. Through the Underground Injection Control program, OGWDW protects underground sources of drinking water. Injection deep into the earth is a common way of disposing of hazardous waste. If not injected properly, these wastes can contaminate sources of drinking water. OGWDW sets standards for safe injection practices, and bans certain types of injection altogether. A number of other EPA programs also protect drinking water from potential sources of contamination. For instance, the Superfund program cleans-up hazardous waste sites, while other programs regulate landfills, discharges to water, underground storage tanks, and chemicals used on farms and lawns. OGWDW works with other EPA offices to support efforts to coordinate these and many other programs to provide comprehensive protection of the nation's groundwater resource.

Public information and public involvement are critically important to the successful implementation of the drinking water program. OGWDW works through an advisory committee, the National Drinking Water Advisory Council, and solicits other input through public meetings with states, tribes, water systems, environmental and other groups, and the public. OGWDW is working with these partners and others to provide information to citizens and communities on the quality of their local drinking water. OGWDW collects information on every public water system, such as how many people each system serves and whether each is meeting drinking water standards. This information is stored in the Safe Drinking Water Information System, and is used to help OGWDW understand whether systems are complying with drinking water safety standards. OGWDW is also collecting information on the occurrence of contaminants which may need to be regulated in the future, and storing this information in the National Contaminant Occurrence Database. OGWDW is providing materials to help water systems prepare annual water quality reports (consumer confidence reports) and notify consumers of water emergencies, and is helping consumers use this information to make decisions.

OGWDW maintains a web site (http://www.epa.gov/safewater/) and the **Safe Drinking Water Hotline (1-800-426-4791)** to make drinking water information easily available, and has also recently established the Drinking Water Academy to provide further training.

DRINKING WATER REGULATIONS

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 was amended in 1986 and 1996. The SDWA establishes a Federal program to monitor and increase the safety of the nation's drinking water supply. The SDWA authorizes the EPA to set and implement health-based standards to protect against both naturally occurring and man-made contaminants in drinking water. The EPA is also responsible for assessing and protecting drinking water sources; protecting wells and collection systems; making sure water is treated by qualified operators; ensuring the integrity of distribution systems; and making information available to the public on the quality of their drinking water. The EPA works closely with each state to establish public drinking water standards and enforce the requirements of the SDWA. In West Virginia, the state government agency with primacy authority is the **WV Department of Health and Human Resources (WVDHHR)**, **Bureau for Public Health (BPH), Office of Environmental Health Services (OEHS)**. Therefore, OEHS has the same primary drinking water regulation enforcement authority over public water systems within the state as EPA. Local governments should be aware that while secondary drinking water standards are not federally enforceable, individual states may adopt any of the secondary standards as part of their own regulations, thus making them enforceable at the state level.

The EPA establishes and implements the SDWA and its amendments through Title 40 **Code of Federal Regulations (CFR)** Parts 141-142, "**National Primary Drinking Water Regulations (NPDWR)**" and Title 40 CFR Part 143 "**National Secondary Drinking Water Regulations (NSDWR)**." These regulations allow the EPA to enforce federally established drinking water standards by setting goals to ensure the highest quality of drinking water, from the source to the tap.

The EPA establishes health goals based on risk and sets a legal limit, or **maximum contaminant level (MCL)**, to help ensure consistent quality of the water supply. MCLs are established based on known or anticipated adverse health effects, the ability of available technology to remove contaminants, their effectiveness, and the cost of treatment. The limit is based on lifetime exposure and represents the highest permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs have been set for over 90 potential drinking water contaminants, seven of which are new standards enforceable as of January 1, 2002. The NPDWR also codifies other specific requirements of the SDWA, including monitoring and analytical requirements, reporting and record keeping, maximum contaminant level goals (MCLG), filtration and disinfection, control of lead and copper, treatment techniques, and information collection requirements for public water systems. This regulation also provides **best available** treatment **technologies (BAT)**.

Secondary drinking water standards under the NSDWR are established for contaminants that primarily affect aesthetic qualities relating to public acceptance of drinking water. These secondary standards are not federally enforceable, but rather serve as guidelines for state use.

The EPA has drinking water regulations for more than 90 contaminants. The SDWA includes a process the EPA must follow to identify new contaminants which may require regulation in the future. The EPA must periodically release a **Contaminant Candidate List (CCL)**. The EPA uses this list of unregulated contaminants to prioritize research and data collection efforts to help determine whether specific contaminants should be regulated.

In February 2005, the EPA published the second CCL of 51 contaminants and provided an update on the efforts to improve the CCL process for the future that is based, in part, on recommendations from the National Research Council and the National Drinking Water Advisory Council. In addition to making the process used for selecting contaminants easier to understand, the EPA goals for the future are to:

- Evaluate a wider range of information;
- Screen contaminants more systematically; and
- Develop a more comprehensive CCL by expanding the number of contaminants being reviewed for inclusion on the next CCL.

WEST VIRGINIA DRINKING WATER REGULATIONS

West Virginia has received approval from EPA to have primacy authority for enforcing public drinking water regulations at the state level. In other words, OEHS ensures all federal and state drinking water requirements are met. These state regulations can be accessed online at the West Virginia Legislature web site at www.legis.state.wv.us/. The OEHS **Environmental Engineering Division (EED)** Director, Walter Ivey, oversees several programs that make up the WV drinking water program. The following programs function as the multiple barrier approach in West Virginia:

- The **Source Water Assessment &** Wellhead **Protection (SWAP)** Program's mission is to assess, preserve, and protect the state's source waters which are used to supply water for the state's PWSs.
- The **Certification & Training (C&T)** Program provides training and/or testing to PWS operators, wastewater treatment works operators, backflow prevention assembly installers/testers, water well drillers, and monitoring well drillers to administer certifications.
- The **Infrastructure & Capacity Development (I&CD)** Program helps drinking water systems improve their finances, management, infrastructure, and operations so they can provide safe drinking water consistently, reliably, and cost-effectively.
- The **Compliance & Enforcement (C&E)** Program determines whether a PWS is in compliance with all state rules and federal regulations pertaining to the SDWA. Such determination is based on results of the chemical/contaminant monitoring required for each PWS. If a system is out of compliance, a violation is then issued requiring the PWS to do public notification activities to inform the public that here was a problem, what happened, and what they are doing to fix it.
- Data Management enters all data received from the **Monthly Operational Reports (MORs),** bacteriological reports, and chemical reports into a specialized database called **Safe Drinking Water Information System (SDWIS)**. Each PWS monitors and samples their water for various chemicals and contaminants that have the potential to be a public health risk.

The entire WV drinking water program is based in the OEHS central office located at 350 Capitol Street, Room 313 in Charleston, WV 25301-3713. The OEHS central office phone number is (304) 558-2981 and fax number is (304) 558-0139. The OEHS website is http://www.wvdhhr.org/oehs/eed OEHS also has 5 district offices to provide technical and administrative support locally to PWSs across the state:

- **Wheeling District Office** (304) 238-1145
- **Fairmont District Office** (304) 368-2530
- **Kearneysville District Office** (304) 725-0348
- **Beckley District Office** (304) 256-6666
- **St. Albans District Office** (304) 722-0611

The OEHS 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 OEHS 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.

OEHS personnel enforce 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 OEHS 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).

SAFE DRINKING WATER ACT

The **Safe Drinking Water Act (SDWA)** sets permissible levels of substances found in water which could be hazardous to public health. These regulations include 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 OEHS.

The SDWA gives the 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 (NPDWR)** 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 MCLs or **Treatment Techniques (TT's).**

A **National Secondary Drinking Water Regulation (NSDWR)** 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.

A list of all the NPDWRs AND NSDWRs is located in the appendix.

Maximum Contaminant Level (MCL) and Maximum Contaminant Level Goal (MCLG)
A 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 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 BATs, in establishing acceptable levels. BAT refers to the technology currently 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 a **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.

Secondary Maximum Contaminant Levels (SMCLs) which apply to public water systems and which, in the judgment of the Administrator, are requisite to protect the public welfare. The

SMCL means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of public water system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

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:

Time Line	Records
2 years	Copies of Backflow Testing Results
3 years	Records of action to correct violation
3 years	Copies of Public Notices
5 years	Monthly Operational Reports
5 years	Bacteria Analysis
5 years	Records concerning a variance or exemption
10 years	Copies of written reports, summaries, or communications relating to sanitary surveys
10 years	Radiological, chemical and turbidity analysis
12 years	Lead and copper results and reports
Indefinitely	CT Benchmarking and Profiling results

SAFE DRINKING WATER RULES AND REGULATIONS THAT APPLY TO WATER DISTRIBUTION SYSTEMS

SDWA Rule	Risk Type	Overview	Monitoring
Revised Total Coliform Rule	Microbial	Monitoring for coliform as indicator of potential contamination.	Sampling based on population; requires confirmation for positive coliform.
Lead and Copper Rule	Chemical and Radiological	Establishes treatment techniques for corrosion control, source water, and lead service line replacement and public education triggered by levels at consumer taps.	Consumer taps during each 6-month period. Two consecutive periods triggers corrosion control, or reduced monitoring.
Stage 2 Disinfection Byproducts Rule	Chemical and Radiological	Reduce levels of disinfectants and DBPs. Sets MCLs for HAA5s, chlorite, bromate, and TTHMs and MRDL and MRDLG**	1. Monitoring for DBP. 2. For surface water and GWUDI, TOC and alkalinity.
Consumer Confidence Reports		CCR to customers about the quality and health implications of community water supply.	Monitoring and results and violations must be reported.
Public Notification		Divides Notification to Public for violations into 3 tiers: Tier 1-Serious Health Effect-within 12 hours Tier 2-Health Potential-within 30 days Tier 3-Not immediate health impact-one year	Tier monitoring results must be reported to public in timely manner.

WHAT ARE SECONDARY STANDARDS?

The EPA has established National Primary Drinking Water Regulations that set mandatory water quality standards for drinking water contaminants. These are enforceable standards called "maximum contaminant levels" or "MCLs", which are established to protect the public against consumption of drinking water contaminants that present a risk to human health. An MCL is the maximum allowable amount of a contaminant in drinking water which is delivered to the consumer .

In addition, EPA has established National Secondary Drinking Water Regulations that set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these "secondary maximum contaminant levels" or "SMCLs." They are established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor. These contaminants are not considered to present a risk to human health at the SMCL.

Since these contaminants are not health threatening at the SMCL, and public water systems only need test for them on a *voluntary* basis, then why it is necessary to set secondary standards? EPA believes that if these contaminants are present in your water at levels above these standards, the contaminants may cause the water to appear cloudy or colored, or to taste or smell bad. This may cause a great number of people to stop using water from their public water system even though the water is actually safe to drink. Secondary standards are set to give public water systems some guidance on removing these chemicals to levels that are below what most people will find to be noticeable.

There are a wide variety of problems related to secondary contaminants. These problems can be grouped into three categories: *Aesthetic effects* -- undesirable tastes or odors; *Cosmetic effects* -- effects which do not damage the body but are still undesirable; and *Technical effects* -- damage to water equipment or reduced effectiveness of treatment for other contaminants. The secondary MCLs related to each of these effects are given in Table 1.

Aesthetic Effects

Odor and Taste are useful indicators of water quality even though odor-free water is not necessarily safe to drink. Odor is also an indicator of the effectiveness of different kinds of treatment. However, present methods of measuring taste and odor are still fairly subjective and the task of identifying an unacceptable level for each chemical in different waters requires more study. Also, some contaminant odors are noticeable even when present in extremely small amounts. It is usually very expensive and often impossible to identify, much less remove, the odor-producing substance.

- **Standards related to odor and taste:** Chloride, Copper, Foaming Agents, Iron, Manganese pH, Sulfate, Threshold Odor Number (TON), Total Dissolved Solids, Zinc.

Color may be indicative of dissolved organic material, inadequate treatment, high disinfectant demand and the potential for the production of excess amounts of disinfectant by-products. Inorganic contaminants such as metals are also common causes of color. In general, the point of consumer complaint is variable over a range from 5 to 30 color units, though most people find color objectionable over 15 color units. Rapid changes in color levels may provoke more citizen complaints than a relatively high, constant color level.

- **Standards related to color:** Aluminum, Color, Copper, Foaming Agents, Iron, Manganese, Total Dissolved Solids.

Foaming is usually caused by detergents and similar substances when water has been agitated or aerated as in many faucets. An off-taste described as oily, fishy, or perfume-like is commonly associated with foaming. However, these tastes and odors may be due to the breakdown of waste products rather than the detergents themselves.

- **Standards related to foaming:** Foaming Agents.

Cosmetic Effects

Skin discoloration is a cosmetic effect related to silver ingestion. This effect, called argyria, does not impair body function, and has never been found to be caused by drinking water in the United States. A standard has been set, however, because silver is used as an antibacterial agent in many home water treatment devices, and so presents a potential problem which deserves attention.

- **Standard related to this effect:** Silver.

Tooth discoloration and/or pitting is caused by excess fluoride exposures during the formative period prior to eruption of the teeth in children. The secondary standard of 2.0 mg/L is intended as a guideline for an upper boundary level in areas which have high levels of *naturally occurring* fluoride. It is *not* intended as a substitute for the lower concentrations (0.7 to 1.2 mg/L) which have been recommended for systems which *add* fluoride to their water. The level of the SMCL was set based upon a balancing of the beneficial effects of protection from tooth decay and the undesirable effects of excessive exposures leading to discoloration.

- **Standard related to this effect:** Fluoride.

Technical Effects

Corrosivity, and *staining* related to corrosion, not only affect the aesthetic quality of water, but may also have significant economic implications. Other effects of corrosive water, such as the corrosion of iron and copper, may stain household fixtures, and impart objectionable metallic taste and red or blue-green color to the water supply as well. Corrosion of distribution system pipes can reduce water flow.

- **Standards related to corrosion and staining:** Chloride, Copper, Corrosivity, Iron, Manganese, pH, Total Dissolved Solids, Zinc.

Scaling and *sedimentation* are other processes which have economic impacts. Scale is a mineral deposit which builds up on the insides of hot water pipes, boilers, and heat exchangers, restricting or even blocking water flow. Sediments are loose deposits in the distribution system or home plumbing.

- **Standards related to scale and sediments:** Iron, pH, Total Dissolved Solids, Aluminum.

PUBLIC 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.

Public notification (PN) is intended to ensure that consumers will always know if there is a problem with their drinking water. PWSs must notify the people who drink their water if the level of a contaminant in the water exceeds EPA and State drinking water regulations, if there is a waterborne disease outbreak or any other situation that may pose a risk to public health, if the water system fails to test its water as required, or if the system has a variance or exemption from the regulations. Depending on the severity of the situation, water suppliers have from 24 hours to one year to notify their customers. PN is provided in addition to the CCR to provide customers with a more complete picture of drinking water quality and system operations.

EPA sets strict requirements on the form, manner, content, and frequency of public notices. Notices must contain:

- A description of the violation that occurred, including the potential health effects
- The population at risk and if alternate water supplies need to be used
- What the water system is doing to correct the problem
- Actions consumers can take
- When the violation occurred and when the system expects it to be resolved
- How to contact the water system for more information
- Language encouraging broader distribution of the notice

EPA specifies three categories, or tiers, of public notification. Depending on what tier a violation or situation falls into, water systems have different amounts of time to distribute the notice and different ways to deliver the notice:

Tier 1 Public Notice - Required Within 12 Hours
Any time a violation and situation with significant potential to have serious adverse effect on human health as a result of short-term exposure, water suppliers have 12 hours to notify people who may drink the water of the situation. Water suppliers must use media outlets such as television, radio, and newspapers, post their notice in public places, or personally deliver a notice to their customers in these situations.

Examples of Tier 1 Violations:

- Violation of the MCL for total coliform, when fecal coliform or **Escherichia coli (herein referred to as *E. coli*)** are present in the water distribution system, or failure to test for fecal coliform or *E. coli* when any repeat sample tests positive for coliform;

- Violation of the MCL for nitrate, nitrite, or total nitrate and nitrite; or when a confirmation sample is not taken within 24 hours of the system's receipt of the first sample showing exceedance of the nitrate or nitrite MCL;
- Exceedance of the nitrate **MCL** (10 **milligrams per liter (mg/L)**) by non-community water systems, where permitted to exceed the MCL (up to 20 mg/L) by the primacy agency;
- Violations of the **maximum residual disinfection level (MRDL)** for chlorine dioxide when one or more of the samples taken in the distribution system on the day after exceeding the MRDL at the entrance of the distribution system or when required samples are not taken in the distribution system;
- Violation of the turbidity MCL of 1 **nephelometric turbidity unit (NTU),** where the primacy agency determines after consultation that a Tier 1 notice is required or where consultation does not occur in 12 hours after the system learns of violation;
- Violation of the TT requirement resulting from a single exceedance of the maximum allowable turbidity limit, where the primacy agency determines after consultation that a Tier 1 notice is required or where consultation does not take place in 24 hours after the system learns of violation;
- Occurrence of a waterborne disease outbreak, as defined in 40 CFR 141.2, or other waterborne emergency; and
- Other violations or situations with significant potential for serious adverse effects on human health as a result of short term exposure, as determined by the OEHS either in its regulations or on a case-by-case basis.

* If your system has any of these violations or situations, in addition to issuing public notice, you must initiate consultation with your primacy agency as soon as practical but within 12 hours after you learn of the violation or situation.

Tier 2 Public Notice - Required Within 30 Days (unless extended to 90 days by State)
Any time a violation and situation with potential to have serious, but not immediate, adverse effects on human health, water suppliers must supply notices within 30 days, or as soon as possible, with extension of up to three months for resolved violations at the discretion of the OEHS. Notice may be provided via the media, posting, or through the mail.

Examples of Tier 2 Violations:

- All violations of the MCL, MRDL, and TT requirements except where Tier 1 notice is required.
- Violations of monitoring requirements where OEHS determines that a Tier 2 public notice is required, taking into account potential health impacts and persistence of the violation.
- Failure to comply with the terms and conditions of any variance or exemption in place.

Tier 3 Public Notice - Required Within 1 Year
When water systems violate a drinking water standard that does not have a direct impact on human health, for all other violations not included in Tier 1 or Tier 2, the water supplier has up

to a year to provide a notice of this situation to its customers. The extra time gives water suppliers the opportunity to consolidate these notices and send them with annual water quality reports (CCRs).

Examples of Tier 3 Violations:

- Monitoring violations, except where Tier 1 notice is required or the primacy agency determines that the violation requires a Tier 2 notice.
- Failure to comply with an established testing procedure, except where Tier 1 notice is required or the primacy agency determines that the violation requires a Tier 2 notice.
- Operation under a variance granted under §1415 or exemption granted under §1416 of the SDWA.
- Availability of unregulated contaminant monitoring results.
- Exceedance of the secondary maximum contaminant level for fluoride.

Tier Determination

In any of the above situations, the water supplier must notify OEHS as soon as possible for a determination of what Tier applies to a given situation. OEHS 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 OEHS and find out**."

What information must be included in a notice?

Your public notice must include specific information in order to be considered complete. Each notice must contain information addressing ten elements, including use of standard health effects language for MCL and treatment technique violations and standard language for monitoring violations. PWSs serving a large proportion of non-English speaking consumers are also required to include information in the notice in languages other than English.

For each violation and situation requiring notice (except for fluoride **secondary maximum contaminant level (SMCL)** exceedances, availability of unregulated contaminant monitoring data, and operation under a variance or exemption), you must provide a clear and easy-to-understand explanation of the following:

1. The violation or situation, including the contaminant(s) of concern, and (as applicable) the contaminant level(s);
2. When the violation or situation occurred;
3. Any potential adverse health effects from drinking the water, using mandatory language;
4. The population at risk, including subpopulations that may be particularly vulnerable if exposed to the contaminant in their drinking water;
5. Whether alternate water supplies should be used;
6. Actions consumers should take, including when they should seek medical help, if known;
7. What you are doing to correct the violation or situation;
8. When you expect to return to compliance or resolve the situation;
9. Your name, business address, and phone number or those of a designee of the PWS as a source of additional information concerning the notice; and
10. A statement encouraging notice recipients to distribute the notice to others, where applicable, using the standard language.

Some required elements may not apply to every violation or situation. However, you must still address these elements in your notice. For example, if it is unnecessary for consumers to boil their water or drink bottled water, you should tell them they do not need to do so. This is especially important for Tier 2 notices, where a violation may have been resolved by the time the notice is issued or may not be an immediate health risk.

Certification of Compliance

After you provide the notice to your consumers, you must, within 10 days, send OEHS a copy of each type of notice you distribute (e.g., newspaper article, press release to TV/radio, mail notices) and a certification that you have met all the public notification requirements

BOIL WATER NOTICE

Water treatment professionals must regard public health protection as the highest priority. Although every water treatment plant operator strives to produce high quality water, if a test result or a condition exists that may threaten public health, a boil water notice (BWN) must be considered.

Therefore, water professionals must develop BWN criteria and action plans **before** there is a problem, not during a crisis. BWNs require a considerable amount of thought if they are to be carried out in timely fashion. One of the most important aspects of BWN's is determining what circumstances will trigger the event, a few examples are:

- A violation of the total coliform rule;
- Loss of disinfection residuals at the point of entry;
- High filter effluent turbidities;
- Loss of pressure in the distribution system;
- Cross-connection/backflow incidents;
- Major water main breaks; or,
- Breaches in the integrity of water storage facilities.

There is no single perfect action plan for all utilities: each must be tailored to the specific system and situation. It is essential that plant staff focus on the challenge of fixing the problem that prompted the BWA thus protecting public health. Text of the public notification regulation can be found in the EPA Public Notification Handbook, on the OEHS website or by contacting your OEHS district office engineer.

Professional judgment and discretion are necessary in making decisions on the issuance of a notice. The water supplier is advised to consult with the local primacy agency to discuss the criteria for issuing public notices or BWNs. These discussions should include the actual wording and conditions for issuing the advisory.

> **DO NOT DRINK THE WATER WITHOUT BOILING IT FIRST.** Bring all water to a boil, let it boil for one minute, and let it cool before using, or use bottled water. Boiled or bottled water should be used for drinking, making ice, brushing teeth, washing dishes, bathing, and food preparation **until further notice**. Boiling kills bacteria and other organisms in the water.

Once the criteria to issue a BWN have been met, prompt action is necessary. Failure to issue a timely BWN could lead to serious public health, financial, and public relations consequences. Customer confidence may be eroded or elevated depending on the timeliness and accuracy of the information they require. BWNs erode public confidence if they are not issued in time or issued too often.

The June 6, 2009, OEHS Environmental Health Procedures Manual Memorandum DW-23 addresses Boil Water Notices for PWSs. There is also the January 9, 2012 DW-18 *Guidance for Public Facilities Affected by Boil Water Notices.* Both policies are available at http://www.wvdhhr.org/phs/manual/Drinking_Water/index.asp

OPERATOR CERTIFICATION

Operator certification helps protect human health and the environment by establishing minimum professional standards for the operation and maintenance of PWSs. In 1999, EPA issued operator certification program guidelines specifying minimum standards for certification and recertification of the operators of community and nontransient noncommunity PWSs. While the specific requirements vary from state to state, the goal of all operator certification programs is to ensure that skilled professionals are overseeing the treatment and distribution of safe drinking water. Operator certification is an important step in promoting compliance with the SDWA.

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 informational resources 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 OEHS-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 OEHS 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 EW-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) 356-4266 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 oversees information on more than 2,300 certified water operators in addition to wastewater operators, backflow prevention & assembly inspector testers, water well drillers, and monitoring well driller training in West Virginia. It is essential we work together and openly communicate.

Responsibilities of the Public Water System and OEHS

The public water system owner and operator, along with OEHS, work together to make sure that safe drinking water is provided to water system users and that all regulatory requirements are met. Providing safe drinking water requires a team effort from systems, operators, and OEHS.

Responsibilities of the Owner and Operator

The owner of a public water system is responsible for meeting all of the legal requirements that apply to the water supply. An operator is a person who conducts day-to-day operational and technical activities related to the operation of a water supply. Although the owner may designate an operator, the owner is ultimately responsible for providing safe drinking water and meeting regulatory requirements. It is important that both the owner and operator work together to ensure that the water system provides safe drinking water and meets all applicable requirements. **The ultimate goal for both the owner and operator is to provide safe drinking water to the public.**

The owners of public water systems shall:

- Employ a Chief Operator with a certification equal to or higher than the system classification, except for lD PWSs. A PWS may have more than one (1) Chief Operator if jurisdiction is bifurcated between the distribution system and treatment plant or otherwise approved in writing by the Commissioner based upon a written request;
    - In the case of a distribution system not under the direct jurisdiction of the treatment plant Chief Operator, employ an additional Chief Operator with WDS, Class I or higher certification and an adequate number of certified operators to operate the distribution system.
    - Place direct supervision of their PWS, including each treatment facility and distribution system, under the responsible charge of the Chief Operator holding an adequate certification.
- Employee and adequate number of certified operators to operate the system;
- Not employ more OITs than the number of employed certified operators, unless written permission is granted by the Commissioner;
- Notify the Commissioner within twenty-four (24) hours if a certified operator or OIT terminates employment for any reason;
- Submit a personnel status report by July 15 every year. The report is to be in a manner and form approved by the Commissioner and required information includes, at a minimum: a list of all certified operators employed, the Chief Operator, and the system owner;
- Post a copy of the current certification of all certified operators employed at the system in a conspicuous location in the plant or system office.
- The owner of a lD system shall ensure it is operated by a lD, Class I or higher water operator.
- The owner of a WDS system shall ensure it is operated by a WDS, Class I or higher water operator.

Operator's 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, free of harmful bacteria and toxic materials.

A certified operator shall:

- Be responsible for their certification in accordance with all aspects of 64CSR04;
- Carry his or her current certification upon them at all times while operating;
- Not work under the certification of another person;
- Notify the Commissioner at least 30 days prior to quitting (EW-74)
- Comply with 64CSR03; and,

- Demonstrate data integrity by providing complete, accurate & true information;

A chief operator shall:

- Be responsible for the PWS operation;
- Be employed on a full-time basis at Class II-IV PWSs;
- Attend a Chief Operator course within 1 year of role;
- Encourage OIT applicants to submit EW-211 within 30 days of hire with their documentation support since experience gained for certification starts only upon the issued date of the OIT certificate;
- Be responsible for the training and job duty assignments of OITs and other certified operators;

The Commissioner may apply progressive enforcement actions against individual operator certifications such as:

1. Written warning with additional requirement (ie. specified training course(s) such as the Chief Operator or reporting information to OEHS for review)
2. Suspension (ie. 10 day or 30 day)
3. Revocation (reinstate-able after 1 year)
4. Revocation permanent
5. Fine penalty

Enforcement actions will progress with each occurrence unless the severity of action(s) warrants immediate and automatic revocation of operator certification to protect public health. The Commissioner will maintain the authority to suspend or revoke certification when seriousness of the violation merits without a written warning.

PUBLIC WATER SYSTEMS OPERATOR REGULATIONS

Title 64 Legislative Rule Bureau for Public Health Series 4 *Public Water Systems Operators* (64CSR4) governs the examination and certification of operators of public water systems. OEHS regularly reviews and revises this rule to ensure compliance with federal rule and clear, consistent statewide application. 64CSR04 was revised in 2007 and 2002, with the current version effective since May 2, 2012.

OEHS recognizes the importance of professionals in the drinking water industry and looks forward to working with each and every individual operator and system to successfully implement any new requirements on a reasonable timeframe. Please read the current version of 64CSR04 entirely. You can contact our office at 304-558-2981 to discuss these rules or if you would like a copy visit the WV Secretary of State website at http://apps.sos.wv.gov/adlaw/csr/ruleview.aspx?document=2606 Periodic rule review and revision enables West Virginia to retain primary enforcement for the Safe Drinking Water Act. Without the PWS operator regulations administered by the operator certification program, one of the important barriers to preventing contamination of PWS' has been compromised.

CHIEF OPERATOR REQUIREMENTS & RESPONSIBILITIES

Every PWS owner must employ a chief operator with certification equal to or higher than the system classification, except at 1D and Class R systems. A certified chief operator is responsible for the day to day operation of the PWS to ensure the delivery of safe water at all times by complying with all state and federal regulations. The way this is accomplished is by the completing the following tasks. These tasks may vary depending on the size of your system, the type of water source and the complexity of treatment.

- Attend training to meet state primacy agency's continuing education requirements;
- Attend training programs and workshops to keep current of technical improvements;
- Be aware of all changes in regulations regarding water treatment;
- Be available to accompany regulatory officials for on-site inspections when given adequate notice;
- Collect or oversee the collection of water samples as specified by OEHS;
- Communicate with the owner, manager, or board about technical and financial needs of your system;
- Conduct frequent system and security inspections;
- Develop and maintain a plan for monitoring system process controls and meet all related goals;
- Educate other staff on emergency procedures and keep contact information up to date;
- Ensure that all samples are tested by a WVBPH certified lab;
- Ensure that all treatment equipment is maintained and operated properly according to the manufacturers' specifications and recommendations;
- Ensure that daily chemical analyses are properly measured and recorded;
- Ensure that OEHS approval has been obtained prior to starting treatment or changing chemical types and/or manufacturers;
- Inspect critical facilities and components, including door locks and fencing, as part of daily inspections;
- Inspect, flush, clean and disinfect the water distribution system as needed per OEHS regulations;
- Investigate water quality and quantity problems and take corrective measures as needed in a timely manner;
- Keep accurate operational records;
- Keep accurate records of repairs and routine maintenance performed on the treatment equipment;
- Keep accurate records of water analyses, repairs, maintenance and correspondence;
- Make all chemical adjustments and add all chemicals when necessary;
- Measure and record all chemical dosage rates as needed;
- Maintain a consumer complaint log, including how complaints are resolved;
- Oversee and monitor all repairs performed on the public water system;
- Review all water quality analyses for completeness prior to submission to OEHS;
- Report all violations to OEHS and issue public notices when needed;
- Update system maps when a significant change to the distribution system has been made; and,

- Utilize appropriate safety equipment.

Chief operators are also responsible for training of any Operators-in-Training (OITs) at their system. The Chief Operator must review and sign the OIT application (EW-211) recommended within 30 days of new employee hire as well as document in writing when the OIT has sufficient work experience to upgrade to a WD or Class I operator. Certified experience is the only experience counted towards upgrade so it is important to ensure all operators or individuals employed by the system conducting operator duties are currently certified. PWSs may not employ more OITs than the number of currently employed certified operators, unless written permission is granted by OEHS.

RENEWAL AND CERTIFICATION REQUIREMENTS

All operator certifications require renewal every 2 years. Although this is not new for all certifications, it adds clarification that OITs are also renewable. The experience requirements for all certifications are now measured in hours instead of years to help improve proper credit with a variety of employment schedules. For example, instead of 1 year (assuming full time) experience, it is listed as 2,000 hours for a Class I operator.

Federal guidelines require continuing education for all certified operators. The regulations require all certified operators (except 1D) continue to receive training related to water treatment and distribution to promote continued learning and professionalism, more efficient operation, and a better understanding of emerging technologies and trends.

OIT minimum education requirements can be waived by the Commissioner, in writing, to a minimum age of 16 and completion of the 10th grade with a current school transcript and 2.0/4.0 grade point average. The intent of this is to allow interested students to receive water treatment related training earlier in their academic career paths and help promote awareness of the water treatment field.

OIT applicants must submit their renewal application at least 30 calendar days prior to their certificate's expiration date, in a manner approved by the Commissioner. The OIT shall attempt to pass the Class WD or I examination at least once during each 2 year renewal. The intent of the OIT CEH requirement is that if the OIT cannot pass the exam, CEHs may help them pass the next time around.

Class WD operators must obtain 6 hours of continuing education hours, Class I operators must obtain 12 hours of continuing education hours, and Class II through IV must obtain 24 hours of continuing education hours for renewal.

Certified operators who qualify for Class WD certification in addition to a current Class I or higher certification shall hold the certifications concurrently, but only maintain the renewal requirements for the highest certification held.

The regulations also clarify that it is the duty of each certified operator to obtain the necessary amount of appropriate CEHs and retain documentation of attendance required for the renewal application. All certified operators must now ensure renewal applications are submitted no earlier than 60 days prior to expiration, in addition to the previous requirements, to facilitate proper data management and timely processing.

Keep in mind, **all operator certification requirements are based on federal and state regulations to ultimately protect public health.** Each certified PWS operator is responsible in providing adequate supply of safe, potable drinking water to consumers who are confident their water is safe to drink. It is essential these operators not only achieve these minimum requirements for certification but continue to gain knowledge and acknowledge the public health foundation of their career choice in the drinking water industry. Please contact the Certification and Training Program at any time to discuss any aspect of the operator certification program.

OPERATOR FORMS

Remember all forms must be complete, legible, signed and dated, and timely with all required documents attached (copy of diploma, CEH certificates, etc.) for processing. Also remember to use the most current version of each form. All forms are available on the OEHS website at http://www.wvdhhr.org/oehs/eed/swap/training&certification/forms.asp or by phone request from the Certification and Training Program at (304) 356-4335.

- EW-102 Request for Water or Wastewater Operator Certification Exam
- EW-211 Request for Water Operator Certification
- EW-212 Request for Water or Wastewater Operator Certification Renewal
- EW-104 Personnel Status Report
- EW-74 Water or Wastewater Operator Resignation Notice
- EW-126 Request for Certification Reinstatement
- EW-108 Request for Water or Wastewater Operator Certification from Another Jurisdiction
- EW-76 Request to be Included on the West Virginia's Contract Operator List
- EW-75 Request for Backflow Prevention Assembly Inspector/Tester (BPAIT) Certification
- EW-78 Operator Continuing Education Hour (CEH) Application

GUIDANCE FOR CERTIFIED WATER OPERATORS

OEHS Certification and Training (C&T) Program staff takes pride in reviewing and processing each operator application based on quality, timeliness, and fulfillment of all current certification regulation requirements. However, if applications are incomplete or required information is not submitted or is illegible, our job is more difficult and timeliness of your certification is reduced. By adhering to the following guidelines, initial certification or renewal will proceed more effectively.

1. Know the rules and regulations for your profession and how to receive and maintain your certification(s). This includes knowledge of education and experience requirements and associated timelines. West Virginia Administrative Rules, Title 64 Series 4, *Public Water Systems Operator Regulations* are available online from the Secretary of State website at http://www.wvsos.com/csr/verify.asp?TitleSeries=64-04. If you have any questions on these regulations, contact C&T for clarification.

2. Know the proper forms required to initially become certified and renew your certification (if required). Knowing what forms to use and having them available in your work area will facilitate meeting the required timelines. All current forms are available on our website at www.wvdhhr.org/oehs/eed/swap/training&certification/forms.asp or by calling us at (304) 558-6988 or (304) 558-6991. Always read carefully and complete the forms in their entirety, which includes a signature and date for proper documentation.

3. Make sure any classes you take toward certification upgrade or renewal are already approved by OEHS. All classes must be approved by the Commissioner and attendance documented by the operator before OEHS will accept the continuing education hours (CEHs) for operator renewal requirements. A list of approved classes is available on our website at www.wvdhhr.org/oehs/eed/i&cd/education_index.asp or by calling C&T at (304) 558-6988. All approved CEHs have a unique, 7-digit CEH number. Taking unapproved classes and failing to provide class certificates upon completion may result in the need for you to take additional classes and delay processing your application. **Contact the instructor or their supervisor if you have not received appropriate certificates with the corresponding approved CEH number and course title for all of your training.**

4. Do not procrastinate on taking classes for renewal. Hundreds of classes have been approved, some indefinitely. By waiting until the last few months before your renewal, you increase the chance of the class being full, cancelled, possible sickness on your part, having to stay at work due to problems, etc. There are two (2) years in between certification renewals for water plant operators and three (3) years between certification renewals for Class III and IV wastewater operators. Requesting extensions for more time to obtain required continuing education is unacceptable and indicates poor career management on your part.

5. Share good information. The articles you are reading often contain valuable information. Please ensure it is reviewed by staff and coworkers.

In Short:

1. Know the rules and regulations for your profession.
2. Use the correct form (s) and make sure they are complete and timely.

3. Take approved CEH classes and contact the instructor(s) for appropriate certificates.
4. Do not procrastinate on obtaining your renewal training.
5. Information is out there for all of you, take advantage of it and manage your careers appropriately.

By following the above guidance, C&T can provide timely certifications and renewals for everyone. Please contact us with any questions or concerns at any time. We oversee approximately 4,000 individual certifications, which are each unique, personal, and very important. Open communication is essential in facilitating all operator certification needs and ultimately protecting drinking water.

PUBLIC WATER SYSTEMS IN WEST VIRGINIA

The jurisdiction of the drinking water program at the OEHS applies only to PWSs, 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 PWS and subject to the regulations of the SDWA.

West Virginia has over 1,100 active PWSs. This number constantly changes and varies year to year. Approximately 90% of all PWSs use groundwater, while only 10% use a surface water or groundwater under the direct influence of surface water source. However, this low number of surface water source PWSs serve large population centers such as the cities of Charleston, Morgantown, Huntington, and Clarksburg.

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. 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.

There are three categories of PWSs: **Community Water System (CWS); Non Transient Non Community Water System (NTNCWS; and, Transient Non Community Water System (TNCWS).** 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 **(TNCWS) 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.

PWSs are further classified into 6 distinct categories (1D, WD, or Class I, II, III or IV) to ensure each is regulated according to its population served, source water, and treatment complexity.

Purpose of Public Water Systems

The main purpose of PWSs is to provide water safe for human consumption. Other important purposes are to provide an adequate quantity of water of acceptable taste, odor and appearance; and meet the needs of fire protection. Providing water service places owners and operators of water systems under an ethical and legal obligation to meet these needs.

Most people in the U.S. take safe, inexpensive drinking water for granted. We assume all water that comes from a tap is okay to drink, whether in a restroom, a gas station or a friend's home. Few of us realize the planning, monitoring, repair and maintenance required to obtain and protect adequate amounts of safe water.

Acute and Chronic Health Effects

These requirements are meant to protect the public from contaminants that may cause acute or chronic health effects.

Contaminants that may have an immediate impact on health after drinking small amounts of water must be dealt with in all public water systems. These are contaminants that cause acute health effects. Examples are disease-causing organisms and nitrates.

Contaminants that cause health effects if consumed over long periods of time must be dealt with in systems where the same residential or non-residential consumers have access to the water on a long-term basis. These are contaminants that cause chronic health effects. Examples include cancer-causing chemicals and chemicals affecting the nervous system or kidneys.

Responsibilities of Public Water Systems

Today with increasing regulatory requirements brought about with the 1996 Amendments to the SDWA, public water systems in West Virginia are finding themselves facing many challenges. Along with the increasing responsibilities in the area of treatment and compliance, there is also the issue of source water protection. Achieving and maintaining financial, technical, and managerial capacity is critical for public water systems. Capacity Development is a concept stated in the 1996 SDWA Amendments that pertains to the successful management and operation of a public water system. This concept illustrates the overlapping influence that each of these areas has upon the other. Capacity Development further implies that there is no static endpoint to success. That is, water systems must strive daily to do the best possible job in technical, financial, and managerial endeavors.

Given the increasing regulatory requirements and scarcity of resources that often exist with small systems, it is more important than ever to make certain that individuals directing and operating these systems have a thorough understanding of their system's operation. The basic responsibility of a water system is to furnish customers with potable drinking water that meets or exceeds customer demands. This responsibility is shared by every member of the utility’s work force, from managers to operators and from clerical staff to field employees. Every member of the team should be aware of their duties and report any condition to the next in command that has the potential to adversely effect the system’s ability to produce safe clean drinking water.

PUBLIC WATER SYSTEM CLASSIFICATION

The classification of PWS is determined by a descriptive definition based on source, population served, and treatment requirements. In general, the system complexity will continue to determine the required operator classification. All PWS classifications are reviewed as part of the sanitary survey conducted by District Office staff. This timeframe enables existing staff to reevaluate each system. Exceptions to this schedule will be made if requested in writing or if other problems arise. If reclassification occurs, systems must communicate with OEHS to ensure proper operator coverage. OEHS recommends operators at systems likely to change to start training and working towards the appropriate classification.

Class 1D
A transient non-community PWS that has groundwater only as a source, and does not use gaseous chlorine or chlorine dioxide as a means of disinfection, and does not treat for the removal of nitrate or nitrite, or both. A groundwater source that uses gaseous chlorine, chlorine dioxide as a means of disinfection or has treatment for removal of nitrate or nitrite, or both is at least a Class I PWS.

Water Distribution (WDS)
A PWS that obtains all of its water from another PWS, and is not owned or operated by the supplying PWS. A WDS does not have any other source of water other than water from the supplying PWS. A WDS may apply chorine for supplemental disinfection but otherwise does not treat its water. A WDS that retreats with anything other than chlorine is at least a Class I PWS.

Class I
A community or non-transient non-community PWS with a GW source that serves a population of less than ten thousand (10,000), including consecutive connection population and does not treat for an identified primary contaminant. A transient non-community PWS that has a groundwater source that uses gaseous chlorine, chlorine dioxide as a means of disinfection or has treatment for removal of nitrate or nitrite, or both.

Class II
A community or non-transient non-community PWS with:

- A GW source that serves a population of less than ten thousand (10,000), including consecutive connections, and either treats for an identified primary contaminant, or has a treatment technique as identified in 40CFR141.73;
- A GW source that serves a population of at least ten thousand (10,000), including consecutive connections that does not treat for an identified primary contaminant; or,
- A GUDI or SW source that serves a population of less than ten thousand (10,000), including consecutive connections.

Class III
A community or non-transient non-community PWS with:

- A GW source that serves a population of greater than ten thousand (10,000), including consecutive connections, and either treats for an identified primary contaminant, or has a treatment technique as identified in 40CFR141.73; or,

- A GUDI or SW source that serves a population of at least ten thousand (10,000), but less than twenty thousand (20,000), including consecutive connections.

Class IV
A community or non-transient non-community PWS with a GUDI or SW source that serves a population of at least twenty thousand (20,000), including consecutive connection population, and has treatment.

PWS REGULATIONS

Regulations affecting PWSs cover a wide range of subjects. The following are the main areas which concern drinking water:

- Monitoring and reporting requirements that deal with water quality, treatment, and public communication;
- Operator certification requirements; and,
- Minimum design standards and the plan review and approval process to ensure water system components are adequately sized and properly installed.

Purpose of PWS Regulations
Regulations governing PWSs serve the primary purpose is to ensure reasonable protection of the health of people who consume the water. Public health protection is obtained by:

- Setting **maximum contaminant levels (MCLs)** for certain contaminants which may not be exceeded by a PWS;
- Ensuring monitoring for contaminants is done in a reasonable fashion; and,
- Requiring treatment be installed to remove contaminants to below levels specified by their MCL.

The MCL for each contaminant is the enforceable drinking water standard, or primary standard. It is based on a **maximum contaminant level goal (MCLG)**, a level below which no adverse health effects are expected to occur from drinking contaminated water. MCL's are set as close to the MCLG's as possible, taking costs and technology into consideration.

For a PWS using groundwater, public health protection includes the following steps:

- Selection of the best source or source location for the water supply;
- Development and implementation of a source water protection plan;
- Providing adequate treatment to remove or eliminate contaminants;
- Monitoring water quality to check the effectiveness of treatment or the occurrence of contaminants;
- Providing sanitary surveys to identify deficiencies which might impact water quality or service; and
- Reporting to the public any contamination events, monitoring failures, or water treatment deficiencies.

Proper design and construction of your water system has a critical role in public health protection. It is also an expensive process regardless of the size of the system. The money you spend is protected if your system is constructed, operated and managed so that it is able to provide safe water for as long as possible. Monitoring water quality indicates if part of the system has failed, is leaking or is exposed to conditions which may shorten its useful life. Conditions which may affect the life of pipe include very hard water which might plug pipes, or corrosive water which “eats away” at the interior of pipes and tanks.

PERMITS

Your water systems may need a permit to have alterations or extensions. These permits must be approved by OEHS prior to initiation of any construction. A permit is an application, which when approved by the Director, gives the applicant permission to complete a task. To minimize contamination, the pumps, pipes, and tanks need to be the right size and strength. Standard treatment processes must also be adequate to address specific system needs. No person may construct, alter, renovate or award a contract for any construction, alteration or renovation of a PWS without obtaining a permit from the Director. This includes addition of any treatment systems, main extensions, or replacing a pipe with a different size or type of pipe than was originally there. The permit is valid for 2 years from the date of issuance. Approval is not needed for repair or replacement of system components as long as the new parts are the same. Plans and specifications submitted to OEHS must meet the state design standards (64SCR77). Copies of the minimum standards are included in the appendix along with all state standards.

Requirements to obtain a permit:

- Apply for the permit on form EW-100.
- Application fee of $300.00, payable to the WVBPH.
- All work must be signed and directed by a professional engineer (PE).

Another standard of particular importance ensures well construction is performed by a certified water well driller for any new water well (64CSR19 and 64CSR46). By following these rules and regulations, WV certified water well drillers are required to obtain a permit to construct a well and following guidelines while constructing the well. The WV DHHR form *Application for a Permit to Construct, Modify or Abandon a Water Well* (SW-256) must be completed and submitted to the local county health department. Guidelines concerning well depth, grouting, and casing material are important to the protection of the quality of the source water. Engineers and other professional staff at OEHS can answer most of your questions on the phone.

MONITORING AND REPORTING

Monitoring for possible contaminants is the process of sampling the water and submitting the samples to a certified laboratory for analysis. Reporting refers to either submitting results of analyses to OEHS or submitting proof of other action, such as issuing a required public notice. Details on monitoring and reporting requirements are not given here. This section provides a discussion of the purpose for and overview of the major monitoring and reporting requirements.

Microbiological Quality Monitoring and Reporting

Disease-causing (pathogenic) organisms can be in found in all water. There are many bacteria, viruses and protozoans known to be able to cause disease if ingested. As a group, they are often referred to as “microbes”, since they are very small and cannot be seen without a microscope. Microbiological quality refers to the presence or absence of microbes in the water.

Some common types of microbes you may be familiar with include organisms that cause cholera (a bacteria), hepatitis (a virus), and giardiasis (a protozoan). Analytical methods do not exist to allow monitoring for every individual disease-causing agent that might contaminate your water. Instead, we rely on monitoring for indicator bacteria which indicate water may be contaminated. The indicator bacteria used for all water systems is a group called coliform bacteria. Coliform bacteria, while not typically disease-producers themselves, are often associated with pathogenic organisms. They are an indicator of the degree of microbiological safety of the water. They commonly come from soil or the fecal material (stools or manure) of warm-blooded animals. Coliforms survive longer in the environment than most disease-causing organisms, making them useful in determining if a contamination event might have occurred.

Quarterly monitoring for bacteriological (Bac-T) samples is looking for total coliform bacteria. If total coliforms are found in the water, the bacteria are further analyzed to determine if they are also *E. coli*. *E. coli* are a specific subgroup of total coliforms which grow only at body temperature of warm-blooded animals. They are used to indicate if fecal contamination of water is more likely to have recently occurred. Microbiological quality monitoring has three important components:

1. Scheduled quarterly monitoring;
2. Repeat sample collection; and
3. Use of a sampling site plan.

You must collect quarterly samples. The sample locations must be rotated to one of the places designated on the sampling site plan so the entire distribution system (or building if the system is in a single building) is covered.

Repeat Samples are collected if a routine sample comes back with an unsatisfactory result - this means coliform bacteria were detected. These samples are often referred to as “positive”. Repeat samples are intended to confirm the occurrence of a contamination event. You must collect repeat samples within 24 hours of being notified the routine sample was “Positive” and before any adjustment is made to the treatment system. The intent is to determine if water already in the PWS is contaminated. Of course, if you find a problem in the system, such as a dead bird in a storage tank or the well cap off of a well casing, you need to notify OEHS and correct the problem as soon as possible. Repeat samples will still be required, however, and public notice may still be necessary to inform consumers of the problem.

Within 24 hours of learning of a total coliform-positive ROUTINE sample result, 4 REPEAT samples must be collected and analyzed for total coliforms:

- One REPEAT sample must be collected from the same tap as the original sample.
- One REPEAT sample must be collected within five service connections upstream.
- One REPEAT sample must be collected within five service connections downstream.
- Systems that collect 1 ROUTINE sample per month or fewer must collect a 4th REPEAT sample.

If any REPEAT sample is total coliform-positive:

- The system must analyze that total coliform-positive culture for fecal coliforms or *E.coli*.
- The system must collect another set of REPEAT samples, as before, unless the MCL has been violated and the system has notified the state.

A positive ROUTINE or REPEAT total coliform result requires a minimum of five ROUTINE samples be collected the following month the system provides water to the public unless waived by the state.

Single Service Connections and Where to Sample

Systems with only one service connection can choose repeat sample locations in order to determine if the contamination is localized. Unless otherwise authorized by District Office, systems with a single service connection should collect all repeat samples the same day, even if it means they are collected from the same tap in rapid succession. Upon special request, the District Office may allow systems with a single service connection to collect the required set of repeat samples over a four-day period.

Sampling site plans are prepared by the owner or operator of a PWS. They are simple maps of the water source, storage and distribution system. The sampling site plans are used to identify where routine and repeat samples will be collected. Each site should have a specific name and that name should be used on the report forms sent in with the water samples. Copies of the sampling site plans must be submitted to OEHS. Sampling site plans are extremely helpful when discussing microbiological monitoring results with OEHS staff, identifying chronic problem areas, and conducting sanitary surveys and other inspections.

Special purpose samples may be collected at any time to investigate system microbiological water quality. They are useful for checking on potential problem areas, as a response to consumer complaints, or to verify a new or repaired main has been adequately disinfected and is ready to return to service. Special purpose samples can be collected in addition to routine or replacement monitoring samples. **Special purpose samples must be clearly marked as such on the sample report form submitted with the water sample to the laboratory.**

Results of all microbiological quality samples must be submitted to OEHS. Certified laboratories must perform coliform analyses. **It is the responsibility of the owner or operator to send OEHS a copy of the results by the 10th day of the next month.** For example, results must be submitted by February 10th for samples collected in January. If the results are not received your system will receive a violation for failing to monitor. This shows how important it is to keep copies of all laboratory results. In West Virginia, copies of all microbiological monitoring results must be kept for a minimum of 5 years.

Chemical Contaminant Monitoring and Reporting
All PWSs must monitor for nitrates and nitrites. These chemicals at levels above the MCL can cause a condition called methemoglobinemia, or "blue baby syndrome". This is a condition in which blood is unable to transmit oxygen to the body, so the body appears to be blue. It is a serious threat to infants and pregnant mothers.

Chemical contaminants differ from biological contaminants in that they can each be identified using specific test methods. Chemical contaminants which cause acute health effects are monitored more frequently, such as nitrates which are typically required to be monitored annually. Chemical contaminant monitoring requirements differ for each system based on the system's monitoring history and vulnerability. Please refer to the Monitoring Schedule below for specific information. It is therefore the responsibility of the system owner/operator to be sure the results are mailed to OEHS by the 10th of the next month.

MONITORING SCHEDULES

TESTING/PARAMETER	**HOW OFTEN & WHERE**
BACTERIOLOGICAL	Once/3 months in the distribution system
FREE CHLORINE RESIDUAL	Once/day at end of contact tank
TOTAL CHLORINE RESIDUAL	Once/day in distribution system*
NITRATES	Once/year at the point of entry
NITRITES	Once at the point of entry**
MORS	Monthly/send to OEHS by the 10th of month
CROSS-CONNECTION DEVICES	Tested annually

*Total chlorine residuals must be analyzed and recorded with bacteriological samples.
**If 1st sample is less than 1 mg/L, no further samples are required.

Chlorine Residual Monitoring and Reporting
West Virginia requires some form of chlorine to be used during disinfection, in order**, to maintain the required 0.2 mg/L of total chlorine residual in the distribution system**. West Virginia requires a 4-log removal/inactivation of viruses for groundwater systems.

When your system is adding chlorine, you must ensure the treatment system is running properly and is adding enough chlorine to kill any pathogenic organisms which may be present. This means daily monitoring of the free chlorine residual (usually at the contact tank) and the total chlorine residual in the system. The chlorine should be from representative taps in the system. A colorimetric test kit using the DPD method is commonly used for testing the chlorine residual. The chlorine sampling sites must be rotated to cover the entire system each week. Chlorine disinfection is discussed later in the manual.

The important message here is that the you must monitor the performance of the disinfection system and report the results to OEHS. Chlorine residuals are reported on the monthly form EW-103. Copies of this form must be made and retained by the system and the original is sent to OEHS by the 10th of the next month. **The original must be signed in ink.**

Secondary Contaminants and Aesthetic Concerns

In addition, EPA has established National Secondary Drinking Water Regulations that set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these **secondary maximum contaminant levels (SMCLs)**. They are established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor. These contaminants are not considered to present a risk to human health at the SMCL.

Since these contaminants are not health threatening at the SMCL, and public water systems only need test for them on a *voluntary* basis, then why it is necessary to set secondary standards? EPA believes that if these contaminants are present in your water at levels above these standards, the contaminants may cause the water to appear cloudy or colored, or to taste or smell bad. This may cause a great number of people to stop using water from their public water system even though the water is actually safe to drink. Secondary standards are set to give public water systems some guidance on removing these chemicals to levels that are below what most people will find to be noticeable.

There are a wide variety of problems related to secondary contaminants. These problems can be grouped into three categories: *Aesthetic effects* -- undesirable tastes or odors; *Cosmetic effects* -- effects which do not damage the body but are still undesirable; and *Technical effects* -- damage to water equipment or reduced effectiveness of treatment for other contaminants.

Secondary Contaminant Levels

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

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.

Iron and manganese are often controllable with a sequestering agent or a polyphosphate chemical such as AquaMag or Calciquest or K5. This agent binds them in a form that will not cause staining, although they are not removed from the water.

Hydrogen Sulfide (H_2S)

Although H_2S gas is associated with groundwater supplies more often that 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 H_2S 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 H_2S odor.

H_2S is a corrosive gas that forms sulfuric acid, which is corrosive to metals such as iron, steel, copper and brass.

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.

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 ($CaCO_3$) scale in hot water heaters and boilers. Low hardness contributes to the corrosive tendencies of water. 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.

Water hardness is expressed in **milligrams per liter (mg/L)** of $CaCO_3$. mg/L is equivalent to **parts per million (ppm)**.

Who Can Help?

OEHS staff are a valuable resource for owners and operators looking into options for controlling these problems. Remember, even if the contaminant is not regulated, you should consult with your District Engineer before adding any other chemicals.

Monitoring Schedules

OEHS has developed a chart which identifies specific monitoring needs for your system. The chart covers microbiological monitoring, nitrate, and other chemical contaminants. Each public water system is strongly encouraged to contact the OEHS to obtain the most up-to-date version of the chart for their system. It will indicate the most recent monitoring results on record, and subsequent samples that must be collected.

Sample Collection and Analysis

Certified laboratories must be used for all microbiological and nitrate and nitrite samples. Certified laboratories are licensed by the state of West Virginia. A list of all certified laboratories is available from **West Virginia Office of Laboratory Services (OLS)**, www.wvdhhr.org/labservices or 304-558-3530. Certified operators must collect all microbiological samples for compliance sampling. If required for the laboratory, they must also take all measurements for pH, temperature, turbidity, and residual disinfectant (chlorine) concentration. As a reminder, it is up to the water system owner/operator to be sure all monitoring results are reported to OEHS. Sometimes it can be arranged with the laboratory to have results sent directly to OEHS. In other situations, the system must make copies and send the results to OEHS by the 10th on the next month.

PUBLIC 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.

Public notification (PN) is intended to ensure that consumers will always know if there is a problem with their drinking water. PWSs must notify the people who drink their water if the level of a contaminant in the water exceeds EPA and State drinking water regulations, if there is a waterborne disease outbreak or any other situation that may pose a risk to public health, if the water system fails to test its water as required, or if the system has a variance or exemption from the regulations. Depending on the severity of the situation, water suppliers have from 24 hours to one year to notify their customers. PN is provided in addition to the CCR to provide customers with a more complete picture of drinking water quality and system operations.

EPA sets strict requirements on the form, manner, content, and frequency of public notices. Notices must contain:

- A description of the violation that occurred, including the potential health effects
- The population at risk and if alternate water supplies need to be used
- What the water system is doing to correct the problem
- Actions consumers can take
- When the violation occurred and when the system expects it to be resolved
- How to contact the water system for more information
- Language encouraging broader distribution of the notice

EPA specifies three categories, or tiers, of public notification. Depending on what tier a violation or situation falls into, water systems have different amounts of time to distribute the notice and different ways to deliver the notice:

Tier 1 Public Notice - Required Within 12 Hours
Any time a violation and situation with significant potential to have serious adverse effect on human health as a result of short-term exposure, water suppliers have 12 hours to notify people who may drink the water of the situation. Water suppliers must use media outlets such as television, radio, and newspapers, post their notice in public places, or personally deliver a notice to their customers in these situations.

Examples of Tier 1 Violations:

- Violation of the MCL for total coliform, when fecal coliform or **Escherichia coli (herein referred to as *E. coli*)** are present in the water distribution system, or failure to test for fecal coliform or *E. coli* when any repeat sample tests positive for coliform;

- Violation of the MCL for nitrate, nitrite, or total nitrate and nitrite; or when a confirmation sample is not taken within 24 hours of the system's receipt of the first sample showing exceedance of the nitrate or nitrite MCL;
- Exceedance of the nitrate **MCL** (10 **milligrams per liter (mg/L)**) by non-community water systems, where permitted to exceed the MCL (up to 20 mg/L) by the primacy agency;
- Violations of the **maximum residual disinfection level (MRDL)** for chlorine dioxide when one or more of the samples taken in the distribution system on the day after exceeding the MRDL at the entrance of the distribution system or when required samples are not taken in the distribution system;
- Violation of the turbidity MCL of 1 **nephelometric turbidity unit (NTU),** where the primacy agency determines after consultation that a Tier 1 notice is required or where consultation does not occur in 12 hours after the system learns of violation;
- Violation of the TT requirement resulting from a single exceedance of the maximum allowable turbidity limit, where the primacy agency determines after consultation that a Tier 1 notice is required or where consultation does not take place in 24 hours after the system learns of violation;
- Occurrence of a waterborne disease outbreak, as defined in 40 CFR 141.2, or other waterborne emergency; and
- Other violations or situations with significant potential for serious adverse effects on human health as a result of short term exposure, as determined by the OEHS either in its regulations or on a case-by-case basis.

* If your system has any of these violations or situations, in addition to issuing public notice, you must initiate consultation with your primacy agency as soon as practical but within 24 hours after you learn of the violation or situation.

Tier 2 Public Notice - Required Within 30 Days (unless extended to 90 days by State)
Any time a violation and situation with potential to have serious, but not immediate, adverse effects on human health, water suppliers must supply notices within 30 days, or as soon as possible, with extension of up to three months for resolved violations at the discretion of the OEHS. Notice may be provided via the media, posting, or through the mail.

Examples of Tier 2 Violations:

- All violations of the MCL, MRDL, and TT requirements except where Tier 1 notice is required.
- Violations of monitoring requirements where OEHS determines that a Tier 2 public notice is required, taking into account potential health impacts and persistence of the violation.
- Failure to comply with the terms and conditions of any variance or exemption in place.

Tier 3 Public Notice - Required Within 1 Year
When water systems violate a drinking water standard that does not have a direct impact on human health, for all other violations not included in Tier 1 or Tier 2, the water supplier has up

to a year to provide a notice of this situation to its customers. The extra time gives water suppliers the opportunity to consolidate these notices and send them with annual water quality reports (CCRs).

Examples of Tier 3 Violations:

- Monitoring violations, except where Tier 1 notice is required or the primacy agency determines that the violation requires a Tier 2 notice.
- Failure to comply with an established testing procedure, except where Tier 1 notice is required or the primacy agency determines that the violation requires a Tier 2 notice.
- Operation under a variance granted under §1415 or exemption granted under §1416 of the SDWA.
- Availability of unregulated contaminant monitoring results.
- Exceedance of the secondary maximum contaminant level for fluoride.

Tier Determination

In any of the above situations, the water supplier must notify OEHS as soon as possible for a determination of what Tier applies to a given situation. OEHS 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 OEHS and find out**."

What information must be included in a notice?

Your public notice must include specific information in order to be considered complete. Each notice must contain information addressing ten elements, including use of standard health effects language for MCL and treatment technique violations and standard language for monitoring violations. PWSs serving a large proportion of non-English speaking consumers are also required to include information in the notice in languages other than English.

For each violation and situation requiring notice (except for fluoride **secondary maximum contaminant level (SMCL)** exceedances, availability of unregulated contaminant monitoring data, and operation under a variance or exemption), you must provide a clear and easy-to-understand explanation of the following:

11. The violation or situation, including the contaminant(s) of concern, and (as applicable) the contaminant level(s);
12. When the violation or situation occurred;
13. Any potential adverse health effects from drinking the water, using mandatory language;
14. The population at risk, including subpopulations that may be particularly vulnerable if exposed to the contaminant in their drinking water;
15. Whether alternate water supplies should be used;
16. Actions consumers should take, including when they should seek medical help, if known;
17. What you are doing to correct the violation or situation;
18. When you expect to return to compliance or resolve the situation;
19. Your name, business address, and phone number or those of a designee of the PWS as a source of additional information concerning the notice; and
20. A statement encouraging notice recipients to distribute the notice to others, where applicable, using the standard language.

Some required elements may not apply to every violation or situation. However, you must still address these elements in your notice. For example, if it is unnecessary for consumers to boil their water or drink bottled water, you should tell them they do not need to do so. This is especially important for Tier 2 notices, where a violation may have been resolved by the time the notice is issued or may not be an immediate health risk.

Certification of Compliance
After you provide the notice to your consumers, you must, within 7 days, send OEHS a copy of each type of notice you distribute (e.g., newspaper article, press release to TV/radio, mail notices) and a certification that you have met all the public notification requirements.

Cross-Connection Control
Cross-connections are connections between a PWS and a non-potable system in such a manner that a flow of water or contamination into the PWS could occur. The “other” water system could be sewage piping or a nonpublic water source such as a private well. Examples of common cross-connections are animal watering hoses left submerged in stock watering tanks, and frost-free hydrants installed on the top of well casings. Cross-connection control programs are very important for drinking water systems. They are covered in later in this manual.

BOIL WATER NOTICE

Water treatment professionals must regard public health protection as the highest priority. Although every water treatment plant operator strives to produce high quality water, if a test result or a condition exists that may threaten public health, a boil water notice (BWN) must be considered.

Therefore, water professionals must develop BWN criteria and action plans **before** there is a problem, not during a crisis. BWNs require a considerable amount of thought if they are to be carried out in timely fashion. One of the most important aspects of BWN's is determining what circumstances will trigger the event, a few examples are:

- A violation of the total coliform rule;
- Loss of disinfection residuals at the point of entry;
- High filter effluent turbidities;
- Loss of pressure in the distribution system;
- Cross-connection/backflow incidents;
- Major water main breaks; or,
- Breaches in the integrity of water storage facilities.

There is no single perfect action plan for all utilities: each must be tailored to the specific system and situation. It is essential that plant staff focus on the challenge of fixing the problem that prompted the BWA thus protecting public health. Text of the public notification regulation can be found in the EPA Public Notification Handbook, on the OEHS website or by contacting your OEHS district office engineer.

Professional judgment and discretion are necessary in making decisions on the issuance of a notice. The water supplier is advised to consult with the local primacy agency to discuss the criteria for issuing public notices or BWNs. These discussions should include the actual wording and conditions for issuing the advisory.

> **DO NOT DRINK THE WATER WITHOUT BOILING IT FIRST.** Bring all water to a boil, let it boil for one minute, and let it cool before using, or use bottled water. Boiled or bottled water should be used for drinking, making ice, brushing teeth, washing dishes, bathing, and food preparation **until further notice**. Boiling kills bacteria and other organisms in the water.

Once the criteria to issue a BWN have been met, prompt action is necessary. Failure to issue a timely BWN could lead to serious public health, financial, and public relations consequences. Customer confidence may be eroded or elevated depending on the timeliness and accuracy of the information they require. BWNs erode public confidence if they are not issued in time or issued too often.

On July 8, 1998, OEHS Environmental Health Procedures Manual Memorandum DW-23 addressed Boil Water Orders at PWSs. Recently, June 2009, DW-23 was reviewed and revised to improve consistent, proper handling of situations requiring boil water orders. Be sure to obtain a copy of the new DW-23.

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.

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.

HYDROPNEUMATIC TANKS

Hydropneumatic tanks are important to the protection of the well pump and adequate pressure in the distribution system. Hydropneumatic tanks (or pressure tanks) are very common in small water systems that use wells to supply drinking water. The hydropneumatic system combines the energy from a pump (usually the well pump) with the principle of air pressure to force water into the distribution system. These tanks are installed between the well pump and distribution system and are intended to:

- Maintain an adequate and relatively even pressure in the distribution system and
- Reduce the number of times the well pump turns on and off.

Hydropneumatic tanks are usually not large enough to provide any water storage or to supply water for fire fighting. Consequently, hydropneumatic tanks are used primarily for residential water supply. The requirements for hydropneumatic tank sizing vary from state to state and therefore the water system operator should consult the state regulatory authority if there is a question about the adequacy of a particular tank. Because the volume of stored water is minimal, operational failures that occur with hydropneumatic tank systems can result in the water system customers being completely out of water within a matter of minutes. It is therefore important for all operators of these systems to be familiar with basic troubleshooting steps to identify and correct problems with the water system.

Types of Hydropneumatic Tanks

While the number and size of hydropneumatic tanks may vary widely from system to system, there are four basic styles of tanks. Depending on the type and size, these tanks can be installed vertically or horizontally. The general differences between the four styles (shown below) involve the method of separating the air and the water inside the tank. Operators should be familiar with the type of tank(s) in their system.

Conventional Tank

The air cushion is in direct contact with the water. Because air can dissolve in the water, an air volume controller is necessary as well as an air compressor system.

Floating Wafer Tank

There is a floating wafer (usually constructed of a ridged material, flexible rubber, or plastic) that separates the air and water. This wafer, however, does not completely separate the air and water, and therefore some dissolving of air is expected. These tanks require occasional recharging with air.

Tanks with Flexible Separator

These tanks provide a complete separation of the air and water. A separator is fastened around the inside of the tank (diaphragm type) or a bag is provided for containing the air (air bladder).

These units may be charged with air at the factory, however most are fitted with an air valve (similar to a tire), which the operator can use to adjust the pressure inside the tank. Care must be taken when adding air to these tanks in order to avoid over-pressurization and a possible rupture of the separator. Manufacturer's literature must be consulted before adding air to these tanks and the procedure should be performed only by qualified personnel.

Maintenance

The well pump and pump control systems are important components of the hydropneumatic tank system. Maintenance to these systems is discussed in greater detail in pump section. As with the pumps and controls, the hydropneumatic tank should be included in an overall preventive maintenance program for the water system. It is important to remember that these tanks are under high pressure. Never strike these tanks with hard objects such as hammers, as serious damage and personal injury could occur. Follow proper lock-out/tag-out procedures when taking these tanks out of service for maintenance, including isolating the water supply and distribution systems from the tank with gate valves and slowly bleeding the air from the tank. Maintenance should only be performed by qualified technicians.

Periodic Inspections

Regular inspections should be carried out by the system operators. During the inspections the operator should, at a minimum, check and record the following:

- Pressure fluctuation during a cycle (actual cut-in and cut-out pressures);
- Number of pump cycles per hour;
- Leaks around water piping, the tank, and fittings;
- Leaking air from the compressor, air lines, or tank;
- Air-to-water ratio (water level in the tank) by visually checking the sight tube;
- Presence of sediment in the tank by visually checking the sight tube;
- Condition of paint on the exterior of the tanks and signs of corrosion;
- If oil lubricated compressor:
    - Any oil leaking from the compressor;
    - Oil separators on the air discharge line;
    - Presence of oil in the water (usually gives the water a milky appearance);
- Air compressor intake air filters;
- Control systems and alarms to insure that they are operating properly and protected from moisture and corrosion; and
- Condition of tank supports to insure that the tanks are adequately secured to the floor.

Because hydropneumatic tanks are constructed of steel they are subject to corrosion, especially inside the tanks where air and water may come into direct contact. This can result in weakening of the structure. Some states require periodic "hydrostatic testing" and certification of larger tanks to insure that these tanks are structurally sound. Operators should check with their state regulatory agency regarding the local requirements for hydrostatic testing. Approximately every five to ten years, the interior of large hydropneumatic tanks should be inspected by a specialist in steel tank structure and coating (paint). This inspection should consider the condition of the tank as well as what type of maintenance should be performed on the tank to increase its useful life. For small hydropneumatic tanks, when they become corroded, the most cost effective option is usually to replace them with new units.

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

Ground Fault Interrupter

Ground fault interrupters are designed to protect from electrical shock by interrupting a household circuit when there is a difference in the currents in the "hot" and neutral wires. Such a difference indicates that an abnormal diversion of current from the "hot" wire is occuring. Such a current might be flowing in the ground wire, such as a leakage current from a motor or from capacitors. More importantly, that current diversion may be occuring because a person has come into contact with the "hot" wire and is being shocked. When a circuit is functioning normally, all the return current from an appliance flows through the neutral wire, so the presence of a difference between "hot" and neutral currents represents a malfunction which in some circumstances could produce a dangerous or even lethal shock hazard.

GFI's are required by the electrical code for receptacles in bathrooms, some kitchen receptacles, some outside receptacles, and receptacles near swimming pools. The horror story scenarios which led to these code requirements are things like dropping a hair dryer or a portable radio into a bathtub with a person, causing electrocution. A typical circuit breaker interrupts the circuit at 20 amperes, but it takes only about 100 milliamperes to electrocute a person in such a scenario. The GFI is designed to detect currents of a few milliamperes and trip a breaker at the receptacle or at the breaker panel to remove the shock hazard.

The GFI has a "Test" button which causes a small difference between "hot" and neutral currents to test the device. The UL requirement for a GFI is that it trip when there is 5 mA of leakage current. There is also a reset button to use after it has been tripped.

IRON AND MANGANESE CONTROL

Iron and manganese are common in groundwater supplies used by many small water systems. Exceeding the suggested maximum contaminant levels (MCL) usually results in discolored water, laundry, and plumbing fixtures. This, in turn, results in consumer complaints and a general dissatisfaction with the water utility. Surface water generally does not contain large amounts of iron or manganese, but iron and manganese are found frequently in water systems that use groundwater.

There are secondary standards set for iron and manganese, but these are not health related and are not enforceable. The secondary (aesthetic) MCLs for iron and manganese are 0.3 milligrams per liter (mg/l) and 0.05 mg/l, respectively. If water contains more than 0.05 ppm iron, or 0.01 ppm manganese, the operator should implement an effective hydrant-flushing program in order to avoid customer complaints.

Small water plants may choose to either sequestrate or remove iron and manganese. Sequestration only works for combined iron and manganese concentrations up to 1.0 mg/L and only in cases where the treatment is not permanent. Removal is usually achieved through ion exchange or oxidation/filtration. There are a number of chemical oxidants and filtration media available that can be used in various combinations.

Problems Associated with Iron and Manganese

Small amounts of iron are often found in water because of the large amount of iron present in the soil and because corrosive water will pick up iron from pipes. Clothing washed in water containing excessive iron may become stained a brownish color. The taste of beverages, such as tea and coffee, may also be affected by iron. Manganese produces a brownish color in laundered clothing, leaves black particles on fixtures, and—as with iron—affects the taste of beverages, including coffee and tea.

Groundwater from the faucet or tap is usually clear and colorless. However, when water containing colorless, dissolved iron is allowed to stand in a cooking container or comes in contact with a sink or bathtub, the iron combines with oxygen from the air to form reddish-brown particles (commonly called rust). Manganese forms brownish-black particles. These impurities can give a metallic taste to water or to food.

The rusty or brown stains on plumbing fixtures, fabrics, dishes, and utensils cannot be removed by soaps or detergents. Bleaches and alkaline builders (often sodium phosphate) can make the stains worse. Over time, iron deposits can build up in pressure tanks, water heaters, and pipelines, reducing the quantity and pressure of the water supply.

Iron and/or manganese in water creates problems common to many water supply systems. When both are present beyond recommended levels, special attention should be paid to the problem. How iron and manganese are removed depends on the type and concentration and this helps determine the best procedure and (possible) equipment to use.

Bacteria and Iron and Manganese

Iron and manganese in water also promote the growth of bacteria (including iron bacteria). These organisms obtain energy for growth from the chemical reaction that occurs when iron and manganese mix with dissolved oxygen. These bacteria form thick slime growths on the walls of the piping

system and on well screens. These shines tend to be are rust-colored from iron and black-colored from manganese. Variations in flow can cause these slime growths to separate from pipe walls, resulting in dirty water in the system.
The growth of iron bacteria can be controlled by chlorination. However, when water containing iron is chlorinated, the iron is converted from the ferrous state to the ferric state--in other words, rust--and manganese is converted into black manganese dioxide. These materials form a coating on the inside of the water main and, when they break loose, a customer will sometimes complain of “dirty” water.

Iron bacteria will use even small amounts of iron present in the ferrous state, oxidize it, and then use the energy. Manganese is also used by other bacteria to form organics, which contribute to the iron bacteria slime in the well and/or water system. Iron bacteria are found any where a food source of iron is available. The presence of one bacterium is all that is needed to start an infestation in a well or a distribution system.

Sequestering

Soluble iron and manganese can be stabilized, or sequestered, instead of removed. Sequestering keeps the iron and manganese in solution. This effectively eliminates the problem of staining because it is the insoluble precipitate that causes the staining. The process also delays the precipitation of oxidized iron and manganese, thereby greatly reducing the layer of scale that forms on the pipe. Red water can sometimes be prevented in this way.

Phosphate compounds are a family of chemicals that can surround minerals and keep them in solution. Pyrophosphate, tripolyphosphate, and metaphosphate may all be effective as iron and manganese sequestering agents. The most effective one, however, seems to be sodium phosphate in low concentrations. The proper dose and type of phosphate should be selected only after a qualified technician or consultant performs bench-scale testing.

Phosphate sequestering is effective where the water contains up to 0.3 mg/L of iron and less than 0.1 mg/L of manganese. The phosphate compounds must be added to the water at a point where the iron is still dissolved in order to maintain water clarity and prevent possible iron staining. This should be before your point of chlorination or as close to the well discharge point as possible.

Phosphate compound treatment is a relatively cheap way to treat water for low levels of iron and manganese. Since phosphate compounds do not actually remove iron, water treated with these chemicals will retain a metallic taste. In addition, too great a concentration of phosphate compounds will make water feel slippery.

If the total detention time in the distribution system exceeds 4 days, the phosphates may break down and release the iron and manganese in the outer portions of the system. If the detention is exceeded, the iron or manganese problem may not be resolved with phosphate.

DISINFECTION

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 primary purpose of disinfection is to kill or inactivate pathogens in the water.

Pathogens are disease-causing organisms. Many of the largest disease outbreaks in history can be attributed to waterborne pathogens. Because of their propensity to kill large numbers of the population, these and all other pathogens should be controlled in the treatment process. In fact, the processes of coagulation, flocculation, sedimentation and filtration were developed to control pathogenic contamination in drinking water.

Pathogens, which are found in either the forms of bacteria, viruses, or protozoa, are not "removed" by disinfection. Some are killed, some are temporarily inactivated, and some are not affected at all by chemical disinfectants or biocides. Because of this fact, it is mandatory to optimize our disinfection processes.

The secondary purpose of disinfection is to provide a residual safeguard. After regulatory standards are met at the treatment process, it will degrade as it moves through the distribution system. The degree of water quality degradation is affected by its chemical and biological composition, as well as the physical condition of the distribution system it travels through. Proper management, which includes flushing, cleaning, pressure maintenance, backflow prevention, monitoring and line replacement programs is necessary to prevent substantial water quality degradation in the distribution system.

We maintain disinfectant residuals to provide a safeguard against pathogenic contamination that could develop in the distribution system. The regulated minimum disinfectant residual requirements are 0.2 mg/L for total chlorine. The **maximum residual disinfectant level (MRDL)** allowable in a distribution system is 4.0 mg/L for chlorine.

The most common disinfection method used by water systems in the US is chlorination. Chlorine may be added to drinking water as a gas or liquid. The liquid form or hypochlorination system is most common for small water systems and therefore is the focus of this guide. A hypochlorination system is composed of a chemical feeder, a liquid chlorine solution (e.g. bleach or sodium hypochlorite) and a drinking water supply.

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 mg/L or 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 it 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 groundwater 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.

Chlorine Demand = Chlorine Dose - 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.

Total Chlorine = Combined Chlorine + Free Chlorine

Chlorine Residual Testing
Chlorine residual determinations and reporting are an important responsibility of the operator. The test kit used for chlorine residual testing must be an EPA approved kit. This can be verified

by checking with the local state regulatory staff. Chlorine residual is most commonly measured using a **DPD** (Diethyl-p-Phenylene-Diamine) colorimeter test kit. The test kits are provided with detailed instructions on proper procedures for running both free and total chlorine residual tests. It is also important to insure that all chemicals used in the testing procedure are used before the posted expiration date shown on the chemical packages.

CONTACT TIME (CT)

This stands for the **contact time (CT)** between disinfectant and microorganism and the concentration of disinfectant. CT is used to calculate how much disinfectant is required to adequately disinfect water. C refers to the final residual concentration of a particular chemical disinfectant in mg/L. T refers to the minimum contact time (minutes) of material that is disinfected with the disinfectant. Therefore, the units of CT are expressed in mg-min/L. For this discussion, chlorine will be used in place of disinfectant.

CT = disinfectant concentration x contact time = C mg/L x T minutes

When chlorine is added to water, it does not only react with pathogenic microorganisms, but also with other impurities, such as soluble metals, particles of organic matter and other microorganisms. The chlorine demand is created when the chlorine reacts with these substances. The chlorine demand must first be satisfied, before a chlorine residual concentration can be established. The chlorine concentration (or chlorine dose) that has to be added to water is made up by the sum of the chlorine demand and the chlorine residual. Once there is a chlorine residual, this chlorine residual has to be maintained during the required contact time to kill pathogenic microorganisms. To adequately disinfect the water it is therefore required to supply the water with a higher chlorine dose than the concentration required to kill pathogenic microorganisms. The time required to deactivate a particular microorganism decreases when the applied chlorine dose is increased.

West Virginia requires PWSs using groundwater to provide the required 4-log inactivation of viruses.

The CT is commonly used to determine the effectiveness of a particular disinfectant against a certain microorganism under specified conditions. There is a difference between the relative affectivity of chemical disinfectants against different microorganisms. Often a certain level is added to the CT, for example 99%. This means that 99% of the microorganisms are deactivated by the disinfectant.

The type of microorganism

Disinfectants can effectively kill pathogenic microorganisms (bacteria, viruses and parasites). Some microorganisms can be resistant. *E. coli* bacteria, for example, are more resistant to disinfectants than other bacteria and are therefore used as indicator organisms. Several viruses are even more resistant than *E. coli*. The absence of *E. coli* bacteria does not mean that the water is safe. Protozoan parasites like *Cryptosporidium* and *Giardia* are very resistant to chlorine.

Temperature

The temperature also influences the effectiveness of disinfection. Increasing temperatures usually increases the speed of reactions and of disinfection. Increasing temperatures can also decrease disinfection, because the disinfectant falls apart or is volatized.

CHLORINE MONITORING

Chlorine monitoring assures proper residual at all points in the system and quickly and reliably signals any unexpected increase in disinfectant demand. Monitoring chlorine levels in the system also can serve as a "surrogate" for detecting potentially threatening contamination, because many chemical and biological contaminants are known to combine with chlorine. Therefore, a significant decline or loss of residual chlorine could be an indication of potential threats to the system.

Monitoring for free residual chlorine and total residual chlorine (free available plus combined available chlorine) is a state requirement. The following sections outline the procedures for monitoring the residual chlorine levels in municipal water.

Chlorine concentrations can be measured either in the field using simple field kits or in the laboratory using more sophisticated procedures and equipment. Most field kits work from a similar principal where an indicator is added to a water sample and the color of the solution is compared to a set of colored standards. The colors in the standards have been calibrated in a laboratory to match set concentrations of chlorine. For instance, if a water sample is placed in a glass vial containing an indicator, and the solution turns dark red, this indicates a higher concentration than if the solution turns faint pink.

The limitation to field kits is their detection limits. The detection limit is typically 0.1 ppm. However, even though it cannot be quantified, these kits can identify trace concentrations of chlorine if a faint color is present. Laboratory methods, on the other hand, have lower detection limits, but are generally not applicable because the chlorine dissipates more quickly and will be lost during transport (unless it is in the combined chlorine form).

DPD Indicator

One kit uses **N, N-Diethyl-p-Phenylenediamine (DPD)** as the indicator solution. This method determines chlorine content according to the DPD Method 409F described in the 21st edition of *Standard Methods for Examination of Water and Wastewater*.

The water is collected in a sample tube and the indicator is added to this tube. It uses tablets or powder pillows to dye water samples to a degree proportional to the chlorine content in the sample. When the water in the tube changes color, the color is compared to 9 or 10 colors present in similar smaller tubes located on a color disk. The color disk is rotated until the color closely matches that inside the test tube. The disk color relates to a concentration. The method can differentiate between combined chlorine and free available forms by using different types of indicator. Fresh indicator should always be used as old DPD can give false readings. This type of kit detects from 0.1 to 5.0 ppm chlorine.

Spectrophotometers

There are a number of field spectrophotometers that can be used for measurement of residual chlorine levels. One model is a pocket-sized instrument that tests for free and total residual chlorine over the operating range of 0 to 4.0 ppm. The meter reads in 0.01 ppm increments with an accuracy of 0.05 ppm. The reagent used in these types of instruments is typically DPD, as described above.

Interferences
The field methods used to measure total residual chlorine can give false readings in some circumstances. For example, the DPD indicator method is subject to interference by oxidized forms of manganese. The test may indicate chlorine is present when it is the interfering compound reacting with the indicator to give a false reading. High sample color and turbidity may also cause interference and give inaccurate readings.

When an interference is suspected, chlorine free samples should be measured to establish background readings. This can be done by taking a water sample and agitating the water for a few minutes to decrease chlorine levels in the sample, and then taking a chlorine reading on that sample. If the reading does not decrease repeat the agitation procedure a few more times. If a positive result is still obtained, it is likely that an interference is present, which must be taken into account during the monitoring program. For example, in the case of the pocket photometer the background reading can be subtracted from the reading obtained with the true sample for low turbidity samples, but not for samples that have a false positive interference.

Another interference may occur when the chlorine residual is a high enough concentration that the reagent (DPD) will bleach out and no color will develop. This will result in a false negative reading.

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, $Ca(OCl)_2$, is a white solid which is available in powder, granular or tablet form. Only about 65 – 70% of $Ca(OCl)_2$ 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 to 15% available chlorine. The 5.25% 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

PWSs must demonstrate that continuous disinfection is being practiced. The PWS operator must monitor daily the amount of chlorine being added and the total chlorine residual obtained in the distribution system.

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

Calcium Hypochlorite
Calcium hypochlorite is usually the less 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 positive displacement or peristaltic pump.

Calcium hypochlorite tablets will not dissolve readily in water colder than 41^{o}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.

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
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.

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.

Troubleshooting Hypochlorination Pumps
Common problems with hypochlorinators are clogged lines and injectors. For systems with periods of no water usage, calcium carbonate will come out of solution and clog up the lines with

a build up of white 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.

If you have plenty of chlorine in your bucket and the feeder appears to be running, but there is no free or total chlorine in you water, check the lines and injectors to be sure they are not clogged. It is recommended to keep spare lines on hand. Follow the manufacturer's recommendations for cleaning your chemical feeder.

There may be times when chlorine taste and odor complaints become a problem in the distribution system. This problem is generally related to high combined residuals and inadequate free residual. The solution to this problem may be to increase the chlorine dose rate to get past the breakpoint. As a rule of thumb, the free residual should be at least 85% of the total residual in order to prevent chlorine taste and odor problems and insure an adequate free residual for effective disinfection.

A sudden increase in chlorine demand may signify contamination by the presence of organic contaminants such as dirt and debris. The sudden presence of organic material may result from a line break, loss of pressure or unprotected cross-connection such as lawn irrigation, etc and may result in the drop of the chlorine residual.

CHLORINE POINTS OF APPLICATION

When chlorination of water was first employed for disinfection, terminal treatment of the plant effluent was almost invariably practiced. Now the use of chlorine in various stages of water treatment, and even in the distribution system, is common practice. Multiple or split chlorination schemes are increasingly employed for disinfection and other purposes and frequently enhance the efficiency of many-unit water-treatment processes. Fundamentally, the points at which chlorine is applied depend on the specific objectives of chlorination-technical, practical, safety, economic, and other considerations. In practice, various terms have come into common usage to specify the point and location at which chlorine is applied.

Plain or Simple Chlorination

Simple chlorination involves the application of chlorine to water that receives no other treatment. More than half of all existing water treatment plants in the US fall in this category; thus, this treatment represents their sole public health safeguard. When applied to impounded or naturally elevated surface systems, chlorine usually is injected to the pipeline leading from such a gravity supply. When applied to water pumped into a system, chlorine usually is added at the pump suction, using pressure beyond the pump to operate the chlorine feeders.

Prechlorination

Prechlorination involves the application of chlorine to water prior to any other unit treatment process. Among benefits that can be achieved are improved filter operation by reduction and equalization of the bacterial and algal lad and by control of slime and mud ball formation; improved coagulation; reduction of taste-, odor-, and color-producing materials by oxidation and retardation of decomposition (in settling units); and the provision of a safety factor in disinfecting heavily contaminated waters while keeping the chlorine residual in the distribution system at a minimum. When prechlorination is employed it usually is desirable to obtain a contact period that is as long as possible, preferably by applying chlorine to the raw water suction intake to provide contact during the entire purification process. The dosage, of course, depends on the objective. In some cases, free chlorine residuals may suffice. Care must be exercised to maintain the proper residual necessary to accomplish the desired objective.

Postchlorination

Postchlorination involves the application of chlorine to water following any other unit treatment process. The most important form of postchlorination is that following filtration for disinfection, to provide either a free or combined residual chlorine in a part of or the entire distribution system. The contact period provided to effect disinfection is an important consideration; chlorine is usually added to the filter effluent. When postchlorination follow prechlorination and precedes filtration, greater filter residual in the delivered water to a predetermined amount and thus reestablishes the portion of chlorine that had been consumed in the purification process.

Rechlorination

Rechlorination involves the application of chlorine to water, following the previous chlorination treatment, at one or more points in the distribution system. The practice, which may involve free or combined residual chlorination, is especially common where the distribution system is long and complex and where the plant effluent residual is insufficient to control bacterial and algal regrets, red-water troubles, etc. The chlorine may be applied at the end of a long main in the distribution system, at a point where a main supplies water to an outlying community, or at such places as a reservoir, standpipe, or booster pumping station.

Dechlorination
When combined residual chlorination or free residual chlorination is employed, chlorine residuals of a certain type and intensity must be attained to accomplish a particular objective. In some instances the residual might be of such magnitude that the water will be aesthetically or otherwise objectionable, and a portion of the residual will have to be removed. Dechlorination is the partial or complete reduction of residual chlorine in water by any chemical or physical treatment.

HYPOCHLORINATION FEED SYSTEMS

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.

The typical hypochlorination system consists of a chemical feed pump, a solution of sodium or calcium hypochlorite, and the appropriate electrical and flow control systems. Hypochlorination systems have become very reliable and safe, however proper techniques should be used in handling these materials to prevent injuries from splashes, spills, or inhaling fumes. This would include the use of protective clothing such as rubber gloves, face or eye shields, and an apron. Many small water systems have hypochlorination over chlorine gas due to safety concerns, as well as new regulations concerning safety, training, and environmental issues. Although hypochlorination systems are safer than gas, OSHA requires hypochlorites be listed in the Hazardous Materials inventory and written procedures for handling, using, and responding to spills.

Sodium hypochlorite provides the least handling hazard to the operator. It may be fed directly from the container that it is delivered in, or can be diluted in a solution tank if desired. It is available in concentrations from 5% to 15% but can lose effectiveness. For this reason, solutions should be made fresh every 2 to 3 days. This chemical should be properly stored in a covered container, out of direct sunlight and away from the electrical control systems associated with the operation of the chemical feed pump.

Calcium hypochlorite is a powder with a chlorine concentration generally in the range of 65%. The powder is mixed with water and fed with the same type of chemical feed pump used for the sodium hypochlorite. Providing a consistent feed rate with calcium hypochlorite can be difficult due to the amount of inert material in this product that can clog chemical feed pump. To prevent chemical feed pump clogging, it may be better to mix the hypochlorite powder with water in one tank, and then transfer the well mixed solution to another tank where it would be pumped into the raw water. By using this approach, the operator could leave the undissolved inert material that could cause clogging problems, in the bottom of the mixing tank and not exposed to the chemical feed pump. The calcium hypochlorite should be stored in a cool, dry environment.

Diaphragm or peristaltic pumps are typical for feeding liquid hypochlorite in small water systems. Diaphragm pumps are controlled by speed and stroke. The stroke determines the amount of hypochlorite to be injected and the speed control determines how often that amount is injected. The lower speed settings may allow several gallons of water to pass before another dose of hypochlorite is injected. The speed and stroke should be adjusted in combination. If both speed and stroke have to be operated at the highest settings to achieve the desired chlorine residual, consider installing an additional chemical feed pump. The peristaltic pump utilizes a flexible hose and two rollers attached a rotating shaft. As the shaft turns, the rollers role along the hose compressing it and forcing the liquid forward. In all cases, a backup pump or at the very least the spare parts should be on hand in the event of a chemical feed pump failure.

CAUTION: Allowing petroleum products such as oils, grease, etc., or moisture to be placed in a calcium hypochlorite container may cause spontaneous combustion and explosion.

Troubleshooting Hypochlorination Problems

Problem	Possible Cause	Possible Solution
1. Chemical feed pump won't run.	1A. No power.	1A. Check to see if plug is securely in place. Insure that there is power to the outlet and control systems.
	1B. Electrical problem with signal from well pump or flow sensor.	1B. Check pump motor starter. Bypass flow sensor to determine if pump will operate manually.
	1C. Motor failure.	1C. Check manufacturer's information.
2. Low chlorine residual at point of entry (POE).	2A. Improper procedure for running chlorine residual test or expired chemical reagents.	2A. Check expiration date on chemical reagents. Check test procedure as described in test kit manual. Speed or stroke setting too low.
	2B. Pump not feeding an adequate quantity of chlorine.	2B. Damaged diaphragm or suction leak.
	2C. Change in raw water quality.	2C. Test raw water for constituents that may cause increased chlorine demand. (e.g. iron, manganese, etc.)
	2D. Pump air bound.	2D. Check foot valve.
	2E. Chlorine supply tank empty.	2E. Fill supply tank.
	2F. Reduced effectiveness of chlorine solution.	2F. Check date that chlorine was received. Sodium hypochlorite solution may lose effectiveness after 30 days. If that is the case, the feed rate must be increased to obtain the desired residual.
	2G. Damaged suction or discharge lines. (cracks or crimps)	2G. Clean or repair lines with problems.
	2H. Connection at point of injection clogged or leaking.	2H. Flush line and connection with mild acid such as acetic or muriatic. Replace any damaged parts that may be leaking.
3. Chemical feed pump won't prime.	3A. Speed and stroke setting inadequate.	3A. Check manufacturer's recommendations for proper settings to prime pump.
	3B. Suction lift too high due to feed pump relocation.	3B. Check maximum suction lift for pump and relocate as necessary.
	3C. Discharge pressure too high. (see section on pumps)	3C. Check well pump discharge pressure. Check pressure rating on chemical feed pump.
	3D. Suction fitting clogged.	3D. Clean or replace screen.
	3E. Trapped air in suction line.	3E. Insure all fittings are tight.
	3F. Suction line not submerged in solution.	3F. Add chlorine solution to supply tank.
4. Loss of prime.	4A. Solution tank empty.	4A. Fill tank.
	4B. Air leaks in suction fittings.	4B. Check for cracked fittings.
	4C. Foot valve not in vertical position.	4C. Adjust foot valve to proper position.
	4D. Air trapped in suction tubing.	4D. Check connections and fittings.
5. Excessive chlorine residual at POE.	5A. Pump speed or stroke setting too high.	5A. Verify dose rate and calibrate pump to get desired dose.
	5B. Siphoning from solution tank.	5B. Insure that 4 in 1 anti-siphon valve on chemical feed pump is operating properly.
	5C. Low well pump discharge pressure.	5C. Insure well pump discharge pressure is at least 25 psi.

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, rubber apron and boots, gloves, face shield) 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.

Chlorine Storage

The room where 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

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.

CAUTION: Allowing petroleum products such as oils, grease, etc., or moisture to be placed in a calcium hypochlorite container may cause spontaneous combustion and explosion.

CHLORINE SAFETY PRECAUTIONS

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.
- Chlorine can react, at times explosively, with a number of organic materials such as oil and grease from sources such as air compressors, valves, pumps, oil-diaphragm instrumentation, pipe thread lubricants, as well as wood and rags from maintenance work.
- Chlorine is neither explosive nor flammable. Chlorine will support combustion under certain conditions. Many materials that burn in oxygen (air) atmospheres will also burn in chlorine atmospheres.
- At ambient temperatures, dry chlorine, either liquid or gas, does not corrode steel. Wet chlorine is highly corrosive because it forms hydrochloric and hypochlorous acids. Precautions should be taken to keep chlorine and chlorine equipment dry.

Piping, valves, and containers should be closed or capped when not in use to keep out atmospheric moisture such as precipitation or humidity. If water is used on a chlorine leak, the resulting corrosive conditions will make the leak worse.

Chlorine Gas Cylinders

The typical 150-lb cylinder is equipped with one valve. The valve outlet threads are not standard pipe threads, but are special straight threads. These outlet threads are intended for securing the valve outlet cap and not for connecting unloading connections or other devices. Typical cylinder connections are made with a yoke and adapter. The valve is also equipped with a fusible metal pressure relief device or, as more commonly named, a fusible plug.

Each ton container is equipped with two identical valves near the center of one end. They are different from the typical cylinder valve in that they have no fusible metal plug and usually have a larger internal passage. Each valve connects to an internal eduction tube. Ton containers are equipped with fusible metal pressure relief devices. Most have six fusible metal plugs, three in each end.

A metal relief device or fusible plug is designed to yield or melt between 158°F and 165°F (70°C and 74°C) to relieve pressure and prevent container rupture if exposed to fire or other high temperature. The relief device is designed to activate only in the event of a temperature increase and will not prevent over-pressurization due to overfilling.

Calcium Hypochlorite

Hypochlorite solution can cause serious burn injuries and can cause permanent damage to the eyes. When working with Hypochlorite solution a great degree of caution should be exercised and protective eye goggles and clothing should be worn at all times. Hands should be protected from contact. The following steps should be taken when handling hypochlorite solution:

1. Protect skin, eyes, and respiratory tract from hypochlorite dust.
2. All containers should be covered to prevent evaporation and the release of fumes.
3. Content of hypochlorite drum must be kept dry, covered and stored in a cool dry area away from direct sunlight.
4. Protective gloves should be worn. Hypochlorite in contact with moisture will burn and damage skin.
5. When mixing a hypochlorite solution, the water should be put in the container before the hypochlorite powder is added.
6. All spills should be flushed away with large amounts of water.
7. The chlorine room should be well ventilated.
8. Calcium hypochlorite should not be stored where it can come in contact with organic matter. The reaction between the two can result in a fire.

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.

DISINFECTION BYPRODUCTS

There is no question that the use of chlorine as the primary disinfectant used for water treatment in the U.S. has had an enormous impact on the prevention of waterborne diseases. However, when free chlorine is added to surface waters containing **natural organic material (NOM)** chemical reactions will occur, which produce Disinfection Byproducts (DBP).

If consumed over long periods of time, some DBPs may cause undesirable health effects, including cancer. Consequently, regulatory standards have been established to limit the amount of various DBPs that are acceptable in a PWS.

Formation of Disinfection Byproduct

Natural organic matter is the precursors of disinfection byproduct formation. Natural organic matter in surface waters are generally naturally occurring organic substances, such as humic and fulvic acids. These acids belong to a family of compounds having similar structure and chemical properties and are formed during the decomposition of vegetation. Humic acids are hydrophobic or water repellent and a portion of these can be removed by coagulation and sedimentation. The fulvic portion is not amenable to conventional treatment. It is always more effective to remove precursors prior to disinfection.

Raw waters containing high levels of organic matter, such as lakes and ponds, are at a higher risk of forming DBPs than waters containing low levels of organic matter, such as most groundwater sources. Consequently, small systems utilizing chlorinated surface water sources are more likely to have DBP problems than those using chlorinated groundwater sources. Therefore, DBPs that result from chlorine disinfection have been studied more extensively than DBPs that might result from the use of alternative disinfectants such as ozone.

Trihalomethanes and Haloacetic Acids

Disinfection byproducts are groups of chemical compounds that are **trihalomethanes (THMs)** and **haloacetic acids (HAA5s)** produced by chlorine in the disinfection process when organic compounds are present.

Disinfection byproducts are produced by the reaction of free chlorine with organics in the source water. In this process the chlorine replaces hydrogen atoms with chlorine. THMs are a particular group of compounds where 3 of the 4 hydrogen atoms in a methane compound have been replaced by chlorine or bromine atoms. The bromine replacement in the methane compound is a particular reaction caused by free chlorine. Bromide compounds are typically present in surface water and chlorine oxidizes bromide ions resulting in the formation of free bromide that reacts with the organic material to produce bromoform, bromodichloromethane, dibromochloromethane, monobromoacetic acid and dibromoacetic acid. Three of these compounds are THMs and two of them are Haloacetic Acids. The S1DBPR regulates four specific Trihalomethane compounds and five specific Haloacetic acids or HAA5s. The additive concentrations in mg/L of these compounds are called **Total Trihalomethanes (TTHMs)** and HAA5s. The MCLs for TTHMs and HAA5s are 0.080 mg/L and 0.060 mg/L, respectively.

DISTRIBUTION SYSTEM

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 groundwater 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 150 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.

Cathodic Protection

When two dissimilar metal rods are connected to a voltage meter and submerged in water that contains dissolved salts, a very small voltage reading (less than 0.0001 volts) will occur. This is the way electric storage batteries work. In an elevated storage tank the impurities in the water and the tank itself can cause a voltage to be generated, with the tank giving up metal as the current flows into the surrounding water and to ground.

Cathodic protection systems can be installed to prevent this corrosion by reversing the flow of the electrical current from the water to the tank. The basic theory of cathodic protection is to supply current, from an outside source, through sacrificial anodes suspended in the tank and back into the tank. This electrical current is D.C. and the voltage should be just enough to compensate for the natural voltage set up between the tank and the water. The tank is now the ground and will not become pitted.

The sacrificial anode is usually a piece of iron, magnesium, carbon, or aluminum that is 1-2 inches in diameter and 12 to 18 inches long. The anodes are designed to give up metal to the water instead of the tank. Therefore, they will eventually need replacing. They should be inspected every six months and usually replaced yearly. Installation and maintenance of a cathodic protection system can be hazardous work and should be done by a professional tank and tower company. The success of an installation depends on the proper spacing of the anodes so that all surfaces of the tank receive the flow of current equally. When cathodic systems run at too high a voltage, above 1.2v on a test cell, hydrogen gas can be generated between the tank and any coating material. This can result in blistering and peeling of the coating, which can also cause corrosion.

Level Indicators
Automatic pump controls are operated by signals from the storage tank that indicate that the water is at the lowest or highest desired level. A signal from the low-level indicator will start the pump. The pump will continue to run until the water fills the tank up to the high level. A signal will then go back to the pump to shut it off. There are three main types of liquid level control systems. They are electrode systems, float systems, and pressure sensing systems.

Electrode Systems
The use of electrodes is the most common system used today. Pump controls are activated as the water level rises above or drops below these electrodes. As the water level drops below the low-level electrode, the circuit is opened triggering a control signal to start the pump. As the water level rises to contact the high level electrode the circuit is closed triggering a control signal to shut off the pumps. The pump will not restart until the water level drops below the low-level electrode again.

Float Systems
Float systems are used primarily in ground storage tanks. As the float rises or falls with the water level, high level or low level switches are tripped activating the pump control circuit. This type of level control will have to be checked on a regular basis to prevent malfunctions. Freezing during the winter is always a problem with floats and electrodes due to damage caused as the water level (and the ice) rises and falls. Circulation of water inside the tank may help minimize ice buildup.

Pressure Sensing Systems
Pressure sensing controls are normally located near the bottom of the storage tank. This type of control is activated by the amount of head pressure in the tank. As the pressure increases, a spring or metal band is expanded tripping a micro-switch or a mercury switch that then activates the pump. The on and off levels on these switches are set by applying or decreasing the tension on the spring, or by setting manual control points on a dial for the mercury switch. These switches must be protected from freezing and extreme vibrations for proper operation. Pressure transmitters can also be used to control multiple wells or pumps and the signal can be converted into a tank level reading.

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; and,
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.

- 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.
- 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.
- 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 manufacturers 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:

- Preliminary flushing. Mains must be flushed, prior to disinfection, by running a sufficient amount of water through them.
- Disinfection. The chlorine dosage should be 50 mg/L for 24 hours.
- 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 Lines

Services connect the customer to the main in the street. Services are installed using a tapping machine to drill and connect a corporation stop to the main. The tap is normally done while the main is under pressure. This is called a “wet” tap or “hot” tap. Taps can be made by inserting the corporation stop directly into the main or the corporation stop can be installed on a saddle that’s strapped to the pipe. Taps should be made at a 45% angle from horizontal so that they are less likely to be pulled by a backhoe.

The service line is usually copper, PVC or polyethylene pipe. Galvanized and lead services should be replaced, since the former is prone to corrosion and the latter can cause lead problems if the water is corrosive. The service line should have a bend or goose neck in it at the corporation stop. This will allow the service to flex slightly if the trench or piping shifts after backfill. A curb stop should be installed in the easement so that the service can be isolated. Sometimes a meter stop on the yoke is used instead of a cub stop. A service line leak may require killing the main or using a crimping tool to isolate for maintenance when a meter stop is used. Service lines and meters must be laid below the frost line for the area or freezing will become a problem in the winter.

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.

Materials and installation practices apply equally to that portion of the service line located on the customer's property. Every water utility should have regulations consistent with the WV CSR Series 64 Title 77 requirements. These regulations shall cover such items as approved materials, depth of lines, installation procedures, inspections, responsibility for the work, responsibility for payment of costs, and other information necessary to provide an understanding of the requirements.

Service Line Parts

Each service connection consists of:

1. The connection at the main, which is made with the use of a corporation stop or valve to control the pressure during installation. This valve will generally be installed by a tapping machine and with the main pressurized, called a wet or hot tap.
2. A length of pipe long enough to reach from the water main to the property line, where another valve is installed to control the water service.
3. A shutoff valve at the property line to allow the water to be shutoff without having to dig in the street. In most cases, this valve remains the property of the utility. The shutoff valve can be operated only with a special wrench, preventing the property owner from operating the valve.
4. Meters installed to measure the amount of water supplied to the customer. In some cases, the meter is installed at the curb line, but in Minnesota the normal location of the meter is inside the customer's premises.

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 x 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.

Pressure Sustaining Valves
In some systems there are areas of very heavy water demand that can sometimes "rob" the pressure of upstream areas. The control valve will act to maintain the desired upstream pressure during these conditions and throttle the flow of water to the area of heavy demand.

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.

Make sure fire hydrants are accessible. Fire hydrants provide water for fire fighting and are a means to flush the system. The hydrants should be easy to get to and highly visible. This includes removing snow drifts during the winter, tall grass or weeds during the summer, and painting the hydrants a highly visible color. Hydrants should be color coded according to the available fire flows. During inspection, be sure to check for tampering or vandalism. Record your findings in a log book. You should develop a log book to document your findings and standardize how these checks are made.

METERS

The meter is the primary piece of equipment in a water system that has a direct bearing on income. It is the cash register for the system. Many small systems do not have meters. Billing is based primarily on the size of the service and is a fixed rate. Water meters encourage conservation and distribute the cost of service in proportion to its use. Even though they are critical to maintaining the cash flow for a system, meters tend to be neglected more than any other piece of water equipment. An inaccurate meter cheats the water system and also all the customers whose meters are accurate.

When a meter becomes worn or broken it always under-registers and will give water away to the customer. This is not a good point to impress upon a customer who is sure he or she is being charged for too much water. Instead check the meter readings for the last month. It may be that an error has been made in reading the meter which can be corrected and re-reading the meter to make sure the books are straight.

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.

PUMPS

Many different types of pumps can be used with the selection depending on the work that needs to be done. Pump selection depends on the maximum flow needed in gallons per minute (gpm) and the head it needs to pump against.

Pumps provide the means for moving water through the system at usable working pressures. The operation and maintenance of these pumps are some of the most important duties for many water utility operators. There are two basic types of pumps used in water and wastewater systems. The most common type of pump is the centrifugal pump. The other type is the positive displacement pump.

All pumps are rated by the flow they produce and the pressure they must work against. Centrifugal pumps are used for high flow and low head pressure applications. Booster pumps or primary service pumps are required to move high volumes of water and usually operated at low head pressures (200-300 feet of head for water and as little as 50 feet of head for wastewater applications). Centrifugal pumps are ideally suited to these types of applications and are much more efficient than positive displacement pumps of comparable size. Positive displacement pumps are used for low flow and high- pressure applications. High pressure water jet systems like those used for well screen or sewer line cleaning use positive displacement pumps since pressure in excess of 2500 feet of head are needed and the flows seldom exceed 100 gpm. Sludge pumps and chemical feed pumps are also likely to be positive displacement pumps. Piston pumps, diaphragm pumps, and progressive cavity screw pumps are the most common types of positive displacement pumps.

Another difference between centrifugal and positive displacement pumps has to do with how they react to changes in discharge pressure. When the pressure that a centrifugal pump has to work against changes, it causes the flow from the pump to change. As the pressure increases, the flow from the pump will decrease, and when the pressure drops the flow will increase. Positive displacement pumps do not react this way. The flow does not change when the discharge pressure changes. This is the main reason that positive displacement pumps are used for chemical feeding and sludge pumping. The operator knows that every time the pump strokes, it is pumping the same amount of fluid. This is important if accurate records are to be kept of chemical dosages and pounds of solids that are moving through the system.

System Pressure and Head

Head is a measurement of the pressure or force exerted by the water. Head is expressed in feet to represent the height of the water above some reference point such as a gauge.

Pressure Head is the amount of energy in water due to pressure. The reading of a pressure gauge can be converted to feet of water by multiplying it by 2.31. For example, the gauge reads 52 psi x 2.31 = 120 feet of head (water above the gauge).

Lift, or suction lift, is the vertical distance in feet from the water surface to the pump, plus friction losses in the pipe and fittings between the pump and the foot valve (this will be zero for a submersible pump).

Friction Head loss is the energy that water loses from friction while it is moving in the system through pipelines and valves. When water moves through a pipe, it must overcome resistance caused by friction from contact with the pipe walls and its own turbulence. The amount of friction loss depends on the flow rate, pipe characteristics such as length, size and type of pipe, and on the number and type of pipe fittings.

Head loss can be significant if the pipe surface is roughened by corrosion (pitting), tubercules (crusty corrosion build-up), slime growth, or sediment. The amount of pipe roughness is referred to as the C factor. The higher the C factor, the smoother the pipe. Head loss can also be caused by water suddenly changing direction or velocity as a result of valves, bends, and reducers.

Elevation Head is the vertical distance in feet from the pump to the highest point of the water system, plus friction losses in pipe and fittings between pump and point of discharge.

Total Dynamic Head (TDH) is the total amount of energy that a pump has to deliver to move water from one point to another. Dynamic means the water is in motion rather than static. For example: the well pump has to lift water from a 150 ft pumping level and push it 120 ft up to the storage tank. Not factoring friction head loss, the total dynamic head would be 150 ft suction lift + 120 ft discharge head = 270 ft TDH.

Diaphragm pumps – the amount of chemical fed is determined by either adjusting the length of the stroke or the number of strokes per minute.

It is recommended that your diaphragm pump be equipped with a four function valve. The functions of this valve are:

1. Anti-siphon (automatic): prevents siphoning when pumping downhill or into a vacuum.
2. Backpressure (automatic): supplies approximately 25 psi backpressure to prevent over pumping when little or no system backpressure is present.
3. Pressure relief (automatic): if the discharge line is overpressurized, the valve opens sending the chlorine solution back to your supply tank.
4. Line depressurization (manual): by pulling both knobs, the discharge line will drain back to your supply tank.

The head of a chemical feed pump should generally be <u>above</u> the top of the liquid solution in the solution barrel, to prevent possible siphoning of the chemical that could create a potentially dangerous overfeed situation. It is also recommended to have a back-up pump.

Centrifugal pumps – are widely used in the water industry and consist of a pump casing and an impeller mounted on a rotating shaft. A motor turns the shaft, spinning the impeller. The impeller creates centrifugal force, which throws water into the outer casing or volute. Water is directed into the discharge.

- Vertical turbine pumps – commonly used for well installations and booster pumps. They are capable of producing high capacities at high head.
- Submersible pumps – common for well installations. The entire pump and motor assembly is submersed in water. The motor is mounted below the bowls (impeller housing) so the pump does not have as long a pump shaft as the turbine.

Centrifugal pumps major parts include:

- Casing – the housing that surrounds the impeller, often called a bowl, for turbine pumps.
- Shaft – the rod the impeller is mounted on and is turned by the motor.
- Impeller – rotating bladed disc that gives force to the water being pumped. Design can vary (enclosed, open, semi-enclosed). Design used depends on pumping requirements.

- Wear rings – brass or bronze rings placed on the impeller or casing to control leakage from discharge to suction side.
- Bearings – support and guide the shaft.
- Shaft seals – packing or mechanical seals are used to prevent air from being sucked into the pump along the shaft and to control water leakage along the shaft from the impeller.
- Motor – provides power to turn the impeller.

Pump Cavitation

Pump cavitation is the formation and collapse of gas pockets or bubbles on the blade of an impeller or the gate of a valve, causes the pump or valve to vibrate and sounds like chattering marbles. Commonly occurs in pumps when the pressure at the pump inlet drops below the pressure of the water being pumped. Cavitation may cause the formation of pits on the impeller and the eventual wearing away of the impeller and can be caused by allowing intakes to become clogged or by using a pump that discharges more water than it is designed to pump. To prevent cavitation:

- The intake of the pump must remain clear.
- If pump discharge is excessive, throttle with discharge valve.
- Coat the impeller and volute with epoxy-metallic materials.

Water Hammer occurs when moving water suddenly stops, such as by closing a valve too fast. Water oscillates in the pipe, causing a loud banging or hammering sound. Fluctuating pressures can damage piping and connections.

Pump Maintenance

Major areas of maintenance concern:

- Couplings must be properly aligned.
- Inspect and lubricate motor/pump bearings on a regular basis.
  - Reduce friction and wear to moving parts.
  - Prevent corrosion by sealing out dirt and contaminants.
  - Lubricating water should be of a quality equal to or greater than the pumped water.
  - Too much lubrication – high heat can result; too little lubrication – excessive wear can result.
  - Wrong kind of lubricant – may contaminate potable supply or may not provide adequate wear protection.
  - Contamination of lubricant – may result in excessive wear and high heat.
- Seals – mechanical or packing type.
  - Packing type must be allowed to leak a small amount (20 drops/min) for lubrication.
  - Mechanical type does not normally leak water.

Motor Maintenance:

- The motor should be properly lubricated.
- Motor should be kept clean, dry, and cool.
- Motor guards/ventilation screens must be in place.

ELECTRIC MOTORS

Very few operators do electrical repairs or trouble shooting because this is a highly specialized field and unqualified operators can seriously injure themselves or damage costly equipment. For these reasons the operator must be familiar with electricity, know the hazards, and recognize his own limitations when working with electrical equipment. Most water systems use a commercial electrician for major problems. However, the operator should be able to explain how the equipment is supposed to work and what it is doing or not doing when it fails. Electric motors are commonly used to convert electrical energy into mechanical energy. A motor generally consists of a stator, rotor, end bells, and windings. The rotor has an extending shaft, which allows a machine to be coupled to it. Most large motors will be three phase motors rated from 220 or 4160 volts.

Vertical turbine line shaft pumps will often have a hollow core or hollow shaft motor. The rotor is hollow and the motor shaft can slide up and down to allow adjustment of impeller clearance. This lateral adjustment is accomplished by raising and lowering the shaft with the adjusting nut on top of the upper bearing.

Phases

The term "phase" applies to alternating current (AC) systems and describes how many external winding connections are available from a generator, transformer, or motor for actual load connections. Motors are either single- phase or three-phase.

Single Phase Motors

Single-phase motors are normally operated on 110-220 volt A.C. single-phase systems. A straight single-phase winding has no starting torque so it must incorporate some other means of spinning the shaft. A single-phase motor requires a special start circuit within the motor to make sure it runs in the right direction. Several different types of starter windings are available in these motors. Single-phase power leads will have three wires, like a three-prong extension cord. The third

Three Phase Motors

Three-phase systems refer to the fact that there are three sets of windings in the motor and three legs of power coming in from the distribution system. This type of motor is used where loads become larger than single-phase circuits can handle. With three legs to carry power, more amps can be delivered to the motor. Three phase motors are the most common types used in water and wastewater systems. Three major types of three phase motors are the squirrel cage induction motor, synchronous motors, and wound rotor induction motors.

Squirrel cage induction motors are widely used because of its simple construction and relative low maintenance requirements. The windings are stationary and are built into the frame of the motor. The power supply is connected to the windings in the stator, which creates a rotating magnetic field. The rotor is made up of bars arranged in the shape of a cylinder and joined to form a "squirrel cage." Squirrel cage induction motors make up approximately 90% of all motors used in industry today.

Three-phase motors do not use a start circuit. The direction of rotation is determined by how the three leads are wired to the motor. If any two of the leads are switched, the motor rotation will be reversed.

Single Phasing

Anytime a lead becomes grounded, a dead short develops, or one of the contacts opens in a three-phase motor, single phasing will result. When this occurs, the speed of the motor will drop and it will begin to overheat. The single phase will draw too many amps and it will quickly burn up. When single phasing occurs while the motor is not running, it simply will not start up again. Special circuit protection is available that will shut the motor off if single phasing occurs.

Circuit Protection

Motors need to be protected from power surges and overloads. Fuses and circuit breakers are designed to open the circuit when the current load threatens to damage the motor. Fuses are generally sized at 120-150% of motor capacity. Circuit breakers can be reset when they trip, instead of being replaced like a fuse. Circuit breakers can react faster than fuses and are usually sized closer to the current rating of the motor.

PUMP & MOTOR MAINTENANCE

Maintenance is one of the most important and most often neglected tasks in water system operations. When money gets tight maintenance is often one of the first things to go. More and more water systems are finding that cutting maintenance to save money is false economy. Almost without fail, the cost to repair damage caused by lack of maintenance is much higher than the cost to maintain the equipment.

All systems should develop a preventive maintenance program. A preventive maintenance program allows virtually all maintenance to be performed during normal operating hours. Emergency maintenance is reduced to a minimum.

In maintaining a pump and motor there are three major areas of maintenance concern: the couplings, the bearings, and the pump staffing box.

Couplings

Close-coupled pumps have no coupling with which to be concerned. All other pumps, in which the pump and motor are separate units, must have some device to attach the motor to the pump. Couplings are used for this purpose. Couplings perform some or all of these functions:

- Connect the motor to the pump to allow the motor to turn the pump.
- Flexible couplings allow for some pump to motor misalignment.
- Because of slack (called internal clearance) in bearings, the pump and motor shafts can move away from and toward each other. Couplings allow for this to happen without damage.
- Vibration can damage equipment. Couplings can reduce the amount of vibration transmitted from one piece of equipment to another.
- Electricity can flow from the motor to the pump causing pitting in bearings and their premature corrosion and failure. Couplings can be used that will insulate the pump shaft against stray current.
- Couplings absorb the torque created when the motor starts.

Energy transfer and compensation for misalignment are the two most important functions performed by a coupling. There are two types of couplings, rigid and flexible couplings. Rigid couplings do not compensate for any misalignment. Flexible couplings allow for small amounts of pump to motor misalignment.

Coupling Alignment

The key to maintaining a flexible coupling or rigid coupling is to monitor the alignment between the drive unit and the pump. Neglect or completely overlooking alignment will certainly result in early failure of the coupling, and result in damage to the motor and pump. The types of misalignment that may be encountered are: angular and parallel.

Angular Misalignment

Angular misalignment is the type most likely to cause severe damage to the pump and motor. A characteristic of this type of misalignment is that the motor is set at an angle to the pump. This angle can either be to the left or right, up or down. If the center lines of the motor and pump were extended, they would cross each other, rather than run parallel. When aligning a pump and motor, angular alignment should be checked first.

Parallel Misalignment
Parallel misalignment occurs when the two center lines are parallel, but they are not in the same plane vertically or horizontally. Generally, parallel misalignment results in less vibration than angular misalignment. Parallel misalignment is also the easiest to detect. If parallel misalignment is beyond the tolerance limits, it is difficult, if not impossible, to join the coupling halves.

Combination Misalignment
The third type of misalignment encountered is combination misalignment. As the name implies, the motor is misaligned angularly, and at the same time is either displaced to the right or left, or on a different level than the pump.

In order to align the pump and motor, it is necessary to let either the pump or motor remain still, while moving the other to bring it into line. It is best to align the motor with the pump. Moving the pump will put stress on the piping system. As the pipe tries to pull back to relieve the stress, the pump will be shifted. If the pump is left in place while the motor is shifted, this problem will not occur.

How to Use a Dial Indicator* to Determine Pump & Motor Shaft Runout
(Determine if shaft is straight or bent).

1. Give the pump and motor shafts a rough, “eyeball,” alignment.
2. Check the pump and motor shaft for run out by placing the dial indicator clamp on the pump shaft.
3. Place the dial indicator in contact near the end of the motor shaft, insuring that the scale is reading off zero.
4. Rotate the dial indicator scale until it reads zero.
5. Rotate the pump shaft until the dial indicator gives its highest reading.
6. Put a mark on the pump shaft to insure this point on the pump shaft remains at the top.
7. Repeat this procedure on the motor shaft.

*(Dial Indicators are available from many machine shop supply houses and auto parts stores).

How to Use a Caliper to Determine Angular Misalignment Between a Motor & Pump

1. Measure the distance between the coupling halves at the top of the couplings.
2. Mark the coupling halves where the measurement was taken.
3. Rotate the coupling 90 degrees and measure again.
4. Rotate the coupling 90 degrees so that the marks are now at the bottom, and measure again.
5. Rotate the coupling 90 degrees and measure again.
6. If the motor is out of alignment horizontally, simply shift the motor toward the side on which the greatest gap is found. If the greatest gap was found at the top of the coupling, add shims to raise the rear of the motor.
7. If the greatest gap was found at the bottom of the coupling, add shims to raise the front of the motor. The shim thickness should be one half as thick as the gap is wide.

How to Check a Pump and Motor for Angular Misalignment Using a Dial Indicator

1. Give the pump and motor shafts a rough, “eyeball,” alignment.

2. Attach the dial indicator to the pump half of the coupling. Attach a block to the motor coupling half, contacting the dial indicator in such a way that the scale reads off zero.
3. Rotate the coupling halves so that the dial indicator is in the three o'clock position, reading the dial indicator.
4. Rotate the coupling halves so that the dial indicator is on the six o'clock position, read the dial indicator.
5. Rotate the coupling halves until the dial indicator is at the nine o'clock position; read the indicator.
6. Shift the motor or add shims to correct the alignment.
7. Re-check the alignment.

How to Use a Straight edge to Check for Parallel Misalignment

1. Lay a straight edge across the top of the coupling halves, insuring it is parallel to the shafts. Check for clearance using a thickness gage.
2. Mark the point at the top, where this measurement was made.
3. Rotate the coupling until the mark is in the 3 o'clock position. Place the straight edge at the marks, insuring the straight edge is parallel to the pump and motor shafts. Using the thickness gauges, measure any gap between the straight edge and either coupling.
4. Check the coupling in the 6 and 9 o'clock positions.
5. Make any corrections necessary in the motor's position; re-check.

How to Use a Dial Indicator to Check for Parallel Misalignment

1. Attach the dial indicator to the pump half of the coupling.
2. Adjust the dial indicator to read off zero.
3. Rotate the dial indicator to read zero.
4. Check the dial indicator readings in the 12, 3, 6, and 9 o'clock positions.
5. Make any adjustments in the motor position and re-check the alignment.

Motor Maintenance

Maintenance of electric motors requires that extreme care be exercised to avoid harm to the person performing the maintenance and to avoid damage to the motor. When performing maintenance on motors be certain to always turn off the power supply. Also lock out the power supply to prevent someone from accidentally turning the power back on while you are working on the equipment.

Exterior maintenance of electric motors is fairly simple. It is a matter of keeping the exterior clean and painted. Do not allow the paint finish to deteriorate to the point that the motor's exterior begins to corrode. Do not allow grease, dust, and dirt to build up on the motor body.

Do not allow paint to build up on the motor body. All of these things prevent the motor from radiating heat. Heat will build up and shorten the life of the motor. Blocking ventilation will also cause heat to build up. When painting a motor, be certain that the data plate is not damaged or covered with paint. The data plate should be readable.

A routine lubrication schedule should be set up and followed. For more information, consult the manufacturer's literature. The manufacturer's literature will have information on what type of lubricant, how much lubricant to use, and how often the equipment should be relubricated. Maintenance of the insulation in the inside of a motor is an important and difficult task. In order to maintain the motor insulation, keep it clean, dry and cool. The insulation should be free of contaminants such as dust, salt, chemicals, lint, and oil. To keep the inside of a motor clean and in working order, you need to:

- Select the motor enclosure type that is best suited to environmental conditions under which the motor must operate;
- Remove the source of contamination, if possible;
- Clean contamination from the windings; and,
- Clean the exterior and keeping the ventilation openings clear.

Insure that the insulation is kept dry. Some insulations are porous and can absorb water, causing failure to the motor. Dirt and other contaminants attract moisture. Proper enclosures can reduce or eliminate most moisture problems. In very cold or humid areas, it may be necessary to provide heaters to keep motors dry.

Contamination problems are generally attributable to the shoddy greasing practices or to water contamination from excessive packing leakage or flooding. Lubricants and all equipment associated with relubrication should be cleaned immediately after use, and inspected before use to insure it is clean. All grease fittings should be wiped off thoroughly with a clean cloth towel before attaching the grease gun.

An oil lubrication system is the simplest system to monitor. It requires the person performing maintenance to monitor and oil level frequently, and add oil to the machinery as needed.

Motor Lubrication

Lubrication is one of the simplest maintenance procedures to perform. It is also the maintenance procedure which is most often neglected or done incorrectly. It is estimated that about 70-80% of all bearing failures in water and wastewater systems are caused by improper lubrication. Lubrication failures will normally fall into one of four categories:

- Too much lubricant;
- Too little lubricant;
- Wrong king of lubricant; and
- Contamination of lubricant.

Too much, too little, and the wrong kind of lubricants are problems which are easily solved. Before relubricating the pump and motor, consult the manufacturer's literature. It will tell how much lubricant to use, how often to lubricate the equipment, and give recommendations as to which brands are compatible with the equipment and service.

Lubrication oil should be changed at the recommended interval. If for some reason the oil should become overly hot in operation, more frequent changing will be required. When choosing an oil the most important characteristic to look for is the viscosity. Viscosity, in simple terms, is a fluid's resistance to flow. Consult the manufacturer's handbook to determine the correct viscosity for the pump or motor. If the viscosity is too high the machinery will have to work harder to turn, especially in cool weather. If the viscosity it too low, the bearing will break through the oil film and wear prematurely, and also build up heat.

To relubricate a pump or motor, using oil, follow this procedure. As in all maintenance procedures, consult the manufacturer's literature before doing the work.

How to Change the Oil in Pumps & Motors

The manufacturer's literature will indicate the proper type of oil, the correct amount, and any special information you may need. The oil should be brought up to operating temperature just prior to changing.

1. Turn off the equipment and lock out the power supply;
2. Remove the drain plug and allow all the old oil to drain out;
3. Replace the drain plug and refill with new oil until the oil level indicator shows the proper levels; and,
4. Return the equipment to service.

Because of adverse reactions due to different additives, DIFFERENT BRANDS of oils should never be mixed. If you must change brands of oil, follow this procedure:

1. Turn off and lock out the power supply;
2. Remove the drain plug, and allow all the old oil to drain out;
3. Replace the drain plug and fill to the proper level with the new brand of oil; and,
4. Operate the equipment until it reaches operating temperature; then repeat drain and fill procedure.

How to Change the Oil in Pumps & Motors

Relubrication procedures using greases depend on the type of fittings furnished. Most grease lubricated equipment is equipped with an alemite grease fitting, to which a grease gun can be attached. Remove the grease relief plug from the pump or motor housing during the relubrication process. This will allow the old grease to be flushed from the bearing housing. If the equipment does not have a grease relief plug, it is very important that the manufacturer's instructions be followed exactly. If the equipment is equipped with a grease relief port, relubrication can be accomplished with little fear of accidental overlubrication. Before relubricating with grease, the manufacturer's literature should be consulted to determine the correct brand, hardness, and amount of grease to be used. Some of the pieces of equipment equipped with grease fittings are also equipped with grease relief plugs.

Mechanical Seals

Water leakage must be controlled at the point where the shaft exits the pump body/volute. In addition to controlling the water that is trying to leak out, we can, at the same time, control air that is trying to get in. There are two ways to control this leakage: through the use of mechanical seals or pump packings.

There are a great variety of brands and styles of mechanical seals from which to choose. Mechanical seals offer several advantages over mechanical packings. Properly installed, mechanical seals control leakage so well that they appear not to leak at all. This eliminates the mess and hazard usually associated with packings—that of having water leaking all over the floor.

Mechanical seals require no maintenance, as packing does. Probably the greatest advantage of mechanical seals is that they put very little demand for extra electricity to drive the pump. They are built with a high degree of precision and require extreme care and skill in installation. The pump must be at least partially disassembled to install or replace a mechanical seal. When they fail, they tend to fail completely and require immediate attention.

There are three key points to remember when deciding whether or not to use a mechanical seal. The first is that a mechanical seal should be installed only on a new pump, or a pump and motor which has been completely rebuilt. Never install a mechanical seal on a pump that has been in service for a time, without first reworking the pump.

The second point is to choose a seal with a multiple spring arrangement. Mechanical seals rely on springs to close the sealing faces. Seals are available with a single, large spring to close the faces. This type of arrangement results in unequal pressure on the sealing faces, resulting in premature failure. The multiple spring arrangement allows for more even pressure on the sealing faces, resulting in longer seal life.

The last consideration is to choose a mechanical seal that is hydraulically balanced. Seals that are hydraulically balanced tend to have a longer operational life.

Pump Packing

The second way to control the leakage around pump shafts is by the use of pump packings. Many types of pump packings are available. Most types of pump packings have been developed to meet specific needs and are not of interest to the water industry. Even so, there is still a large variety of packings from which to choose. Packing selection is simplified if packings are selected following these guidelines:

- Determine the pH of the water being pumped;
- Determine the pressure inside the stuffing box; and,
- Estimate the shaft speed in feet per minute.

Federal regulations require that drinking water pH be within a range of 6.5 to 8.0. Because of this narrow range for pH, pH is the least significant of the three factors under consideration for water system packing selection.

The stuffing box pressure is a factor which is difficult to measure so most people use a general rule of thumb that the stuffing box pressure is usually two-thirds of the pump discharge pressure. Therefore, to determine the stuffing box pressure, put a gauge on the discharge pipe to determine the discharge pressure. Then multiply the pump discharge pressure by 0.67. For example, a pump with a discharge pressure of 150 psi would have a stuffing box pressure of 150 psi X 0.67, or approximately 100 psi. The stuffing box on a pump must be allowed to leak, but the leakage should be controlled. The higher the stuffing box pressure, the more leakage there will be.

Packing comes in several weaves, from a very loose twisted packing to a moderately tight weave. In some instances it may be necessary to abandon woven packing material all together and use solid packing materials. Solid packing materials control leakage well in pumps with very high stuffing box pressures. Because of the abrasiveness associated with all packing materials, shaft speed is a very important factor to consider. The faster the shaft speed, the better and less abrasive the packing must be.

Pump Packing Procedure

As in all maintenance procedures, the manufacturer’s literature for the pump should be consulted. You should be able to find out how many packing rings are needed, what size packing is needed, and where the lantern ring should be placed in the stuffing box. Before going further it would be wise to stop and examine in more detail some of the pump parts we are going to be dealing with when we pack a pump. The four parts of the stuffing box are: the gland, the sleeve, the packing and the lantern ring (or seal cage).

There must be some way to control the leakage around where the shaft protrudes into the pump volute. In order to control leakage, a pump is provided with a stuffing box and related parts. The stuffing box and its parts allow us to use packing to control the leakage.

Controlling Water Leakage

Since any material used in the stuffing box to control leakage is going to be abrasive to some extent, and this abrasiveness will result in wear and damage to the pump shaft, most pump shafts are equipped with sleeves. The sleeve is a device, slipped over the portion of the pump shaft that passes through the stuffing box, designed to take the wear from the packing and prevent damage to the shaft. Sleeves are cheaper and more easily replaced than shafts.

In order to reduce wear and extend the life of the sleeve, the sleeve and packing must be lubricated. This is accomplished using water. Most centrifugal pumps have an inlet for clean water into the stuffing box. This is called a water seal. Water is injected into the stuffing box under pressure and this water flows out of the stuffing box between the packing material and sleeve. In so doing, friction between the packing and sleeve is reduced, the sleeve is cooled, and debris is flushed from the stuffing box.

In order for water to flow into the stuffing box unobstructed, a device called a lantern ring or seal cage is sometimes placed in the stuffing box under the water seal inlet port.

The lantern ring is designed to allow the water used for cooling and lubrication to flow into the stuffing box unimpeded. Seal cages also help keep air from entering the pump. In order to function properly the lantern ring must be placed in the correct location within the stuffing box. Consult the manufacturer’s handbook.

The gland serves several functions in the stuffing box. The most obvious function is to hold the packing in. The pressure from the water leaking into the stuffing box from the impeller casing (volute) and the water being injected through the inlet port would push the packing out, if the gland were not there to hold the packing in place. The gland also allows for control of leakage from the stuffing box.

In no case should the gland be tightened to the point that water flow from the stuffing box is cut off completely. The gland should only be tightened enough to stop excessive leakage. A general rule to follow in determining the proper amount of leakage from the stuffing box, is to allow at least 20 drops per minute per inch of shaft diameter. For example, a two inch shaft would need 40 drops per minute to leak from the stuffing box.

The gland also serves as an indicator of packing wear. When the gland has been adjusted until it is flush with the stuffing box, it is an indication that the packing is worn out and it is time to change it.

How to Pack a Centrifugal Pump

In replacing the pump packing, first consult the manufacturer’s literature. A general guideline to packing replacement is given below:

1. Turn off the pump and lock out the power supply.

2. Close the discharge and suction valves.
3. If there is a separate pump supplying the stuffing box with lubricating water, turn off this sealing water.
4. Remove the gland, and using the packing puller, remove the old packing material. Use proper packing tools, not ice picks, screwdrivers, or coat hangers. These can damage the sleeve or stuffing box housing, causing other problems.
5. Examine the old rings of packing material for damage or unusual wear.
6. Using a wash bottle, clean out all of the debris lift in the stuffing box.
7. With a flashlight and mirror, check the sleeve for rust, burrs and wear. Make any necessary repairs to the sleeve or stuffing box before proceeding.
8. Using a straight edge and thickness gages or a dial indicator, check the pump and motor for proper alignment. These procedures are listed elsewhere in the text.
9. Cut the packing material. Packing that is not cut correctly will not function properly and will eventually cause damage to the pump. There are two methods you can use to cut packing correctly. Using a shaft, sleeve, or mandrill of the same size as the shaft as the pump to be packed, wrap either one wrap at a time, or the required number of rings around the sleeve or shaft. Using a sharp knife, make the cut. If no other device is available, wrap the packing around the shaft of the pump to be packed, and make the cut. The cut is critical. If it is not done correctly, the packing should not be used. An improperly cut piece of packing material will have a joint that will not seal tightly. This loose joint will allow water to flow through the joint, rather than forcing the water to flow between the ring of packing and the shaft.
10. Replace the packing rings individually, seating each ring completely. This will require a tamping tool, or a mandrill like the one shown in the photo.
11. As you replace the rings, do not line up the packing joints. Stagger them at about 90^{o} to each other. It is a good idea to alternate the joints by placing them at 9, 12, 3 o'clock.
12. After placing the last ring of packing, install the gland, making certain that it is square with the stuffing box housing. Run the gland nuts up finger tight.
13. Using a wrench, snug up the gland. DO NOT OVERTIGHTEN.
14. Back off on the gland nuts and tighten again finger tight. Insure that each nut is tightened equally and the gland remains square with the housing.
15. Turn on the sealing water.
16. Turn on the pump.
17. Open the discharge and suction valves.
18. Check the leakage from the stuffing box to insure that it is neither excessive nor insufficient. If it is insufficient, loosen the gland nuts.
19. Allow the pump to operate for about 16 to 24 hours. If the pump is still leaking too much water, carefully tighten each gland nut about one-quarter turn. Wait about 1 to 2 hours. If the pump is still leaking excessively, give the gland nuts about one quarter turn each, insuring the gland remains square with the housing. Recheck in one to two hours and make adjustments as necessary until the proper leakage rate is reached.
20. Recheck daily to insure the leak rate remains acceptable, and make one-quarter turn adjustments as necessary.

PREPARATION OF AN OPERATION & MAINTENANCE PLAN

This plan should be developed by every public water supplier to provide a written source of material that can be easily referred to for guidance in operating a water system. This plan will be a valuable reference tool for the operating personnel because standard operating procedures for the system and guidelines for start-up and emergency situations will beat their fingertips.

The Operation & Maintenance (O&M) Plan will also provide a ready reference for all equipment data which is necessary for performing normal maintenance and for ordering replacement parts and supplies. It will be an organized system for keeping records of the operation of the system. These records are useful for monthly and annual reports, as supporting documentation of proper operation, and to support the need for replacement or upgrading of treatment facilities. It will have detailed instructions for water sampling and testing which are required for compliance with the Safe Drinking Water Act (SDWA) and for routine monitoring of the treatment process for compliance with generally accepted good waterworks procedures.

The plan will contain information regarding start-up and normal operating procedures and emergency operating procedures; descriptions of equipment and facilities; organization responsibilities; names, addresses, and phone numbers of all key personnel; all contractors and suppliers; and state and local officials.

The O&M Plan will become a training manual to provide personnel with a handy source reference while they learn to operate the facilities. The O&M Plan will be used by experienced operating personnel to monitor normal procedures for changes or emergency conditions; as a source for names and phone numbers when emergency notification is required; and as a check of proper maintenance procedures.

How to Develop an Effective O& M Plan

O&M Plans are often prepared by engineers and managers; however, they must be certain that they obtain information from persons actually experienced in plant operation and maintenance. The procedures must be described in terms and language which are readily accepted and understood by the operators. Because of the technical nature of the water treatment process, a basic level of knowledge and understanding by the operators must be assumed. The experienced operator will usually refer to the O&M Plan for confirmation of normal operation and maintenance procedures and as a reference guide for unusual operating conditions. The entry level operator should frequently refer to the O&M Plan for guidance and instruction.

Some water suppliers may have O&M Plans or certain parts of O&M Plans established or their system. These may include Emergency Response Plans, Safety Programs, Water Conservation Programs, Cross-Connection Control Programs, or other formalized procedures. This guidance manual is not intended as a required format which must be followed, but as a presentation of procedures which can be considered for your use in the preparation of your O&M Plan.

Plans and programs which have been accepted as good, operating procedures can be directly included in your O&M Plan without rewriting; however, it would be a good idea to review and update your procedures. Your O&M Plan will be a collection of plans and programs which will probably be stored in loose-leaf notebooks. The appearance of your plan is not as important as the availability of the information to the operating personnel and the ability to revise and update it.

CROSS-CONNECTIONS & BACKFLOW PREVENTION

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 in a drinking water system can be deadly and are consistently the cause of more reported waterborne outbreaks than any other source. Safe drinking water can become unsafe when drinking (potable) water lines are cross-connected to an undrinkable (nonpotable) liquid such as an undiluted sodium hypochlorite solution, hose bib with hose immersed in a bucket of soapy water or swimming pool, etc.

Backflow

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

Backsiphonage

Backsiphonage is backflow caused by negative (sub-atmospheric pressure) in the distribution system or supply piping, for example a main break. 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.

Cross-connections are easy to create and can be in place for a long time without notice until the right set of conditions occur. Cross-connections usually become active when the water system loses pressure, such as would occur with a break in a distribution line or a water pump failure. In order to prevent contamination, a PWS should maintain at least a pressure of 20 psi, under all flow conditions in the system.

The most typical example of a cross-connection is the common garden hose. This indirect cross-connection occurs when one end of a hose is attached to an unprotected hose bib/faucet and the other end of the hose is in the hypochlorite solution tank. If the water system pressure drops due to a waterline break, the undiluted hypochlorite solution can be pulled back (backsiphoned) into the distribution system piping. This is backsiphon backflow in which the contaminant enters the system as the result of a vacuum created by a negative pressure in the system and the flow of water backwards to meet the demand for water at the waterline break.

Backflow can also occur when there is a backpressure such as a boiler heating system for hot water and/or heat. The Boiler pressure can exceed the water system pressure and cause backpressure backflow. This can result in boiler heating water, often containing chemicals such as antiscalants, to be pushed into the distribution system.

Cross-connections can contribute to all kinds of water quality and health problems:

- Cloudy or turbid water;
- Positive coliform tests;
- Color; and,
- Introduction of concentrated chemicals such as hypochlorite solution.

The first step in controlling cross-connections is to identify the cross-connections. You may want to have someone with experience in cross-connections to come in and assist you. Resources include your local state drinking water office, state environmental training center or other technical assistance provider. Trace the flow of water and look for any connections between potable and non-potable liquids. Color coding, labeling, and flow direction arrows on pipes can be very helpful in determining which pipes are carrying potable water and which are not and the direction of flow. The following are the most typical examples of where cross-connections occur:

- Garden hose attached to an unprotected hose bib and immersed in nonpotable liquid;
- Garden hose attached to a hose bib with an atmospheric vacuum breaker but with a spray shutoff valve on the other end;
- Make-up water for the hypochlorination feed/solution tank;
- Chemical feed pump with 4 in 1 valve;
- Boilers such as heating units;
- Many hand-held pesticide or herbicide applicators;
- In-ground lawn irrigation systems; and,
- Connections with un-approved, abandoned or non-potable water wells.

The second step in controlling cross-connections is to correct the problem. The following are the traditional approaches to controlling cross-connections:

1. Air gap - The most effective backflow prevention is an air gap. The air gap from the outlet fixture to the flood rim of the receiving container must be twice the diameter of the outlet fixture. A good example is the design of modern sinks which have the end of the faucet terminating well above the flood rim of the sink. Another typical example is the following drawing of the make-up water hook up to add potable water to a dilution tank for feeding sodium hypochlorite.
2. Atmospheric Vacuum Breaker (AVB) - An inexpensive device that is activated when the supply line develops negative pressure and prevents backsiphonage. An atmospheric vacuum breaker will not prevent backpressure backflow. The device must be installed six inches above the highest outlet and there can be no downstream shutoffs which would keep the AVB under continuous pressure. For example, a hose bib with a vacuum breaker will prevent backsiphonage backflow unless there is a downstream shut off valve such as a hose spray nozzle. This downstream shutoff puts the AVB under continuous pres sure which interferes with the operation of the device.
3. Pressure-type Vacuum Beaker (PVB) - This device is similar to the AVB except the PVB can be held under continuous pressure and will operate when a drop in water system pressure occurs. PVB's are spring loaded and consequently can

become inoperable due to corrosion and sediments. PVB's must be installed a minimum of 12 inches above the highest outlet

4. Double-check valve assembly - Useful for low and intermediate hazard levels and must be inspected annually. Homemade double-checks such as two single checks hooked up in series are not an acceptable substitute.
5. Reduced Pressure Zone Backflow Preventer (RPZ) - This device is for the highest hazards and must be properly maintained and tested annually. This device consists of two spring loaded pressure-reducing check valves with a pressure regulated relief valve located between the two check valves. Periodic discharge of water from the center valve indicates that the valve has responded to a drop in water system pressure. A continuous discharge of water from the relief port may indicate malfunctioning of one or both of the check valves or relief valve. Under no circumstances should the relief port be plugged because the device depends on an open port for effective operation. RPZ's must be protected from freezing and vandals.

West Virginia Requirement

The type of protection required under this rule depends on the degree of hazard that exists or may exist, as determined by the PWS and shall involve the installation of either:

- An approved air gap separation when the public water system determines that contamination with substances could cause a severe health hazard;
- An approved air gap separation or approved reduced pressure principle backflow prevention assembly when the public water system determines that contamination with substances could cause a health hazard; or
- An approved double-check valve assembly, approved reduced pressure principal backflow prevention assembly, or an approved air gap separation when the public water system determines that contamination with substances could degrade the water quality of the public water system.

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 WV certified Backflow Prevention Assembly Inspector/Tester (BPAIT) at the time of installation, repair, or relocation, and at least on an annual schedule thereafter. A list of current BPAITs can be found online at www.wvdhhr.org/oehs/backflow/default.aspx

SUPERVISORY CONTROL AND DATA ACQUISTION (SCADA)

Supervisory Control and Data Acquisition (SCADA) refers to a system that collects data from various sensors at a plant or in other remote locations and then sends this data to a central computer which then manages and controls the data. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via **Programmable Logic Controllers (PLCs)**, or other commercial hardware.

Data Acquisition
Data acquisition refers to the method used to access and control information or data from the equipment being controlled and monitored. The data accessed are then forwarded onto a telemetry system ready for transfer to the different sites. They can be analog and digital information gathered by sensors, such as flowmeter, ammeter, etc. It can also be data to control equipment such as actuators, relays, valves, motors, etc.

Operational Considerations
SCADA can be used to monitor and control plant or equipment. The control may be automatic, or initiated by operator commands. The data acquisition is accomplished firstly by the **remote terminal units (RTUs)** scanning the field inputs connected to the RTU (RTU may also be called a PLC - programmable logic controller). This is usually at a fast rate. The central host will scan the RTU's (usually at a slower rate.)

The data is processed to detect alarm conditions, and if an alarm is present, it will be displayed on special alarm lists. Data can be of three main types. Analogue data (i.e. real numbers) will be trended (i.e. placed in graphs). Digital data (on/off) may have alarms attached to one state or the other. Pulse data (e.g. counting revolutions of a meter) is normally accumulated or counted.

The primary interface to the operator is a graphical display (mimic) usually via a personal computer screen which shows a representation of the plant or equipment in graphical form. Live data is shown as graphical shapes (foreground) over a static background. As the data changes in the field, the foreground is updated. A valve may be shown as open or closed. Analog data can be shown either as a number, or graphically. The system may have many such displays, and the operator can select from the relevant.

One of key processes of SCADA is the ability to monitor an entire system in real time. This is facilitated by data acquisitions including meter reading, checking statuses of sensors, etc that are communicated at regular intervals depending on the system. Besides the data being used by the RTU, it is also displayed to a human that is able to interface with the system to override settings or make changes when necessary.

In West Virginia, Environmental Health Procedures DW-36 *Operator Exception Requests for Automated Public Water Systems* (April 2012) outlines additional exceptions allowable for Class II – IV public water systems (PWS) only based on proven automation. This policy covers unattended operation with or without remote monitoring and does not allow for remote treatment changes. It is available online at http://www.wvdhhr.org/phs/manual/Drinking_Water/

SAMPLING

Importance of Good Sampling Procedures

The importance of obtaining samples by proper methodology cannot be emphasized enough. Proper sampling is a vital part of protecting the water supply. Without proper sampling techniques the laboratory data obtained from tests conducted on those samples are meaningless, and more importantly, any maintenance of the water supply based on that data could result in situation which would endanger human health.

Representative Sampling

Remember with sampling a small quantity of water is being used to evaluate a great quantity of water. Every precaution must be taken to ensure that the small quantity is a good representative sample of the greater quantity. A representative sample is a sample portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of material or water being sampled.

Grab Sampling

A grab sample is a single water sample collected at no specific time. A grab sample only represents the characteristics of that particular sample at that particular time. There may be times when a grab sample is preferred over a composite sample. These situations may include the following:

- The water to be sampled does not flow continuously;
- The characteristics of the water are relatively constant; and
- The water needs to be tested for water quality indicators that may change with time, such as dissolved gases, coliform bacteria, residual chlorine, temperature and pH.

Composite Sampling

A composite sample is a collection of individual samples obtained at regular intervals over a 24-hour period. The combined sample (the composite sample) forms a single larger representative sample and is analyzed to determine the average conditions during the sampling period. If the individual samples are combined in proportion to the rate of flow when the sample was collected, then it is called a flow proportional composite sample.

Sampling Locations

Sampling location usually depends on the type of system and the analyses required. The sampling locations to be used and the rationale behind selecting the sites are to be presented in a sample-site plan, which is to be submitted to the State for approval.

<u>Water Taps</u>

To collect samples from taps connected to water mains the service line must be flushed for a brief period of time before collecting the sample. The following precautions should be taken:

- Do not take samples from drinking fountains, restrooms, or taps with aerators.
- Do not take samples from taps surrounded by excess foliage such as leaves or flowers.
- Do not take samples from taps that are dirty, corroded, or are leaking.
- Never collect a sample from a hose or other attachment fastened to a faucet.

- Care should be taken that the person collecting the sample does not touch the faucet in any way that could contaminate the sample.

Sometimes, as in the collection of samples for lead and copper testing, a 'first draw' or 'first flush' sample will be required. For this, the water needs to stand in the pipes undisturbed for at least six hours before the sample is drawn. No water is flushed from the faucet before the sample is collected. Usually, this sample will be taken first thing in the morning before any water has been used.

<u>Distribution Systems</u>
The most representative samples of the water supply would be taken from the water main before any branching off occurs. Analyses of water main samples can be compared to analyses of tap samples to help pin point a possible problem for instance.

Sampling points should be selected so that the pathway of water from the source to the endpoint will be represented. Ideal sampling locations are those that provide a short, direct connection with the main and are made of corrosion-resistant material. Not just any faucet will do, and fire hydrants are not acceptable due to how they are constructed and their infrequent use. Allow the water line to flush long enough to replace the water in the lines twice. About 5 minutes is usually sufficient. Do not turn the faucet on wide open to make flushing quicker as this will stir up any deposits in the lines.

Sampling Containers, Preservation and Holding Times
The type of container used for collecting a sample depends on what tests need to be conducted on that collected sample. The Code of Federal Regulations, Protection of Environment, CFR 40, Part 136.3 contains a complete list of analyses that can be conducted along with information on approved sample containers, volume required, preservatives and maximum holding time between sampling and analysis.

The container must be clean and will usually be supplied by the laboratory performing the analysis. The container must be clearly labeled and at a minimum contain the following information:

- PWS ID Number
- Sample location
- Sample date
- Time of collection (exact time)
- Name of collector

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 at the point of use. Samples must be taken from locations that are representative of the water delivered to the consumer, and points of use. In selecting sampling points, each location 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.
- Samples collected should be grab samples. Grab samples are a single sample collected at a particular time and place which represents the composition of the water only at that time and place.
- 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.

Analysis and Test Kits CN-66 procedures and pocket colorimeter

Chlorine residual testing equipment shall enable measurement of free and total chlorine residuals to the nearest 0.2 mg/L. All test kits 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. If a test results in a low chlorine residual, check the expiration dates of the chemicals.

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

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.

SAMPLING & MONITORING

Coliform bacteria and chlorine residual are the only routine sampling and monitoring requirements for small ground water systems with chlorination. The coliform bacteriological sampling is governed by the **Revised Total Coliform Rule (RTCR)** of the SDWA. Although there is presently no requirement for chlorination of groundwater systems under the SDWA, state regulations will usually require chlorine residual monitoring of those systems that do chlorinate the water.

The RTCR requires all PWSs to monitor their distribution system for coliform bacteria according to the approved written Sample Site Plan for that system. The Sample Site Plan identifies sampling frequency and locations throughout the distribution system that are selected to be representative of conditions in the entire system. Coliform contamination can occur anywhere in the system, possibly due to problems such as; low pressure conditions, line breaks, or well contamination, and therefore routine monitoring is required. A copy of the sample site plan for the system should be kept on file and accessible to all who are involved in the sampling for the water system.

The number of samples to be collected monthly depends on the size of the system. The RTCR specifies the minimum number of coliform samples collected but it may be necessary to take more then the minimum number in order to provide adequate monitoring. This is especially true if the system consists of multiple sources, pressure zones, booster pumps, long transmission lines, or extensive distribution system piping. Since timely detection of coliform contamination is the purpose of the sample site plan, sample sites should be selected to represent the varying conditions that exist in the distribution system. The sample site plan should be updated as changes are made in the water system, especially the distribution system.

The Sample Site Plan must be followed and all operating staff must be clear on how to follow the sampling plan. In order to properly implement the sample site plan, staff must be aware of how often sampling must be done, the proper procedures and sampling containers to be used for collecting the samples, and the proper procedures for identification, storage and transport of the samples to an approved laboratory. In addition, proper procedures must be followed for repeat sampling whenever a routine sample result is positive for total coliform.

Each water system should have specific procedures for RTCR sampling to address the issues described. The Sample Site Plan and sampling procedures must be readily available to all operations personnel at the facility. In order to prevent obtaining inaccurate sample results that could cause compliance problems, it is critical that the operator be aware of some key issues relating to the collection and transport of the total coliform samples.

RTCR Sampling Considerations

- Samples must be collected in sterile containers provided by the approved laboratory that will be doing the coliform analysis.
- All sample containers should be labeled with the date, time, and location of sample collection as well as the signature of the person who collected the sample.
- Use only clean sample taps. If cleanliness is questionable, apply a solution of bleach or alcohol to the surface the tap before collecting the sample.
- The sample should be taken from a smooth nosed cold water tap if possible.

- Aerators, strainers, and hose attachments should be removed before collecting a sample.
- Samples should not be taken from:
  - Leaky taps that allow water to flow from around the stem and over the outside of the faucet.
  - Swivel faucets.
  - Houses with home treatment units.
  - Taps with non-removable aerators, strainers, or hose attachments.
- The spout of the sampling tap should face the ground so that water cannot stand in the spout when the tap is shut off.
- Prior to collecting the sample, open the tap and flush to clear the service line.
- Reduce the flow enough to prevent splashing, open and fill the sample container without rinsing, leaving a 1 inch space in the container.
- Do not rinse out the bottle, while collecting a bacteriological sample. The bottle contains sodium thiosulfate, which is a preservative used to neutralize the chlorine present in the sample.
- If sample will be in transport to the laboratory for more than 1 hour, use an iced cooler to maintain sample temperature of 4°C. Do not submerse the tops of the sample containers.
- Samples can be held for up to 30 hours before analysis if kept refrigerated.
- It may be necessary to mail the sample to a lab if the PWS is in a remote location. Insulation and mailing is acceptable as long as the time from collection to analysis is less that 30 hours and a chain of custody is maintained.

All of the information described above, relating to the RTCR requirements, is readily available from local, state, and federal regulatory agencies. Include your state's monitoring requirements and policies on file with your sample site plan. There are a number of operator guidance manuals available describing the detailed requirements and procedures necessary to comply with the RTCR. It is the operator's responsibility to obtain the necessary information to insure compliance.

Chlorine Residual Monitoring

The state of West Virginia requires total chlorine monitoring at the time of bacteriological sampling. Results of all microbiological quality samples must be submitted to OEHS. Certified laboratories must perform coliform analyses. **It is the responsibility of the owner or operator to send OEHS a copy of the results by the 10th day of the next month.** For example, results must be submitted by February 10th for samples collected in January. If the results are not received your system will receive a violation for failing to monitor. This shows how important it is to keep copies of all laboratory results. In West Virginia, copies of all microbiological monitoring results must be kept for a minimum of 5 years.

Normally, the free and total chlorine residuals are very close to the same number. As a rule of thumb, the free residual should be at least 85 % of the total residual. The inability to maintain the free residual at 85% of the total chlorine residual throughout the distribution system can result in water quality problems such as chlorine taste and odor and possibly positive coliform results. The problem of chlorine taste and odor is generally related to high combined residual and the solution may be to increase the chlorine dose rate to get past the breakpoint so that an adequate free residual can be maintained. A comprehensive sampling and monitoring program for both free and total chlorine residual is critical in providing the highest quality water to the public.

Troubleshooting Sampling & Monitoring

Problem	Possible Cause	Possible Solution
1. Positive Total Coliform.	1A. Improper sampling technique.	1A. Check distribution system for low pressure conditions, possibly due to line breaks or excessive flows, that may result in a backflow problem.
	1B. Contamination entering distribution system.	1B. Insure all staff are properly trained in sampling and transport procedures as described in the TCR.
	1C. Inadequate chlorine residual at the sample site.	1C. Check the operation of the chlorination feed system. Refer to issues described in the sections of pumps and hypochlorination systems. Insure that residual test is performed properly.
	1D. Growth of biofilm in the distribution system.	1D. Thoroughly flush effected areas of the distribution system. Superchlorination may be necessary in severe cases.
2. Chlorine taste and odor.	2A. High total chlorine residual and low free residual.	2A. The free residual should be at least 85% of the total residual. Increase the chlorine dose rate to get past the breakpoint in order to destroy some of the combined residual that causes taste and odor problems. Additional system flushing may also be required.
3. Inability to maintain an adequate free chlorine residual at the furthest points in the distribution system or at dead end lines.	3A. Inadequate chlorine dose at treatment plant.	3A. Increase chlorine feed rate at point of application.
	3B. Problems with chlorine feed equipment.	3B. Check operation of chlorination equipment.
	3C. Ineffective distribution system flushing program.	3C. Review distribution system flushing program and implement improvements to address areas of inadequate chlorine residual.
	3D. Growth of biofilm in the distribution system.	3D. Increase flushing in area of biofilm problem.

REVISED TOTAL COLIFORM (RTCR) SAMPLING SITE PLAN REQUIREMENTS

All systems must have a written sampling site plan, which are subject to State review and revision that includes the requirements listed below.

Plan must be detailed enough for the State reviewer to verify the routine sampling sites are representative of quality throughout the distribution system, each pressure zone is represented, sample sites in areas of high water age (oldest water areas), areas served by each source and areas served by each storage tank (if applicable). Files should be submitted in an electronic format (Microsoft Excel). Contact your District Office if electronic submission is not available. A Revised Sampling Site Plan must be submitted and approved through the District Office prior to changing sampling sites. If submitted samples are not clearly marked, incorrectly marked or collected at an unapproved location, based on the information provided in the Sampling Site Plan, a violation could occur.

1. Routine sampling site locations must be specifically identified (i.e. street address or street intersection).
2. A collection schedule for the above specified locations is also required as samples must be collected at regular time intervals throughout the month.
3. Repeat monitoring locations must be identified in the sampling site plan.
   a. One (1) repeat sample from the sampling tap where the original total coliform positive sample was taken
   b. One (1) repeat sample within five (5) service connections upstream
   c. One (1) repeat sample at a tap within five (5) service connections downstream of the original sampling site.
   d. If a total coliform positive sample is at the end of the distribution system or one service connection away from the end of the distribution system, the system must still take all required repeat samples. The State may allow an alternative sampling location in lieu of the requirement to collect a repeat sample within five (5) service connections.
4. A map, reflecting the sampling site locations within the distribution system must be submitted to the District Office. This map may be submitted via mail, fax, hand delivery or email. Contact your District Office for more information.

Sampling Sites

Sampling sites specified in the sampling plan should be selected carefully throughout the distribution system to represent the varying conditions that occur there. (See the figure below on the next page for examples.) It is especially important to identify and include in the sampling plan areas that may adversely affect the microbiological quality of the water. These include cross-connections, varying population densities, low-pressure zones, sites of deteriorating water mains, shared connections, and areas of low velocity water movement.

Customers' faucets and specially installed sampling taps are the two most common types of sampling sites. Customer faucets may not always be conveniently accessible. Also, samples from a customer's faucet may not accurately reflect distribution system conditions, for reasons that have to do with the customer's plumbing, which are not under the water supplier's control. If customers' faucets are to be used, each faucet should be examined carefully to ensure its suitability. Some examples of **undesirable** conditions are:

- Swivel-type faucets that have a single valve for hot and cold water.
- Faucets that have leaky packing material around the stem.
- Faucets that supply areas, such as janitorial or commercial sinks, where bacterial contamination is likely.
- Faucets close to or below ground level.
- Faucets that point upward.
- Faucets that have threads on the inside of their spouts.
- Faucets that have aerators. (If such faucets are to be used, the aerators must be removed before a sample is collected.)

To avoid the problems inherent with customer faucets, many water suppliers collect water samples for coliform analysis from special taps connected directly to distribution pipes. These special taps can be simply a faucet at the end of a riser pipe connected to the distribution line, or a more sophisticated manufactured sampling station installed at the water meter or into the distribution main.

TYPES OF COLIFORM SAMPLES

Testing for total coliforms is performed by collecting water samples. There are five types of samples that a NCWS generally takes. These are routine samples, repeat samples, additional routine samples, replacement samples, and special samples.

Compliance Samples

Routine Samples: Routine samples are those that you are required to take on a routine basis, whether that is monthly or quarterly. These samples, as well as the other types of samples noted below, are collected from representative locations throughout your water system in 125mL containers. These samples, as with all coliform samples, should be submitted to a certified laboratory for testing within **30 hours** after collection.

Repeat Samples: These compliance samples are required each time a coliform positive sample is detected and must be collected within 24 hours after you receive notification of a positive coliform result. These samples confirm any positive detection of coliform bacteria and help to identify the extent of the coliform contamination within your system, the type of coliform present, and the location or source of the contamination. Samples above and beyond the repeat sample requirement may be collected until either the system no longer detects the presence of any coliform bacteria or until the source of the contamination has been identified, eliminated, and/or prevented.

If any routine sample is total coliform-positive, repeat samples are required.

Within 24 hours of learning of a total coliform-positive ROUTINE sample result, at least 3 REPEAT samples must be collected and analyzed for total coliforms:

- One REPEAT sample must be collected from the same tap as the original sample.
- One REPEAT sample must be collected within five service connections upstream.
- One REPEAT sample must be collected within five service connections downstream.
- Systems that collect 1 ROUTINE sample per month or fewer must collect a 4th REPEAT sample anywhere in the system.

If any REPEAT sample is total coliform-positive:

- The system must analyze that total coliform-positive culture for fecal coliforms or *E.coli*.
- The system must collect another set of REPEAT samples, as before, unless the MCL has been violated and the system has notified the state.

Additional ROUTINE Sample Requirements

- A positive ROUTINE or REPEAT total coliform result requires a minimum of five ROUTINE samples be collected the following month the system provides water to the public unless waived by the state.

Non-Compliance Samples

Additional Samples: This type of sample refers to any additional non-compliance samples required by your state primacy agency in order to help identify the extent of the contamination, provide better information about water quality, or to provide further monitoring of the water within the PWS.

Replacement Samples: If a compliance sample is collected and does not get analyzed, it may be replaced by a new sample. There are several reasons why a certified laboratory may not analyze samples:

- The sample may be outdated or too old;
- The sample container may be broken upon arrival at the lab;
- The sample container may have leaked;
- The sample amount may be not be enough (remember, 100mL is the minimum);
- The sample does not indicate a date or time to tell the lab how old it is; and
- The sample may have been frozen.

Special Samples: These, too, are non-compliance samples that are collected due to repairs, complaints, or maintenance reasons. Collection of these types of samples is often necessary to ensure that coliform has not entered your distribution system as a result of events such as water line repairs, line breaks, or routine maintenance.

BACTERIOLOGICAL SAMPLING INFORMATION

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.

Bacteriological Sampling Procedure

Analysis must be completed within 30 hours

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. PWS ID Number and name of system.
    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.

GENERAL CHLORINE TEST KIT
CN-66 COLOR WHEEL INFORMATION

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.

Measuring Hints and General Test Information

- Wash all labware between tests. Contamination may alter test results. Clean with a nonabrasive detergent or a solvent such as isopropyl alcohol. Use a soft cloth for wiping or drying. Do not use paper towels or tissue on plastic tubes as this may scratch them. Rinse with clean water (preferably distilled water).
- Rinse all viewing tubes thoroughly with the sample water before testing.
- To open Powder Pillows:
    1. Tap the bottom of the pillow on a hard surface.
    2. Tear open the pillow along the dashed line.
    3. Open the pillow and form a spout by squeezing the side edges.
    4. Pour the contents into the sample.
- Accuracy is not affected by undissolved powder.
- Read the result of the Free Chlorine Test within one minute of the addition of the powder.
- Read the result of the Total Chlorine Test between three and six minutes after addition of the powder.

Testing Free Chlorine Residual (using DPD Method) Procedure

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 l 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. Fill a viewing tube to the first (5-mL) line with sample water. This is the blank.
13. Place this tube in the top left opening of the color comparator.
14. Fill another viewing tube to the first (5-mL) line with sample water.
15. Add the contents of one DPD Free Chlorine Reagent Powder Pillow to the second tube. Complete the test and read the result within one minute of the addition of the powder.
16. Swirl to mix.
17. After adding reagent to the sample cell, a pink color will develop if free chlorine is present.
18. Place the second tube in the top right opening of the color comparator.
19. Hold comparator up to a light source such as the sky, a window or a lamp. Look through the openings in front.
20. Rotate the color disc until the color matches in the two openings.
21. Read the mg/L free chlorine in the scale window.

Reference: HACH, Water Analysis Handbook

Testing Total Chlorine Residual (using DPD Method) Procedure

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 l 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. Fill a viewing tube to the first (5-mL) line with sample water. This is the blank.
13. Place this tube in the top left opening of the color comparator.
14. Fill another viewing tube to the first (5-mL) line with sample water.
15. Add the contents of one DPD Total Chlorine Reagent Powder Pillow to the second tube.
16. Swirl to mix. Wait three minutes. The result of the test must be read within six minutes of the addition of the powder.
17. After adding reagent to the sample cell, a pink color will develop if free chlorine is present.
18. Place the second tube in the top right opening of the color comparator.
19. Hold comparator up to a light source such as the sky, a window or a lamp. Look through the openings in front.
20. Rotate the color disc until the color matches in the two openings.
21. Read the mg/L total chlorine in the scale window.

Reference: HACH, Water Analysis Handbook

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POCKET COLORIMETER™

Hach Pocket Colorimeter™ instruments* are low-cost, high-quality filter photometers designed for single wavelength colorimetric measurement. This model is calibrated to measure free or total chlorine content (depending on the indicator reagent used) in water samples from 0 to 2.00 mg/L with the 1-inch sample cell and 0 to 4.5 mg/L with the 1-cm/10-mL sample cell and adapter. The liquid crystal display provides a direct readout in milligrams per liter chlorine. The factory calibration can be over-ridden with an operator-entered two-point calibration if desired

Safety Precautions

As part of good laboratory practice, please familiarize yourself with the reagents used in these procedures. Read all product labels and the material safety data sheets (MSDS) before using them. It is always good practice to wear safety glasses when handling chemicals. Follow instructions carefully. Rinse thoroughly if contact occurs. If you have questions about reagents or procedures, please contact Hach.

Operation

All instrument functions are performed using two keys and the digital display. For the normal operation of measuring the concentration of chlorine in the sample solution, a simple, five-step procedure is performed as follows. This is a general procedure. When measuring actual samples for chlorine follow the more detailed procedures on the following pages.

1. Fill a clean sample cell to the 10-mL mark with the blank solution (usually untreated sample). Fill another clean sample cell to the 10-mL mark with sample.

2. Add the contents of one pillow of the appropriate DPD chlorine reagent to the cell containing the sample. Cap and shake the cell for 20 seconds. This is the prepared sample.

3. Place the blank in the cell compartment. Cover the sample cell with the instrument cap.
Note: *When using the instrument cap as a light shield during measurements, place the cap with the curved surface toward the keypad. This position will allow the cap to match the grooves in the instrument case to provide a good seal against stray light.*

4. Press the **ZERO** key. After approximately 2 seconds, the display will read: **0.00**.

5. Place the sample cell containing the prepared sample into the cell holder and cover with the instrument cap. Press the **READ** key. After approximately 2 seconds, the display will indicate the chlorine concentration in milligrams per liter (mg/L). For example: **1.15** on the display means 1.15 mg/L as Cl_2.
Note: *For accurate readings, make sure sample cells are wiped free of liquid or fingerprints. Any liquid entering the sample cell compartment can damage the instrument.*

CALIBRATION

The Pocket Colorimeter™ instrument is factory-calibrated to save you the time and expense required to construct your own calibration curve. It is ready for use without calibration by the user. See *Using Spec√™ Secondary Standards* to verify consistent instrument operation.

Interferences

Samples containing more the 250 mg/L alkalinity or 150 mg/L acidity as $CaCO_3$ may inhibit full color development, or the color may fade instantly. Neutralize these samples to pH 6–7 with 1 N Sulfuric Acid or 1 N Sodium Hydroxide. Determine the amount required on a separate 10-mL sample. Add the same amount to the sample to be tested. Correct for the additional volume.

Samples containing monochloramine will cause a gradual drift to higher chlorine readings. When read within one minute of reagent addition, 3.0 mg/L monochloramine will cause an increase of less than 0.1 mg/L in the free chlorine reading.

Bromine, iodine, ozone, and oxidized forms of manganese and chromium may also react and read as chlorine. To compensate for the effects of manganese (Mn^{4+}) or chromium (Cr^{6+}), adjust the pH to 6–7 as described above. To a 25-mL sample, add 3 drops of 30 g/L Potassium Iodide Solution, mix, and wait one minute. Add 3 drops of 5 g/L Sodium Arsenite and mix. If chromium is present, allow exactly the same reaction period with DPD for both analyses. Subtract the result of this test from the original analysis to obtain the accurate chlorine concentration.

Free Chlorine (0 to 2.00 mg/L Cl_2) Procedure

For water, wastewater and seawater DPD Method USEPA accepted for reporting*

Measuring Hints

If the sample temporarily turns yellow after reagent addition, or the display shows overrange (flashing **2.20** in display), dilute a fresh sample and repeat the test. A slight loss of chlorine may occur because of the dilution. Multiply the result by the appropriate dilution factor.

1. Fill a 10-mL cell to the 10-mL line with sample (the blank). Cap.
Note: *Samples must be analyzed immediately and cannot be preserved for later analysis.*

2. Remove the instrument cap.
Note: *For best results, zero the instrument and read the sample under the same lighting conditions.*

3. Place the blank in the cell holder with the diamond mark facing you. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).
Note: *Wipe liquid off sample cells.*

4. Press: **ZERO** The instrument will turn on and the display will show **- - -** then **0.00**.
Note: *The instrument automatically shuts off after one minute and the last zero is stored in memory. Press* **READ** *to complete the analysis.*

5. Remove the cell from the cell holder.

6. Fill a 10-mL cell to the 10-mL line with sample.

7. Add the contents of one DPD Free Chlorine Powder Pillow to the sample cell (the prepared sample). Cap and shake gently for 20 seconds.
Note: *Accuracy is not affected by undissolved powder.*
Note: *Shaking dissipates bubbles that may form in samples with dissolved gases.*

8. Within 1 minute after adding DPD to the sample, place the prepared sample in the cell holder.
Note: *A pink color will develop if chlorine is present.*
Note: *Wipe liquid off sample cells or damage to the instrument may occur.*

9. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).

10. Press: **READ** The instrument will show **- - -** followed by the results in mg/L free chlorine.
Note: *If the sample temporarily turns yellow after reagent addition, or shows overrange (flashing* **2.20***), dilute a fresh sample and repeat the test.*

Reference: HACH, Water Analysis Handbook

Total Chlorine, Low Range (0 to 2.00 mg/L Cl_2) Procedure

For water, wastewater and seawater DPD Method USEPA accepted (powder pillows only)*

Measuring Hints

If the sample temporarily turns yellow after reagent addition or the display shows overrange (flashing **2.20** in display), dilute a fresh sample and repeat the test. A slight loss of chlorine may occur because of the dilution. Multiply the result by the appropriate dilution factor.

1. Fill a 10-mL cell to the 10-mL line with sample. Cap.
Note: *Samples must be analyzed immediately and cannot be preserved for later analysis.*

2. Add the contents of one DPD Total Chlorine Powder Pillow to the sample cell (the prepared sample). Cap and gently shake for 20 seconds.
Note: *Gently shaking dissipates bubbles which may form in samples containing dissolved gases.*

3. Wait 3 minutes. During this period, proceed with *steps 4–8*.
Note: *A pink color will form if chlorine is present.*
Note: *Accuracy is not affected by undissolved powder.*

4. Fill a 10-mL sample cell to the 10-mL line with sample (the blank). Cap.

5. Remove the instrument cap.
Note: *For best results, zero the instrument and read the sample under the same lighting conditions.*

6. Place the blank in the cell holder, with the diamond mark facing you. Tightly cover the cell with the instrument cap (flat side should face the back of the instrument).
Note: *Wipe liquid off sample cells.*

7. Press: **ZERO** The instrument will turn on and the display will show **- - -** followed by **0.00**.
Note: *The instrument automatically shuts off after 1 minute and stores the last zero in memory.*

8. Press **READ** to complete the analysis.

9. Remove the cell from the cell holder.

10. Within 3 minutes after the 3-minute reaction period, place the prepared sample in the cell holder.
Note: *Wipe liquid off sample cells.*

11. Cover the cell with instrument cap.

12. Press: **READ** The instrument will show **- - -** followed by the result in mg/L total chlorine.
Note: *If the sample temporarily turns yellow after reagent addition or shows overrange (flashing* **2.20***), dilute a fresh sample and repeat the test. Some loss of chlorine may occur. Multiply the result by the dilution factor.*

Reference: HACH, Water Analysis Handbook

USING Spec√™ SECONDARY STANDARDS

Spec√ Secondary Standards are available to quickly check the repeatability of the Pocket Colorimeter™ instrument. After initial readings for the Spec√ standards are collected, the standards can be re-checked as often as desired to ensure the instrument is working consistently. The standards do not ensure reagent quality nor do they ensure the accuracy of the test results. Analysis of real standard solutions using the kit reagents is required to verify the accuracy of the entire Pocket Colorimeter system. The Spec√ Standards should *NEVER* be used to calibrate the instrument. The certificate of analysis lists the expected value and tolerance for each Spec√ Standard.

Using the Spec√ Standards

1. Place the Spec√ blank into the cell holder with the alignment mark facing the keypad. Tightly cover the cell with the instrument cap.

2. Press **ZERO**. The display will show **0.00**.

3. Place the STD 1 cell into the cell holder. Tightly cover the cell with the instrument cap.

4. Press **READ**. Record the concentration reading.

5. Repeat steps 3 and 4 with cells labeled STD 2 and STD 3.

6. Compare these readings with previous readings to verify the instrument is returning consistent readings. (If these are the first readings, record them for comparison with later readings.)

Note: *If the instrument is user-calibrated, initial standard readings of the Spec√ Standards will need to be read again when using the user calibration.*

SAFETY

Based on past studies, the water and wastewater industry has one if the highest injury rates in the nation. Workers in these areas are involved in construction and excavations, confined spaces, hazardous chemicals, and mechanical equipment that pose a serious injury risk when proper training, equipment, and procedures are not utilized. The **Occupational Safety and Health Administration (OSHA)** is responsible for developing regulations regarding worker safety and protection.

This section will introduce the topic of safety but is not intended to provide detailed information on all the safety topics important to operators. Each of us is responsible for his/her own safety and for the safety of others working in or entering our facilities. The water industry is one of the most hazardous, so it is very important for operators to be informed about situations that pose a safety risk.

Safety Conditions

You may encounter potentially hazardous conditions on a regular basis while operating, maintaining, and repairing water system equipment. You should be aware of these hazards and use good judgment when you encounter a potentially hazardous situation. The life you save may be your own.

Accident prevention is everyone’s job, but it is the employer who is ultimately responsible for providing a safe workplace. Some of the hazards an operator may encounter include, but are not limited to:

- Lifting injuries
- Electric shock
- Slips and falls
- Sprains and strains
- Chemical burns
- Eye injuries
- Inhalation accidents (dust, toxic gases and vapors)

Accidents are the result of unsafe actions by employees or unsafe conditions that exist in the water system. Unsafe actions include, but are not limited to:

- Negligence and carelessness
- Removing or disabling machinery safety devices
- Failure to wear personal protective equipment
- Using equipment or tools not designed for the job
- Using defective equipment or tools
- Standing on or riding the outside of moving equipment
- Failure to secure or tie down heavy loads
- Operating vehicles, including heavy equipment, at an unsafe speed
- Failure to use lockout/tagout devices

Some of the more common unsafe conditions found at a small water system may include, but are not limited to:

- Poor housekeeping
- Improper storage of chemicals

- Doors removed from electrical panels
- Machinery guards or safety devices missing
- Fire and explosion hazards
- Low clearance hazards
- Protruding objects
- Inadequate lighting
- Noise above safe decibel levels
- Lack of warning placards

You should keep your water system facilities clean and orderly. Emergency equipment and doorways should be kept clear and machine guards replaced after repairing equipment. Doors should be replaced on the electrical panels when you complete a wiring job or replace a breaker.

The door to the pump house or chlorine room should open outward for ease in entering and leaving the structure. Abnormal machine or equipment operation, electrical hazards or other unsafe conditions should be corrected promptly. Do not let unsafe conditions become commonplace. Eventually, an unsafe condition will result in an accident.

Unfortunately, it is often the 5 minute task that causes many injuries. Quick fixes usually promote unsafe acts. Do not let 5 minute tasks result in an injury to yourself or an employee.

Become skilled at recognizing unsafe conditions. Your knowledge of unsafe conditions and unsafe acts gives you foresight to correct a hazardous situation before an accident occurs. Together materials handling, falls, falling objects and machinery cause more than 60% of all workplace injuries.

Employers are responsible for providing employees with the proper safety equipment and training in its use. They are also responsible for development and implementation of safety policies for their workplace. The employees, after proper training, are responsible for recognizing the safety issues; following approved safety procedures, and properly utilizing the associated safety equipment.

Personal Protective Equipment

Personal Protective Equipment (PPE) may be uncomfortable and increase stress, but is for your protection. When wearing PPE, the body's ability to cool is usually diminished. Nevertheless, PPE is frequently required to reduce the risk of injury. PPE includes steel-toed boots, safety glasses or goggles, face shields, earplugs, gloves or chemical protective clothing. The employer is responsible for providing PPE for their employees.

Respiratory protection equipment is commonly used because of the danger of inhalation, which provides a route of entry into the bloodstream for dangerous volatile chemicals. There are 2 types of respiratory protection devices called respirators: air purifying and air supplying. Both consist of a face piece connected to either an air source or an air-purifying device. The air-purifying respirator uses cartridges with filters to purify air before it is inhaled. This type of protection is not adequate in an oxygen deficient atmosphere.

Hazard Communications

OSHA established the Hazard Communication Standard in 1986. The standard was created to provide an information system on hazardous chemicals for both employers and employees. The

Haz-Com Standard requires employers to ensure their employees know what hazardous materials exist in the workplace, how to safely use these materials, and how to deal with any emergencies that arise during use. Employers are required to provide the proper safety equipment, train employees in the safe use of any hazardous materials on a jobsite, and maintain records of both.

Producers of hazardous materials are required to provide customers with a **Material Safety Data Sheet (MSDS)** for each individual chemical or material. MSDS's must be kept on file and available to employees. Employee training should also include how to read and understand the information on the MSDS. The hazards that are involved fall into two basic categories: Health Hazards and Physical hazards.

Health hazards refer to immediate or long-term harm to the body caused by exposure to hazardous chemicals. Physical hazards like flammability or corrosivity can also cause injury to skin, eyes and the respiratory system. MSDS's are divided into 8 sections.

1. Manufacturers Contact Information
2. Hazardous Ingredients/Identity Information
3. Physical/Chemical Characteristics
4. Fire and Explosion Hazard Data
5. Reactivity Data
6. Health Hazard/First Aid Information
7. Precautions for Safe Handling and Use
8. Control/Cleanup Measures

NFPA Color-Code Warning System

OSHA uses a system based on the **National Fire Protection Association (NFPA)** diamond warning symbol as part of the MSDS information. This code is also required for all container labels. The NFPA symbol has four color-coded diamond-shaped sections. The top (Red) diamond is the Flammability Hazard rating. The left (Blue) diamond is the Health Hazard rating. The right (Yellow) diamond is the Reactivity Hazard rating. The bottom (White) diamond contains special symbols to indicate properties not explained by the other categories. A number–based rating system is used for each section, ranging from 0 – least dangerous to 4 – extremely dangerous.

Lock Out/Tag Out

Lock out/tag out (LOTO) regulations deal with the need to isolate a machine from its energy source to prevent it from starting while work is being done in and around the equipment. Energy sources can include electrical energy, hydraulic energy, pneumatic energy, thermal energy, and chemical energy. This can be either active energy or stored energy. Stored energy can take many forms. Some examples of stored energy are; electrical energy stored in capacitors, pneumatic energy stored in a compressor tank, and hydraulic water pressure in an isolated line. Any stored energy must be dissipated prior to working on the equipment. Employers are responsible for establishing an “Energy Control Plan” for LOTO work and supply each worker with their individual LOTO locking devices.

LOTO requires workers to isolate and de-energize these sources and lock and tag them prior to working on the equipment or process. To de-energize an electric switch, it must be locked in the closed/on position. Only trained personnel should conduct lock out/tag out procedures. Each individual involved in the work should attach their personal LOTO lock to disconnect or isolation device. This assures that the equipment cannot be restarted until each individual is finished with their task and remove their LOTO lock and is clear of the equipment. Tags are used to provide information regarding the date and nature of the lockout and the individual responsible for removing the lockout. Tags are not substitutes for locks. Any isolation that can be locked must be locked and tagged. Lockout devices may also include chains, valve clamps, wedges, jacks, or key blocks.

Anyone who enters a LOTO work area must be informed that a LOTO situation exists. If they are to be involved in the work, they must also apply their own LOTO locks. Workers that leave a LOTO site must take their LOTO locks with them. If work is not completed at the end of a shift, all LOTO locks must be removed and be replaced with an equipment protection lock until work resumes. If equipment must be temporarily restarted, the LOTO must be removed during the restart and reapplied before work can continue.

Confined Space Entry

The water and wastewater industry has one of the highest numbers of confined space injuries per capita in the country. The vast majority of confined space related injuries result in fatalities. Another disturbing fact is that 40% of the confined space related fatalities are people who tried to rescue someone else from a confined space.

A confined space is defined by the following parameters. It must be large enough for a person to enter and do work. It has openings that make entry or exit difficult. It is not intended for continuous occupancy. Any open surface tank that is deeper than four feet is also considered a confined space. Confined spaces fall into two categories; permit required and non-permit required. A confined space becomes permit required when it has potential for a hazardous atmosphere, potential for engulfment, a hazardous internal configuration, or other recognized hazards such as dangerous equipment or hot work (welding, cutting torch, etc.) that is in progress.

All employees involved in confined space entries must have the proper training in entry procedures and use of safety equipment. An entry supervisor is responsible for conducting the testing and completing the permit. Atmospheric testing should include oxygen concentration, Lower Explosive Limit for explosives, and any toxic gases that may be present. The oxygen concentration must be between 19.5-23.5%. The alarm point for explosives is 10% of Lower Explosive Limit (LEL).

An attendant must be present and stationed outside the confined space to monitor the entrants while they are working. The attendant must maintain constant verbal and visual communications with the entrants. The attendant must also be prepared to instruct the entrants to exit the confined space should the equipment fail or the entrants exhibit impaired judgment.

Any confined space must be tested for a hazardous atmosphere before the entry. Monitoring must continue while the entrants are in the confined space. Permit required confined spaces also require ventilation during the entry and self-contained or supplied air must be used if ventilation fails to produce a safe atmosphere. Permit required confined space entries also require rescue equipment such as a harness and tripod for emergency rescues. If the space is configured in a way that prevents the use of self-rescue equipment, an emergency rescue team must be on-site during the entry. When the entry is completed, the entry supervisor must complete the permit form and file a copy with the appropriate supervisor and a confined space entry master file.

Nonpermit confined spaced must be reassessed periodically. Any non-permit space can be reclassified, as permit required, based on the results of these assessments.

System security

The three "D"s of security are: Deter, Detect and Delay. Intrusion should be deterred, and detected if it occurs. Intruders should be slowed down (delayed) as much as possible to allow more time for their apprehension.

Water system security steps include:

1. Vulnerability assessment - Identify vulnerabilities such as doors, windows, hatches and locations in remote areas.
2. Eliminate or mediate vulnerabilities - Install locks and use them. Install fences, alarms and security lights. Ask for police patrols. Consider asking neighbors to watch over your facilities for you (adopt-a-facility).
3. Emergency response - Know who to call in an emergency. Create a list of emergency telephone numbers.
   - Fire
   - Police
   - IDEM
   - Local health department
   - Critical users
   - Your boss
   - Government officials
   - Nearby water systems
   - Laboratories
   - Contractors
   - Chemical suppliers
   - Parts/equipment suppliers
   - Insurance agent
   - Local media (radio, TV and newspaper)

Plan ahead for your emergencies. Think about what might go wrong, and try to plan for it. Like a good scout, "be prepared." Always remember, people come first, then property. Be safe and do not take unnecessary risks.

UNACCOUNTED-FOR WATER

Unaccounted-for water is water which is produced but is not used or sold to the consumers. There are many factors which are considered in the determination of the percentage of unaccounted-for water. This percentage is a measure of the efficiency of the operation of the system.

Factors to Consider

Factors to consider in the determination of the unaccounted-for water are:

- The water produced - Is this quantity accurately deter-mined, has the meter been calibrated, and does the meter measure all of the water?
- The water used for water system purposes such as chemical feed water, backwash water, fire hydrant and blow-off flushing - How is each of these uses measured? Careful accounting in the treatment plant is necessary because, in some plants, plant use water is used before the master meter, and in other plants, it is used after the master meter.
- The water sold or used by the consumer - A meter testing program should be in place to periodically test the accuracy of the meters. All consumer use must be accounted for. For example, free water may be provided for parks, cemeteries, or for municipal purposes at sewage treatment plants, borough buildings, and fire companies. All of this water must be measured and accounted for.
- Water used for fire fighting purposes - This water only can be estimated, but some careful calculations by the fire company and the water system can develop a reasonable value.

Basic Calculation

The basic calculation is:

$$\frac{(\text{Water Available for Sale}) - (\text{Water Sold or Used})}{\text{Water Available for Sale}} \times 100 = \text{Percent of Unaccounted for Water}$$

1. The water available for sale is the water produced, adjusted for the company uses of water, as follows:
   - Subtract any plant use water that is taken off the system after the master meter,
   - Subtract any water used on the distribution system for flushing fire hydrants and blow-offs and for fire protection.

2. The water sold or used is the total quantity of water sold to customers through meters plus an estimate of all unmetered uses either to flat rate customers or for public purposes.

3. When making the calculation, the time interval must be considered since the amount of water sold only may be determined monthly, quarterly, or annually, and usually all meters are not read on the same day or at the same time. It is recommended that a one-year (four-quarters or 12-months) period be considered since this will level off the variables for meter reading, and seasonal variations. This calculation can be made on a monthly basis by using the totals for the previous 12 months.

Normal Operating Ranges

The normal operating range should not exceed 15% for a well maintained system. There are many factors which should be considered when determining what an acceptable percent of unaccounted-for water is for a particular system. These are:

1. The age and condition of the system. A very old water system which has deteriorated pipe will have many undetected leaks at joints. Although the goal may be the 15%, it only can be accomplished by replacing large segments of the system. Therefore, a range of 35 to 40% may not be unusual until funds for replacement of mains are available.

2. The pressure in the system can affect the rate of leakage. Thus high pressure systems may have a higher percentage of unaccounted-for water.

3. The number of customers per mile of main can affect the unaccounted-for-water. Therefore, if a system has a high ratio of miles of pipeline to the number of customers, the percentage of unaccounted-for water will increase.

4. Under-registration of customer meters or unauthorized use can increase the percentage of unaccounted-for water.

Control of Unaccounted-for Water

To reduce the percentage of unaccounted-for water, the following are suggested actions:

1. Calculate the cost of producing 1,000 gallons or 100 cubic feet of water and then calculate the amount of money which is being "lost" as unaccounted-for water each month. By identifying this cost, you can justify the cost of the programs to correct the problem.

2. A meter testing program should be installed to test the master meter and other system meters at least annually and to test all customer meters (on a continuing basis) at least once every 10 years.

3. An adequate leakage control program includes:
    - A program of listening to all fire hydrants valves and services to detect leaks;
    - The use of detector type meters on fire lines;
    - Training personnel to listen for leaks and to detect unauthorized use of water; and
    - Review of meter readings to detect stopped meters or obvious under-registering meters.

4. A record of leaks repaired and the estimated amount of water lost at each leak can help to justify replacement of sections of mains which have a high incidence of leakage.

PUBLIC RELATIONS

Public relations is a way of promoting understanding, support, and goodwill between your water system and the public. You can influence the public's image of your system by following the public relations steps presented in this training guide.

Good public relations doesn't happen overnight. It must be developed over time. Moreover, once your system has gained the community's confidence, you must continue your efforts to ensure that the support you need will always be there.

The main purpose of public relations is to gain and keep the public's confidence and support. Good relations with the public can also:

- Strengthen the system's position in the community;
- Help the system form fair guidelines and policies;
- Promote goodwill between employees and customers;
- Educate the public about water use;
- Overcome misconceptions about the water system;
- Gain the support of local government;
- Weaken the impact of any negative publicity the system may receive; and
- Justify reasons for capital improvements or rate hikes.

Once you know *where you are* and *where you are going*, you need to determine the *public image* your system needs to have to accomplish your goals. Your public image is an accurate picture of your operation that spotlights key aspects of your work.

For example, if your system needs public support for a major purchase, it may help to let customers know about the complexity of water system operation. Most people don't realize that water system operation can be very difficult. Customers may be more likely to support water system improvements if they understand that water system operation is a demanding job that requires the best equipment available.

A different goal may be to build public confidence in your system. To do this, **let people know about the good work you are doing!** Assure them that system employees are well trained. You may wish to inform the public of any continuing education classes your employees have attended. Also make sure the public knows that their water is tested. You may even want to report the positive findings from state health agencies or labs.

Even though most water systems are organized as "nonprofits," they must operate like any business. Because the success of any business relies on its customers, systems should keep customers informed and respond promptly to their needs.

A good public relations practice to develop is to always let customers know when their service may be affected. This might include:

- Interruption of service;
- Repairs (especially when the streets are affected);
- Changes in water taste, odor, or pressure;
- Unusual findings during state health inspections;
- Proposed changes in rates; and

- New construction.

Explain what is happening, apologize for any inconvenience, and reassure the public that what is happening is in their best interest.

Early in this step of the public relations cycle, your system needs to select a representative. Your representative should be someone from the system that can communicate well with the public. This representative should also:

- Be well-respected in the community;
- Have a pleasant appearance;
- Be a good speaker;
- Get along with people; and
- Be knowledgeable about your system.

Select your representative carefully. In some cases, you may wish to choose more than one. Make sure the person you choose reflects the image you want for your system.

The two main forms of communication are **personal communication and written communication.** Personal communication is more than just talking to the public. A person's appearance, behavior and work habits are also important elements of personal communication. Specifically, personal communication is any direct professional contact between system personnel and the public they serve. Personal communication can occur in the office, in the field, or in any other public setting. Always practice positive personal communication in the office. Ask office staff to greet customers promptly and give them full attention.

The telephone is a powerful public relations tool. Not only is it much faster than written messages, but it also often eliminates the need to travel. A major disadvantage of the phone is that you can't see the person you're talking to. This may make it more difficult to tell how a caller is reacting to your conversation. You have to rely totally on the person's spoken message. Because the spoken message is so important, employees should be aware of how they answer and use the phone. Some guidelines for effective telephone communication are listed below.

Answering the Telephone

1. *Always answer the phone promptly.* Clearly state your name and the name of your system.
2. *Try to sound pleasant you are talking.* Some people actually smile when they are on the phone because it makes them sound more pleasant.
3. *Never interrupt callers.* This makes them feel that you are bored or disinterested.
4. *Listen carefully.* If you are unsure of what callers are talking about, repeat what they have said to make sure you have understood them.
5. *Don't put customers on hold for more than 30 seconds.* If you must search through records or discuss the subject with someone else, take the caller's name and number and call back as soon as you can.

Handling customer complaints

Complaints present an excellent opportunity to build positive customer relations. A customer whose complaint receives prompt attention can become a valuable supporter. When dealing with complaints in the office or on the phone:

- Listen and sympathize;
- Do NOT argue;
- Ask questions;
- Work to find an acceptable course of action for both sides; and
- Follow-up the complaint to make sure the problem is resolved.

No one enjoys receiving complaints, but resolving a complaint quickly and professionally can actually improve your image with the public.

Personal communication in the field

The way system employees act and appear when they are working can have a big impact on your system's public image. Employees should appear neat and clean whenever possible. They should also be encouraged to be patient and courteous to every customer. Pay special attention to the way employees work at construction sites:

- Has the system constructed barriers to prevent possible accidents?
- Have employees completed the job quickly and safely?
- What was the condition of the area after the work was finished?
- Did the system replace or repair any property that was affected by the job?

Each employee represents your system. Only by behaving and dressing professionally can they reflect a positive public image.

Personal communication door-to-door

The most visible people working for your system are the meter readers. Because of this, it is especially important that they have a professional appearance and a positive attitude. Sometimes it is necessary for other employees to go door-to-door. For example, they may need to inform customers when service is going to be interrupted. Ask them to take the time to explain what is happening and answer any questions the customer might have.

The condition of your system's facilities and equipment also affects your public image. Check all visible parts of the system. One of the first things visitors see is the storage tank. Keep it painted and free from graffiti. Hydrants are another highly visible part of the system. Make sure they are painted and free from obstructions such as weeds and trash. It is also important that vehicles and equipment are clean and in good repair. Check the system office and other buildings as well, such as garages, pump and well houses, and storage sheds. Keep these neat and well-maintained.

Reporting bad news

One of the hardest parts of public relations is giving customers bad news. Business letters can be an effective way to report bad news and make customers feel that their individual concerns are taken seriously. Report honestly and openly what has happened. Reassure people that their water system is working to correct the problem. It is up to you to work with the media and use other communication techniques to make sure the public really knows what has happened.

If you have a good working relationship with the media, you may also be able to participate in a feature story or an interview about the event. In either case, you have an opportunity to give your system's response to the situation and to reassure the public that you are working to solve the problem.

Interview tips

Whenever television or newspaper reporters create their own stories, they often prefer to conduct interviews. If you are going to be interviewed:

1. Be prepared. Make sure you know the subject you are supposed to talk about. Have the facts and figures to support your comments.
2. Stick to the subject.
3. Try not to answer questions with just "yes" or "no." These may cut your interview short.
4. Stay calm. Don't lose your temper or get pulled into an argument.
5. Keep your answers short but include all necessary information.
6. Speak in generalities whenever possible.
7. Keep in mind that you are reflecting your water system, not yourself.
8. Never lie or try to bluff the interviewer. If you don't know, say so.
9. If possible, practice. Sometimes the interviewer will rehearse with you if you ask.

Public relations work never ends. As long as your system is providing an essential service, you will need to communicate with customers and other members of the public about the good work you do.

CUSTOMER COMPLAINTS

When dealing with a customer complaint, a water utility must keep a full and complete record of all relative information. At a minimum, keep the:

1. Date of the complaint;
2. Name of complainant;
3. Nature of complaint; and,
4. What the utility did to resolve it.

If an informal complaint becomes a formal complaint case, the PSC will attempt to determine what the utility did during the informal complaint stages. Without proper documentation, there is not much of a defense.

The PSC frequently sends a representative to investigate or may ask the utility to send copies of their records. The PSC will want to look at the records to determine what the utility has already done. If the utility's actions seem to be complete and proper the PSC will be prone to join the utility in a statement that no further action is necessary, but if no record exists to show that the complaint has been investigated by the utility, the utility may lose because no investigation can be proven. Complaint records are kept primarily to protect the utility. The required information for water customers is in Water Rule 4.5. Once a formal complaint is filed against a utility, the Commission will issue an order for the utility to respond to the complaint within 10 days.

Based on the utility's response, PSC will conduct its investigation which may include a field investigation and/or a request for additional information from the complainant and/or the utility. If there is no settlement of issues, then the case will be set for an evidentiary hearing. Also, any formal complaint can result in a general investigation of the utility. One can easily see where good record keeping will be invaluable in such situations. Utilities are not required to keep a record of inquiries. The difference between a complaint and an inquiry hinges on whether the utility has to take some investigative or corrective action. If a customer calls and states that his/her water is off, to fix a leak or to flush lines, for example, then it is not a complaint. If a customer calls and says his/her bill is incorrect and in a phone conversation, it is determined that the customer was correct and the utility has to issue a corrected bill, then it was a complaint.

When handling complaints either over the phone or in person, it is a good idea to take notes. Another important point to remember is that after the customer has finished airing the complaint, repeat back the alleged complaint. This ensures that the problem has been identified correctly. Remember it is beneficial to practice good **public relations (PR)** to keep complaints at a minimum. Surprisingly, handling customer complaints can be one of the most effective opportunities to build positive customer relations. Handling a complaint promptly and courteously can turn a negative situation into a positive one and can cause an unhappy customer to become a valuable supporter. In this regard, when dealing with complaints, always strive to:

- Listen and sympathize;
- Not argue;
- Negotiate to find an acceptable solution; and,
- Follow up to make sure customer is satisfied and problem is resolved.

Complaint records are also a valuable management tool as it is a good idea to go through such records from time to time or at the end of the year to see what types of complaints were received and note any patterns that may have developed. For example, several water quality complaints from the same area may indicate a problem that has gone undetected until the number and frequency of complaints are acknowledged. By dealing with one customer at a time, the immediate problem may be solved, but if that problem keeps recurring, then the underlying problem is not being identified or corrected.

All individual complaint records are to be kept until a year end summary has been prepared which is to be used as a permanent record. The summary has to show the character of the complaints made, the number of each type received in each month, and the disposition of the complaints.

POTABLE VS. PALATABLE

We have discussed at some length now various types of pathogens and methods of destroying them in the process of making water potable -- **safe to drink**. This is highly important, but it is not the whole story; for water must be palatable as well as potable. What makes water palatable? To be palatable water should be free of detectable taste and odors. Turbidity, sediment, and color also play important roles in determining whether water is palatable.

Various odors and tastes may be present in water. They can be traced to many conditions. Unfortunately, the causes of bad taste and odor problems in water are so many, it is impossible to suggest a single treatment that would be universally effective in controlling these problems.

Tastes are generally classified in four groups -- sour, salt, sweet and bitter. Odors, on the other hand, possess many classifications. There are some 20 of them commonly used, all possessing rather picturesque names. In fact, the names in many cases, are far more pleasant then the odors themselves, to name a few of them -- nasturtium, cucumber, geranium, fishy, pigpen, earthy, grassy, and musty. Authorities further classify these odors in terms of their intensity from very faint, faint, distinct and decided to very strong. All taste buds and olfactory organs are not necessarily of the same acuteness, but generally you should not be aware of any tastes or odors in water if there is to be pleasure in drinking it. If you are conscious of a distinct odor, the water is in need of treatment.

In many cases it is difficult to differentiate between tastes and odors. Both the taste buds and olfactory organs work so effectively together it is hard to determine where one leaves off and the other begins. To illustrate: hydrogen sulfide gives water an "awful" taste, yet actually it is the unpleasant odor of this gas that we detect rather than an unpleasant taste. Unfortunately there is little in the way of standard measuring equipment for rating tastes and odors. Tastes and odors in water can be traced to a number of factors. They include:

- Decaying organic matter;
- Living organisms;
- Iron, manganese and the metallic products of corrosion;
- Industrial waste pollution from substances such as phenol;
- Chlorination;
- High mineral concentrations; and,
- Dissolved gases.

In general, odors can be traced to living organisms, organic matter and gases in water. Likewise, tastes can be traced generally to the high total minerals in water. There are, however, some tastes due to various algae and industrial wastes. Now how can these objectionable tastes and odors be removed from water?

Some tastes and odors, especially those due to organic substances, can be removed from water simply by passing it through an activated carbon filter. Other tastes and odors may respond to oxidizing agents such as chlorine and potassium permanganate. Where these problems are due to industrial wastes and certain other substances, some of the above types of treatment may completely fail. In some cases, for example, chlorination may actually intensify a taste or odor problem. Potassium permanganate has been found to be extremely effective in removing many musty, fishy, grassy and moldy odors. Two factors make this compound valuable: it is a strong oxidizing agent; and it does not form obnoxious compounds with organic matter. However, a filter must be used to remove the manganese dioxide formed when the permanganate is reduced.

In any case, you may have to try a number of methods in an attempt to rid a water of objectionable tastes and odors. If methods considered here do not work, it may be more economical to seek out a new source of drinking water.

COMMON INQUIRIES

Color, Taste and Odor, and Particles in Drinking Water

At times, water can have an unusual odor, taste or appearance. In most cases, these aesthetic characteristics do not pose a public health threat. The first step in solving a water quality problem is to identify whether it originates from the household plumbing or the water utility. One way to tell is to ask others in the service area if they have a similar problem. Below are typical concerns, their most common causes, and what to do about them.

Discolored Water

If the water changes color suddenly – no matter what color it becomes – it could indicate a public health concern. Do not use the water. Something likely has disturbed the direction or rate of water flow in the water main, such as a water surge caused by a power outage or use of a fire hydrant.

Avoid running hot water if the cold water is discolored. This will prevent filling the hot water tank with discolored water. If you are washing clothes, you can minimize the potential for staining by stopping the washer while it is full and waiting until clear water is available to finish.

<u>Green</u> water is usually caused by corrosion of copper plumbing. If corrosion is occurring, dripping water will leave a bluish-green stain on porcelain fixtures. Certain metals, such as copper, that get into drinking water from corrosion may pose a health concern. The problem could be in the home's piping or corrosive water from the utility.

<u>Blue</u> water is rare. The blue disinfectant you use in your toilet can cause discoloration of your tap water. If your water supply was recently turned off, a condition may have been created in which water from the toilet tank was siphoned into the plumbing of your house. These disinfectants contain chemicals that may pose health hazards if ingested or touched. Flush your plumbing by opening each tap until the water runs clear. **Do not drink this water.**

<u>Black or dark brown</u> water is usually due to manganese or pipe sediment and should clear up without further action when the sediment settles in the water main. Manganese does not pose a threat to human health. If it doesn't clear after a few minutes of flushing the cold water faucets and toilets, wait about an hour and try again.

<u>Brown, red, orange or yellow</u> water is usually caused by iron rust. Rusty water can be caused by galvanized iron, steel or cast iron pipes either in a home or business, or the water main. While unpleasant and potentially damaging to clothes and fixtures, iron in drinking water is not a human health concern.

<u>Milky white or cloudy</u> water is almost always caused by tiny d bubbles. If the water is white, fill a clear glass with water and set it on the counter. If the water starts to clear at the bottom of the glass first, the cloudy or white appearance is a natural occurrence. It is not a health threat and should clear in about 5 minutes.

Taste and Odor Problems

If the taste or odor occurs at every water faucet on the property, the cause could be the water supply. If it occurs only in certain faucets, the problem is with the fixture and pipe supplying those specific faucets. If the problem goes away after running the water for a few minutes, the problem is somewhere in your plumbing system.

Petroleum, gasoline, turpentine, fuel or solvent odor is rare and potentially serious. It is possible a leaking underground storage tank may be near your water supply. Do not use the water.

Metallic taste is usually due to minerals, such as iron or copper that can leach into water from pipes. Metals such as zinc and manganese are less common causes. Only a certified laboratory can analyze the water to determine if metals are present. Certain metals may have human health effects if consumed over long periods of time.

Chlorine, chemical or medicinal taste or odor is usually caused by the addition of chlorine to the water by your public water system, or the interaction of chlorine with a build-up of organic matter in your plumbing system. This is not a health threat. The best way to reduce taste and odor is to run the faucet for several minutes, put some water in a container, and store it in the refrigerator.

Sulfur or rotten egg taste or odor is most commonly caused by bacteria growing in your sink drain or water heater. But, in some cases, this smell is caused by naturally occurring hydrogen sulfide. To problem-solve the cause, put a small amount of water in a narrow glass, step away from the sink, swirl the water around inside the glass and smell it. If the water has no odor, then the likely problem is bacteria in the sink drain. If the water does have an odor, it could be your water heater. This occurs if the hot water has been unused for a long time, the heater has been turned off for a while, or the thermostat is set too low. If the drain or water heater have been ruled out, and the odor is definitely coming from the tap water, do not use the water.

Moldy, musty, earthy, grassy or fishy taste or odor is commonly caused by bacteria growing in a sink drain or from organic matter such as plants, animals or bacteria that are naturally present in lakes and reservoirs. To problem-solve the cause, put a small amount of water in a narrow glass, step away from the sink, swirl the water around inside the glass and smell it. If the water has no odor, then the likely problem is the sink drain. If it does have an odor, the source could be organic matter in your drinking water. Although harmless, it can affect the taste and smell of your drinking water even at very low concentrations. The best way to reduce taste and odor is to run the faucet for several minutes, put some water in a container, and store it in the refrigerator.

Particles in the Water

Brown or orange particles are usually small pieces of rusted steel that have broken off the inside of your water pipes or the city's water mains. These particles are very hard, irregular in size and shape, and can be several different colors. They consist of mostly iron and are not a health hazard but they can be a nuisance if they clog your washing machine screens, shower heads, and/or the screens at the ends of your faucets. If the water is clear with these particles in it, they probably came from the plumbing in your home. If the particles come from the water mains, the water itself will usually be discolored as well. For more details on discoloration, see the "Brown, Red, Orange or Yellow Water" section under Color Problems.

Another cause of brown or orange particles in the water could be a defective water softener. Inside a water softener are many small, round beads. The mechanism that keeps these beads in the tank can break, releasing the beads into your water. These beads vary in size and color depending on the manufacturer; however, some commonly used beads are about the size of fish eggs and are brown or orange in color. If you see that the particles in your water are uniform in shape, size and color, and you have a water softener; contact your service agent for repairs.

Black particles can come from four common sources: the inside of a steel pipe, a broken water filter, a degrading faucet washer or gasket, or a disintegrating black rubber flexible supply line hose (for a water heater, washing machine, or kitchen faucet, etc.).

- Particles from the inside of a steel pipe are discussed in more detail under the "Brown or Orange Particles" section.
- If the particles are very hard, similar in size and shape, and look like large coffee grounds, they are probably granular activated carbon (GAC) particles from the inside of a GAC water filter that you have installed. Replace the filter cartridge or consult with the manufacturer or the vendor who sold it to you
- If the particles are solid but rubbery in texture, they could be pieces of an old disintegrating faucet washer or gasket. If this is the problem, the particles would likely only be present at one faucet and that faucet is already leaking. Replace the faucet washers and the packing at the ends of the supply lines.
- If the particles are small black particles that can be easily smeared between two fingers, they are probably from the inside of a flexible hose. These black rubber hoses are covered with a braided stainless steel mesh. Over time, the chloramine in the water causes the rubber to break down. Replace the hose, ideally with a liner that is identified as chemical or chloramine resistant. Black rubber hoses typically have a one-year warranty while the more chemical resistant hoses have a five-year warrant

White or tan particles usually come from one of three places:

- The inside of your pipes
- Your water heater
- Your water softener

White or tan particles can be a combination of calcium carbonate and magnesium carbonate; this material is often referred to as pipe scale. Calcium and magnesium carbonates are naturally occurring minerals and are found in varying concentrations in most water around the world. These minerals are not a health threat; in fact, they are beneficial to human health. The amounts of these minerals in the water determine the hardness of the water, higher mineral concentrations make the water "harder." Over time, these minerals can deposit on the inside of your pipes and then begin to flake off. If the water supplied by the city becomes softer, or if you add a water softener to your plumbing system, the softer water can begin to re-dissolve the minerals from the pipes and pieces may begin to break loose. These are all common causes of pipe scale in the water and account for most customer complaints about white or tan particles in the water. Although pipe scale is not a health hazard, it can be a nuisance by clogging inlet screens to washing machines, shower heads, and faucet aerators.

Pink particles or mildew develop on the flat surfaces of their shower, in their pet's water bowls, or toilets that are not used frequently. This is a colored organism that is present in the air and grows in these areas. It is a harmless bacterium and exists in moist/humid conditions. The customer can remove the pink ring by cleaning the area periodically with a commercial cleaning product that contains bleach.

STANDARD OPERATING PROCEDURES

A **Standard Operating Procedure (SOP)** is a set of instructions or steps someone follows to complete a job safely, with no adverse impact on the environment (and which meets regulatory compliance standards), and in a way that maximizes operational and production requirements. Write SOPs for any processes an individual or group performs: unloading raw materials, manufacturing products, shutting down an operation, repairing a faulty electrical circuit, and thousands of other workplace activities.

Write different SOPs for people who perform jobs by themselves, people who work together on a job, and people who supervise other people doing a job. The primary audience for an SOP, however, is the person who will perform a particular job. Consider such factors as the age, education, knowledge, skills, experience and training of a person who will perform a job, and the "social culture" or work history within which the individual works. Some work cultures disdain SOPs so you must work to overcome rejection.

SOPs also can be used by managers, government safety inspectors, environmental regulators, lawyers, engineers, planners, vendors, contractors and customers. Sometimes the same SOP material is used to write a description of how a job is done—a process—which can be useful if a company representative must explain operations to the media and public.

Ideally, SOPs should be written before a job is begun. Test SOPs before putting them into final application. Revise SOPs after an on-the-job trial. Also revise SOPs when any changes or modifications are made to equipment, machinery, buildings or other structures, or procedures within the immediate work area that might affect performance of a job or the "environment" in which it is performed.

You can't write SOPs for every job overnight, so set priorities. Write SOPs when new equipment or processes create new work situations. Write or rewrite SOPs when new information suggests benefits from modifying work practices to improve performance. Accident investigations might show you that procedural, safety and environmental guidelines are insufficient, incomplete, or even missing for certain jobs or parts of jobs.

Systematically update all safety and environmental guidelines by asking workers to evaluate existing SOPs, work practice guidelines and other documents that contain work, safety and environment guidelines. Then rank these jobs as to which should be revised first through last. These procedures could be revised, perhaps by the groups that ranked them.

SOP writers often don't know how long an SOP should be. Sometimes writers are pressured by operations supervisors to "make it short" rather than comprehensive. Clearly these supervisors don't understand the purposes and audiences an SOP serves.

SOPs can be either long, short or both. Because SOPs are used for a variety of reasons and audiences, they first must be comprehensive, which means they are as long as necessary to cover a job. For long SOPs or for jobs performed infrequently, it pays to keep the long-form SOP handy. Once an employee is familiar with a process, he or she will most likely be able to perform a series of short SOP steps from memory. These steps can be written as a short-form SOP. If someone is going to use a short-form SOP, it should be prepared after a full long-form SOP has been tested and approved and should be handed out after an employee has passed the appropriate training.

- Keep in mind that the average person is uncomfortable following a long list of steps for the following reasons:
- A long list looks formidable, which makes the task daunting and tedious for many people who then don't want to perform the steps.
- A long list is difficult for your eyes to follow. You forget where you are on the list and forgetting leads to mistakes.
- A long list scares people and makes them nervous or anxious to "get it over with."
- A long list can hide steps that should be done with caution.
- A long list is difficult for writers to write while ensuring that the step sequence is clear.

The solution to SOPs that involve a long list of steps is to break the steps into logical sections of about 10 steps per section, such as "Getting ready for the process," "Initial steps," "Final steps."

Most importantly, SOPs should be reviewed by several people qualified to evaluate the SOP in terms of its completeness and clarity of safety, environmental and operational components.

Write SOPs for the following reasons:

1. To provide individuals who perform operations with all the safety, health, environmental and operational information required to perform a job properly;
2. To ensure that operations are done consistently to maintain quality control of processes and products;
3. To ensure that processes continue and are completed on a prescribed schedule;
4. To ensure that no failures occur in manufacturing and other processes that would harm employees or anyone in the surrounding community;
5. To ensure that approved procedures are followed in compliance with company and government regulations;
6. To serve as a training document for teaching users about a process;
7. To serve as a historical record of the how, why and when of steps in a process for use when modifications are made to that process and when a SOP must be revised; and,
8. To serve as an explanation of steps in a process that can be reviewed in incident investigations that seek to improve safety practices and operating conditions.

What should be included in a standard operating procedure (SOP)?
Here are suggestions for what to include in an SOP. Be sure to modify as necessary. Use an organization that favors simplicity and ease of reading.

1. Write a title (with a descriptive verb) that defines the purpose of the SOP. Include the word "safety" in the title, if applicable.

2. Use document reference numbers and revision dates on the title or cover page and a second page such as the table of contents or first page of text.

3. Identify general and specific points of activity for which an SOP has been written.

4. State the purpose of the SOP including the specific audience (user) in one or two sentences. Include information about process and regulatory standards, and both desirable and undesirable consequences.

5. Write a "scope" statement that tells what related subjects the SOP will not cover if there is any chance someone will be confused and make a mistake. Use scope statements for two reasons: to focus your attention as a writer and to clarify things for a reader. Many SOPs do not require scope statements, but consider the value of one before dismissing it as too much trouble to write.

6. List by category, any items or tools required for following the SOP whenever they apply. Think of this list as being a "tools and parts kit" for doing a job. Use general terms for common tools and equipment. For example, instead of listing every tool, a chemist or technician might simply list "gas cylinder tools." Add other categories or subcategories as desired. Sometimes a table instead of a paragraph is an appropriate format for this information.

7. Give an overview of the steps in the SOP that describes the process in terms of its major functions. Include anticipated safety, health, environmental and operational results.

8. Describe the machinery, mechanism, processing system and major components. Complete operating instructions contain overall descriptions of the major system and its components so that readers can orient themselves to the system as a whole and to its major parts.

9. Define terms and concepts. If the SOP contains terms and concepts that readers may be unfamiliar with, define these in their own paragraph so that readers (1) know that there are unusual words or concepts, and (2) can find them easily for use when needed. A long list of terms may fit better in a glossary at the beginning of a document. If you decide that a simple list of terms and definitions is better, include the list within the write-up, perhaps right before the list of steps to be performed.

10. Place safety warnings, cautions and notes prominently within the SOP before the actual step to be described. Never place safety items at the end of a step. Depending on the SOP, a writer might include an overall warning or caution that describes the general safety concerns. This should be placed at the beginning of an SOP where it is the first thing read after the title on the first page of text. If more than one safety warning, caution or note exists, list them in boldface type at the beginning of the SOP. The purpose of placing the cautions first is to alert the reader to read the warnings first. Often a page of safety cautions appears immediately after the title page and before the first page of text. Write warnings and cautions in clear sentence form. If there are only one or two warnings, these might be best placed at the top of the first page of text rather than on a separate page. The goal is to place warnings where the reader will read them. Sometimes this placement is determined by the size of the final printed version of an SOP. It is easy to place several warnings on an 8-1/2"x11" sheet of paper, but not so easy to do on a pocket-size handbook. Write Notes to provide people with information that can help them satisfy safety, health, environmental and operational procedural requirements. For example, if it is permissible to use an extension cord of a certain length, this information should be stated in the SOP.

11. List and explain the process steps in sequential order in which an SOP user should perform the steps.

12. If two steps must be done at once, explain them in a sentence that clearly says so. You may wish to highlight (with italics or underlining) the first part to differentiate it from the actual step.

13. Provide a more detailed explanation if a reader needs more information to fully understand the reason for performing a step.

14. Provide readers with alternative steps to take in case a desired step does not work.

15. When an SOP is time-dependent, indicate the times clearly.

16. When a step depends on informational input (data), include the source, reference document number and date if possible.

17. Decide where to use graphics (drawings, photographs and thumbnail icons) to communicate clearly. Well-labeled drawings often are better than text. Use drawings of labeled (named) parts of objects to show proper relations hips and orientations among the parts or other objects. Show the positioning of hand tools, other tools and even hands and feet if applicable when work is to be performed. For example, show the positioning of a wrench or direction for turning a valve. Show the individual parts of a device in a final assembled position. Consider using thumbnail graphics to visually alert readers that they have come to a safety item.

18. Write a reference and writers' section that includes a complete list of source material used for the SOP. If someone wants to confirm something, they will know where to look. List the names of those who wrote the SOP.

19. Test the SOP in the field and then develop troubleshooting instructions. Anyone who has ever assembled a consumer product knows there are always problems to solve either while trying to assemble something or after it has been assembled. Anticipate all these problems for a reader and include them in a troubleshooting section. Also incorporate troubleshooting tips at each step in a process where they actually occur.

20. One way to anticipate safety, health, environmental and operational problems is to ask an inexperienced person to "walk through" a mock (inactive) process (under close supervision of an expert) and try the steps. Such unknowledgeable person could ask questions or demonstrate behaviors that an experienced or familiar person would not.

MAINTENANCE PROGRAM

An important aspect of any effective and efficient water service organization is a maintenance program. The objectives of a maintenance program should be to eliminate the interruption of service caused by equipment failure and to extend the service life of all equipment for as long as practically possible and economically feasible. With this in mind, a good maintenance program will consist of a preventive maintenance plan, a general maintenance plan, an emergency maintenance plan, and a program evaluation. While each of these program topics will be discussed separately below, it is important to remember the effectiveness of the overall maintenance program will be determined by how closely each plan fits together.

Preventive maintenance provides a water system with three basic benefits:

1. Better service to all customers;
2. Increased equipment service life; and,
3. Efficient use of resources.

A preventive maintenance plan can be established by the use of planned work orders, planned work schedules and an evaluation process for all water system equipment. The use of planned work orders is an integral part of any preventive maintenance plan. Planned works orders should include the complete procedures to be performed, the total manpower (number of personnel, skill type, and total time) needed, and a list of materials required for the each preventive maintenance job. Compiling all planned work orders in an organized work schedule provides an efficient way of using the resources available to the water system, completing the work in a timely manner, and producing a framework for quality maintenance records. Equipment evaluation is one area overlooked when discussing a preventive maintenance plan. In order to evaluate the effectiveness of any preventive maintenance plan, a benchmark of the existing conditions of all equipment is required. When preventive maintenance work is completed, the water system should have the ability to evaluate equipment performance on both a short term and long term basis. Also, the preventive maintenance work itself can be evaluated to better improve the individual components of the plan. Preventative maintenance can be considered a time efficient and cost effective way of maintaining a water system. Scheduled preventative maintenance can lower total maintenance costs by allowing the system to purchase quality materials when time is available to obtain the best price. Scheduled preventative maintenance can be time efficient by the productive use of manpower and work schedules to complete the work while retaining some control over both the maintenance and operation of the equipment.

General maintenance is usually the largest component of any maintenance program. A general maintenance plan can be established by developing planned work orders, prioritizing work within daily, weekly, and monthly schedules, developing a material purchasing system, and evaluating the overall performance of all general maintenance work. As with the preventive maintenance plan, the use of planned work orders is vital to an effective general maintenance plan. Planning work in advance can assure that proper procedures are followed by each staff member, correct materials and supplies are available to complete the work, and a record of the completed work is available for filing in project and equipment files. Reviewing planned work orders will provide the water system with a means of fine tuning their general maintenance plan. Another key is a prioritized work schedule. Prioritizing work on a daily, weekly, and monthly basis creates a productive working environment for personnel. This results in more maintenance being completed at a much lower overall cost. Efficient maintenance requires that adequate materials and supplies be available for use at a moment's notice. It is important that water systems realize the need for developing a material purchasing system. This system would include a complete material and supply inventory, standardized purchasing procedures, and a tracking method of all materials used by the water system. It is important to have a centralized area designated for the storage of all materials and supplies used by the water system. An evaluation process should be developed to determine the overall performance of all maintenance work along with its effectiveness over the service life of the equipment. **C**hanges in the types of procedures and materials used can be detected and corrected during the evaluation process. Also, the efficiency of a water system's use of resources and manpower as they pertain to the general maintenance plan can be determined.

An emergency maintenance plan is an invaluable component of most maintenance programs. This specialized plan will save both time and money when utilized properly. The foundation in developing an emergency plan is knowing the capabilities and limitations of the water system's staff and resources. The next step is to formulate contingencies for all types of emergencies that your water system has encountered in the past or could encounter in the future. It is important to be as specific as possible in identifying the many emergencies that could occur. Finally, a comprehensive list of consulting engineers, contractors, technical sales representatives, and material supply companies should be developed. This list should contain information as to the contact people, phone numbers (business and emergency), and the specific time and reasons each would be contacted. This contact list and a material/supply inventory list should be updated as often as possible and readily available for use at any time. Experience and planning are the keys to assuring the emergency maintenance plan operates properly. When the dust has settled and normal operation has resumed, a comprehensive evaluation of all actions taken as a part of the emergency plan should occur in a timely manner. At this point, evaluating the actions taken will hopefully result in a better emergency plan and, thus, an improved response to the next emergency.

The final component of a comprehensive maintenance program is a program evaluation. The only way to improve a water system's maintenance program is to periodically evaluate it to ensure the main objectives of eliminating the interruption of service caused by equipment failure and extending the service life of all equipment for as long as practically possible and economically feasible are being met. By applying the knowledge and experience gained from successful and unsuccessful maintenance work along with proper planning and training, the evaluation process will improve the overall maintenance program by strengthening the individual preventive, general, and emergency plans. As more evaluations are conducted, the water system will find itself gaining more experience, performing improved maintenance work, increasing the service life of all equipment, benefiting from more productive work, saving more money, and providing the best possible water service to the customers.

Preventive Maintenance

Preventive maintenance involves the regular inspection, testing, and replacement or repair of equipment and operational systems. As a **best management practice (BMP)**, preventive maintenance should be used to monitor and inspect equipment and other conditions that could cause breakdowns or failures of structures and equipment. A preventive maintenance program can prevent breakdowns and failures through adjustment, repair, or replacement of equipment before a major breakdown or failure occurs.

Preventive maintenance procedures and activities are applicable to almost all facilities. This concept should be a part of a general good housekeeping program designed to maintain a clean and orderly work environment. Preventive maintenance takes a proactive approach and seeks to prevent problems before they occur. Preventive maintenance programs can also save a facility money by reducing the likelihood of having a system breakdown. In addition, a preventive maintenance program can bean effective community relations tool.

The primary limitations of implementing a preventive maintenance program include:

- Cost;
- Availability of trained preventive maintenance staff technicians; and,
- Management direction and staff motivation in expanding the preventive maintenance program.

Key Program Components

Elements of a good preventive maintenance program should include the following:

- Identification of equipment or systems that may malfunction.
- Establishment of schedules and procedures for routine inspections.
- Periodic testing of plant equipment for structural soundness.
- Prompt repair or replacement of defective equipment found during inspection and testing.
- Maintenance of a supply of spare parts for equipment that needs frequent repairs.
- Use of an organized record-keeping system to schedule tests and document inspections.
- Commitment to ensure that records are complete and detailed, and that they record test results and follow-up actions. Preventive maintenance inspection records should be kept with other visual inspection records.

Implementation

The key to properly implementing and tracking a preventive maintenance program is through the continual updating of maintenance records. Update records immediately after performing preventive maintenance or repairing an item and review them annually to evaluate the overall effectiveness of the program. Then refine the preventive maintenance procedures as necessary.

No quantitative data on the effectiveness of preventive maintenance as a BMP is available. However, it is intuitively clear that an effective preventive maintenance program will result in improved water system.

Costs

The major cost of implementing a preventive maintenance program is the staff time required to administer the program. Typically, this is a small incremental increase if a preventive maintenance program already exists at the facility.

SAFETY

Based on past studies, the water and wastewater industry has one if the highest injury rates in the nation. Workers in these areas are involved in construction and excavations, confined spaces, hazardous chemicals, and mechanical equipment that pose a serious injury risk when proper training, equipment, and procedures are not utilized. The **Occupational Safety and Health Administration (OSHA)** is responsible for developing regulations regarding worker safety and protection.

This section will introduce the topic of safety but is not intended to provide detailed information on all the safety topics important to operators. Each of us is responsible for his/her own safety and for the safety of others working in or entering our facilities. The water industry is one of the most hazardous, so it is very important for operators to be informed about situations that pose a safety risk.

Safety Conditions
You may encounter potentially hazardous conditions on a regular basis while operating, maintaining, and repairing water system equipment. You should be aware of these hazards and use good judgment when you encounter a potentially hazardous situation. The life you save may be your own.

Accident prevention is everyone's job, but it is the employer who is ultimately responsible for providing a safe workplace. Some of the hazards an operator may encounter include, but are not limited to:

- Lifting injuries
- Electric shock
- Slips and falls
- Chemical burns
- Eye injuries
- Excavation accidents (cave-ins)
- Construction accidents
- Inhalation accidents (dust, toxic gases and vapors)
- Oxygen deficient confined spaces (less than 19.5% oxygen)

Accidents are the result of unsafe actions by employees or unsafe conditions that exist in the water system. Unsafe actions include, but are not limited to:

- Removing or disabling machinery safety devices
- Failure to wear personal protective equipment
- Using equipment or tools not designed for the job
- Using defective equipment or tools
- Standing on or riding the outside of moving equipment
- Failure to secure or tie down heavy loads
- Operating vehicles, including heavy equipment, at an unsafe speed
- Failure to use lockout/tagout devices

Some of the more common unsafe conditions found at a small water system may include, but are not limited to:

- Poor housekeeping

- Improper storage of chemicals
- Doors removed from electrical panels
- Machinery guards or safety devices missing
- Fire and explosion hazards
- Low clearance hazards
- Improperly secured ladders or scaffolds
- Protruding objects
- Inadequate lighting
- Noise above safe decibel levels
- Lack of warning placards
- Confined spaces

You should keep your water system facilities clean and orderly. Emergency equipment and doorways should be kept clear and machine guards replaced after repairing equipment. Doors should be replaced on the electrical panels when you complete a wiring job or replace a breaker.

The door to the pump house or chlorine room should open outward for ease in entering and leaving the structure. Abnormal machine or equipment operation, electrical hazards or other unsafe conditions should be corrected promptly. Do not let unsafe conditions become commonplace. Eventually, an unsafe condition will result in an accident.

Unfortunately, it is often the 5 minute task that causes many injuries. Quick fixes usually promote unsafe acts. Do not let 5 minute tasks result in an injury to yourself or an employee.

Become skilled at recognizing unsafe conditions. Your knowledge of unsafe conditions and unsafe acts gives you foresight to correct a hazardous situation before an accident occurs. Together materials handling, falls, falling objects and machinery cause more than 60% of all workplace injuries.

Employers are responsible for providing employees with the proper safety equipment and training in its use. They are also responsible for development and implementation of safety policies for their workplace. The employees, after proper training, are responsible for recognizing the safety issues; following approved safety procedures, and properly utilizing the associated safety equipment.

Personal Protective Equipment (PPE) may be uncomfortable and increase stress, but is for your protection. When wearing PPE, the body's ability to cool is usually diminished. Nevertheless, PPE is frequently required to reduce the risk of injury. PPE includes steel-toed boots, safety glasses or goggles, face shields, earplugs, gloves or chemical protective clothing. The employer is responsible for providing PPE for their employees.

Respiratory protection equipment is commonly used because of the danger of inhalation, which provides a route of entry into the bloodstream for dangerous volatile chemicals. There are 2 types of respiratory protection devices called respirators: air purifying and air supplying. Both consist of a face piece connected to either an air source or an air-purifying device. The air-purifying respirator uses cartridges with filters to purify air before it is inhaled. This type of protection is not adequate in an oxygen deficient atmosphere.

Hazard Communications

OSHA established the Hazard Communication Standard in 1986. The standard was created to provide an information system on hazardous chemicals for both employers and employees. The Haz-Com Standard requires employers to ensure their employees know what hazardous materials exist in the workplace, how to safely use these materials, and how to deal with any emergencies that arise during use. Employers are required to provide the proper safety equipment, train employees in the safe use of any hazardous materials on a jobsite, and maintain records of both.

Producers of hazardous materials are required to provide customers with a **Material Safety Data Sheet (MSDS)** for each individual chemical or material. MSDS's must be kept on file and available to employees. Employee training should also include how to read and understand the information on the MSDS. The hazards that are involved fall into two basic categories: Health Hazards and Physical hazards.

Health hazards refer to immediate or long-term harm to the body caused by exposure to hazardous chemicals. Physical hazards like flammability or corrosivity can also cause injury to skin, eyes and the respiratory system. MSDS's are divided into 8 sections.

1. Manufacturers Contact Information
2. Hazardous Ingredients/Identity Information
3. Physical/Chemical Characteristics
4. Fire and Explosion Hazard Data
5. Reactivity Data
6. Health Hazard/First Aid Information
7. Precautions for Safe Handling and Use
8. Control/Cleanup Measures

NFPA Color-Code Warning System

OSHA uses a system based on the **National Fire Protection Association (NFPA)** diamond warning symbol as part of the MSDS information. This code is also required for all container labels. The NFPA symbol has four color-coded diamond-shaped sections. The top (Red) diamond is the Flammability Hazard rating. The left (Blue) diamond is the Health Hazard rating. The right (Yellow) diamond is the Reactivity Hazard rating. The bottom (White) diamond contains special symbols to indicate properties not explained by the other categories. A number–based rating system is used for each section, ranging from 0 – least dangerous to 4 – extremely dangerous.

Lock out/tag out (LOTO) regulations deal with the need to isolate a machine from its energy source to prevent it from starting while work is being done in and around the equipment. Energy sources can include electrical energy, hydraulic energy, pneumatic energy, thermal energy, and chemical energy. This can be either active energy or stored energy. Stored energy can take many forms. Some examples of stored energy are; electrical energy stored in capacitors, pneumatic energy stored in a compressor tank, and hydraulic water pressure in an isolated line. Any stored energy must be dissipated prior to working on the equipment. Employers are responsible for establishing an “Energy Control Plan” for LOTO work and supply each worker with their individual LOTO locking devices.

LOTO requires workers to isolate and de-energize these sources and lock and tag them prior to working on the equipment or process. Only trained personnel should conduct lock out/tag out procedures. Each individual involved in the work should attach their personal LOTO lock to the disconnect or isolation device. This assures that the equipment cannot be restarted until each individual is finished with their task and is clear of the equipment. Tags are used to provide information regarding the date and nature of the lockout and the individual responsible for removing the lockout. Tags are not substitutes for locks. Any isolation that can be locked must be locked and tagged. Lockout devices may also include chains, valve clamps, wedges, jacks, or key blocks.

Anyone who enters a LOTO work area must be informed that a LOTO situation exists. If they are to be involved in the work, they must also apply their own LOTO locks. Workers that leave a LOTO site must take their LOTO locks with them. If work is not completed at the end of a shift, all LOTO locks must be removed and be replaced with an equipment protection lock until work resumes. If equipment must be temporarily restarted, the LOTO must be removed during the restart and reapplied before work can continue.

Confined Space Entry

The water and wastewater industry has one of the highest numbers of confined space injuries per capita in the country. The vast majority of confined space related injuries result in fatalities. Another disturbing fact is that 40% of the confined space related fatalities are people who tried to rescue someone else from a confined space.

A confined space is defined by the following parameters. It must be large enough for a person to enter and do work. It has openings that make entry or exit difficult. It is not intended for continuous occupancy. Any open surface tank that is deeper than four feet is also considered a confined space. Confined spaces fall into two categories; permit required and non-permit required. A confined space becomes permit required when it has potential for a hazardous atmosphere, potential for engulfment, a hazardous internal configuration, or other recognized hazards such as dangerous equipment or hot work (welding, cutting torch, etc.) that is in progress.

All employees involved in confined space entries must have the proper training in entry procedures and use of safety equipment. An entry supervisor is responsible for conducting the testing and completing the permit. Atmospheric testing should include oxygen concentration, Lower Explosive Limit for explosives, and any toxic gases that may be present. The oxygen concentration must be between 19.5-23.5%. The alarm point for explosives is 10% of Lower Explosive Limit (LEL).

An attendant must be present and stationed outside the confined space to monitor the entrants while they are working. The attendant must maintain constant verbal and visual communications with the entrants. The attendant must also be prepared to instruct the entrants to exit the confined space should the equipment fail or the entrants exhibit impaired judgment.

Any confined space must be tested for a hazardous atmosphere before the entry. Monitoring must continue while the entrants are in the confined space. Permit required confined spaces also require ventilation during the entry and self-contained or supplied air must be used if ventilation fails to produce a safe atmosphere. Permit required confined space entries also require rescue equipment such as a harness and tripod for emergency rescues. If the space is configured in a way that prevents the use of self-rescue equipment, an emergency rescue team must be on-site during the entry. When the entry is completed, the entry supervisor must complete the permit form and file a copy with the appropriate supervisor and a confined space entry master file. Non-permit confined spaced must be reassessed periodically. Any non-permit space can be reclassified, as permit required, based on the results of these assessments.

Excavation Safety

Proper shoring or sloping of trenches and excavations is a major safety issue for many distribution system operators. New construction usually involves more controlled conditions than emergency repairs. Excavations for emergency repairs almost always involve digging and shoring in saturated soils and flooded trenches. A "competent person" must supervise all excavation operations. A competent person is someone who has extensive training in soil mechanics and shoring operations.

All trenches over 4 feet deep must have ladder from entry and exit. The ladders must extend at least 3 feet above the top of the trench and ladders must not be stationed more than 25 feet apart. Trenches over 5 feet deep must be properly shored or sloped to protect entrants from trench wall collapse and cave-ins. The competent person must determine the proper Maximum Allowable Slope, formerly referred to as Angle of Repose, for the given soils type. Soils are either Type 1, 2, or 3. Type 3 soils are the least stable and require the shallowest Maximum Allowable Slope. Spoil from the excavation must be placed at least 2 feet from the edge of the excavation (farther with more unstable soils.)

Shoring must be installed without worker entry into the excavation. Trench boxes are useful for long trenches where it can be moved along the trench. This saves some of the setup and breakdown time required with shoring. Ladders must be positioned so that workers can enter and exit without stepping outside the shoring or trench box. Excavations may become confined spaces if they are located close to a source of potentially hazardous gases (underground gas tanks, landfills, etc.)

Environmental Hazards

<u>Heat Stress</u>

Heat stress is caused by a number of interacting factors, including environmental conditions, clothing, workload, etc., as well as the physical and conditioning characteristics of the individual. Since heat stress is one of the most common illnesses associated with heavy outdoor work conducted with direct solar load and, in particular, because wearing PPE can increase the risk of developing heat stress, workers must be capable of recognizing the signs and symptoms of heat related illnesses. Personnel must be aware of the types and causes of heat-related illnesses and be able to recognize the signs and symptoms of these illnesses in both themselves and their coworkers.

<u>Heat Rashes</u>

Heat rashes are one of the most common problems in hot work environments. Commonly known as prickly heat, a heat rash is manifested as red papules and usually appears in areas where the clothing is restrictive. As sweating increases, these papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently wetted by unevaporated sweat, and heat rash papules may become infected if they are not treated. In most cases, heat rashes will disappear when the affected individual returns to a cool environment.

<u>Heat Cramps</u>

Heat cramps are usually caused by performing hard physical labor in a hot environment. These cramps have been attributed to an electrolyte imbalance caused by sweating. It is important to understand that cramps can be caused both by too much or too little salt. Cramps appear to be caused by the lack of water replenishment. Because sweat is a hypotonic solution (plus or minus 0.3% NaCl), excess salt can build up in the body if the water lost through sweating is not replaced. Thirst cannot be relied on as a guide to the need for water; instead, water must be taken every 15 to 20 minutes in hot environments.

Heat Exhaustion

Heat exhaustion occurs from increased stress on various body organs due to inadequate blood circulation, cardiovascular insufficiency, or dehydration. Signs and symptoms include pale, cool, and moist skin; heavy sweating; dizziness; nausea; headache; vertigo; weakness; thirst; and giddiness. Fortunately, this condition responds readily to prompt treatment. The signs and symptoms seen in heat exhaustion are similar to those of heat stroke, which is a medical emergency. Workers suffering from heat exhaustion should be removed from the hot environment, be given fluid replacement, and be encouraged to get adequate rest.

Heat Stroke

Heat stroke is the most serious form of heat stress. Heat stroke occurs when the body's system of temperature regulation fails and the body's temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. Heat stroke is a medical emergency. The primary signs and symptoms of heat stroke are confusion; irrational behavior; loss of consciousness; convulsions; a lack of sweating (usually); hot, dry skin; and an abnormally high body temperature. If body temperature is too high, it causes death. The elevated metabolic temperatures caused by a combination of workload and environmental heat load, both of which contribute to heat stroke, are also highly variable and difficult to predict. If a worker shows signs of possible heat stroke, professional medical treatment should be obtained immediately. The worker should be placed in a shady area and the outer clothing should be removed. The worker's skin should be wetted and air movement around the worker should be increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first-aid treatment.

Cold Stress

Cold stress normally occurs in temperatures at or below freezing, or under certain circumstances, in temperatures of 40°F. Extreme cold for a short time may cause severe injury to exposed body surfaces or result in profound generalized cooling, causing death. Areas of the body that have high surface area-to volume ratio, such as fingers, toes, and ears, are the most susceptible. Two factors influence the development of a cold weather injury: ambient temperature and the velocity of the wind. For instance, 10 °F with a wind of 15 **miles per hour (mph)** is equivalent in chilling effect to still air at 18 °F.

Frostbite

Frostbite is the generic term for a local injury resulting from cold. Several degrees of tissue damage are associated with frostbite. Frostbite of the extremities can be categorized into:

- Frost Nip or Incipient Frostbite — characterized by sudden blanching or whitening of skin.
- Superficial Frostbite — skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.
- Deep Frostbite — tissues are cold, pale, and solid; extremely serious injury.

Systemic Hypothermia

Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature. It can be fatal. Its symptoms are usually exhibited in five stages:

- Shivering;
- Apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95°F;
- Unconsciousness, glassy stare, slow pulse, and slow respiratory rate;
- Freezing of the extremities; and
- Death.

Trauma sustained in freezing or sub-zero conditions requires special attention because an injured worker is predisposed to secondary cold injury. Special provisions must be made to prevent hypothermia and secondary freezing of damaged tissues in addition to providing for first-aid treatment. To avoid cold stress, site personnel must wear protective clothing appropriate for the level of cold and physical activity. In addition to protective clothing, preventive safe work practices, additional training, and warming regimens may be utilized to prevent cold stress.

Biological Hazards

Portions of the field work will be conducted in grassy and wooded areas along the river. Numerous biological hazards may be present, including poison ivy, snakes, thorny bushes and trees, ticks, mosquitoes, and other pests.

Tick-Borne Disease

The following tick-borne diseases may present hazards when conducting field work. These diseases are transmitted primarily by the deer tick, which is smaller and redder than the common wood tick. The disease may be transmitted by immature ticks, which are small and hard to see. The tick may be as small as a period on this page.

Lyme Disease

The disease commonly occurs in the spring and summer and is transmitted by the bite of infected ticks. Symptoms of Lyme disease include a rash or a peculiar red spot, like a bull's eye, which expands outward in a circular manner. The victim may have headache, weakness, fever, a stiff neck, swelling and pain in the joints, and eventually, arthritis.

Tick repellant containing **diethyltoluamide (DEET)** should be used when working in tick-infested areas, and pant legs should be tucked into boots. In addition, workers should search the entire body every three or four hours for attached ticks. Ticks should be removed promptly and carefully without crushing, since crushing can squeeze the disease-causing organism into the skin. A gentle and steady pulling action should be used to avoid leaving the head or mouth parts in the skin.

Poisonous Plants Hazards

Poisonous plants may be present all along the river. Personnel should be alerted to their presence, and instructed on methods to prevent exposure. The main control is to avoid contact with the plant, cover arms and hands, and frequently wash potentially exposed skin. Particular attention must be given to avoiding skin contact with objects or protective clothing that have touched the plants. Treat every surface that may have touched the plant as contaminated, and practice contamination avoidance. If skin contact is made, the area should be washed immediately with soap and water, and observed for signs of reddening.

Snakes

The possibility of encountering snakes exists, specifically for personnel working in grassy, wooded, and vegetated areas. Snake venoms are complex and include proteins, some of which have enzymatic activity. The effects produced by venoms include neurotoxic effects with sensory, motor, cardiac, and respiratory difficulties; cytotoxic effects on red blood cells, blood vessels, heart muscle, kidneys, and lungs; defects in coagulation; and effects from local release of substances by enzymatic actions. Other noticeable effects of venomous snake bites include swelling, edema, and pain around the bite, and the development of ecchymosis (the escape of blood into tissues from ruptured blood vessels). To minimize the threat of snake bites, all personnel walking through vegetated areas must be aware of the potential for encountering snakes and the need to avoid actions which might lead to encounters, such as turning over logs, etc. If a snake bite occurs, an attempt should be made to safely kill the snake for identification. The victim must be transported to the nearest hospital within 30 minutes; first aid consists of applying a constriction band and washing the area around the wound to remove any unabsorbed venom.

Spiders

Personnel may encounter spiders during work activities along the river. Two spiders are of concern, the black widow and the brown recluse. Both prefer dark sheltered areas such as basements, equipment sheds and enclosures, and around woodpiles or other scattered debris. The black widow is shiny black, approximately one inch long, and found throughout the United States. There is a distinctive red hourglass marking on the underside of the black widow's body. The bite of a black widow is seldom fatal to healthy adults, but effects include respiratory distress, nausea, vomiting, and muscle spasms. The brown recluse is smaller than the black widow and gets its name from its brown coloring and behavior. The brown recluse is more prevalent in the southern United States. The brown recluse has a distinctive violin shape on the top of its body. The bite of the brown recluse is painful and the bite site ulcerates and takes many weeks to heal completely.

To minimize the threat of spider bites, all personnel walking through vegetated areas must be aware of the potential for encountering these arachnids. Personnel need to avoid actions that may result in encounters, such as turning over logs and placing hands in dark places such as behind equipment or in corners of equipment sheds or enclosures. If a spider bite occurs, the victim must be transported to the nearest hospital as soon as possible; first aid consists of applying ice packs and washing the area around the wound to remove any unabsorbed venom.

System security

The three "D"s of security are: Deter, Detect and Delay. Intrusion should be deterred, and detected if it occurs. Intruders should be slowed down (delayed) as much as possible to allow more time for their apprehension.

Water system security steps include:

4. Vulnerability assessment - Identify vulnerabilities such as doors, windows, hatches and locations in remote areas.

5. Eliminate or mediate vulnerabilities - Install locks and use them. Install fences, alarms and security lights. Ask for police patrols. Consider asking neighbors to watch over your facilities for you (adopt-a-facility). Once a shift, operators should inspect facilities for evidence of unauthorized persons or unusual events.
6. Emergency response - Know who to call in an emergency. Create a list of emergency telephone numbers, such as:
   - Fire
   - Police
   - IDEM
   - Local health department
   - Critical users
   - Your boss
   - Government officials
   - Nearby water systems
   - Laboratories
   - Contractors
   - Chemical suppliers
   - Parts/equipment suppliers
   - Insurance agent
   - Local media (radio, TV and newspaper)

Plan ahead for your emergencies. Think about what might go wrong, and try to plan for it. Like a good scout, "be prepared." Always remember, people come first, then property. Be safe and do not take unnecessary risks.

PERSONAL SAFETY

Sometimes you may be working in remote areas that could potentially put you at risk of getting lost or hurt. You should take the following steps to ensure you can work safely when conducting sanitary surveys and field visits in remote locations:

Plan Ahead

- Notify your supervisor or a fellow worker that you will be working in a remote area.
- Have a check-in time set up before you leave. A check-in/check-out procedure can be used so that it is known where you are and when you have safely returned at the end of the day.
- Carry a fully charged cell phone (available for checkout at the regions).
- Know your site's emergency call-in number or your supervisor's pager number.
- Always wear your ID badge to clearly identify yourself.
- Wear appropriate footwear for the conditions, such as non-slip soled shoes for rough trails, mossy or slippery rocks, uneven or slippery floors, ladders, etc.
- If you are injured or involved in an accident, report to your supervisor immediately and submit an Accident/Incident Report Form.

Vehicle Safety

- Always drive defensively and safely. Obey all driving laws, including wearing your seat belt. Be aware of other vehicles and surroundings.
- Know who to call if your vehicle breaks down.
- If someone bumps you from behind or is following you, don't pull over at that spot, especially if it is isolated. Go to a public place with lots of lights and people and report to your supervisor immediately or call 911.
- Driving precautions in rural areas: watch for debris and potholes; lanes are narrow, be aware of oncoming traffic; watch for surface changes; watch for slow going vehicles; be aware of unguarded railroad crossings; and watch for animals.

Methamphetamine (Meth) Labs

- Be alert to homes whose view to the interior is obstructed in some manner by blinds, or the windows are boarded over, etc. Some drug labs have excessive security (more than one deadbolt, metal security doors, bars on windows, or vicious dogs). They also may have yards filled with discarded propane tanks and glassware that could have been used in a meth lab operation.
- Meth labs can be identified by their strong smell, similar to stale cat urine.
- Be careful when walking in yards with discarded glassware that could have been used in a meth lab operation because the chemicals they contained can contaminate you. Also, there may be booby traps set around the premises of the building.
- You **SHOULD** leave if you suspect the area is a meth lab operation.

In the Event of an Assault

If you are attacked or threatened you have the right to defend yourself in any manner necessary proportionate to the threat. How you choose to defend yourself will depend on the circumstances of the assault and your abilities. Consider that you could be attacked and think about what you can or are willing to do to protect yourself. There is no one guaranteed method of defense. You will need to consider alternatives and optional responses.

Trust Your Instincts

If you are feeling uncomfortable, cancel the visit, reschedule, or request back-up from another staff member or the police. If you are in a tight situation:

- Don’t show fear. Watch their body language.
- Try not to show any facial expression.
- Control your breathing.
- Speak slowly and lower the pitch of your voice, talk from your diaphragm.
- Watch your hands so they don’t move nervously. Maintain personal space.
- Maintain eye contact, but don’t try to stare anyone down.
- Don’t challenge, but be assertive, especially if lewd comments are made.
- Check your watch; say you need to call your office because they are waiting for your call.
- Repeat what you are there for.
- Stand up and leave.

WATER SECURITY

Security practices should be incorporated into a utility's every day business functions. Activities such as fence cutting and lock picking, often dismissed as harmless, may be indications of more serious threats to a water or wastewater system. Utilities must be prepared to respond to this type of threat, as well as a wide range of other emergencies, including natural disasters. Improved security preparations provide for a more effective and efficient response.

Water and wastewater utilities are responsible for taking action to protect their infrastructure. The federal government and EPA are helping utilities to accomplish these actions by providing tools, trainings, and technical assistance.

Several resources designed specifically to help small drinking water and wastewater utilities better protect their systems are available through this site.

BIOTERRORISM ACT - On June 12, 2002, President Bush signed into law the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (PL 107-188, referred to as the Bioterrorism Act). In the Bioterrorism Act, Congress recognizes the need for drinking water systems to undertake a more comprehensive view of water safety and security. The Act amends the SDWA and specifies actions CWSs and the EPA must take to improve the security of the Nation's drinking water infrastructure.

The Bioterrorism Act defines small community drinking water systems as those serving a population of more than 3,300 but less than 50,000. If a community drinking water system serves more than 3,300 people, that utility must:

- Conduct a vulnerability assessment
- Certify to EPA that the assessment has been completed
- Send a copy of the assessment results to EPA
- Certify that the system has an emergency response plan.

VULNERABILITY ASSESSMENTS - Vulnerability assessments help water systems evaluate susceptibility to potential threats and identify corrective actions that can reduce or mitigate the risk of serious consequences from adversarial actions (e.g., vandalism, insider sabotage, terrorist attack, etc.). Such an assessment for a water system takes into account the vulnerability of the water supply (both ground and surface water), transmission, treatment, and distribution systems. It also considers risks posed to the surrounding community related to attacks on the water system. An effective vulnerability assessment serves as a guide to the water utility by providing a prioritized plan for security upgrades, modifications of operational procedures, and/or policy changes to mitigate the risks and vulnerabilities to the utility’s critical assets. The vulnerability assessment provides a framework for developing risk reduction options and associated costs. Water systems should review their vulnerability assessments periodically to account for changing threats or additions to the system to ensure that security objectives are being met. Preferably, a vulnerability assessment is "performance-based,” meaning that it evaluates the risk to the water system based on the effectiveness (performance) of existing and planned measures to counteract adversarial actions.

The following are common elements of vulnerability assessments. These elements are conceptual in nature and not intended to serve as a detailed methodology:

1. Characterization of the water system, including its mission and objectives;
2. Identification and prioritization of adverse consequences to avoid;
3. Determination of critical assets that might be subject to malevolent acts that could result in undesired consequences;
4. Assessment of the likelihood (qualitative probability) of such malevolent acts from adversaries;
5. Evaluation of existing countermeasures; and
6. Analysis of current risk and development of a prioritized plan for risk reduction.

The vulnerability assessment process will range in complexity based on the design and operation of the water system itself. The nature and extent of the vulnerability assessment will differ among systems based on a number of factors, including system size, potential population affected, source water, treatment complexity, system infrastructure and other factors. Security and safety evaluations also vary based on knowledge and types of threats, available security technologies, and applicable local, state and federal regulations.

EMERGENCY RESPONSE PLANS - An **Emergency Response Plan (ERP)** is a documented plan that describes the actions that a CWS would take in response to various major events. A major event refers to:

- Credible threats, indications of terrorism, or acts of terrorism;
- Major disasters or emergencies such as hurricanes, tornadoes, storms, earthquakes, fires, flood, or explosion regardless of cause; and
- Catastrophic incidents that leave extraordinary levels of mass casualties, damage, and disruption severely affecting the population, infrastructure, environment, economy, and government functions.

Protecting public health is the primary goal of community drinking water systems, and having an up-to-date and workable ERP helps achieve this goal in any crisis situation. The ERP should be updated annually. The Bioterrorism Act amends the SDWA by adding, among other requirements, section 1433. Section 1433(b) requires community water systems serving populations greater than 3,300 to either prepare or revise an ERP that incorporates the results of its Vulnerability Assessment (VA). The ERP must include "plans, procedures, and identification of equipment that can be implemented or utilized in the event of a terrorist or other intentional attack" on the CWS. The ERP also must include "actions, procedures, and identification of equipment which can obviate or significantly lessen the impact of terrorist attacks or other intentional actions on the public health and the safety and supply of drinking water provided to communities and individuals."

Core elements form the basis, or foundation, for responding to any major event. EPA has identified 8 core elements common to an ERP that you should plan to utilize or bring to bear during water emergencies:

1. System Specific Information;
2. CWS Roles and Responsibilities;
3. Communication Procedures: Who, What, and When;
4. Personnel Safety;

5. Identification of Alternate Water Sources;
6. Replacement Equipment and Chemical Supplies;
7. Property Protection; and
8. Water Sampling and Monitoring

Your ERP may contain sensitive information, so you should consider steps you need to take to ensure the security of your ERP. Sensitive information should be placed in appendices, or in sections that are not readily available to unauthorized personnel. The ERP, however, should be easily accessible to authorized personnel and should be easily identifiable during a major event. Steps taken to limit access by unauthorized persons should consider local and state **Freedom of Information Act (FOIA)** laws. Alternatively, you can opt to make your ERP general in nature so that everyone can use it and not include specific information about system vulnerabilities. A secure copy of your ERP should be maintained in an off-premises location in the event that your primary copy cannot be accessed.

MANAGEMENT COMPONENTS

Owning and operating a public drinking water system is a big responsibility. There are few things more important to maintaining good health than having access to safe drinking water. The purpose of this section is to assist owners/operators of small water systems to meet the requirements of state and federal drinking water laws, and ultimately to protect the health of their customers.

Much of this guide will be useful on a day-to-day basis. The guide can be used as a filing system for system personnel and can serve many purposes including providing a:

- central location for numerous water system records and system policies;
- process to evaluate present and future system deficiencies and improvements necessary for continued water system operation; and
- a list of operation and maintenance duties that can be reviewed, used and improved as necessary by existing and future water system perso+nnel so they may effectively manage and operate the water system.

This section contains a description of content of the 18 elements. Some elements can be completed quickly (e.g., fill in information that should be readily available or attach documents you should have in your files). Other elements may take more effort (e.g., if one does not exist, create a service area and facility map or develop a cross-connection control program).

Working through this section may appear challenging at first, but from the perspective of assuring effective long term management of the system, each element is important. **To help prioritize the efforts, please focus on the first five elements of this section first.** These elements primarily focus on accurate record keeping and water quality monitoring/reporting. They are absolutely essential and need immediate attention. Once these are completed, continue to work through the section and develop the other technical, managerial, and financial elements.

- **Water Facilities Inventory**: Provides information about the water system (e.g., source capacity, number of connections and population served, etc.).
- **Water Quality Monitoring Program**: Identifies the type, frequency and location of baseline water quality monitoring required for each existing, permanent and seasonal source and distribution system.
- **Preparing for Your Sanitary Survey**: Identifies things a system can perform to prepare for sanitary surveys.
- **Annual Operating Permit**: Provides a compliance status report to system to correct any identified problems.
- **Cross-Connection Control Program**: Documents cross-connection control program efforts to protect system from possible contamination.
- **Emergency Response Plan**: Contains phone numbers of parties to contact in case of a system emergency.
- **Service Area and Facility Map**: Contains service area boundaries and lists major system components.
- **Operation and Maintenance Program**: Lists system personnel information (name, title, phone #) and identifies functions, frequency (e.g., weekly, monthly), and location of component maintenance.
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- **Water Usage**: Charts the number of system users, the average consumption per user, and the estimate of total system usage.
- **Component Inventory and Assessment**: Verifies component approval status. Inventories system components. Identifies possible system improvements in the next 6 years.
- **List of System Improvements**: Identifies the year, cost, and financing method for anticipated system improvements.
- **Budget**: Includes revenues, expenses and capital improvement financing.
- **System Management**: Documents the system's management practices including the decision making process.

GENERAL RECORD KEEPING

Importance of Records

Keeping of adequate records of performance is an integral part of good water treatment plant operation. Only by making a clear and concise memorandum of what has happened and what has been accomplished will the experiences be of assistance in meeting future operation situations. Pertinent and complete records are a necessary aid to control procedures. Above all, records should be used as a basis for plant operation and for interpreting the results of water treatment.

Records also provide an excellent check on things done or to be done, especially regarding maintenance problems. Equipment in water treatment plants requires periodic services; some daily, some weekly, and others monthly or yearly. Adequate records show when service was last performed and when the time for service approaches. Thus a schedule can be maintained, with nothing overlooked or forgotten.

Significant details of day-to-day experience provide a running account of plant operation and thus have an important historical value. When accurately kept, records provide an essential basis for the design of future changes or expansions of the treatment facilities for other locations where similar problems may be encountered. In the event of legal questions in connection with water treatment or plant operations, accurate and complete records would be urgently required as evidence of what actually occurred at any given time or over nay particular period of time. Thus, records and their proper maintenance are essential in any type of water treatment. However, only those records should be kept which are known to be useful; the temptation to accumulate minutiae of no significant value must be guarded against.

In summary the main functions of records are to:

- Satisfy legal requirements
- Aid the operator in solving treatment problems
- Provide an alert for changing raw water quality
- Show that the final product is acceptable to the consumer
- Show that the final product meet plant performance standards
- Show that the final product complies with the WV Drinking Water Standards
- Determine equipment, plant, and unit process performance
- Aid in answering complaints
- Anticipate routine maintenance
- Provide cost analysis data
- Provide future engineering design data
- Provide the basis for monthly or annual reports

Information to be Included

The extent to which record keeping should be practiced depends entirely upon their potential use. The type of treatment, the volume of water treated, and the kind and importance of installations auxiliary to the treatment plant will control the amount of necessary record keeping.

State regulations require that certain operating records be maintained and reported at specified intervals. These records must be kept, but should be in addition to adequate plant operating data and should not be considered a substitute for plant records.

Maintaining Records & Reports

It is important that water system personnel maintain various reports and records for planning and proper management of the system operation. It is equally important to know the significance of each report and record because the operator is responsible for them. Technical reports and records are generally viewed as those dealing with the physical operation and maintenance of the water system's facilities. These reports, like financial reports, can be valuable tools for good decision-making and good day-to-day management, and can be used as a gauge to help determine the financial integrity and condition of the system.

Good records also allow operators to react to potential problems and plan for future expansion. Accurate historical data allows Board Members to make more informed decisions regarding projections for system improvements. This data can also be an invaluable asset in helping to recognize areas of preventative action. The following reports or records should be used by systems:

Daily Operating Report
This report lists such things as the amount of water purchased or produced, meter readings, and the amount of chemicals used in the treatment process. The report is completed on a daily basis. It is advisable to maintain these records in the files for ten years.

Water Loss Report
The term "water loss' is generally defined as the difference between the amount of water produced or purchased and the amount of water sold to the customers (as described above).

Operation and Maintenance Records
It is essential to know when equipment was installed or repaired, the number of hours operated or other maintenance performed. Operation and maintenance records cover all the physical facilities of the water system including storage tanks, meters, pumps, vehicles, fire hydrants, valves, etc. Operation and maintenance manuals should be available for all appurtenances.

Emergency Response
Emergency planning is an important responsibility for governing bodies of water systems. Mayors/Board Members should make sure that the water system has contingency plans to handle emergency situations. Good emergency planning includes guidelines to help the system initiate preventive measures directed toward potential emergencies. Several areas in which Mayors/Board Members should plan for emergency response and prevention include the following:

- Emergency and standby systems including supply options for contamination, main breaks, drought, flood, or other disasters.
- Mayors/Board members should have access to all federal and state disaster emergency service numbers in the event of an emergency.
- Emergency conservation plans.
- Plans for emergency staffing.

COMPLIANCE RECORD KEEPING

PWS Control Tests and Record Maintenance

All records must be retained at a convenient location on or near the premises of the PWS. All tests and analyses required by the state or federal regulations must be conducted by a certified laboratory or person approved by the WVBPH (certified operator). The approved tests and analysis that a Class 1D can analyze are:

- Chlorine residual;
- pH; and
- Temperature.

The records must include

- PWS ID Number;
- Date, Time and Location of sample;
- Sampler;
- Type of sample;
  - Routine, resample, distribution, raw, effluent, or special purpose
- Date and time of analysis;
- Result of analysis;
- Laboratory and person conducting analysis; and
- Method used for microbiological testing.

Recordkeeping Time Lines

Time Line	**Type of Record**
2 years	Records of backflow preventer testing
3 years	Records of action or correct violation
3 years	Copies of Public Notices
5 years	Monthly Operational Reports & Bacteria Analysis
5 years	Records concerning a variance or exemption
10 years	Copies of written reports, summaries, or communications relating to sanitary surveys
10 years	Radiological, chemical and turbidity analysis
12 years	Lead and copper results and reports

GLOSSARY

Accountability - When a manager gives power/responsibility to an employee, the employee ensures that the manager is informed of results or events.

Accuracy - How closely an instrument measures the true of actual value of the process variable being measured or sensed.

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

Action Level - The level of lead or copper which, if exceeded in over 10% of the homes tested, triggers treatment or other requirements that a water system must follow.

Acute - Effects of an exposure which causes severe symptoms to occur quickly.

Acute Contaminant - A harmful substance that has a rapid effect on humans and/or animals.

Acute Health Effect - An immediate (i.e., within hours or days) adverse health effect that may result from exposure to certain drinking water contaminants (e.g., pathogens).

Aesthetic Qualities - The taste, odor and appearance of drinking water.

Air Bladder - A flexible container located inside of a hydropneumatic tank to hold air.

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.

Altitude Valve - A valve that automatically shuts off the flow into an elevated tank when the water level in the tank reaches a predetermined level. The valve automatically opens when the pressure in the distribution system drops below the pressure in the tank**.**

Amperage - The measurement of electron flow.

Analysis - The process of determining the concentration of a material 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.

As-built Plans - Drawings such as blue-prints that show the actual components and their relationships.

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-Day Demand - A water systems average daily use based on total annual water production (total annual gallons or cubic feet divided by 365); multiple years can be used to account for yearly variations.

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.

Backfill - To refill an excavated area with removed earth; or the material itself that is used to refill an excavated area.

Backflow - A reverse flow condition, created by a difference in water pressures, which causes non-potable water to flow into a potable water system.

Backpressure - 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 Prevention - The best defense for backflow is a proactive backflow prevention program requiring backflow preventers in areas where backflow can occur.

Backflow Prevention Assembly Installer/Tester (BPAIT) - An individual who meets all the requirements of 64CSR25 and is certified to inspect and test backflow prevention assemblies or methods.

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

Bacteria - Living organisms, microscopic in size, which consist of single cell. Most bacterial utilize organic matter for their food and produce waste produces as the result of their life processes.

Bacteriological Sampling - The process of collecting samples for testing for coliform bacterial.

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.

Best Management Practices (BMPs) - Structural, nonstructural and managerial techniques that are recognized to be the most effective and practical means to control nonpoint source pollutants yet are compatible with the productive use of the resource to which they are applied. BMPs are used in both urban and agricultural areas.

Bioterrorism Act - The Public Health Security and Bioterrorism Preparedness and Response Act of 2002.

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

Boil Order Notice - A directive issued to water system users to boil their water because of known or suspected bacteriological contamination.

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 form 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

Calibrate - The process of determining the rate that a pump produces.

Capacity - The volume, usually expressed in gpm, that a pump will produce.

Capacity Development - The process of determining the managerial, financial and technical capacities of a water system.

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

Cathodic Protection - An electrical system for prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. A low-voltage current is made to flow through a liquid (water) or a soil in contact with the metal in such a manner that the external electromotive for renders the metal structure cathodic. This concentrates corrosion on auxiliary anodic parts which are deliberately allowed to corrode instead of letting the structure corrode.

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 of 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.

Certified Operator – An individual holding a valid West Virginia public water system certification in accordance with Section 6 of 64CSR4.

Chain of Custody - A written record that shows who handled a sample over what periods of time from the beginning to the end of the sampling and testing process.

Check Valve - A special valve with a disc or flap which has a hinge on one edge so that it opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.

Chemical Oxidizing Agent - Chemicals which are very reactive, such as chlorine, which combine readily with both organic and inorganic compounds by adding a oxygen, e.g. ferrous iron has two oxygens and will stay in solution, but if an oxidizing agent such as chlorine is added, an oxygen is added to the ferrous iron to create ferric iron with three oxygens and comes out of solution as a reddish-brown sediment.

Chemical Reactions - The chemical interaction between two or more materials.

Chemical Reagents - Most test kits used to test for chemicals such as chlorine use other chemicals as part of the testing process, these chemicals which are provided with the test kit are known as chemical reagents.

Chief Operator - The certified operator whom the owner designates who is responsible for managing the daily operational activities of an entire public water system or a water treatment facility, or a distribution system in a manner that ensures meeting state and federal safe drinking water rules and regulations.

Chlorinate - The process of adding chlorine to water.

Chlorination - The application of chlorine to water, sewage, or industrial wastes, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

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.

Chlorine Dose – The total amount of chlorine fed into a volume of water by the chlorine feed equipment is referred to as dosage and is calculated in milligram per liter (mg/L).

Chlorine Residual - The amount of chlorine left in solution after a period of time. For instance with new water lines, the reaction time is 24 hours. The residual is usually expressed in mg/L.

Chronic Health Effect - The possible result of exposure over many years to a drinking water contaminant at levels above its Maximum Contaminant Level.

Circuit Breaker - A device used to protect wiring from burning as a result of over-current. Serves the same function as a fuse.

Coliform Bacteria - The Coliform group of bacteria is a bacterial indicator of contamination. This group has as one of its primary habitats the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals, and in plants, soil, air and the aquatic environment.

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.

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.

Combined Distribution System - The interconnected distribution system consisting of the distribution systems of wholesale systems and of the consecutive systems that receive finished water from those wholesale system(s).

Community Water System (CWS) - A public water system which serves at least 15 service connections used by year round residents or regularly serves at least 25 persons year-round residents. Also see non-community water system, transient water system and non-transient non-community water system.

Compliance - The act of meeting all state and federal drinking water regulations.

Compliance Samples – Required sample your system takes to comply with regulations. Compliance samples are identified in your monitoring plan. All compliance samples identified in your monitoring plan must be included in your compliance calculations, even if you take more than the minimum number of samples.

Compound Meters - These meters are used where there is a need to measure both high and low flows, like in a hotel, school, or a commercial account where both domestic use and production use need to be measured by one meter. They are typically available in sizes from 2" through 6".

Contaminates - Toxic material, microorganisms, or other deleterious agents that make water unfit for its intended use.

Confined Space - A space defined by the concurrent existence of the following conditions:

1. Existing ventilation is insufficient to remove dangerous air contamination and/or oxygen deficiency which may exist or develop, and

2. Ready access or egress (getting out) for the removal of a suddenly disabled employee (operator) is difficult due to the location and/or size of the opening(s).

Consecutive System - Includes all systems that buy or otherwise receive some or all of their finished water from another public water system on a regular basis.

Consumer Confidence Report (CCR) - All community water systems are required to deliver to their customers an annual report. This report must contain information on the quality of the water delivered by the system and characterize the risks, if any, from exposure to contaminants detected in the drinking water in an accurate and understandable manner. Systems shall deliver their reports no later than July 1 annually. Each report must contain data collected during, or prior to, the previous calendar year. A community water system that sells water to another community water system shall deliver the applicable information noted above to the buyer system no later than April 1 annually.

Contamination - The introduction into water of toxic materials, bacteria, or other deleterious agents that make the water unfit for its intended use.

Cooling Vents - Openings on the ends of a motor.

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.

Cross-Connection - Any physical arrangement whereby a potable water supply is connected, directly or indirectly, with an non-potable or unapproved water supply or system.

Cross-Connection Control Device - Any device or assembly, approved by the Commissioner for construction on or installation in water supply piping, which is capable of preventing contaminants from entering the public water supply distribution system.

Customer Service Line - The pipeline from the public water supply to the: (1) First tap, fixture, receptacle, or other point of customer water use; or (2) Secondary source of supply or pipeline branch in a building.

Cut-in Pressure - The low pressure of the system where the system pump will start.

Cut-out Pressure - The high pressure of the system where the pump will stop.

Cycle Rate - The frequency that a pump operates per day or hour.

Demand - When related to chlorine, the amount of chlorine neutralized by iron, manganese, algae, and microorganisms in a specified period of time.

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.

Diaphragm - A flexible device, usually circular, that is used by a chemical feed pump to move fluid.

Discharge Head - The pressure (in pounds per square inch or psi) measured at the centerline of a pump discharge and very close to the discharge flange, converted into feet.

Discharge Pressure - The pressure in the system to which the chemical feed pump is pumping.

Disinfectant - A chemical that destroys pathogenic microorganisms.

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.

Disinfection Byproducts - A contaminant formed by the reaction of disinfection chemicals (such as chlorine) with other substances such as plant matter and other naturally occurring materials in the water. These byproducts may pose health risks in drinking water.

Disinfectants/Disinfection By-Products Rule (DBPR) - The purpose of this rule is to reduce public exposure to three chemical disinfectants (chlorine, chloramines, and chlorine dioxide) and many disinfection by-products (total trihalomethanes, haloacetic acids, chlorite, and bromate).

Disinfectant Residual - Lingering disinfectant in the water distribution system to kill any other bacteria that might enter the distribution system later.

Displacement Meters - These are used for measurement of low and intermediate flows, like domestic use applications. They are typicall available in sizes from 5/8" through 2".

Distribution System - A system of pipes, valves, and related components by which a water supply is distributed to consumers. The term applies particularly to the network or pipelines in the streets in a domestic water system.

Double Check Valve Assembly - A type of backflow prevention device. This device or assembly is composed of two tightly closing shut-off valves surrounding two independently acting check valves, with four test cocks, one upstream of the four valves, and one between each of the four check and shut-off valves.

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.

Draw Down - The difference between the static water level and the pumping level.

Drinking Water Primacy Agency - The agency that has primary enforcement responsibility for national drinking water regulations, namely those promulgated under the Safe Drinking Water Act as amended. Drinking water primacy for a particular State may reside in one of a variety of agencies such as the State Health Agency, the State Environmental Agency, or the USEPA regional office. In West Virginia, this is WVDHHR/BPH/OEHS.

Ejector - A device used to disperse a chemical solution into water being treated.

Elapsed Running Time Meter - A meter that records the total amount of time, usually in hours, that a device is operating.

Emergency Response Plan - A document that describes the actions that a drinking water utility would take in response to various emergencies, disasters, and other unexpected incidents.

Environmental Protection Agency (EPA) - The federal agency charged with protecting the quality of water and air in the United States.

Escherichia Coli (E. COLI) **-** Microorganisms commonly found in the lower intestine of warm-blooded animals. An ideal indicator organism to test environmental samples for fecal contamination from human and animal waste. Can cause gastrointestinal illness (e.g., diarrhea, vomiting, cramps).

Feed Rate - A feed rate that does not vary from hour to hour or day to day.

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 one-way valve placed at the entrance of a suction line which is opened by the flow of water. The purpose of the valve is to prevent reverse flow.

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.

Friction Losses - The head, pressure or energy (they are the same) lost by water flowing in a pipe of channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure or energy as a result of friction losses. Also see HEAD LOSS.

Frost Line - The lower depth of frost penetration.

Fuse Panel - An electrical panel that contains the fuses for the system.

Gate Valves - A valve in which the closing element consists of a disk which slides over the opening or cross-sectional area through which water passes, and fits tightly against it.

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.

Gravity Storage Tanks - Water storage tanks that provide system pressure by gravity.

Haloacetic Acids (Five) (HAA5) - A group of disinfection by-products. The sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid), rounded to two significant figures after addition.

Hand / off / automatic switch - A three position switch that allows the operator to select between hand operations, off, and automatic operations.

Hardness - A characteristic of water, caused primarily by calcium and magnesium ions. Harness causes deposits and scale to form on pipes and fixtures.

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.

Head Loss - The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result or turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls or restrictions caused by fittings. Water flowing in a pipe loses head, pressure or energy as a result of friction losses. Also see FRICTION LOSSES.

Health Advisory - An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water.

Hydropneumatic Pressure Tank - A small, usually less than 1000 gallon, tank used by a hydropneumatic system. The tank contains water and air, typically 1/3 air to 2/3 water.

Hypochlorination - The addition of hypochlorites, such as sodium hypochlorite (bleach) or calcium hypochlorite to water or wastewater to be treated. Hypochlorite is used where chlorine requirements are small or where chlorine gas may pose a hazard.

Hypochlorinators - Hypochlorinators are devices that are used to feed calcium, sodium, or lithium hypochlorite as the disinfecting agent.

Impeller - A rotating set of vanes in a pump designed to pump or lift water.

Influencing - Changing the quality of the water in the well.

Injection - The point at which chlorine is added to the system.

Intrusion - The flow of surface water into the well.

Inventory - The purchase and storage of spare parts.

Iron - This metal causes a rust stain and metallic taste when present in water in concentrations above 0.3 mg/L.

Iron or Sulfur Reducing Bacteria - Bacteria that use iron or sulfur as an energy source.

Jet Pumps - A pump utilizing the Venturi effect to move water.

Line-shaft Pumps - A type of vertical turbine. With this type of vertical turbine, the motor is mounted above the ground and the pump unit is mounted below the water surface. A column extends from the pump to a discharge head that is mounted above the ground just below the motor. A shaft extends on a straight line from the center of the motor to the pump. The pump may be mounted a few feet away from the motor or several hundred feet away.

Local Emergency Planning Committee (LEPC) - Established by the Emergency Planning and Community Right-to-Know Act, LEPCs have the job of increasing community hazardous materials safety through public education, emergency planning, responder training, conducting exercises, and reviewing actual responses to releases.

Low Water Demand - The days or hours with the lowest water use.

Low Voltage Pump Control Systems - A control system that uses low DC voltage, usually 24 volts DC.

Manganese - This metal causes black stains and objectionable taste when present in water in concentrations above 0.05 mg/L.

Master Metering - Large meter at a point of distribution to multiple uses or users that could be further sub metered.

Maximum Contaminant Level (MCL) - The largest allowable amount. The highest level of a contaminant that is allowed in drinking water.

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

Maximum-Day Demand - Total production for the water system on its highest day of production during a year.

Maximum Residence Time (MRT) – location where samples are collected for routine monitoring for TTHM and HAA5. The point of MRT for each plant is an active point (that is, the location is currently providing water to customers) in the distribution system where the water has been in the system the longest. This active point may not necessarily be the same as the most distant point from the treatment plant. Many factors can affect the location or locations determined to represent MRT, including the number of plants operating at the time of monitoring and seasonal variations in population.

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

Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. Maximum Residual Disinfectant Level Goals do not reflect the benefits of the use of disinfectants to control microbial contaminants.

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.

Mercury Type Switches - A float or pressure switch that uses mercury contained in a capsule along with two electrodes. When switch is rotated the mercury flow either onto the electrodes or away from the electrodes making or breaking contact.

Meter - An instrument for measuring and recording water volume.

Meter Maintenance Program - Scheduled program whereby meters are tested and repaired before there is a noticeable drop in consumption.

Microorganisms - Minute organisms, either plant or animal, invisible or barely visible to the naked eye.

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).

Monitoring - Testing that water systems must perform to detect and measure contaminants. A water system that does not follow EPA's monitoring methodology or schedule is in violation, and may be subject to legal action.

Monitoring Requirements - The type and frequency of sampling and testing the water quality.

National Pollutant Discharge Elimination System Permit - NPDES 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.

National Primary Drinking Water Regulations (NPDWR) - Legally enforceable standards that apply to public water systems. These standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and which are known or anticipated to occur in public water supplies. Also known as Primary Standards.

National Secondary Drinking Water Regulations (NSDWR) - Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water. Also known as Secondary Standards.

Non-Account Water - Metered source water less metered water sales.

Non-potable Water - Water that is not suitable for drinking.

O&M - Operation and Maintenance.

Occupational Safety and Health Administration (OSHA) - The federal agency responsible for the development and enforcement of employee safety and health regulations.

Office of Environmental Health Services (OEHS) – The agency with designated regulatory power under the Safe Drinking Water Act (SDWA).

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 **Outlet Fixture -** A device such as a faucet which controls the flow of water from a point of use.

Operation And Maintenance Costs - The ongoing, repetitive costs of operating a water system; for example, employee wages and costs for treatment chemicals and periodic equipment repairs.

Organic - Substances that come from animal or plant sources. Organic substances always contain carbon. (Inorganic materials are chemical of mineral origin.) Also see INORGANIC.

Organics - A term used to refer to chemical compounds made from carbon molecules. These compounds may be natural materials (such as animal and plant source) or man-made materials (such as synthetic organics). Also see ORGANIC.

Overload Relays with Reset Switches - A device designed for overload protection of electric motors. The device is heat sensitive and is placed in the power circuit with an electrical connection to the control circuit.

Oxygen Deficiency - An atmosphere containing oxygen at a concentration of less than 19.5 percent by volume.

Palatable - Water at a desirable temperature that is free form objectionable tastes, odors, colors, and turbidity. Pleasing to the senses **Particulate -** Small solids.

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.

Per-Capita Use - Total use divided by the total population served.

Pedestal - A concrete structure holding the well casing and supporting the discharge head and pump motor.

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.

Personal Protective Equipment (PPE) - Equipment and supplies designed to protect employees from serious injuries or illnesses resulting from contact with chemical, radiological, biological, or other hazards. PPE includes face shields, safety glasses, goggles, laboratory coats, gloves, and respirators.

pH - An expression of the intensity of the basic or acidic strength of a water.

Pitot Gauge - Measures pressure of flowing water

Point of Entry (POE) - The point at which water enters the distribution system.

Pollutants - Organic or inorganic material that deteriorates the quality of the water.

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.

Potable Water - Water satisfactory for drinking purposes from the standpoint of its chemical, physical, and biological characteristics and in compliance with the Safe Drinking Water Act.

Power Surge - Typically a sudden drop or rise in voltage.

Precision - The ability of an instrument to measure a process variable and to repeatedly obtain the same result. The ability of an instrument to reproduce the same results.

Preserve - A process of protecting a sample from deterioration by cooling or the addition of chemicals.

Pressure Control - A switch which operates on changes in pressure. Usually this is a diaphragm pressing against a spring. When the force on the diaphragm overcomes the spring pressure, the switch is actuated (activated).

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.

Pressure Gauges - A mechanical device used to register system pressure.

Pressure Regulator - A post-meter device used to limit water pressure.

Pressure Relief Valve - A valve that opens automatically to ample area when the pressure reaches an assigned limit, to relieve the stress on a pipeline.

Preventive Maintenance - The process of preventing or reducing failure of equipment by performing routine and non-routine scheduled maintenance.

Preventive Maintenance Program - The process identifying, scheduling, and performing predictable operations and maintenance tasks.

Primacy - Primary enforcement authority for the drinking water program. Under the Safe Drinking Water Act, states, U.S. territories, and Indian tribes that meet certain requirements, including setting regulations that are at least as stringent as EPA's, may apply for, and receive, primary enforcement authority, or primacy.

Primacy Agency – The state agency that has been granted primary enforcement responsibility for administration and enforcement of primary drinking water regulations and related requirements applicable to public water systems within a state (40 CFR 142.2)

Prime - The process of maintaining water in the volute case of a pump.

Prime Pump - The process of causing the pump to pump fluid.

Production Meter - Meters on wells for water leaving the plant or pumping station.

Psi - Pounds per square inch.

Public Notification - An advisory EPA or the state requires a water system to distribute to affected consumers when the system has violated Maximum Contaminant Levels or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.

Public Water Systems - A system for the provision to the public of piped water for human consumption, If such system has at least fifteen service connections or regularly least 60 days out of the year. Such term includes: 1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and 2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a “community water system” or a “non-community water system.”

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.

Quality Assurance - An integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement, to ensure that a process, item, or service is of the type and quality needed and expected by the client.

Quality Control - The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the client; operational techniques and activities that are used to fulfill requirements for quality.

Rate - Monies collected for water provided. Every water utility must receive sufficient total revenue to ensure proper operations and maintenance, development and perpetuation of the system, and the preservation of the utility’s financial integrity.

Rater Structure - Means of establishing charges for water usage.

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.

Recharging - The process of introducing air into a hydropneumatic tank.

Reduced Pressure Zone Assembly (RPZ) - A device composed of two tightly closing shut-off valves surrounding two independently acting pressure reducing check valves that, in turn, surround an automatic pressure differential relief valve, and four test cocks, one upstream of the five valves and one between each of the four check and shut-off valves. The check valves effectively divide the structure into three chambers; pressure is reduced in each downstream chamber allowing the pressure differential relief valve to vent the center chamber to atmosphere should either or both check valves malfunction.

Representative Sample - A sample portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of material or water being sampled.

Residual Chlorine - The amount of free and/or available chlorine remaining after a given contact time under specified conditions.

Retail Water Meter - Meters to monitor large customer water usage.

Revenue-Producing Water - Water metered and sold.

Revised Total Coliform Rule (RTCR) - A rule of SDWA requiring water systems to monitor for coliform bacteria on a monthly basis.

Rotameter - A device used to measure the flow rate of gases and liquids. The gas or liquid being measured flows vertically up a tapered, calibrated tube. Inside the tube is a small ball or bullet-shaped float (it may rotate) that rises or falls depending on the flow rate. The flow rate may be read on a scale behind or on the tube by looking at the middle of the ball or at the widest part or top of the float.

Safe Drinking Water Act (SDWA) - The federal law that authorizes and requires EPA and state health agencies to monitor drinking water quality.

Safety Data Sheet (SDS) - 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.

Sample - The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers.

Sample Taps - A point in the discharge piping used to obtain water quality samples.

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.

Secondary Maximum Contaminant Level (SMCL) - exceedances, availability of unregulated contaminant monitoring data, and operation under a variance or exemption), you must provide a clear and easy-to-understand explanation of the following:

Sediments - The mineral or organic matter that settles to the bottom of a liquid.

Service lines - The smaller diameter piping which delivers water to the individual hook-ups.

Shoring Equipment - Equipment installed in trenches to prevent the collapse of the trench.

Short-Circuiting - A condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction, or settling times in comparison with the theoretical (calculated) or presumed detention times.

Sight glass - A glass tube which connects the top half of a container to the lower half and serves to show the level of liquid in the container.

Single or Three Phase Power Single phase - Two sources of power 120° out of phase with each other. Three phase - Three sources of power that are 120° out of phase with each other.

Siphoning - The transferring of a liquid from an upper level to a lower level by means of suction created by the weight of the liquid as it flows from to the lower level.

Specifications - The detail description of materials, and/or practices and procedures to be used in constructing a water system project.

Spontaneous combustion – Hypochlorite solution can ignite or become flammable in the presence of petroleum based products (e.g. gasoline or motor oil).

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.

State Revolving Fund (SRF) - State loan funds for water utilities established under the Safe Drinking Water Act.

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 Pressure - 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 level of water in the well when the well pump is not pumping, i.e. the level of ground water when no water is being removed.

Stored Water - The volume of water stored in the distribution system.

Stroke - the amount of vertical movement of the pump diaphragm.

Suction Lift - A pumping condition where the eye of the impeller of the pump is above the surface of the water that the pump is pumping from.

Suction Side - The water inlet side of a centrifugal pump.

System Failures - The inability of the system to operate.

Telemetry - The electrical link between the transmitter and the receiver. Telephone lines are commonly used to serve as the electrical line.

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.

Timer (Cycle Counter) - An electrical device that records the number of times a pump operates, i.e.: comes on and shuts off.

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 though the filter is evaporated and the residue represents the dissolved solids. Also see SPECIFIC CONDUCTANCE.

Total Dynamic Head (TDH) - The sum of all the energy needed to move water from one elevation to another. Includes static head, velocity head, and headless due to friction.

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.

Transmission Facilities - Pipes used to transport raw or treated water to distribution facilities.

Trihalomethanes (THM) - A byproduct of drinking water disinfection. Can cause liver, kidney, or central nervous system problems, as well as increase the risk of cancer.

Troubleshooting - A systematic process of assessing the problem and determining the most probable cause of the problem.

Tuberculation - Development or formation of small mounds of corrosion products on the inside of iron pipe. These tubercules roughen the inside of the pipe, increasing its resistance to water flow.

Tubercule - A protective crust of corrosion products (rust) which builds up over a pit caused by the loss of metal due to corrosion.

Unaccounted-For Water - The amount of non-account water less known or estimated losses and leaks.

Turbid - Unclear or murky because of stirred-up sediments.

Turbidity - A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.

Un-Metered Water - Water delivered but not measured for accounting and billing purposes.

Usage - The amount used, e.g. the number of gallon of water used per hook up.

Valves - Any device for controlling the flow of a liquid.

Variance - State or EPA permission not to meet a certain drinking water standard. The water system must prove that: (1) it cannot meet a Maximum Contaminant Level, even while using the best available treatment method, because of the characteristics of the raw water, and (2) the variance will not create an unreasonable risk to public health. The state or EPA must review, and allow public comment on, a variance every three years. States can also grant variances to water systems that serve small populations and which prove that they are unable to afford the required treatment, an alternative water source, or otherwise comply with the standard.

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.
Vertical - Perpendicular or upright, the opposite of horizontal.

Vinegar - A mild acid which can be used to clean chemical feed lines and valves.

Violation - A failure to meet any state or federal drinking water regulation.

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.)

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.

Waterborne Disease Outbreak - The significant occurrence of acute infectious illness, epidemiologically associated with the ingestion of water from a public water system that is deficient in treatment, as determined by the appropriate local or state agency.

Water Hammer - A sudden increase in water pressure caused by a quick reduction or stopping of flow.

Water Main Lines - The piping from the water source, e.g. well, to the point of disinfection and storage.

Water Meters - Devices used to measure the volume of water in gallons or cubic feet.

Water Table - The upper surface of the zone of saturation of groundwater in an unconfined aquifer. All water beneath is considered groundwater.

Wholesale Water - Water purchased or sold for resale purposes.

Wholesale System - A public water system that treats source water as necessary and then delivers finished water to another public water system. Delivery may be through a direct connection or through the distribution system of another consecutive system.

LIST OF ACRONYMS

ART	Average residence time
ASTM	American Society for Testing and Materials
ANSI	American National Standards Institute
AVB	Atmospheric Vacuum Breaker
AWWA	American Water Works Association
BAT	Best Available Technology
BMP	Best Management Practice
BPH	Bureau for Public Health of WVDHHR
C&E	Compliance & Enforcement Section of OEHS
C&T	Certification & Training Section of OEHS
CCR	Consumer Confidence Report
CDC	Center for Disease Control
CDS	Combined Distribution System
CEH	Continuing Education Hour
CEU	Continuing Education Unit
CFR	Code of Federal Regulations
COC	Chain of Custody
CWS	Community Water System
DCVA	Double Check Valve Assembly
D/DBP	Disinfectants/Disinfection Byproducts
DBP	Disinfection Byproduct
DBPFP	Disinfection Byproduct Formation Potential
DBPR	Disinfection Byproduct Rule
DPD	*N*,*N*-diethyl-*p*-phenylenediamine
DWSRF	Drinking Water State Revolving Fund
EED	Environmental Engineering Division of OEHS
EPA	Environmental Protection Agency
ERL	Emergency Response Lead
ERP	Emergency Response Plan
FOIA	Freedom of Information Act
GIS	Geographic Information System
GCPD	Gallons Per Capita Per Day
HAA5	Haloacetic Acids, group of 5: mono-, di-, and trichloroacetic acids; and mono- and dibromoacetic acids
HAAFP	Haloacetic Acid Formation Potential
HDPE	High Density Polyethylene
HTH	High Test Hypochlorite
I&CD	Infrastructure & Capacity Development Section of OEHS
IDHL	Immediately Dangerous to Health or Life
LEL	Lower Explosive Limit
LEPC	Local Emergency Planning Committee
LOTO	Lock Out/Tag Out
LRAA	Locational Running Annual Average
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
M-DBP	Microbial-Disinfectants/Disinfection Byproducts

MRDL	Maximum Residual Disinfection Level
MRDLG	Maximum Residual Disinfectant Level Goal
MOR	Monthly Operational Reports
MRDL	Maximum Residual Disinfectant Level
MRDLG	Maximum Residual Disinfectant Level Goal
MRT	Maximum Residence Time
NFPA	National Fire Protection Association
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety & Health
NPDWR	National Primary Drinking Water Regulation
NPSH	Net Positive Suction Head
NSDWR	National Secondary Drinking Water Regulation
NSF	National Sanitation Foundation
NTNCWS	Non-transient, Non-community Water System
O&M	Operation and Maintenance
OEHS	Office of Environmental Health Services
OIT	Operators-in-Training
OSHA	Occupational Safety & Health Association
PC	Personal Computer
PDF	Portable Document Format
PE	Performance Evaluation
PLC	Programmable Logic Controller
PN	Public Notification
PPE	Personal Protective Equipment
PR	Public Relations
PSC	West Virginia Public Service Commission
PVB	Pressure Vacuum Breaker
PVC	Polyvinyl Chloride
PWS	Public Water System
PWSID	Public Water System Identification
RAA	Running Annual Average
RPZ	Reduced Pressure Zone Assembly
RTCR	Revised Total Coliform Rule
RTU	Remote Terminal Units
SCBA	Self-Contained Breathing Apparatus
SCADA	Supervisory Control and Data Acquisition
SDS	Safety Data Sheets
SDS	Simulated Distribution System
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SMCL	Secondary Maximum Contaminant Level
SPADNS	Sodium 2-(parasulfophenylazo)-1,8-dihydroxhy-3,6-napthalene disulfonate
TDT	Theoretical Detention Time
THM	Trihalomethane
TTHFP	Total Trihalomethane Formation Potential
TNCWS	Transient Non-community Water System
TOC	Total Organic Carbon
TT	Treatment Techniques

TTHM	Total Trihalomethanes
UEL	Upper Explosive Limit
USB	Universal Serial Bus
USGS	United States Geological Survey
WD	Water Distribution
WVDEP	West Virginia Department of Environmental Protection
WVDHHR	West Virginia Division of Health and Human Resources
WVDHHR	West Virginia Division of Health and Human Resources

CONTACTS

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Charleston, West Virginia 25301-3713
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Fairmont District Office	Phone: 304-368-2530	Fax: 304-367-2755
St. Albans District Office	Phone: 304-722-0611	Fax: 304-722-0615
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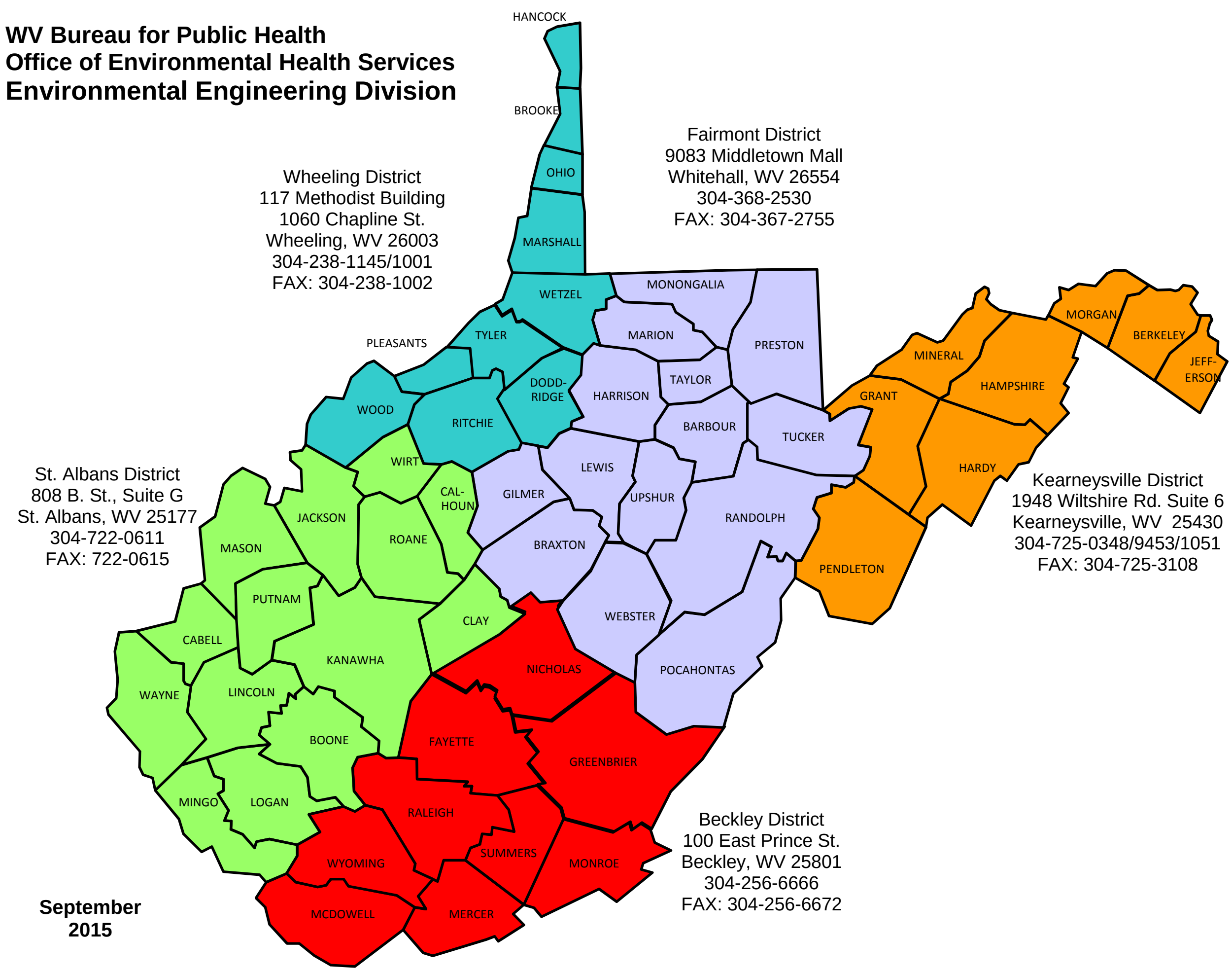
South Charleston, WV 25303
http://www.wvdhhr.org/labservices/index.cfm

Office of Environmental Health Services

District Offices/Counties Served



DDITIONAL CONTACTS

OFFICE OF LABORATORY SERVICES

167 Eleventh Avenue
South Charleston, West Virginia 25303
(304) 558-3530
www.wvdhhr.org/labservices

OLS is part of the West Virginia Department of Health and Human Resources Bureau for Public Health. OLS is dedicated to the promotion and protection of West Virginia's public health by supporting state and local infectious disease control efforts through diagnostic testing, preventing metabolic disorders detectable at birth, and assuring the quality of testing in clinical and environmental laboratories. OLS's duties include water quality laboratory certification.

WEST VIRGINIA DEPARTMENT OF ENVIRONMENTAL PROTECTION

601 57th Street, S.E.
Charleston, West Virginia 25304
(304) 926-0441
www.dep.wv.gov

DEP's Division of Water and Waste Management's mission is to preserve and enhance West Virginia's watersheds for the benefit and safety of all. The Division of Water and Waste Management strives to meet its mission through implementation of programs controlling surface and groundwater pollution caused by industrial and municipal discharges as well as oversight of construction, operation and closure of hazardous and solid waste and underground storage tank sites. In addition, the Division works to protect, restore, and enhance West Virginia's watersheds through comprehensive watershed assessments, groundwater monitoring, wetlands preservation, inspection and enforcement of hazardous and solid waste disposal and proper operation of underground storage tanks. Very generally speaking, PWS chief operators may be involved with them for any system discharges to streams or waste management issues, among other things.

WEST VIRGINIA DEPARTMENT OF TRANSPORTATION

Division of Highways
Building 5, Room A-110
1900 Kanawha Boulevard, East
Charleston, West Virginia 25305-0430
(304) 558-3505
www.wvdot.com

DOT's Division of Highways is responsible for planning, engineering, right-of-ways acquisition, construction, reconstruction, traffic regulation and maintenance of more than 34,000 miles of state roads. Contact information was included because very generally speaking, PWS chief operators must coordinate with them during any activity (ie. repairs or main line extensions) on right-a-ways.

WEST VIRGINIA ENVIRONMENTAL TRAINING CENTER
HC 88, Box 21
Ripley, West Virginia 25271
(304) 372-7878
www.wvetc.org

WVETC was established in 1983 under the administration of the West Virginia Department of Education. Federal grant funds were obtained from the USEPA to construct and equip the facility for the purpose of providing training to wastewater and water plant operators. Continued operation is overseen by the Department of Education through Regional Education Service Agency (RESA) V.

WEST VIRGINIA PUBLIC SERVICE COMMISSION
201 Brooks Street
P.O. Box 812
Charleston, West Virginia 25323
(304) 340-0300
www.psc.state.wv.us

PSC contact information was included because very generally speaking, PWS chief operators may be involved with them for line extensions, rate changes, and construction, among other things.

The Water and Wastewater Division, formerly the Public Service District Division, was renamed on September 6, 1996, by Commission General Order No. 195.30. The Division was renamed to meet the directives of Senate Bill 568, enacted during the 1996 regular legislative session, which required the Commission to provide advice and assistance to Class III cities and Class IV towns or villages upon their request. By General Order No. 195.30, the Commission also delegated the Public Service District Division the responsibility for processing cases for municipalities and homeowner associations. The Public Service District Division, in the same General Order, was renamed the Water and Wastewater Division. On December 1, 2005, the Commission issued General Order 195.53, which placed the financial regulatory responsibility for all water and wastewater utilities in the Division. Employees include a director, two managers, two supervisors, two secretaries, and nineteen staff members with various technical and educational backgrounds. These employees are assigned to two operating sections: Case Control and Assistance. A delineation of the Water and Wastewater Division's current responsibilities for all water and sewer utilities include:

- Investigating formal cases and making recommendations to the Commission;
- Performing detailed management and operation audits known as Focused Management Audits;
- Participating in hearings before the Commission and offering evidence and testimony regarding revenue requirements, operating performance, quality of service, and construction activities;
- Investigating informal complaints and responding to customer requests for information; and,
- Responding to water and wastewater utility inquiries for technical, operational, financial, and regulatory assistance.

WEST VIRGINIA RURAL WATER ASSOCIATION
100 Young Street
Scott Depot, West Virginia 25560
(304) 201-1689
1 (800) 339-4513
www.wvrwa.org

Created in 1985, WVRWA's mission is to provide West Virginia public water and wastewater systems with responsive, comprehensive and high quality leadership and support services. WVRWA offers free training and technical assistance to all public utilities in the State of WV and has an extensive library of technical materials that utilities can take advantage of. There are six circuit riders who travel the state visiting utilities and offering their expertise in water and wastewater needs. In addition, WVRWA conducts over eighty training sessions each year in an effort to keep utility system employees informed in all matters concerning water and wastewater. WVRWA works in conjunction with the WV Bureau for Public Health and the Rural Utilities Services in providing the needed expertise for all utility systems and their employees. WVRWA is committed to providing the training and technical assistance wherever it is needed.

MISS UTILITY OF WEST VIRGINIA
5608 MacCorkle Ave. S.W.
South Charleston, West Virginia 25309
1 (800) 245-4848
www.muwv.org

Effective July 15, 1996 (and modified June 10, 2006), West Virginia Chapter 24-C, Underground Facility Damage Prevention act became law. The state law provides for the certification and operation of a statewide one call system. Miss Utility of West Virginia, Inc. (MUWV), a not-for-profit, private corporation and in operation since 1981, meets all requirements to function in this capacity. Its purpose is to receive notification of proposed excavation, demolition or other earth disturbing activities from persons planning to do such work. MUWV will relay this information to member owners/operators of underground facilities in order for them to determine the location of and mark their facilities. Damage to underground facilities is prevented, the general safety of the public is maintained and unnecessary lost time is avoided by the excavator. MUWV can be contacted twenty-four (24) hours a day, seven (7) days a week by calling toll free 1-800-245-4848. Whenever possible, it is best to call between 7AM and 5PM, Monday through Friday. Routine 48 hour notifications can be made via Fax, Email or MUWV provided software.

The statute is an effort to provide for public and worker safety in West Virginia by providing certain requirements before excavation and/or demolition work can take place near underground facilities. The law makes it a requirement to notify the state one call system before any excavation or demolition activities are done and now provides for monetary penalties (up to $5,000) for non-compliance.

TROUBLESHOOTING GUIDES

1. Storage Facilities
2. Hypochlorination Problems
3. Distribution Systems
4. Cross-connections
5. Sampling and Monitoring

Troubleshooting guide for storage facilities		
Problem	**Possible cause**	**Possible solution**
Loss of disinfectant residual.	Long detention time. Increase in temperature. Depletion of disinfectant from exposure to sunlight. Entry of chlorine demanding contaminants.	Cover reservoir. Reduce detention time with baffles, recirculation, inlet diffuser, mechanical mixer, pumps. Relocate inlet/outlet in tank. Size facility for more frequent turnover. Check screens on vents. Install bird wires and fences if necessary. Clean and disinfect storage facility.
Increase in heterotrophic plate count.	Loss of chlorine residual or contaminant entry.	Prevent loss of chlorine residual (see above) and rechlorinate storage tank. Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Clean and disinfect storage facility.
Coliform bacteria occurrence.	Loss of chlorine residual. Contaminant entry. Sediment or biofilm build-up.	Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Clean and disinfect storage facility.
Disinfection byproducts formation.	Long detention time. Increase in pH or chlorine residual. Boosting chlorine. Organic matter contamination or algae growth.	Reduce detention time with baffles, recirculation, inlet diffuser, mechanical mixer, pumps. Relocate inlet/outlet in tank. Size facility for more frequent turnover. Look at alternative disinfectants.
Nitrification	Long detention time.	Reduce detention time with baffles, recirculation, inlet diffuser, mechanical mixer, pumps. Relocate inlet/outlet in tank. Increase turnover rate or size facility for more frequent turnover.
Sediment build-up	Excess suspended materials, lime, iron or manganese in source water. Minimal velocities allowing depositions. Contaminant entry.	Improve influent water quality. Reduce detention time with baffles, recirculation, inlet diffuser, mechanical mixer, pumps. Avoid scouring. Inspect and clean tank more frequently.
Floating material or surface film.	Build-up of iron or manganese sediments. Growth of iron or manganese forming bacteria.	Improve influent water quality. Avoid scouring. Inspect and clean tank more frequently.
Taste and odor complaints.	Long detention time. Growth of algae or other organisms. Contaminant entry. Leaching from internal coatings or new concrete tank. Source water potential for taste and odor such as high levels of hydrogen sulfides.	Cover open reservoirs. Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Improve influent water quality. Chlorinate. Flush distribution system. Clean and disinfect storage tank.

Troubleshooting guide for storage facilities (Cont.)		
Problem	**Possible cause**	**Possible solution**
Growth of algae or other biological organisms.	Exposure to sunlight. Loss of chlorine residual. Long detention time. Sediment or biofilm build-up.	Cover open reservoirs. Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Improve influent water quality. Flush distribution system. Clean and disinfect storage tank.
Contaminant entry.	Uncovered reservoirs or improper design of floating cover. Damaged or missing screens on vents and entry of bats, birds, rodents, or insects. Cross connection at drain or overflow.	Cover open reservoirs. Check seals on hatches and screens on vents. Install bird wires and fences if necessary. Flush distribution system. Clean and disinfect storage tank.
Increase in pH.	Long detention time in concrete storage.	Provide coating on concrete walls. Increase turnover rate. Fluctuate water levels more frequently.
Biodegradation of internal coatings.	Loss of chlorine residual allowing biological growth. Selection of wrong internal coating.	Prevent loss of chlorine residual. Chlorinate. Clean and disinfect storage tank.
Biofilm growth.	Loss of chlorine residual. Nutrients from coatings or contaminants. Corrosion of surface promoting biological and algae growth. Bacterial seeding.	Prevent loss of chlorine residual. Chlorinate. Clean and disinfect storage tank. Flush distribution system.
Color.	Decaying vegetative material. Algae growth in uncovered reservoirs. Sediment scouring. Iron or manganese.	Improve source water quality. Install treatment for iron and manganese. Increase cleaning frequency.
Red water.	Metals uptake from metal surfaces from lack of or improper cathodic protection. Iron or manganese.	Provide proper corrosion treatment. Install or calibrate cathodic protection. Use sequestering agent. Apply coatings properly.
Build-up of iron and manganese.	Iron and manganese in source water and long detention times. Oxidation and settling of iron or manganese. Improper sequestering agent dose.	Improve source water quality. Install or optimize sequestering system. Increase cleaning frequency.

Troubleshooting guide for hypochlorination problems		
Problem	**Possible cause**	**Possible solution**
Chemical feed pump won't run.	No power.	Check to see if plug is securely in place. Ensure that there is power to the outlet and control systems.
	Electrical problem with signal from well pump or flow sensor.	Check pump motor starter. Bypass flow sensor to determine if pump will operate manually. If you have a liquid level control, check the low-level cut-off switch. Repair or replace if necessary.
	Motor failure.	If the motor is cool and the power is on, the motor may have to be repaired or replaced. Check manufacturer's information.
	Motor overheating.	The motor is over-heated. The overload protection in the motor has opened. The motor will start again when it cools. Make sure that you have a proper voltage supply. Try to turn the motor shaft. If it does not turn, check for a binding pump mechanism.
Motor runs but diaphragm doesn't move.	The stroke adjustment may be set at zero.	Reset stroke adjustment control knob.
	The gear train may be stripped.	Replace any defective parts.
Motor runs, diaphragm moves but no solution is pumped.	Solution tank may be empty.	Check the solution level in the tank. If it is too low refill the tank.
	The pump may not be primed.	If not, prime it.
	Suction line may have an air lock.	Check the suction line for air locks. If there is an air lock, remove the anti-siphon spring from the discharge valve until the air lock is removed.
	The fittings may be loose.	Remove the fittings, clean off the old tape, put on new teflon tape, and replace FINGER tight.
	Leaks from the pump housing.	If there is solution dripping from the pump housing just behind the pump head, replace the diaphragm.

Troubleshooting guide for hypochlorination problems (Cont.)		
Problem	**Possible cause**	**Possible solution**
Motor runs, diaphragm moves but no solution is pumped.	Valves and O-rings may be dirty.	Check the valves. Clean them if they are dirty. Replace the O-rings if they are damaged. Make sure they are well- seated.
	Discharge line is blocked.	Check the discharge line for kinks or blockages.
Abnormal noise.	The chlorinator is probably mechanically damaged.	Check with your service representative. Switch operation to back up chlorinator.
Motor starts and stops.	The motor may be overheating.	If it is, a thermal protection switch may be causing the start- stop action. Check with the service representative.
Low chlorine residual at point of entry.	Improper procedure for running chlorine residual test or expired chemical reagents.	Check expiration date on chemical reagents. Check test procedure as described in test kit manual. Speed or stroke setting too low.
	Pump not feeding an adequate	Damaged diaphragm or suction leak.
	Change in raw water quality.	Test raw water for constituents that may cause increased chlorine demand, such as iron and manganese.
	Pump air bound.	Check foot valve.
	Chlorine supply tank empty.	Fill supply tank.
	Reduced effectiveness of chlorine solution.	Check date that chlorine was received. Sodium hypochlorite solution may lose effectiveness after 30 days. If that is the case, the feed rate must be increased to obtain the desired residual.
	Damaged suction or discharge lines (cracks or crimps).	Clean or repair lines with problems.
	Connection at point of injection clogged or leaking.	Flush line and connection with mild acid such as acetic or muriatic. Replace any damaged parts that may be leaking.
Discharge line is blocked.	Speed and stroke setting inadequate.	Check manufacturer's recommendations for proper settings to prime pump.
	Suction lift too high due to feed pump relocation.	Check maximum suction lift for pump and relocate as necessary.

Troubleshooting guide for hypochlorination problems (Cont.)		
Problem	**Possible cause**	**Possible solution**
Discharge line is blocked.	Discharge pressure too high.	Check well pump discharge pressure. Check pressure rating on chemical feed pump.
	Suction fitting clogged.	Clean or replace screen.
	Trapped air in suction line.	Ensure all fittings are tight.
	Suction line not submerged in solution.	Add chlorine solution to supply tank.
Loss of prime.	Solution tank empty.	Fill tank.
	Air leaks in suction fittings.	Check for cracked fittings.
	Foot valve not in vertical position.	Adjust foot valve to proper position.
	Air trapped in suction tubing.	Check connections and fittings.
Excessive chlorine residual at point of entry (POE).	Pump speed or stroke setting too high.	Verify dose rate and calibrate pump to get desired dose.
	Siphoning from solution tank.	Ensure the 4-in-1 anti-siphon valve on chemical feed pump is operating properly.
	Low well pump discharge pressure.	Ensure well pump discharge pressure is at least 25 psi.
Failure to pump against pressure.	Worn seal rings.	Worn seal rings and cartridge valves may need to be replaced. Use spare parts kit.
	Pumps maximum pressure rating to pump against may be exceeded by injection pressure.	Injection pressure cannot exceed the pump's maximum pressure. See information plate on pump.
	Ruptured diaphragm.	Replace pump diaphragm.
	Incorrect stroke length setting.	Check zero on pump and re-zero pump. See manufacturer's instructions.
	Tubing run on discharge is too long.	Longer tubing runs may create friction loss sufficient to reduce the pump's pressure rating. Consult manufacturer for more information.
	Clogged foot valve strainer.	Remove foot valve strainer when pumping slurries or when solution particles cause the strainer to clog.

Troubleshooting guide for distribution systems		
Problem	**Possible cause**	**Possible solution**
Dirty water complaints.	Localized accumulations of debris, solids/particulates in distribution mains.	Collect and preserve samples for analysis if needed. Isolate affected part of main and flush.
Red water complaints.	Cross connection between water system and another system carrying non-potable water.	Collect and preserve samples for analysis if needed. Conduct survey of system for cross connections. Contact our regional office.
	Iron content of water from source is high. Iron precipitates in mains and accumulates.	Collect and test water samples from water source and location of complaints for iron. If high at both sites, contact our regional office, your technical assistance provider, consulting engineer or water conditioning company for help with iron removal treatment.
	Cast iron, ductile iron, or steel mains are corroding causing rust in the water.	Collect and analyze samples for iron and corrosion parameters. Contact our regional office, your technical assistance provider, consulting engineer or water conditioning company for help with corrosion control treatment.
No or low water pressure.	Source of supply, storage or pumping station interrupted.	Check source, storage and pumping stations. Correct or repair as needed.
	System cannot supply demands.	Check to see if demands are unusually high. If so, try to reduce demand. Contact our regional office, your technical assistance provider or consulting engineer.
	Service line, meter or connections shutoff or clogged with debris.	Investigate and open or unclog service.
	Broken or leaking distribution pipes.	Locate and repair break or leak.
	Valve in system closed or broken.	Check and open closed isolation and pressure-reducing valves. Repair or contact contractor if valves are broken.

Troubleshooting guide for distribution systems (Cont.)		
Problem	**Possible cause**	**Possible solution**
Excessive water usage.	More connections have been added to the system.	Compare increase in usage over time with new connections added over same period. If correlation evident, take action to curtail demand or increase capacity if needed. Contact our regional office, your, technical assistance provider or consulting engineer.
	Excessive leakage (>15% of production) is occurring, meters are not installed or not registering properly.	Conduct a water audit to determine the cause. If leakage is the cause, contact our regional office, your consulting engineer or leak detection contractor.
	Illegal connections have been made.	Conduct survey to identify connections.

Troubleshooting guide for cross connections		
Problem	**Possible cause**	**Possible solution**
Sudsy or soapy water.	Hose connected to an unprotected hose bib with the other end in a bucket or sink of soapy water.	Equip all hose bibs with an Atmospheric Vacuum Breaker.
Positive coliform.	Hose connected to an unprotected hose bib with the other end lying on the floor of the pump house, on the ground in the car wash area, in the wading or swimming pool or other nonpotable liquid.	Equip all hose bibs with an Atmospheric Vacuum Breaker.
	Unprotected potable water line feeding a lawn irrigation system.	Install a backflow preventer on the potable water line feeding the irrigation system.
	Submerged inlet, e.g. faucet submerged.	Relocate faucet above flood level.
Color in the water (unusual colors such as bright blue).	Backflow from toilet.	Get help. Bring in someone who understands cross-connections to evaluate your system.
Organic odors.	Handheld pesticide/herbicide applicator attached to unprotected hose.	Don’t use these devices.

Troubleshooting guide for sampling and monitoring		
Problem	**Possible cause**	**Possible solution**
Positive total coliform.	Improper sampling technique.	Check distribution system for low-pressure conditions, possibly due to line breaks or excessive flows that may result in a backflow problem.
	Contamination entering distribution system.	Ensure all staff are properly trained in sampling and transport procedures as described by lab procedures.
	Inadequate chlorine residual at the sampling site.	Check the operation of the chlorination system. Refer to issues described in the chapter on pumps and hypochlorination systems. Ensure that residual test is performed properly.
	Growth of biofilm in the distribution system.	Thoroughly flush affected areas of the distribution system. Superchlorination may be necessary in severe cases.
Chlorine taste and odor.	High total chlorine residual and low free chlorine residual.	The free chlorine residual should be at least 85% of the total chlorine residual. Increase the chlorine dose rate to get past the breakpoint to destroy some of the combined residual that causes taste and odor problems. Additional system flushing may also be required.
Inability to maintain adequate free chlorine residual at the furthest points of the distribution system or at dead end lines.	Inadequate chlorine dose at treatment plant.	Increase chlorine feed rate at point of application.
	Problems with chlorine feed equipment.	Check operation of chlorination equipment.
	Ineffective distribution system flushing program.	Review distribution system flushing program and implement improvements to address areas of inadequate free chlorine residual.
	Growth of biofilm in the distribution system.	Increase flushing in area of biofilm problem.