Operator's Guide

For Small Treated and Untreated Public Water Systems in Alaska

Alaska Department of Environmental Conservation
Division of Water
Operator Training & Certification Program

January 2024

This page left blank.

Table of Contents

Acknowledgments

This manual when originally created in 2002 was researched and written by the Alaska Training/Technical Assistance Center (ATTAC) staff.

Editors:
John W. Carnegie, Ph.D. – ATTAC/University of Alaska Southeast Sitka
Nicole A. Duclos – ATTAC/University of Alaska Southeast Sitka
Paula C. Jackson – ATTAC/University of Alaska Southeast Sitka
Kerry L. Lindley – Alaska Department of Environmental Conservation Division of Facility Construction & Operation
Peter T. Nathanson – ATTAC/University of Alaska Southeast Sitka

Thank you to the following for their contributions to the outline and review of the manual:

Tim Chittenden – US Forest Service
Pat DeSmet – Lake & Peninsula Borough Schools
Dave Ferree – Fairbanks North Star Borough School District
Dennis Kogl – National Park Service
Adam Owen – Alyeska Pipeline
Jim Ridgway – Anchorage Well & Pump
Joe Sanks – Denali Resorts
Ken Smith – Alaska Department of Environmental Conservation

In 2022, Yukon University, under contract, combined the *Well Owner's Guide for Small Untreated Public Water Systems in Alaska* and the *Operator's Guide for Small Treated Public Water Systems in Alaska* into this current manual.

Editors:
Alison Anderson, Instructor/Coordinator, Water and Wastewater Operator Program, Yukon University

Further review was provided by:
Martin Suzuki – Alaska Department of Environmental Conservation
Dan DeSloover – Alaska Department of Environmental Conservation
Brian Berube – Alaska Native Tribal Health Consortium

Introduction

The federal Safe Drinking Water Act (SDWA) Amendments of 1996 requires the State of Alaska to implement a plan in which all small water systems must be operated by a "certified individual." In response to this federal requirement, the State adopted revised operator certification regulations on January 18, 2001, that require all Community Water Systems (CWS), all Non-Transient Non-Community (NTNC) water systems, and Transient Non-Community (TNC) water systems using surface water or Groundwater Under the Direct Influence of Surface Water (GWUDISW) be operated by a certified operator.

Operator certification requirements for those small water systems serving less than 500 persons and having less than 100 service connections are dependent on the classification of the water system. Small groundwater systems that provide no chemical treatment are classified as Small Untreated water systems. Small water systems that add a single chemical are classified as Small Treated water systems.

Small water systems that add more than one chemical for water treatment or employ more complex treatment processes, e.g., chemically-aided filtration or membrane technologies, are classified according to the point rating system used by the State to classify larger systems. Depending on the complexity of the water treatment and processes employed, even small water systems may need an operator certified at a higher level.

It should be noted that Small Treated water systems, as well as Small Untreated water systems, might employ a variety of "passive" treatment technologies. Passive treatments may include cartridge filters, ion exchange softening or ion exchange iron removal devices, ultraviolet (UV) disinfection not used to meet a surface water treatment inactivation requirement, or sand filtration with no chemical addition. Passive treatment devices, although essential to the treatment goals of a particular water system, generally require minimal routine operator attention. If you are unsure about the classification of your water system, you should contact the Operator Certification Program at the Alaska Department of Environmental Conservation (ADEC).

Water system owners who wish to employ the services of a contract operator can apply for approval by completing a form provided by the Operator Certification Program.

All operator certificates have a 3-year active period. Once certified, operators of Small Treated water systems must earn 1.0 drinking water core Continuing Education Unit (CEU) during that 3-year active period to renew their certificates and operators of Small Untreated water systems must earn 0.5 drinking water core Continuing Education Unit (CEU) during that 3-year active period to renew their certificates.

This manual will provide general information necessary for operators of Small Untreated and Small Treated water systems to prepare for certification examinations. The manual will also be used as the basis for certification training courses. Not all topics are covered in detail. For more information on specific topics, contact your local ADEC office.

Please understand that not all items discussed in this manual apply to all Small Untreated and Small Treated water systems in Alaska. However, competent operation of Small Untreated and Small Treated water systems requires that individuals in responsible charge have sufficient knowledge to understand chemicals used for water treatment, their health benefits, how to apply correct dosages, and recognize and correct water system problems. An operator must recognize and eliminate potential contamination that might enter the water system through a cross-connection, repair equipment, or oversee equipment replacement projects. Although operators may not perform all aspects of a corrective action themselves, they must be able to identify when additional expertise and assistance are needed. The major responsibility of an operator of Small Untreated and Small Treated water systems is to protect public health.

This manual has been written to provide operational information for both Small Treated and Untreated water systems in Alaska. Some sections of this manual pertain to only Small Treated water systems. In those cases, the section will include a note at the heading that says, ***"This section applies to Small Treated Systems only".*** If there is no note on a section, then the section is relevant to both Small Treated and Small Untreated water systems.

Definitions for **bolded words** in the text can be found in the Glossary, starting on page 186.

Chapter 1 – Introduction to Water Treatment

1.1 Background

Water treatment processes have been developed over the past century in an effort to protect public health and minimize **waterborne disease** outbreaks. Water treatment techniques have been established in response to local conditions with various objectives including disinfection, removal of harmful dissolved substances, color reduction, turbidity removal, softening, taste and odor control, and corrosion control.

Water used for drinking and food preparation must be free from **pathogenic organisms** – organisms capable of causing disease, and from minerals, inorganic and organic substances that produce adverse physiological effects. Water meeting the above criteria is termed **potable**, meaning that it is safe to drink.

To encourage people to drink water from a safe source, it must be aesthetically acceptable. Aesthetically acceptable water is pleasant in appearance, odor, and taste. The water should be free from apparent turbidity, color, odor, and from any objectionable taste. Water meeting the above criteria is termed **palatable**, meaning that it is pleasing to the senses.

The driving force for water treatment finds its roots in the work of Dr. John Snow who related a disease outbreak to a contaminated London water source in the mid-19th century. Snow is credited with taking bold action when he sensed that contaminated water from the public drinking water pump on Broad Street was the cause of a deadly cholera outbreak in London in 1854.

On the night of August 31, 1854, what Snow later called “the most terrible outbreak of cholera which ever occurred in the Kingdom,” broke out. During the next three days, 127 people living in or around the Broad Street drinking water pump died. By September 10th, the number of fatal attacks had reached 500. The main reason the death toll did not rise even higher was because of Dr. John Snow’s bold actions after identifying the source of the cholera outbreak.

Dr. Snow’s investigation led him to a pump on the corner of Broad and Cambridge Street, the center of the epidemic. “I found,” he wrote afterward, “that nearly all the deaths had taken place within a short distance of the pump.” In fact, houses closer to another pump had only suffered ten deaths, and of those, five victims had always drunk the water from the Broad Street pump. Three were schoolchildren who had probably drunk from the pump on their way to school.

Dr. Snow was convinced that the well water was the source of infection. He took his findings to the Board of Guardians of St James’ Parish; in whose parish the pump was located. Though they were reluctant to believe him, they agreed to remove the pump handle as an experiment. Once the pump handle was removed the spread of cholera dramatically ended. At the end of September, the outbreak was all but over, with the death toll standing at 616.

What could have caused the Broad Street well to become contaminated and result in so many deaths? One theory is that seepage of fecal matter through the decayed brickwork of a cesspool to the well that was less than three feet away was the source of the contamination. The cause of the outbreak was clearly waterborne, and Dr. Snow identified with a microscope “white, flocculent particle” from a sample of the contaminated Broad Street well water as the infective agents. He did not know it at the time, but he had correctly implicated bacteria as the culprit.

Over the next few decades, indicators for the microbiological quality of water were developed. These bacteriological tests determine whether pathogenic organisms may be present by testing for certain **indicator organisms**.

The potential for waterborne disease increases when water is polluted with fecal matter. Polluted water may contain pathogenic (disease-causing) fecal bacteria, viruses, or other microorganisms. Testing for all pathogens is complex and expensive, so the normal practice is to look for indicator bacteria. The indicator organisms are the coliform group of bacteria. A list of Alaska laboratories certified for microbiology and chemical testing of drinking water is available on the ADEC Drinking Water Program website at *https://dec.alaska.gov/eh/dw.aspx*.

By the early 20th century, the United States Public Health Service (PHS) had established bacteriological standards for drinking water. By the mid-20th century, the PHS water quality standards were revised to include various chemical constituents as well as bacteriological indicators. This was significant since it extended the concern over water quality from waterborne disease to long-term **toxicological** (and eventually **carcinogenic**) effects from long-term ingestion.

The **Safe Drinking Water Act (SDWA)** was passed in 1974. The United States Environmental Protection Agency (USEPA) was mandated to identify substances present in drinking water that have adverse public health effects. As a result, national interim primary drinking water regulations were established by the USEPA in 1977. In 1979, a group of chlorination by-products known as **trihalomethanes (THMs)** were also regulated. In 1986, with the passage of the amendments to the SDWA, the USEPA was mandated specifically to regulate microbiological constituents, inorganic and organic compounds, and radioactivity to better safeguard public health.

The SDWA Amendments of 1996 established a new charter for the nation's public water systems, the States, and the USEPA in protecting the safety of drinking water. The amendments included, among other things, new prevention approaches, improved consumer information, changes to improve the regulatory program, revised operator certification requirements, and funding for States and local water systems. Congress intended that the SDWA would be a partnership between the States, the USEPA, and local water utilities. The USEPA provides the overall national guidance by determining health effects and establishing standards for contaminants, researching treatment technologies for contaminants, and monitoring State programs.

Alaska is the primacy agency for implementing the SDWA within the State. Primacy means that USEPA has delegated the primary enforcement responsibility for public water systems to the State of Alaska. Water utilities must meet the requirements of the law, thereby providing the day-to-day surveillance of the water supplies.

1.2 Source Water

Source water is generally classified as **surface water** or **groundwater**. However, some groundwater may be classified as Groundwater Under the Direct Influence of Surface Water (GWUDISW).

Surface water is all water on the surface of the earth, as distinguished from subsurface water or groundwater. Surface water is usually water that is found in a river, lake, or other surface impoundment. The area where surface water flows from is called a **drainage basin**. With a surface water source, this drainage basin is called the **watershed** (Figure 1.1). The area of a basin is commonly measured in square miles, sections, or acres. The area that contributes water to the groundwater supply is called the **recharge area**.

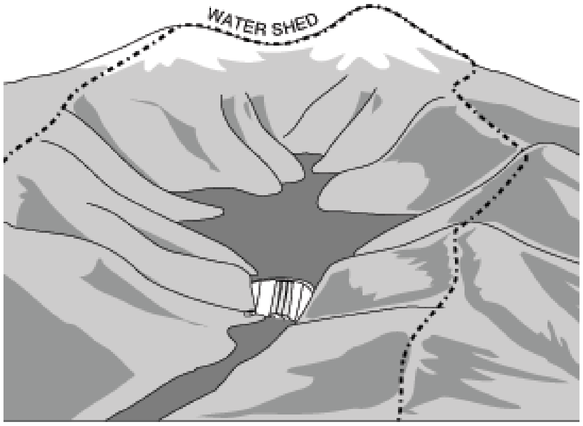


Figure 1.1: Watershed

Surface water is open to the atmosphere and is subject to overland flow making it easily contaminated by animal wastes, pesticides, insecticides, industrial wastes, algae, and many other inorganic and organic materials.

A contaminant is any biological, chemical, physical, or radiological substance or matter in water. As related to water, contamination is the introduction into the water of toxic materials, bacteria, or other harmful agents that make the water unsafe for its intended use. Even surface water found in Alaska's pristine mountain streams might be contaminated with *Cryptosporidium*, *Giardia,* or coliform bacteria from wildlife feces, and should be boiled or disinfected before drinking.

Groundwater is water that fills space between rocks and soil particles underground, in much the same way as water fills a sponge. It is trapped beneath the ground. Groundwater begins as **precipitation** and soaks into the ground where it is stored in geological formations called **aquifers**. Aquifers are explained and discussed in Section 1.4 of this chapter.

Rain that soaks into the ground, rivers that disappear beneath the earth, and melting snow are a few of the sources that recharge the supply of underground water. Since groundwater must travel through many layers of natural filtration before entering an aquifer, there is little to no microbiological contamination. However, during this travel to the aquifer and while in the aquifer, groundwater may dissolve minerals from the surrounding geological formations resulting in a high mineral content. . Groundwater is the principal source of water for over 80% of public water supply systems in Alaska.

GWUDISW is defined by the USEPA in the Surface Water Treatment Rule as any water beneath the surface of the ground that has:

1. a significant occurrence of insects or other macroorganisms, algae, organic debris, or large diameter pathogens such as *Giardia lamblia or Cryptosporidium*, or
2. significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH that closely correlate with climatological or surface water conditions.

GWUSISW determinations for individual sources are conducted in accordance with the State of Alaska Drinking Water Regulations (18 AAC 80) by the ADEC Drinking Water Program.

Water is an important and precious natural resource that needs to be protected and managed, whether for use as drinking water or recreational purposes. Surface water, groundwater, and GWUDISW are susceptible to contamination. If not monitored or treated, water may be the vehicle for the spread of **infectious diseases**. The most economical way to keep treatment costs low is to protect your water source from contamination as discussed in Chapter 3, Source Water Protection and Development.

1.3 The Hydrologic Cycle

Surface water and groundwater are part of what can be called the earth's oldest recycling program, the **hydrologic cycle**. After 3.8 billion years you would think the water would be all used up! It has not, because of one special process: the hydrologic cycle, more commonly called “the Water Cycle.” Figure 1.2 illustrates nature’s method of continuously recycling the earth’s renewable water supply.

The hydrologic cycle begins with the **evaporation** of water from surface waters. As moist air is lifted into the sky, it cools, and water vapor condenses to form clouds. Moisture is transported around the globe until it returns to the surface of the earth as precipitation. Precipitation can be in the form of rain, hail, sleet, or snow. Once the water reaches the ground, one of three processes may occur.

1. Some of the water may evaporate back into the atmosphere,
2. The water may penetrate the surface and become groundwater, or
3. The water will become **run-off** that goes into lakes, streams, and rivers and eventually flows back to the ocean.

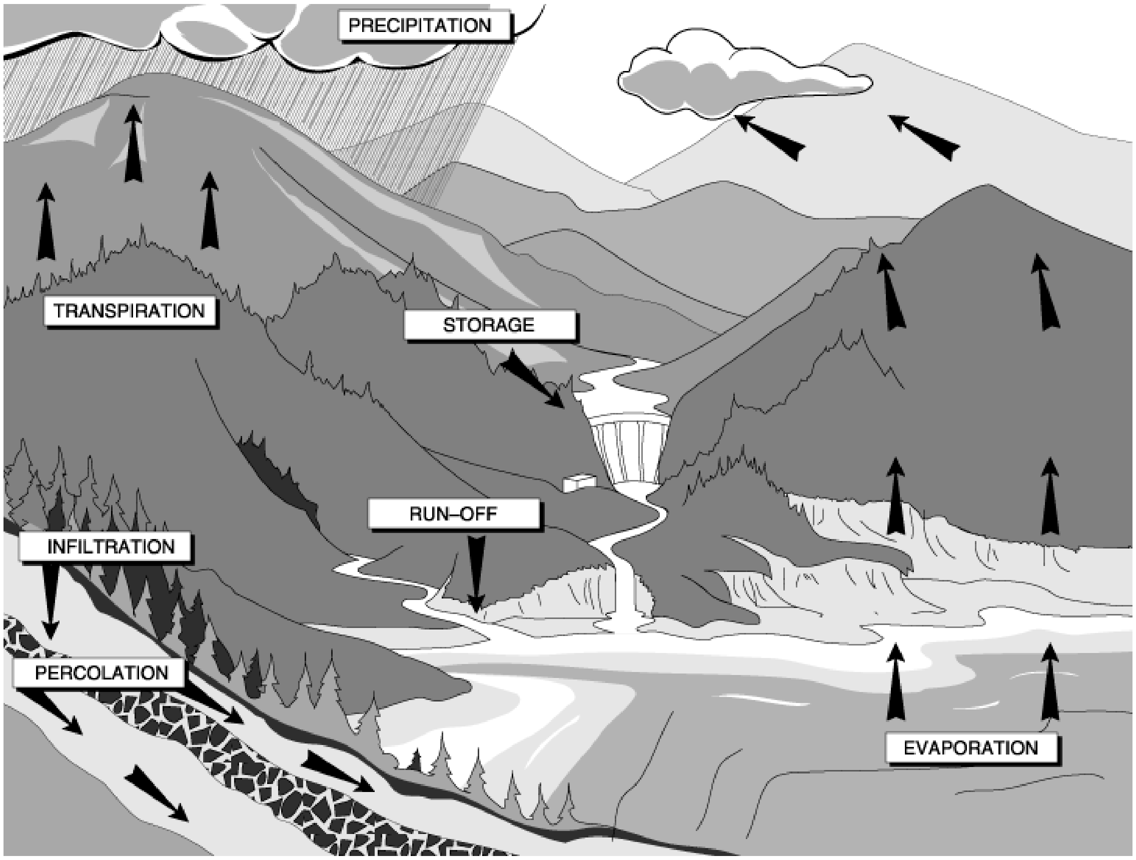


Figure 1.2: The Hydrologic Cycle

When water hits the ground, it either **percolates** through the ground or travels over land. Sometimes groundwater feeds springs, lakes, and other surface waters, or is drawn out of the ground through wells. The water can then evaporate, form clouds, and return to the earth to begin the cycle over again.

The hydrologic cycle is an important concept because it shows how the amount of groundwater available to a water well is influenced by the amount of precipitation, **infiltration**, and underground water flow occurring in a given area.

In summary, surface water and groundwater begin as local precipitation that seeps into and through the ground or becomes run-off.

1.4 Aquifers

Underground formations where groundwater exists in sufficient quantities to supply wells or springs are called aquifers, a term that means water bearer. Water that infiltrates the soil and is not picked up by plant roots moves downward through spaces in the soil and subsurface material until it reaches an impervious layer of rock, clay, or permafrost. An impervious layer is difficult for the water to seep through. The porous layer of soil above the impervious layer becomes saturated with water forming an aquifer.

Some of the water fills pores and crevices of soil and rock beneath the surface of the earth. Water percolates, or moves down, through the soil until it reaches a level where all of the available space is completely filled with water. This is called the **zone of saturation**. The water contained in this zone is called groundwater and the upper most limit of this zone is known as the **water table**.

Wells obtain their water from aquifers. A common misconception is that groundwater is obtained from underground lakes. Actually, wells tap into voids containing water below the earth's surface. Most of the rocks near the earth's surface are composed of both solids and voids. The solid parts are more obvious than the voids, but without the voids, there would be no water to supply wells and springs. There are three types of aquifers:

1. Confined aquifers
2. Unconfined (or water table) aquifers
3. Springs

A **confined aquifer** is bound above and below by impermeable material. The water-bearing materials are found between layers of impermeable material such as clay or **permafrost**. When water completely fills an aquifer that is overlaid by a confining layer, the water in the aquifer is said to be confined. Confined aquifers are also known as **artesian** aquifers. Confined aquifers generally contain water that is under a pressure greater than atmospheric pressure. If a well is drilled into a confined aquifer, the water can rise above its level in the aquifer because of the pressure exerted on the fluid by the confining layers. This is called an artesian system. Confined aquifers commonly yield large quantities of high-quality water. One exception is water confined by permafrost layers. This water is typically poor quality. A confined aquifer is recharged by snow or rain in the mountains where it is close to the surface of the earth. Because the recharge area is away from the area of contamination, the possibility of contamination of a confined aquifer is very low. However, once contaminated, it may take hundreds of years before it recovers.

An **unconfined aquifer** may have an impermeable layer below the water-bearing strata, but there is no confining layer on top. Permeable rocks and soil directly overlie the aquifer. An unconfined aquifer may be recharged by infiltration over the whole area underlain by that aquifer because there is nothing to stop the downward flow of water from the surface to the aquifer. If a well is drilled into an unconfined aquifer, the water will rise in the well to the same height as the water table in the aquifer. Figure 1.3 illustrates a confined and unconfined aquifer.

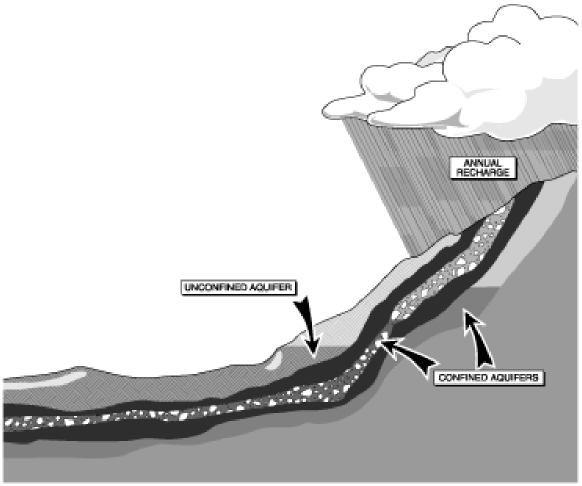


Figure 1.3: Aquifers

Consequently, the water-bearing material can fill up with water until the water level reaches the surface. The top of the water level in an unconfined aquifer is called the water table. Therefore, unconfined aquifers are sometimes called water-table aquifers.

An opening in the ground surface, from which groundwater flows, is a **spring**. Groundwater becomes surface water at springs or intersections of a water body and a water table. Water may flow by force of gravity from water-table aquifers or be forced out by artesian pressure from a confined aquifer.

1.5 Water – The Universal Solvent

Two elements, hydrogen and oxygen, combine to form the compound we refer to as water. Each molecule of water is composed of 2 atoms of hydrogen and 1 atom of oxygen (H_2O).

Water appears to be a simple compound. However, the simple appearance of water is deceiving. The water molecule has several characteristics that make it unique. One of its many important properties includes being a good solvent. It is often referred to as the universal solvent because it will dissolve most anything it comes into contact with to some extent.

Water plays an important role as a chemical substance. The chemical formula for water is H_2O. The two hydrogen atoms that combine with oxygen to make up the water molecule always attach to the oxygen atom at an angle of approximately 105^o from each other (Figure 1.4).

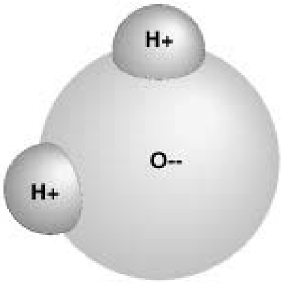


Figure 1.4: Water Molecule

The hydrogen atoms are positively charged, and the oxygen atom is negatively charged. This gives the water molecule an electrical polarity; one end is positively charged, and one end is negatively charged. The molecule's polarity is the main reason water is able to dissolve so many other substances.

Pure water contains no impurities, but in nature, water contains many dissolved and suspended elements and particles.

Recall the hydrologic cycle, where precipitation falls upon the earth and percolates down through the soil and rock layers to become groundwater. As the water falls through the atmosphere and then percolates through the earth’s surface, it dissolves and attaches to many of those substances. Also, as water flows over the surface of the earth, it dissolves and carries with it almost everything with which it comes in contact.

Consequently, natural and man-made impurities are present in all surface water and groundwater. Some impurities in groundwater, such as fluoride and calcium can be beneficial. Others, like arsenic, and pesticides, can be harmful. Still others, like iron and color, although not harmful to your health, can make the water less desirable to the consumer.

Various water treatment methods are used to inactivate pathogens and remove substances that are dissolved or suspended in the water.

Water treatment methods used to make water safe to drink are discussed in Chapter 4 — Water Treatment. Water from a well supply or water sipped from a pristine Alaska mountain stream may appear clear, have no odors, and taste fine, yet may have high levels of dissolved substances or tiny organisms that are not visible to the naked eye. Since it is impossible to judge the quality of the water with the eye, it is necessary to analyze the water we supply to consumers for physical and chemical properties. When it comes to drinking water, it is what you cannot see, smell, or taste that might hurt you.

Chapter 2 – Source Water Quality and Characteristics

2.1 Introduction

Regardless of the source, untreated water is usually referred to as **raw water**. Occasionally, raw water will be of such high quality that no further treatment is necessary. However, most raw water sources require some type of treatment to make the **finished water** safe to drink and aesthetically pleasing to the consumer. For public water supplies, the raw water quality and characteristics generally determine the treatment requirements.

Remember the hydrologic cycle from Chapter 1? Let's follow the path of a raindrop as it hits the earth's surface. When the raindrop falls from the atmosphere to the surface of the ground, one of two things can happen. It can either flow across the surface of the ground and into a stream or lake becoming part of the area's surface water supply or it can seep into the earth's surface becoming part of an area's underground water (groundwater) resource.

Precipitation contains few impurities. Trace amounts of minerals, gases, and other substances may be picked up as the precipitation forms into clouds and falls through the earth's atmosphere, but precipitation has virtually no harmful bacteria. Keep in mind that water is a very good solvent – it will dissolve, to some extent, most everything with which it comes into contact. Consequently, once the precipitation reaches the earth's surface, many foreign substances can either be dissolved in the water or be carried along with the flow.

Groundwater picks up numerous minerals and contaminants as it percolates through the soil on its way to an underground aquifer. Surface run-off will pick up almost any mineral or contaminant it passes over and carry those contaminants into adjacent surface water supplies.

Depending on what it comes in contact with, the quality of the water may be lowered to the point that it constitutes a health hazard or impairs its usefulness. The water may then require treatment.

Based on an understanding of the hydrologic cycle and water's universal solvent properties, it is easy to see why pure water is never found in nature. These impurities contribute to the specific characteristics of any given source water, and it is these water quality characteristics that determine the need for specific types of treatment.

2.2 Source Water Characteristics

As a general rule of thumb, groundwater is consistently of higher quality than surface water because it has undergone considerable natural purification through straining and prolonged storage in an aquifer. In some cases, groundwater may be used without any treatment whatsoever or may require only disinfection. Surface water, on the other hand, may require complex treatment. Fortunately, groundwater is readily available in most areas of the state in sufficient quantities to meet the needs of most water systems. Eighty-five percent of the public water systems in Alaska use groundwater while only fifteen percent of the water systems use surface water or GWUDISW as their source.

Surface water requires a relatively high degree of treatment because both nature and humans expose surface waters to potentially severe contamination. In addition, the quality of a given surface water supply may vary considerably because of fluctuating influences such as **hydrological events** (i.e., rainstorms), seasonal changes, and periodic human activity.

For these reasons, surface water treatment is generally more complex and sophisticated than groundwater treatment and requires more diligent operation and maintenance. Regulatory requirements for systems utilizing a surface water source are more stringent than those utilizing a groundwater source. Not surprisingly, costs associated with surface water treatment are greater than with groundwater treatment.

To understand why certain treatment processes are necessary for small-treated water systems, owners and operators need a basic knowledge of the physical, chemical, and biological characteristics of groundwater and surface water.

The following sections provide basic information on source water characteristics and are intended for operators of small groundwater and surface water systems in which only one chemical is used for treatment. There are numerous publications and textbooks that deal with advanced water treatment and water chemistry. Please contact the Operator Certification Program at ADEC if you are interested in obtaining more detailed information.

2.3 Physical Characteristics

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

Turbidity

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

High turbidity in finished water is a potential health risk because viruses and bacteria can “hide” within the turbidity-causing particulates making disinfection difficult. Removal of the particulates reduces the chance of pathogenic microorganisms in finished water. Inactivation of pathogenic microorganisms by chlorine, ozone, and other disinfectants is covered in Chapter 5 – Disinfection.

Turbidity is measured with an instrument called a **turbidimeter**, which reads in units called Nephelometric Turbidity Units (NTUs). Typically, for the reasons mentioned above, groundwater is lower in turbidity than surface water.

Color

If water is colored, it is less pleasing to the consumer and may be rejected in favor of a drinking water source that is less safe. Color occurs most frequently in surface water due to the decay of **organic material**. In Alaska, one common source is decayed tundra vegetation which results in brownish-colored water often called “tundra tea.” Color can be measured in the laboratory and, generally, a measurement of 15 color units or higher is objectionable.

Taste and Odor

Tastes and odors in groundwater can be caused by the presence of hydrogen sulfide gas and dissolved minerals, such as iron, manganese, zinc, and copper. Although these substances are generally not harmful in quantities typically encountered in most groundwater, their presence can lead to consumer complaints. Various taste rating scales have been developed, but they are very subjective and do not mean much to the individual consumer. If water tastes bad, people will not drink it.

2.4 Chemical Characteristics

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

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

Information about analytical laboratories in Alaska that are certified for microbiological and chemical testing of drinking water can be found on the ADEC Drinking Water Program website.

2.4a Groundwater Characteristics

Groundwater moves very slowly within an aquifer. Its flow is measured in feet per year compared to surface streams where flows are measured in the feet per second range. Consequently, the water quality of any specific well is usually quite constant.

The water quality of any specific well is directly related to the chemical composition of the geological formation (a body of rock that has a set of characteristics that differentiates it from other nearby bodies of rock) through which the water has percolated. As water passes through the earth’s crust and travels through the aquifer, it will dissolve some of the minerals with which it comes in contact. Typically, wells drilled through the same formation will have similar chemical characteristics.

Depending on the minerals that are present, the water may have high concentrations of iron and manganese, which can cause taste, odor, and color problems and, in the case of manganese, potential health effects. The water may be very hard due to dissolved calcium and magnesium. Groundwater in areas having both high levels of iron and sulfur deposits will often have the characteristic rotten egg odor of hydrogen sulfide. Some chemical contaminants are toxic or poisonous and have direct adverse health effects. Common chemical contaminants found in groundwater are:

- Iron
- Manganese
- Fluoride
- Calcium
- Sulfate
- Magnesium
- Arsenic
- Hydrogen sulfide
- Nitrate
- Radiological contaminants

If you are considering drilling a new well, you might want to talk to neighboring property owners regarding the characteristics of their water and/or consult with a local well driller. Many well drillers keep records including well yield and chemical characteristics for wells they have drilled.

The State Drinking Water Standards establish maximum amounts of chemical contaminants allowed in public drinking water. These standards are discussed in Chapter 8 – Public Water Supply Regulations & Monitoring.

2.4b Surface Water Characteristics

(This section applies to Small Treated Systems only)

While groundwater quality is generally quite consistent, the quality of any given surface water supply can be highly variable and change rapidly. Consequently, more complex treatment may be required.

As mentioned earlier, surface water supplies are subject to climatic changes, seasonal disturbances, and human activity. As water flows over the surface of the earth, it dissolves and carries with it almost everything with which it comes in contact. Substances picked up by overland flow can be classified as biological, chemical (both inorganic and organic), physical, and radiological impurities. They include industrial and commercial solvents, metal and acid salts, sediments, pesticides, herbicides, plant nutrients, radioactive materials, road salts, decaying animal and vegetable matter, and living microorganisms, such as algae, bacteria, and viruses. So, surface water supplies are heavily influenced by natural pollutants and by a wide range of manufactured contaminants, as well.

Surface water quality problems are generally associated with the presence of particulate matter, color, taste, odor, and microbial contaminants. **Filtration** and disinfection are usually required for the treatment of surface water supplies.

2.5 Common Water Quality Indicators

Regardless of the water source, raw water is usually evaluated for certain common water quality indicators or chemical constituents. The suitability of a given raw water for use as a public water supply can often be determined by evaluating these common water quality indicators. They include pH, total dissolved solids (TDS) or conductivity, hardness, alkalinity, iron and manganese, dissolved gases, and corrosivity.

2.5a pH

The acidic or basic nature of a solution is expressed as the **pH**. The pH scale (Figure

2.1) ranges from 0 to 14, with 7 being neutral. Numbers below 7 are acidic and numbers above 7 are basic. Acids can be defined as compounds that release hydrogen ions (H^+) when added to water. Bases can be defined as compounds that release hydroxide ions (OH^-) when added to water.

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 pHs can cause scaling or reduce the efficiency of chlorine.

A rough indication of pH can be obtained using pH paper or liquid color indicators that change color as the pH level varies. These indicators are limited in their accuracy and can be difficult to interpret correctly. A more accurate way to determine pH is by using a pH meter.

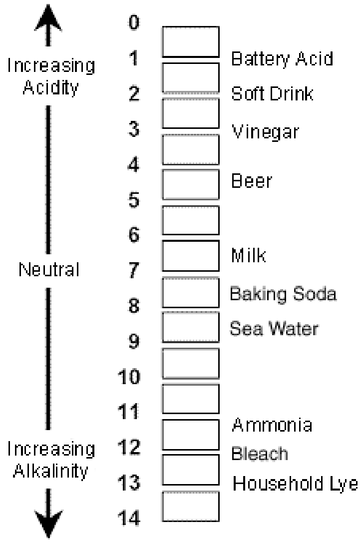


Figure 2.1: pH of Common Liquids

2.5b Total Dissolved Solids: Conductivity

Conductivity is defined as the ability of a substance to conduct electric current. There is a direct relationship between conductivity and the minerals dissolved in water (**total dissolved solids, TDS**). Therefore, conductivity can be used to estimate the TDS concentration of a specific water. It can be measured quite easily and quickly with a portable meter and is much more convenient than the TDS test which takes hours to complete.

For water treatment applications, the use of conductivity has the advantage of an almost direct relationship with impurities, especially at low concentrations. For this reason, a rising conductivity reading shows increasing impurities in the water. The drawback to conductivity is that it is a non-specific measurement; that is, it cannot distinguish between various types of minerals and the reading is proportional to the combined effect of all minerals present.

For most natural waters, conductivity multiplied by a factor that may vary between 0.55 and 0.75 will give a good estimate of the dissolved solids concentration in mg/L. Typically, groundwater will have higher TDS levels than surface water.

High TDS concentrations in drinking water can produce laxative effects and can give an unpleasant mineral taste to water. It is generally accepted that the TDS concentration of palatable water should not exceed 500 mg/L. For this reason, the USEPA has established a **secondary standard** of 500 mg/L TDS in drinking water. Secondary standards are not enforceable but recommended guidelines for contaminants that may cause aesthetic effects in drinking water. See Chapter 8 – Public Water Supply Regulations & Monitoring regarding primary and secondary standards.

2.5c 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 a particular 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 hard to wash off.

Hardness is caused by the presence of magnesium and calcium 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 (Table A).

However, numerical values for hardness have little significance for the average consumer. To an individual living in Fairbanks, water with a hardness of 100 mg/L may seem soft while someone from Southeast Alaska, where waters tend to be extremely soft, may think the same water is very hard. Typically, groundwater is harder than surface water.

Hard water can lead to calcium carbonate ($CaCO_3$) scale in hot water heaters, boilers, and cooking utensils. Low hardness contributes to the corrosive tendencies of water.

Water hardness is expressed in milligrams per liter (mg/L) of $CaCO_3$. Hardness can also be expressed in grains per gallon (gpg); 1 gpg = 17.1 mg/L.

Classification	mg/L as $CaCO_3$
Soft water	0-60
Moderately Hard	61-120
Hard	121-180
Very Hard	Over 181

Table A: Hardness Scale

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. In small systems, water is usually softened by the ion exchange process. The ion exchange process is explained in Chapter 4.

2.5d Alkalinity

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

Most of the alkalinity in water is provided by carbonate and bicarbonate compounds. Alkalinity is expressed as mg/L of $CaCO_3$. Typically, groundwater will have adequate alkalinity, but surface water sources usually have very low alkalinity, and the pH can easily change. Alkalinity does not pose a health risk.

When using chlorine gas or hypochlorite compounds for disinfection the alkalinity of the water should be considered. When chlorine gas is added to water, it tends to consume alkalinity and lower the pH through the formation of hydrochloric acid. On the other hand, the addition of hypochlorite to water tends to raise the pH from the addition of calcium or sodium hydroxide.

2.5e 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. . .

Many groundwater supplies in Alaska have high levels of iron and manganese. Iron and manganese removal is one of the most common types of municipal water treatment in Alaska. The **Secondary Maximum Contaminant Level (SMCL)** 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. In 2004, the USEPA issued a Drinking Water Health Advisory for Manganese which provides a lifetime health advisory value for Manganese of 0.3mg/L to protect against concerns of potential neurological effects.

2.5f Dissolved Gases

Gases, as well as minerals and organics, can be easily dissolved by water. Groundwater usually contains more dissolved gases than surface water. Gases frequently found in both raw water and treated water include oxygen, carbon dioxide, methane, hydrogen sulfide, and radon. Some of these gases dissolved in water can cause significant problems including objectionable taste and odor, **corrosion**, and health and safety concerns.

Troublesome dissolved gases can usually be removed by aeration, which exposes the gases to the atmosphere until the concentration of the gas in the water is in equilibrium with the concentration of the gas in the atmosphere.

Oxygen (O_2)
Well-oxygenated water is usually desirable because it gives water a pleasant, fresh taste. In the absence of dissolved oxygen (under **anaerobic** conditions) water may support the growth of bacteria that produce foul-smelling methane and hydrogen sulfide. However, on the negative side, water with a high dissolved oxygen content will tend to be corrosive..

Carbon Dioxide (CO_2)
CO_2 is highly soluble in water and is commonly found in excess in Alaskan groundwater supplies because of the cold temperatures of the groundwater. Although CO_2 does not pose a health risk it can contribute to operational problems for water systems.

Dissolved CO_2 increases the acidity of water, which increases corrosive tendencies. Excess CO_2 may keep iron in solution, making iron removal more difficult and CO_2 can consume more lime when it is being used for pH adjustment. Aeration can effectively reduce the concentration of CO_2 in water. Aeration is discussed Chapter 4.

Methane (CH_4)
CH_4, often called “swamp gas,” is frequently found in groundwater supplies located near natural gas deposits. It is produced by the decay of organic material buried in old river channels under permafrost. When dissolved in water, CH_4 can make the water taste like garlic. CH_4 poses an explosion hazard if it is allowed to accumulate in an enclosed space. Methane can be easily removed by aeration.

Hydrogen Sulfide (H_2S)
Although H_2S gas is associated with groundwater supplies more often than with surface waters, it can also occur in lakes and reservoirs under ice cover in winter. It produces the offensive rotten egg or sulfur odor and taste found in some groundwater. Even at low concentrations, i.e., 0.05 mg/L, H_2S 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 the hot water is used. Heat forces the gas into the air which 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. High concentrations of dissolved H_2S also can foul the resin bed of ion exchange water softeners. Finally, H_2S is a poisonous gas that can be hazardous if released in a treatment plant. Levels as low as 0.1 percent by volume of H_2S in air can be fatal if breathed for less than 30 minutes.

H_2S can easily be removed by aeration; however, due to the risk of poisoning, ensure you take proper ventilation precautions.

Radon (Rn)
Radon is a colorless and odorless **radioactive** gas that is a carcinogen (cancer-causing agent). It is a natural decay product of uranium and is present at unacceptable levels in many groundwater supplies in Alaska. Radon must be removed from drinking water because of the potentially extreme health risk associated with it. Radon is released from showers, washing machines, and other plumbing fixtures and can concentrate in enclosed spaces, creating an inhalation hazard.

2.5g Radium

Radium (Ra) is a naturally occurring radioactive element that is present in varying amounts in rocks and soil within the earth’s crust. Surface water is usually low in radium but groundwater can contain high levels of radium depending on local geology. The most common isotopes of radium found in groundwater are Ra-226 and Ra-228. Radium in water may pose a hazard to human health when the water is used for drinking or cooking. A small portion of ingested radium is absorbed from the digestive tract and distributed throughout the body. Internally deposited radium emits alpha particles that may then damage surrounding tissue. A number of treatment methods are available to remove radium from water. Ion exchange, lime softening, and reverse osmosis are the most common and can remove up to 90 percent of radium present.

2.5h Corrosivity

Corrosivity can be defined as the tendency of water to dissolve metal. It can affect metal structures and equipment, such as pipes, valves, and pump parts. Water that has a strong tendency to do this is said to be highly corrosive; water that does not do so readily is said to be weakly corrosive or non-corrosive.

Highly corrosive water (water having high corrosivity) poses both a health hazard and an economic burden. Undesirable metals dissolved by corrosive water may be detrimental to health. An example of this is lead or copper dissolved in water because of the corrosive action on copper pipes and lead-based solder. If corrosion goes unchecked, metal pipes and equipment will be severely damaged or destroyed. Replacement of corrosion-damaged material and equipment can be very costly.

Corrosion is an extremely complex phenomenon and not well understood. Corrosion is affected by many water quality parameters: pH, hardness, alkalinity, temperature, dissolved oxygen, and total dissolved solids (TDS). Of these, pH has the greatest influence. Generally, the lower the pH the more corrosive the water will be. The presence of hardness and alkalinity tends to lessen the corrosivity, so water with higher hardness and alkalinity is usually less corrosive than water with lower hardness and alkalinity. TDS, dissolved oxygen, and temperature are less important, but an increase of in any of these factors tends to increase corrosivity.

As a general rule, surface water sources are more corrosive than groundwater sources. This is due to the fact that most surface water sources have low pH, low hardness, low alkalinity, and low TDS, whereas groundwater tends to be just the opposite: higher pH, higher hardness, higher alkalinity, and higher TDS.

Since pH has the greatest impact, corrosivity can be controlled by the addition of chemicals to raise the pH. The most common chemicals used to raise pH (lime and soda ash) also increase hardness and alkalinity, which help reduce corrosivity.

Corrosivity is considered a secondary contaminant with an SMCL of “non-corrosive.” The Langelier Saturation Index, (LI) which takes into consideration pH, total dissolved solids, hardness, alkalinity, and temperature, is commonly used to determine if water is corrosive or not. The analytical lab doing your water tests can determine your LI.

2.6 Biological Characteristics

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

Most do not pose a health risk, but as you recall from the description in the introduction to this manual of the London cholera epidemic, the presence of some microorganisms in drinking water can be devastating. In fact, providing microbiologically safe drinking water is the primary goal of all water providers.

Generally, surface water sources are more likely to contain greater numbers and more diverse populations of microorganisms than groundwater sources. This is because surface water can easily pick up microorganisms from contaminated areas as it flows across the earth’s surface. On the other hand, the filtering action of aquifer material results in fewer microorganisms in groundwater. However, shallow wells and unprotected wellheads can provide an opportunity for contaminated surface water to enter the groundwater. Consequently, groundwater cannot be assumed to be free of microorganisms either.

Disease-causing organisms are called **pathogens**. Water-borne pathogens include bacteria, protozoa, and viruses. These pathogens can be transmitted from person to person through fecal contamination of drinking water. Consequently, disinfection is required for surface water sources per the Surface Water Treatment Rule (SWTR) and may be necessary for groundwater sources if they become contaminated.

Bacteria are single-celled organisms ranging in size from 0.5 - 2 **microns** in diameter and about 1-10 microns long. A micron is a metric unit of measurement equal to 1 thousandth of a millimeter. To visualize the size of bacteria, consider that it would take approximately 1,000 bacteria lying side by side to reach across the head of a straight pin. They are among the most common microorganisms in water. Typhoid fever and cholera are examples of bacterial waterborne diseases. Most bacterial pathogens are easily controlled with normal disinfection processes.

Protozoa are single-celled organisms, several hundred times larger than bacteria. They range in size from 4 to 500 microns. Two species of protozoa, *Cryptosporidium* (Figure 2.2) and *Giardia lamblia,* (Figure 2.3) have been found to be the cause of waterborne gastrointestinal disease outbreaks in the United States. Both have been found in Alaskan waters. Some protozoans go through two-phase life cycles, alternating between reproduction and resting cysts phases. The cyst phase results in an extremely resistant form that makes them very difficult to control with normal disinfection.

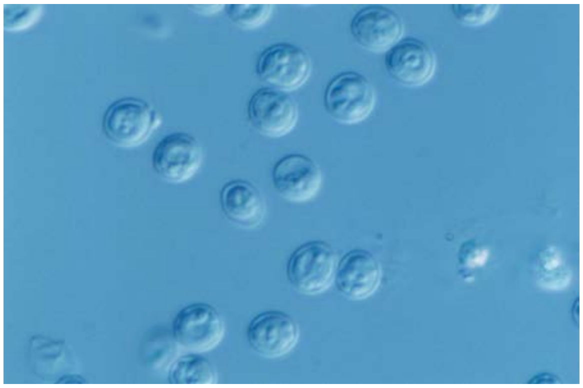


Figure 2.2: ***Cryptosporidium***

Figure 2.3: ***Giardia***

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

2.7 Other Organisms Found in Water Sources

Algae, small aquatic, plant-like organisms are frequently found in surface water supplies but not in groundwater because they require sunlight to survive. Algae contribute to taste and odor problems in finished drinking water. These problems are caused by natural chemicals produced by the algae and by chemicals released when algae cells die.

Not all organisms found in freshwater supplies are microscopic. Do not be surprised to find small, animal-like organisms in both surface and groundwater supplies. Freshwater shrimp, crustaceans, arthropods, and other "critters" are occasionally present.

If they are present in unusually large numbers, the chemicals released when they die can cause taste and odor problems. Otherwise, they are simply a nuisance, plugging screens and filters.

Iron bacteria

One special group of bacteria, iron bacteria, causes problems with water supplies. If iron is present, it will promote the growth of these bacteria. Iron bacteria metabolize iron and will flourish when iron levels are high. During this metabolic process, the bacteria will produce by-products that give the water a metallic taste.

Iron bacteria can also cause “red water,” or clog well screens which reduce water production. If reddish or green slime builds up in your toilet flush tank, you probably have an iron bacteria problem.

Iron bacteria problems are very hard to eliminate. High dosages of chlorine must be used throughout the distribution system to kill all of the bacteria. It may be necessary to feed chlorine continuously to prevent regrowth. A filter alone will not solve this problem.

Chapter 3 – Source Water Protection and Development

3.1 Introduction

“An ounce of prevention is worth a pound of cure.” This old saying can also apply to protecting your water source. The best way to keep water safe to drink and, at the same time, treatment costs low, is to prevent contaminants or pollutants from getting into the source water to begin with.

Protecting the quality of your source water should be a major concern because it is expensive to remove contaminants from water. Source water protection is probably the most cost-effective way of assuring safe and aesthetically pleasing drinking water. Often, it is cheaper to abandon a contaminated groundwater source and develop a new one than to pay expensive treatment costs to remove contaminants from a low-quality source.

For surface water, the characteristics of the watershed determine both the quality and quantity of the raw water from that area. For groundwater, it is the characteristics of the recharge area that determines the quality and quantity of water.

Congress adopted amendments to the Safe Drinking Water Act (SDWA) that require states to develop and implement a program to protect the water sources of public water systems. In Alaska, the Drinking Water Protection (DWP) group with the Drinking Water Program at ADEC is responsible for implementing these amendments. . .

3.2 Source Water Assessment and Protection

Both natural and human factors influence the quality of a water source. To effectively manage the quality of a source water, you must first identify those factors that can affect the source water quality. The degree of impact of the factors varies depending on the source involved. Surface water, for example, is generally more vulnerable to human contamination than groundwater because of the direct exposure to human activity. Oil spills or chemical releases may be contained or isolated in the case of surface water, presenting only temporary problems, but once present in the aquifer they may persist for decades.

A source water assessment is a study and report that provides basic information about the area and activities that can affect your drinking water source. Source water assessments consist of three components:

1. A delineation on a map of the source water area. This means, the zone contributing water to the system’s wells (for groundwater systems) or intakes (for surface water

systems). The zone typically includes the watershed for surface water systems or the aquifer for groundwater systems.

2. An inventory of potential pollution sources within the source water area. For example, landfills and underground storage tanks are potential pollution sources. Any existing or potential contaminant source(s) found within the designated protection area is(are) identified and ranked by the risk they pose.

3. A susceptibility analysis should provide a well-reasoned and well-supported judgment of the likelihood that a system will suffer contamination from any of the potential threats.

Delineation areas are used to identify recharge areas that must be controlled to protect the quality of water. These areas are referred to as Wellhead Protection Areas or Source Water Protection Areas.

The state previously completed source water assessments for all public water system sources (groundwater and surface water). The state is no longer completing source water assessments. However, the state continues to delineate drinking water source protection areas for all public water system sources and further awareness of these protection areas through outreach efforts. The state continues to review and comment on proposed permitted activities near public water system sources.

To assess the vulnerability of your drinking water source to existing and potential sources of man-made contaminants, Community and Non-Community Public Water Systems (PWS) may engage a qualified consultant and gather information such as:

- A copy of your well log(s)
- Maps or other information, such as latitude and longitude are used to establish the location of your drinking water source(s)
- The rate of production of your drinking water source(s)
- A list of existing and potential sources of man-made contaminants within your drinking water protection area
- Photographs of each wellhead, spring, or surface water intake
- Photographs of the area surrounding each wellhead, spring, or surface water intake

Climate change impacts are also considered in the source water assessment. Climate change threatens the quality of source water through increased runoff of pollutants and sediment, decreased water availability from drought and saltwater intrusion, as well as adversely affecting overall efforts to maintain water quality.

The final Source Water Assessment Report will describe the potential vulnerability of the source water protection area for your drinking water source. The information will assist the PWS owner and/or operator, local governments, regulatory agencies, communities, and the public in planning and coordinating protection efforts. The assessment report is a tool that you can use to help protect your public drinking water supply.

For more information regarding Source Water Assessment and Protection programs in Alaska, contact the Drinking Water Program at the Anchorage ADEC office.

3.3 Wellhead Protection Program

Whether a well taps an aquifer just below the surface or hundreds of feet deep, its location on top of the ground is a crucial safety factor. Locating a well in a safe place takes careful planning and consideration of factors such as where the well is in relation to surface drainage and groundwater flow. A well downhill from a dog team yard, a leaking fuel tank, or a septic system runs a greater risk of contamination than a well uphill of those types of pollution sources.

A wellhead protection program is a way to actively protect both your drinking water resources and your capital investment. A wellhead protection program is designed to prevent contamination in and around the well and consequently, reduce the likelihood that the well field will become contaminated.

The State of Alaska included the wellhead protection plan in its Source Water Assessment Program. Each assessment compiles an inventory of land uses and sites that constitute threats to drinking water quality. Using the source water assessment, the owner can use the resulting report to design their own wellhead protection plan.

To help protect your wellhead from contamination, the State of Alaska requires that a public water system maintain minimum separation distances between potential sources of contamination and a drinking water source (see Table B and Figure 3.1).

Groundwater, in its natural state, is generally safe to drink. But groundwater is never completely pure. Minerals, organics, or pathogens can easily move with water as it travels down through the soil. Gasoline, diesel fuel, or other chemicals from leaking underground storage tanks may seep through the soil and into groundwater. Some sources of groundwater contamination that may threaten human and animal health, as well as the environment, include:

- Human and animal wastes from septic tanks, lagoons, and other waste storage and treatment facilities
- Any chemicals that are poured down household sinks
- Landfills
- Leaking underground storage tanks
- Fuel pipelines
- Abandoned vehicles

- Saltwater encroachment in coastal areas
- Improper use of fertilizers and pesticides

Minimum Separation Distances Between Drinking Water Sources and Potential Sources of Contamination (Measured horizontally in feet)	
Potential Sources of Contamination	**Public Water Systems**
Wastewater treatment works, wastewater disposal system, pit privy, sewer manhole, lift station, cleanout.	200 feet
Community sewer line, holding tank, other potential sources of contamination.	200 feet
Private sewer line, petroleum lines and storage tanks, drinking water treatment waste.	100 feet

Table B: Minimum Separation Distances

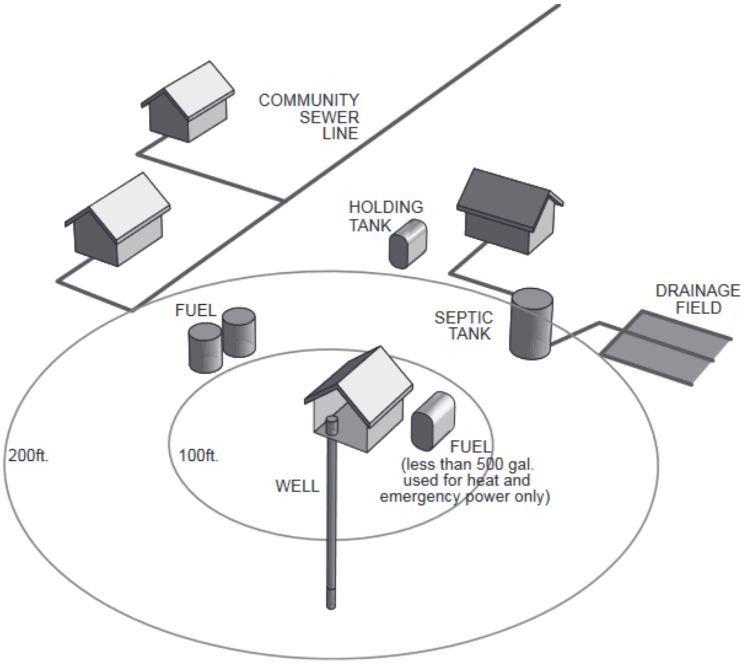


Figure 3.1: Minimum Separation Distances

3.4 Well Decommissioning (Abandonment)

An abandoned well that has not been properly decommissioned is a serious threat to an aquifer. An open well casing serves as a direct route for surface contaminants to enter the aquifer. The contamination of an abandoned well may contaminate an aquifer and thereby contaminate nearby wells making them unusable. A contaminated aquifer is difficult or impossible to decontaminate.

Check for unused wells that may be on your property or close to your water source. Abandoned wells that are not properly sealed can cause loss of artesian pressure, as well as contamination. Alaska's well decommissioning standards are designed to prevent contamination of the well or aquifer from surface and subsurface leakage that may carry harmful chemicals or bacteria to the water you drink. ADEC has minimum standards that describe acceptable methods for permanent well abandonment. Please visit the Drinking Water Program's website to review these minimum standards.

A well is considered temporarily abandoned when it is taken out of service but still exists. Owners of a temporarily abandoned well intend to bring the well back into service at a future date. A watertight cap or seal that prevents any materials from entering the well must cover temporarily abandoned wells. Locking well caps provide extra security.

A well is considered permanently decommissioned, or abandoned when it is completely filled in, so that movement of water within the well is permanently stopped. The appropriate permanent abandonment method depends on information obtained from an examination of the well log and an onsite investigation of the well.

Generally, drilled wells with steel or plastic casing are permanently decommissioned by removing or ripping the casing and filling the borehole with cement from the bottom up. Any pump, wiring, or debris in the well must be removed before the cement is placed in the bore hole.

The method for abandonment must conform to . the Alaska Best Management Practices for Maintaining or Decommissioning Water Wells and Boreholes available on the ADEC Drinking Water Program website..

3.5 Water Rights

A water right is your legal right to use surface or groundwater under the Alaska Water Use Act (AS 46.15). A water right establishes your right to use the groundwater or surface water resource and your seniority subsequent to any future water right applications. A water right allows a specific amount of water from a specific water source to be diverted, impounded, or withdrawn for a specific use.

When a water right is granted, it becomes appurtenant (a right or privilege) to the land where the water is being used for as long as the water is beneficially used. If the land is sold, the water right transfers with the land to the new owner, unless the Department of Natural Resources (DNR) approves its separation from the land. An owner can decide to sell, or not sell, the water right with the land.

In Alaska, because water is a common property resource, landowners do not have automatic use rights to groundwater or surface water. For example, if you have a creek running through your property, you need a water right to protect your use of the water. Using water without a patented water right does not necessarily give the user a legal right to that water.

To obtain water rights in Alaska, you must submit an application to the DNR office in your area. After your application is processed, you will be issued a permit. Once you have determined the full amount of water that you will use beneficially and have complied with all the permit conditions, a certificate of appropriation will be issued. This is the legal document that establishes water rights.

3.6 Source Water Development

Most small systems in Alaska utilize groundwater as their source. However, in areas where groundwater is not readily attainable or of questionable quality or quantity, a surface water source may be developed to supply the needs of the system. Regardless of the water source, the source must be properly developed to protect water quality and ensure that treatment requirements are minimized.

3.7 Surface Water Development

(This section applies to Small Treated Systems only)

Lakes, ponds, rivers, and streams are all occasionally used as source waters for small systems. However, considerable effort is required to develop and maintain surface water intakes and raw water transmission lines. Consequently, the use of surface water as a source for small, treated systems in Alaska is limited. However, if suitable groundwater sources are not available, the system may be forced to develop a surface water source or, perhaps, use rainwater catchment structures.

Very small, seasonal operations may use a surface source. Systems located in Southeast Alaska, where groundwater resources are limited and freezing is less likely, may also use surface water.

Water quality standards are the primary concern when developing surface water as the source. These standards include the physical, chemical, biological, and radiological quality of the water. Surface water of low quality is expensive to treat. Surface water systems must also meet strict standards ,i.e., the Surface Water Treatment Rule, when used as a public drinking water source. When selecting a surface water source, there are some other items you should consider besides quality:

- The distance from your distribution system
- Elevation
- Rainfall
- Area of watershed
- Type of soil
- Activities occurring in the watershed
- Sources, types, and amount of polluting material entering the surface water
- Ownership and control of the watershed

If a source water protection plan has been completed on a water system near the source you plan to develop, most of these items will be addressed and that plan will be valuable in helping you decide if the development is worthwhile.

Determining acceptable quality and quantity levels and evaluating the distance of the surface water source from the area to be served can help determine costs. After establishing parameters for the quality and quantity of the surface water, the next concern is the raw water collection.

Impoundments, or raw water storage reservoirs, can be natural or man-made. An impoundment may be a pond, lake, tank, or basin that is used for storage and flow control of the raw water. Man-made impoundments are built across a waterway to control the flow or raise the level of water and serve as the location for the raw water intake structure. An impoundment may be built for storing raw water to meet peak demands. An impoundment might be built by piling rocks across a stream or by constructing a wooden or cement dam. Damming the water slows the velocity (speed) of the water. An advantage of slowing the water flow is that heavier particulates and sand naturally settle out. This helps lower the turbidity of the raw water, improves water quality, and, in some cases, lowers treatment costs.

The next step is installing an intake structure. An intake structure is a device placed in a surface water source to permit the withdrawal of water from the source. Intake pipes are used to collect the raw water and move it by gravity or by pumping it to an intake well or water plant. Intake pipes located within impoundments have screens, bars, or both to prevent fish, leaves, sticks, or other large debris from entering the intake well or piping system. The most common intake structure used by small systems is a Johnson screen (Figure 3.2).

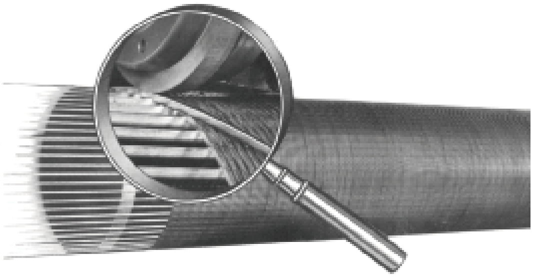
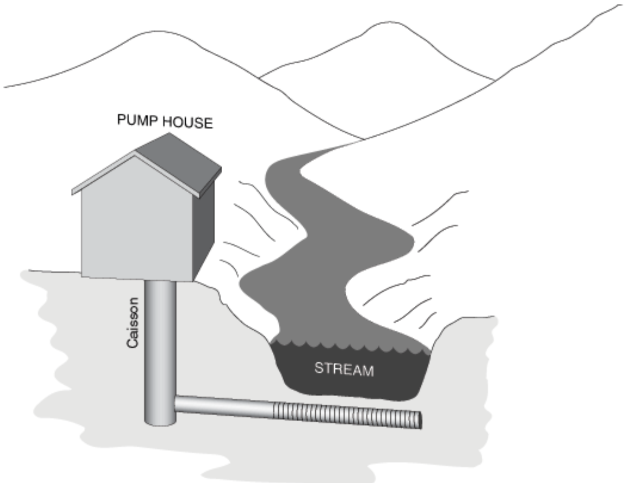


Figure 3.2: Johnson screen

Some water systems collect their surface water by burying a perforated pipe in a shallow stream or beneath a riverbank. The perforated pipe is covered with sand or gravel. As the raw water percolates through the sand or gravel, sand, leaves, and larger particulates are strained from the water. Straining the water through the sand or gravel decreases turbidity and improves water quality. This type of intake structure is referred to as an infiltration gallery (Figure 3.3).

Mounting an end-suction centrifugal pump or submersible pump on a float in a river or pond is sometimes used (Figure 3.4). Water is pumped from the river or pond to a raw water collection well or to the plant. The intake is tied to the bank or shore to keep it from being carried away.



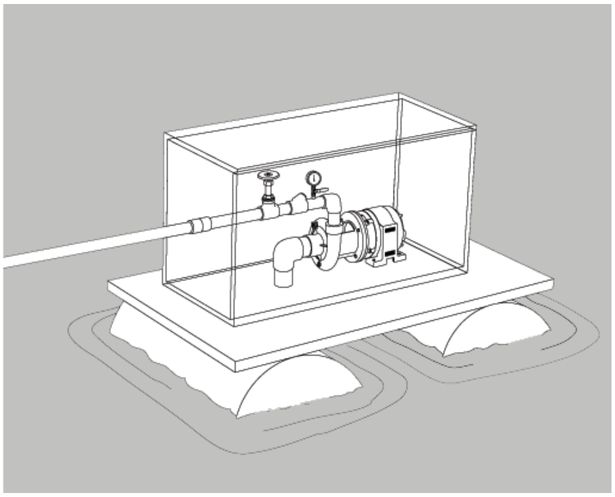


Figure 3.3: Infiltration gallery

Figure 3.4: Floating intake

Intakes should be inspected regularly. Leaves, sticks, and large debris must be removed to ensure that water can flow to the pump. Centrifugal pumps may be damaged if the intakes are choked off by debris that restricts or stops the flow of water to the pump.

Once the intake method for the raw water is established, a transmission system is needed to carry the raw water to the plant. The size of the transmission piping is determined by taking into consideration both the amount of water needed and the amount available at the source. Valves are placed in the transmission piping system to isolate the transmission line in case the raw water source becomes contaminated. Valves are also used to divert water for special needs and to isolate portions of the lines during repair or construction.

3.8 Groundwater Development

Water well drillers have local knowledge of groundwater conditions and experience with state regulations. They can help you select your well site. The driller must choose a well site so that potential contaminants from known nearby pollutant sources are avoided and construct the well in a way that surface pollutants cannot reach the aquifer. There are certain minimum requirements, which must be met in constructing and developing wells, springs, and treatment facilities. ADEC Drinking Water Program must issue a permit before construction is begun.

One of the main considerations in locating your well is convenience. If conditions allow, try to locate the well close to where you will use the water and near a power source. The further away the source water is from the service area, the greater your costs will be to build and operate the water system.

Applying the following standards during siting and placement of your well will save you money:

- Locate the well away from septic tanks, sewage disposal areas (such as drainfields), and other sources of contamination, such as storm sewers, privies, or refuse dumps (refer to Table B for minimum separation distances).
- Identify potential contamination sources that are found in agricultural, commercial, residential, industrial, or undeveloped areas.
- Provide for drainage away from the well on all sides by diverting up-slope drainage away from hillside wells.
- Locate the well upgradient of disposal areas, if possible.
- Locate the well far enough from buildings to allow easy access during maintenance, repair, testing, or redevelopment. Remember to plan future well construction or repairs before building a shelter around the well.
- Locate the well in an area free from flooding or plan extra precautions to protect it.
- Site your well as far as possible from neighboring wells. When wells are close together, they can interfere with each other and may produce less water.

ADEC well construction standards are designed to protect your groundwater resource and public health. The standards attempt to prevent contamination of the well or aquifer from surface and subsurface leakage that may carry harmful chemicals or bacteria to the water source, and they attempt to prevent physical injury and waste of water.

In some cases, due to site conditions, it may not be possible to construct or abandon a well in a manner that meets the minimum state standards. When the minimum construction standards cannot be met, the person responsible for drilling, altering, or abandoning the well must obtain a variance from ADEC Drinking Water Program. The variance, allowing exception from the standards, must be obtained before completing the work and must adequately protect the groundwater resource. The cost involved in well construction is not a compelling reason to grant a variance.

An important step in well construction is the development of the well so that it can supply the maximum sustainable amount of water that the aquifer is capable of producing. Factors related to the development of a groundwater supply that must be considered include water system needs, the location of the well, the design and construction of the well, and well operation. These factors determine the success and the costs of using a well as a public water supply.

Well construction is one of the most important aspects of source development. Owners and operators need to have a basic understanding of well construction techniques, components, terminology, and maintenance.

3.9 Well Types

A well is a hole in the ground that penetrates down into an aquifer. A pump and pipe are used to pull water out of the well, and a screen filters out unwanted particles that could clog the pump and pipe.

There are four major types of wells constructed in Alaska: dug wells, sand point or driven wells, bored wells, and drilled wells.

A **dug well** is a large-diameter hole (usually more than 2 feet wide), which is often constructed by hand. Most dug wells were either built before drilling equipment was available or because drilling was considered too expensive. Modern dug wells are typically lined with concrete tile and have a large diameter, which provides a big opening to the aquifer. The large diameter allows water from aquifers made of very fine sand, silt, or clay, to easily enter the well. Dug wells pose the highest risk of contamination because they are shallow and often poorly protected from surface water.

Driven (sand point) wells, pose a moderate to high risk of contamination. They are constructed by driving assembled lengths of pipe into the ground. Driven wells are normally smaller in diameter (two inches or less) and less than fifty feet deep. These wells are relatively simple and economical to construct, but they can only tap shallow aquifers and, similar to dug wells, may be easily contaminated. They can only be installed in areas of relatively loose soils, such as sand or sandy gravel.

Bored wells are constructed with a large auger. The depth of a bored well is usually about 50 to 70 feet and is commonly constructed in soft materials such as sand, silt, clay, and soft rock. Contamination risk is similar to driven wells.

All other types of wells, including those constructed by a combination of jetting and driving, are considered **drilled wells**. These wells can be more than 1,000 feet deep. Wells that penetrate material that is not hard and solid require a casing and a screen to prevent the inflow of sediment, which could cause the well to collapse.

3.10 Problems Due to Natural Minerals and Other Chemicals

Table C lists problems associated with some groundwater sources due to naturally occurring minerals and materials in the soil.

The methods and procedures selected for the treatment of a specific groundwater depend upon the results of chemical and bacteriological analyses. Chlorination is usually used for bacteriological treatment, and several treatment processes may be used for the removal of minerals or gases and turbidity. These topics are discussed in Chapter 4 – Water Treatment.

Problems Due to Natural Minerals and Materials

Problem	**Cause**	**Solutions**
Hard water (scales/deposits in kettles and water heaters)	Excess magnesium and calcium	Water softeners Reverse osmosis Distillation
Rusty (red to brown) staining of fixtures and laundry and/or metallic taste	Excess iron	Aeration-filtration Chlorination-filtration Distillation Ion-exchange Greensand filtration
Black staining of fixtures and laundry and/or metallic taste	Excess manganese	Aeration-filtration Chlorination-filtration Distillation Ion-exchange Greensand filtration
Rotten egg smell	Hydrogen sulfide	Chlorination-filtration Greensand filtration Aeration-filtration

Water has a laxative effect	Excess sulfate	Reverse osmosis Distillation
Turbidity/grittiness	Mud/silt/clay/sediment in water	Sediment filters
Organic (tea) color	Tannins	Chlorination-filtration Ozonation-filtration

Table C: Problems Due to Natural Minerals and Materials

3.11 Well Components

The components that make up a well system include the well itself, the well house or building, the pump, and the related piping system. Many components of a well cannot be observed. Components that make up the well itself are discussed in this section. Many of these components are shown in Figure 3.5.

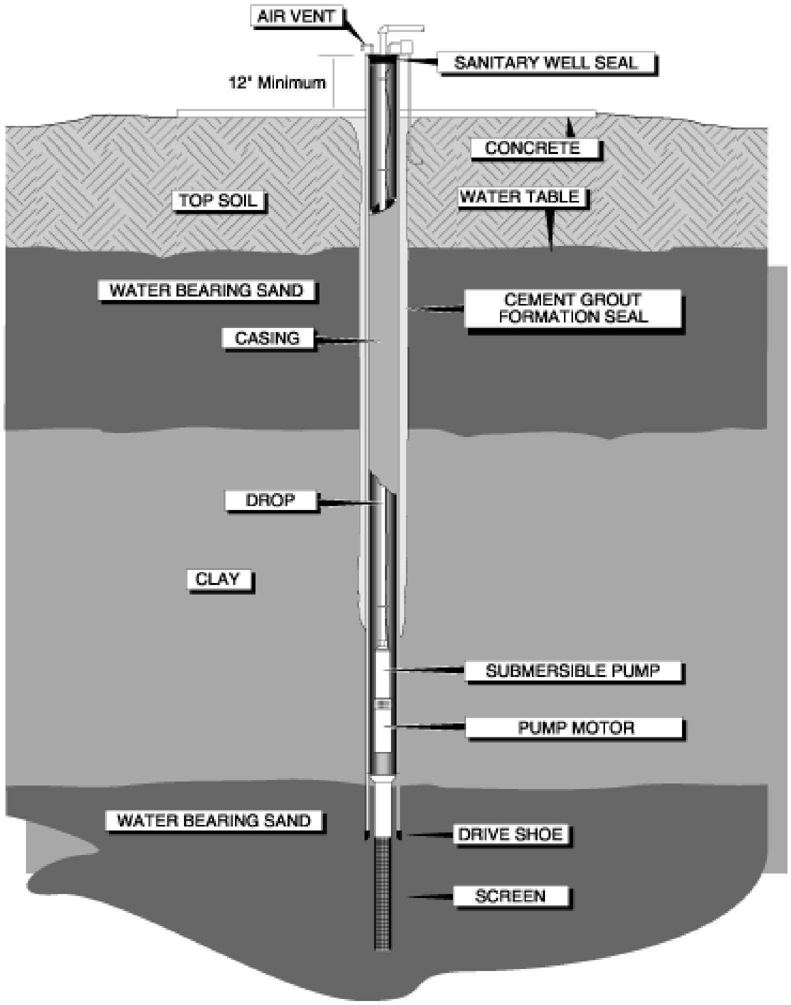


Figure 3.5: Well Components

Well Casing

The well begins as a hole in the ground called the borehole. During construction, the well driller installs in the borehole a steel or plastic pipe called the well casing. The borehole is protected from collapse by the casing. The well casing provides a column of stored water and a housing for the pump mechanisms and discharge pipe. The well casing also prevents contaminants (either surface or subsurface) from entering the water source. The well casing must extend a minimum of twelve inches above the finished grade.

Casing Vent

When water is being pumped up out of a well, the water level in the casing drops. This can create a vacuum inside the well casing. A vent allows air into the casing preventing the vacuum condition. The vent should terminate a minimum of eighteen inches above the floor or ground with a bend pointing downward at or above the top of the casing. The opening of the vent should be screened with #24 mesh stainless steel. The screen must be small enough to prevent the entry of insects, rodents, or dust.

Sanitary Seal

To prevent contamination of the well, a sanitary seal is placed on the top of the casing. The type of seal varies depending upon the type of pump used. The sanitary seal may have openings for power and control wires, pump support cables, a draw-down gauge, discharge piping, pump shaft, and air vent while providing a tight seal around each of them.

Electrical Cable

If a submersible pump is being used, a waterproof electrical cable extends from the top of the unit down the inside of the casing to the pump’s electric motor. The submersible electric motor is attached to the lower end of the pump assembly. Generally, the cable is secured to the drop pipe.

Well Pad

The well pad provides a ground seal around the casing. The pad is constructed of reinforced concrete 6 feet by 6 feet (6 inches thick) with the wellhead located in the middle and the pad sloped away from the wellhead. The well pad prevents contaminants from collecting around the well and seeping down around the casing.

Grout

The **annular space**, the space between the borehole and well casing, or between an inner and an outer casing**,** presents a direct pathway for contaminants to enter a well and into the groundwater. Sealing the annular space helps prevent this contamination. Grouting is required by regulation.

A cased well must be grouted with a watertight cement grout, sealing clay, bentonite, or an equivalent material. Grout, in liquid form, is pumped into the annular space where it solidifies. There must be at least ten feet of continuous grouting within the first twenty feet below the ground surface. ADEC Drinking Water Regulations 18 AAC 80 also allows alternate methods of grouting.

Pitless Adapter

A pitless adapter (Figure 3.6) is a unit designed to permit water service pipes to pass through the wall of the well casing below the frost line. It also prevents the entrance of contaminants and allows unobstructed access to the inside of the casing and the components within the well.

Installation of a pitless adapter requires cutting a hole in the side of the well casing below the frost line. A fitting to accommodate the pump discharge line inside the casing is inserted into the opening in the well casing. The other part of the pitless adapter connects to the distribution pipe or service line on the outside of the casing. Watertight connections are assured by a system of rubber seals compressed by clamps or by the weight of the equipment itself. The top of the casing, which provides access to the well, must be sealed and vented as discussed above.

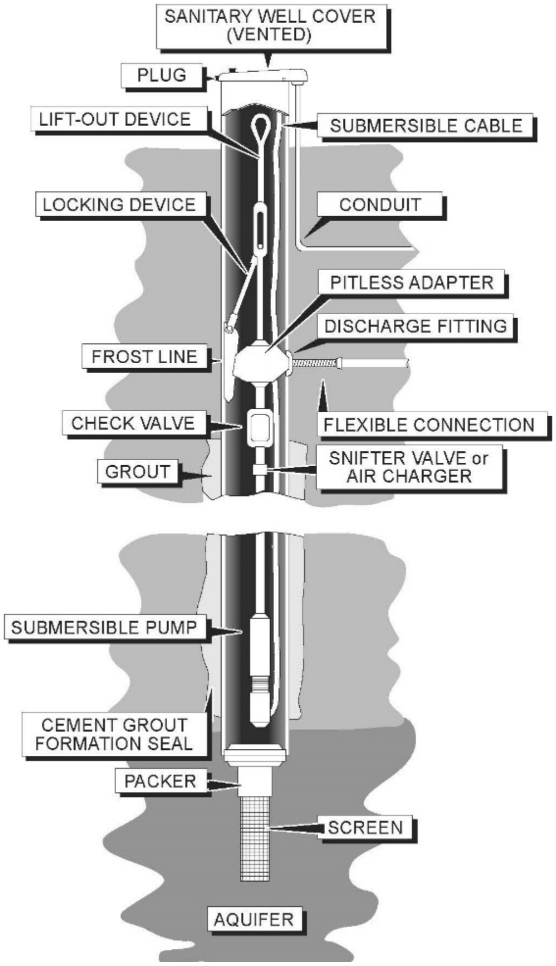


Figure 3.6: Pitless Adapter

Drop Pipe – Riser

The drop pipe or riser is the pipeline leading from the pump up to the wellhead. It assures adequate support so that an above-ground pump does not move and so that a submersible pump is not lost down the well. The drop pipe is the pipe through which water is transported from the pump up to the water system distribution piping.

Foot Valve

A foot valve is a type of check valve. The foot valve is installed at the bottom, or foot, of the drop pipe. Water flow forces the valve open when the pump starts and closes when the pump stops. For instance, when the pressure in a hydropneumatic tank drops to 30 psi, the pump starts. When the pump starts, the foot valve opens and water flows to the pressure tank until the shutoff pressure of 60 psi is attained. At 60 psi, the pump shuts down, and the foot valve then closes. This prevents the water from flowing back down into the well and keeps the drop pipe and water distribution lines full. Because of freezing concerns, some wells have a weep hole in the riser, so the riser pipe does not have standing water in it. Small particles of sand or foreign material may cause the foot valve not to seat tightly. A properly functioning foot valve is particularly important for wells with a lineshaft turbine pump because if the foot valve leaks, the water will drain down out of the riser pipe and the pump will lose its **prime**.

Well Screen (or filter pack)

Screens, or slotted casings, are installed at the intake point(s) on the bottom end of a well casing or the end of the inner casing on a gravel pack well. These screens perform two functions:

1. Supporting the borehole
2. Reducing the amount of sand that enters the casing and the pump

In an artificially gravel-packed well, the aquifer formation material around the well screen is removed. The removed materials are replaced by more coarse material of high uniformity, approximately five times the diameter of the native material, such as pea gravel. It is designed to:

- increase the permeability of the formation and screen;
- exclude virtually all of the formation material beyond the gravel pack; and
- stabilize the formation.

The filter pack material is poured down the annular space between the drill hole and casing before the installation of the grout.

The size of the slots for the screen or perforated pipe is based on a sieve analysis of samples of the aquifer material. The screen manufacturer usually conducts the sieve analysis. If the slot size is too large, the well may yield sand when pumped. If the slots are too small, they may become plugged with fine material and the well yield will be reduced. In a drilled well, the screens are usually placed after the casing has been installed. In a driven well, the screen is a part of the drive assembly and is sunk to its final position as the well is driven.

Packers

Packers are devices that create sand-tight seals between the top of a telescoped screen assembly and the casing... Packers are made of material such as neoprene or rubber that will not impart taste, odor, toxic substances, or bacterial contamination to the well water.

Lightning (Ground) Protection

Voltage and current surges produced in power lines by lightning discharges are a serious threat to electric motors. High voltage can easily perforate and burn the insulation between motor windings and motor frame. A **submersible pump** motor is highly vulnerable to voltage and current surges because it is submerged in water. Groundwater serves as the natural ground sought by an electrical discharge. There are simple lightning arresters available to protect motors from near-miss lightning strikes although arresters are seldom effective against direct hits.

Small water system operators unfamiliar with the basics of electricity and lacking hands-on experience should contact a local electrical firm or pump service company to install lightning protection or perform electrical maintenance and/or repairs.

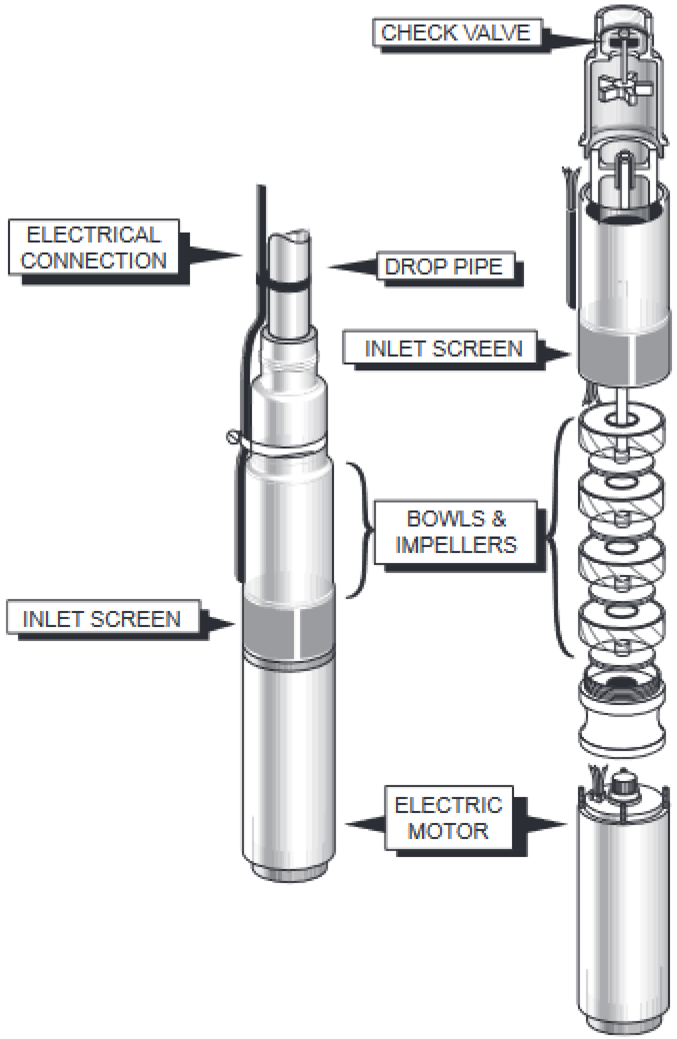
3.12 Well Pumps

Three common centrifugal pumps installed in groundwater systems are submersible turbines, lineshaft turbines, and jet-equipped centrifugal pumps.

A submersible pump (Figure 3.7) is a vertical turbine pump with the motor **close-coupled** to it and placed in a watertight enclosure. The pump and motor are submersed in the well and are connected to the surface by the drop pipe and electrical connections. It is a pump that is usually designed to be multi-staged (the pump has more than one **impeller**). How far the water must be lifted and how much pressure is needed in the distribution system determines the number of stages.

Since the pump is submerged, it requires no suction line, and the motor is located on the bottom of the pump. The motor is sealed and designed to operate under water. No external lubrication is required. The motor is completely enclosed and may be oil-filled; however, most new models are water-filled. The entire unit is lowered into the well on the end of the drop pipe.

Submersible pumps are extremely reliable, and maintenance is minimal since there is no line shaft or oil tube requiring operator attention. However, if either the pump or motor needs to be repaired or replaced, the entire pump must be removed from the well. Removal of a submersible pump requires specialized equipment, such as a truck with a boom and winch to raise the drop pipe and pump.



igure 3.7: Submersible Pump

The lineshaft turbine pump (Figure 3.8) is also a vertical turbine pump with multiple submerged bowls and impellers. The motor is mounted above ground, usually on a cement pedestal, with a vertical shaft that connects the motor to the pump at the bottom of the well column. A turbine pump will usually be staged with more than one bowl and impeller to produce the required pressure. The water from one stage will be discharged into the suction eye of the next stage, gaining pressure with each successive stage. The size or diameter of the first (lowest) impeller dictates the volume capacity of the pump in gallons per minute (gpm).

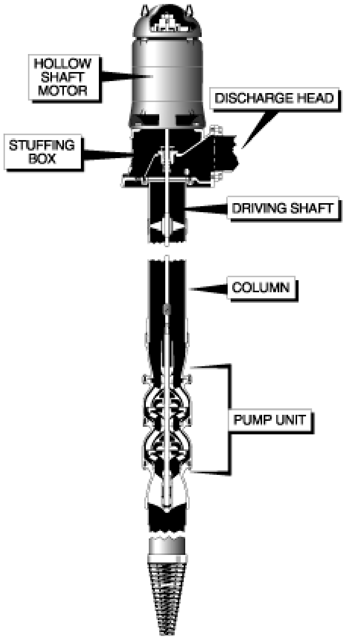


Figure 3.8: Lineshaft turbine

Vertical turbine pumps contain the following parts: power source, discharge head, pump column, pump shaft, shaft bearings, and the pump assembly (bowls and impellers) itself.

A jet pump (Figure 3.9) is a combination of a centrifugal pump and a venturi tube. The jet pump includes a centrifugal pump above ground, a drive pipe from the centrifugal pump down to the jet nozzle, a jet nozzle, a venturi tube, and the suction pipe for the centrifugal pump (also the discharge for the jet nozzle). The jet nozzle receives water at high pressure from the centrifugal pump, and as it passes through the venturi jet, the water speed (velocity) increases, and pressure drops in the nozzle. The velocity of the water coupled with the pressure drop allows water to be sucked into the inlet of the unit. A portion of the water is always re-circulated back down to the nozzle, which makes jet pumps inherently inefficient.

Jet pumps are seldom used in Alaska public water systems because of their low efficiency. They are commonly used for private wells because of their initial low cost and low maintenance. Jet pumps are used successfully in shallow wells and small diameter domestic wells.

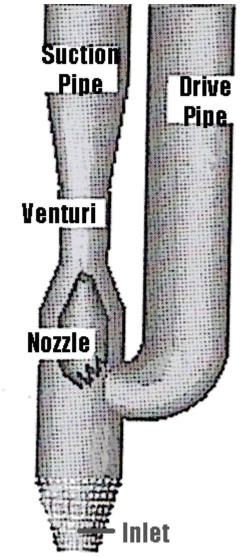


Figure 3.9: Jet pump

3.13 Well System Components

Specialized equipment is required to meet the State of Alaska construction standards for drilling a well and installing the well casing, screen, and various components that make up a well system.

An understanding of the components that make up your well system will assist you with maintenance and troubleshooting. Not every well component an owner/operator may encounter is covered in this section.

Check Valve
The check valve acts as an automatic shutoff when the pump stops. Water is prevented from draining back down the drop pipe providing the same reverse flow functions as the foot valve (Figure 3.10). The check valve is usually above ground located on the discharge side of the pump.

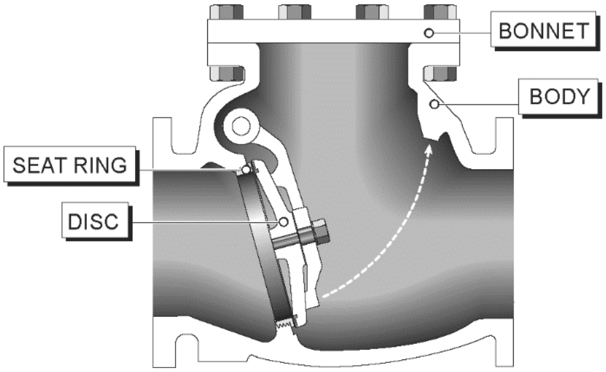


Figure 3.10: Swing Check Valve

Sample Tap

A spigot, referred to as the raw water sample tap, is located in the well house, on the pump discharge line before any storage or treatment and is used to sample water coming directly from the well.

Flow Meter

A flow meter records the total amount of water produced by the well in gallons or cubic feet. Well discharge data can be used to track pump efficiency. It can also be used to establish fair rates for customers. Also, any unexplained increase in water usage may be the first indication of a water leak.

Blow-Off Valve

A blow-off valve is normally located in the well house before the main control valve (isolation valve). The blow-off valve is used to flush the well of sediment or chlorine after emergency disinfection.

Isolation Valve

In order to work on the pump, it must be isolated from the rest of the system. A gate valve or butterfly valve installed on the discharge line can serve as an isolation valve.

Pressure Gauge

The pressure gauge on a pump should be installed in the well house on the discharge piping, but as far from the pump as practical. If mounted on the pump casing directly, it will not give accurate readings.

A properly operating discharge pressure gauge is a handy tool to diagnose pump problems. If readings begin to show a steady increase in pressure, there may be an obstruction building downstream from the gauge. If gauge readings show a steady decrease in pressure, check for a leak or break in the piping downstream. If your system is not equipped with a flow meter, the flow rate can be estimated using the readings from the pressure gauge, although a flow meter is recommended.

3.14 Groundwater Withdrawal

As the well is pumped, groundwater flows through the aquifer toward the well and is removed from the aquifer surrounding the well. The level of the water table in the vicinity of the well will be lowered. This lowering, or draw down, causes the water table or artesian pressure surface, depending on the type of aquifer, to take the shape of an inverted cone called a **cone of depression** (Figure 3.11).

The cone of depression, roughly conical in shape with the well at the center axis, is produced by the extraction of water from a well. As a pump turns on and off, the depth of water will move up and down. If the pump were shut off for several hours and the water level allowed to recover and stabilize, the level would be called the static water level.

At increasing distances from the well, the drawdown of water decreases until the slope of the cone merges with the static water table. The distance from the well at which this occurs is called the **zone of influence**. The zone of influence is not constant but tends to expand with continued pumping. Any contamination in this zone will be drawn into the well. At a given pumping rate, the shape of the cone of depression depends on the characteristics of the water-bearing formation. Shallow and wide cones will form in highly permeable aquifers composed of coarse sands or gravel. Steeper and narrower cones will form in less permeable aquifers. As the pumping rate increases, the drawdown increases, and consequently the slope of the cone steepens.

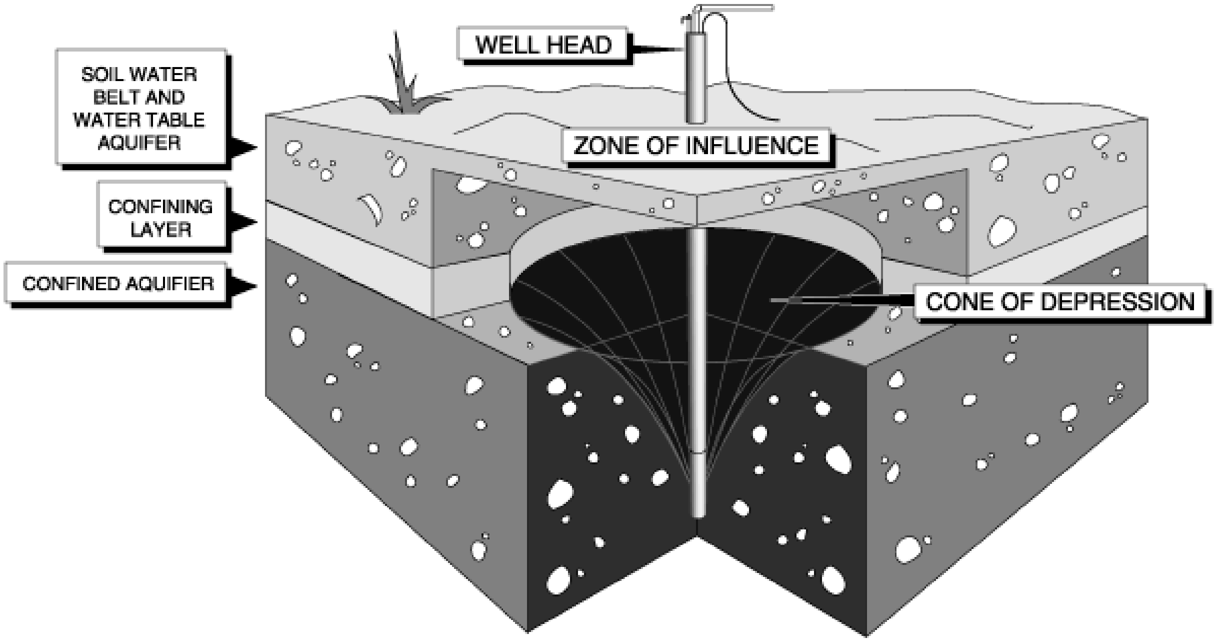


Figure 3.11: Cone of Depression

3.15 Well Log

A **well log** is a written report produced by the well driller during the drilling and includes:

- A description of the material (soil, rock, or ice) that was encountered during drilling
- The depths at which they occurred
- The depth to groundwater
- The total well depth
- The length, diameter, wall thickness, and type of casing
- Location and type of casing perforations or screen
- Location and type of grouting

The well log report should also include the yield and results of the drawdown test and the names of the water system owner and the well driller. This original information will be collected when the driller performs a pump test. Pumping tests, when properly performed, provide information about the performance and efficiency of the well and the pump.

Measurements of static water level, pumping water level, well yield, and discharge pressure are recorded on the original well log report. At a minimum, the system operator should repeat these measurements quarterly. From these measurements, the operator can determine the drawdown, specific capacity, and pump performance. These results may then be compared with the original well log and previous results to estimate changes in well and/or aquifer conditions and pump performance.

You should receive a copy of your well log report from the well driller within 30 days. Alaska state law requires that you send a copy of the well log to DNR within 45 days. The well driller is required to file a copy with ADEC within 30 days after completion of the well. Appendix 1 is an example of a Well Log Report.

3.16 Well Production

If you use groundwater as your source, the following well production terms and well testing terminologies are important:

- **Static water level** – This is the level where water stands when the well is not being pumped. It is generally expressed as the distance in feet from the top of the well casing down to the water level in the well.
- **Pumping water level** - The level at which water stands when the well is being pumped. Pumping level is measured the same as the static water level.
- **Drawdown** - The difference in feet between the static and pumping water levels in a well (Figure 3.12).

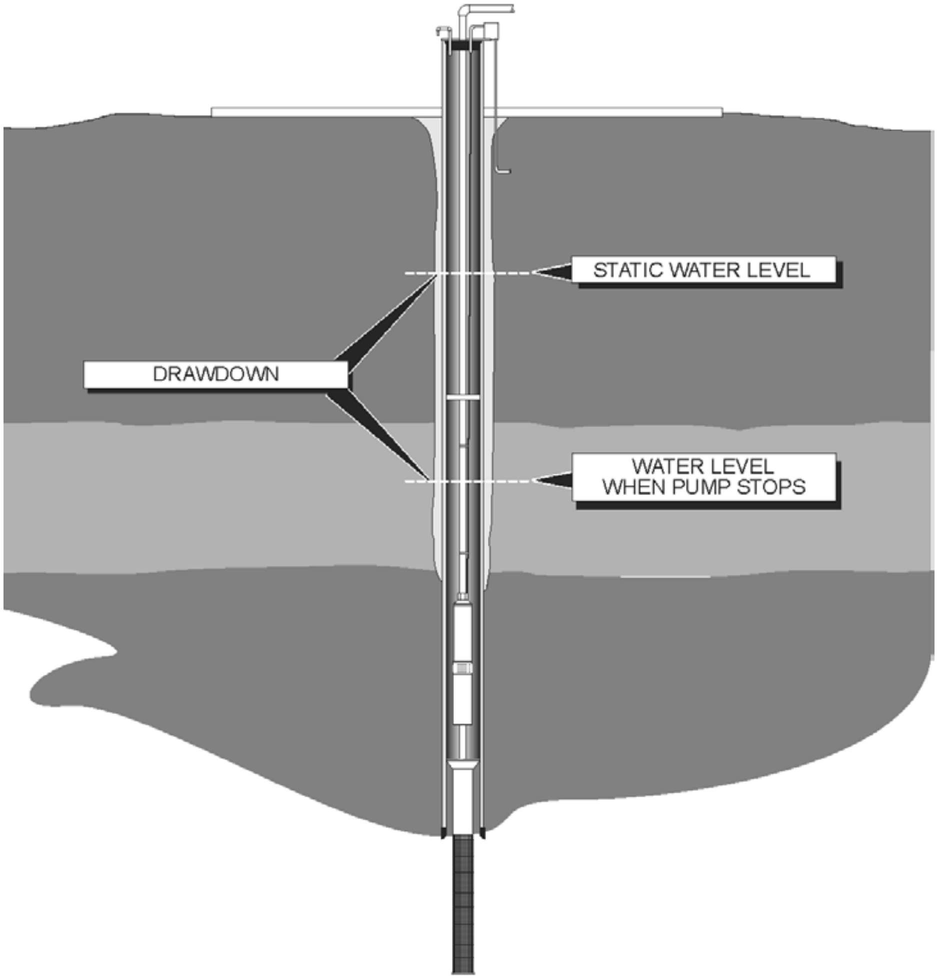


Figure 3.12: Well Drawdown

- **Well capacity (Yield)** - The volume of water per unit of time discharged from the well is usually recorded as gallons per minute (gpm) or gallons per day (gpd).
- **Specific capacity** - The well yield per unit of drawdown. Commonly expressed as gpm/ft.
- **Well development** - Involves vigorously pumping the well to help clean out drill cuttings and to maximize production of the well. Development should result in a well that produces sand-free water when operated properly.
- **Top terminal height** - The casing head must extend twelve inches minimum above the finished ground surface or pump house floor, and twelve inches above the local surface runoff level.

Well depth can be measured by using a weighted line or by measuring the drill pipe in the hole when drilling is completed. Tie a heavy weight to a string and lower it into the well until it touches the bottom and measure the length of the string used. The depth should be close to the depth recorded on the well log report.

A variety of methods are used to determine the static water level in a well, but all wells should have an access port or some feature that allows water level measurements to be easily taken.

Two common methods used to measure static water level are the electric tape method and the air line method. The electric tape method consists of a battery connected to a pair of insulated wires molded into a measuring tape. When the wires touch the water, the circuit is completed, and a sensor (meter, light, or buzzer) indicates that the water surface has been reached and the depth can be read from the tape.

The air line method measures the water level depth by determining the air pressure required to push all the water out of a submerged tube of a known length. There is a direct correlation between pressure (pounds per square inch, psi) and feet of water (0.433 psi = 1 foot of water).

Submersible well level transducers are also available which can be installed in a well and provide continuous level readings via a remote display.

Pumping level is measured the same as the static water level.

To determine drawdown, first determine the static water level. Then, after the well has been pumping at a constant rate for several minutes, or until you are confident that the pumping water level has stabilized, measure the depth to the water again. The difference between these two readings is recorded as feet of drawdown.

Specific capacity is calculated by dividing the well yield in gallons per minute (gpm) by the drawdown. This data should be plotted on a chart so you can visually track the performance of the well. Industry standards suggest that a ten percent reduction in specific capacity signals that it is time to consider pump maintenance and/or well rehabilitation.

The frequency of well testing depends entirely upon the performance of your well. For example, a well that produces plenty of water, recovers quickly, has good water quality, and has a consistent drawdown level may only need to be tested occasionally. Other wells may need to be monitored constantly. Initially, you may want to test your wells weekly, monthly, or bimonthly to become comfortable with the procedures.

Chapter 4 – Water Treatment

4.1 Introduction

The primary purpose of water treatment is to produce water that is safe to drink. Unfortunately, unless the water is also pleasant to drink, it may be rejected by the consumer in favor of an alternate supply that may not be safe.

Consequently, water delivered to the consumer from a public water supply should meet certain basic requirements, such as:

- It should contain no disease-causing organisms.
- It should contain no toxic metals or chemicals.
- It should be colorless and clear.
- It must taste good and be free from offensive odor.
- It should be non-corrosive.
- It must be free from objectionable gases, such as hydrogen sulfide.
- It should be free from objectionable staining minerals, such as iron and manganese; and
- It should be plentiful and low in cost.

Alaska is fortunate to have some very high-quality water sources. Some groundwater sources, for example, are of such high quality that they can be piped directly from the well to the consumer with no treatment whatsoever. However, with a few exceptions, it is difficult to find a source of water that will meet all of the basic requirements for a public water supply without some type of chemical addition or treatment.

For most small systems, water treatment is relatively simple. Various low-flow technologies are available that enable small systems to remove or inactivate undesirable contaminants and make the water safe for consumers at a reasonable cost.

Occasionally, source waters are of such poor quality that a small system must resort to more complicated treatment methods, such as those used by large municipal systems. This manual discusses only the chemicals and “passive treatment” methods utilized by Alaska’s Small Treated and Untreated water systems.

Passive treatment includes processes that require only minimal operator interaction, such as cartridge or bag filtration, ion-exchange softening or ion-exchange iron removal, ultraviolet disinfection, sand filtration with no chemical addition (commonly referred to as straining), or pH adjustment using passive limestone contactors.

The type of treatment selected depends upon the contaminants that need to be inactivated or removed from the water. Contaminants, and other objectionable characteristics of water, which are of concern include the following categories:

- Turbidity and particulate matter
- Microorganisms

- Iron and manganese
- Color, taste, and odor, and other organics
- Objectionable gases
- Hardness
- Nitrate
- Corrosive properties
- Radon
- Biological nuisances (algae, iron bacteria, etc.)

Refer to Appendix 2 for a list of potential chemical contaminants and their health effects.

The following discussion will address each of these categories individually. Treatment methods and strategies, both passive and those involving chemical addition, that are typically used by Small Treated and Untreated water systems to deal with each category will be presented. Some methods may be applied to more than one category.

There are many books and manuals that discuss the water treatment methods that are common to larger systems. Operators interested in more detailed information should refer to these resources. Please contact the Operator Certification Program at the Juneau ADEC office to obtain additional reference materials on water treatment.

4.2 Water Quality Problems and Solutions

Problem	**Typical Corrective Procedures**
Fine sand, clay, other particles	Remove using a mechanical filter
Bacterial contamination	Remove the source of contamination or treat using chlorination or other forms of disinfection
Hydrogen sulfide gas (rotten egg odor)	Remove using chlorination and a sedimentation filter or an oxidizing filter followed by activated carbon filter
Many odor and taste problems other than rotten egg odor	Remove using activated carbon filter
Suspended iron and manganese particles	Remove using a mechanical filter
Small amounts of dissolved iron	Remove using a water softener
Higher amounts of dissolved iron and manganese	Remove using a potassium permanganate regenerated oxidizing filter
Very high amounts of dissolved iron	Remove using a chlorinator followed by a mechanical filter
Hardness	Treat using a water softener
Acidity	Treat using a neutralizing filter

Volatile organic chemicals, trihalomethanes, certain pesticides, and radon	Remove using an activated carbon filter
High total dissolved solids, sodium, sulfates, nitrates	Remove using reverse osmosis unit or a distiller
Heavy metals (lead, mercury, arsenic, cadmium)	Remove using reverse osmosis unit or a distiller

Table D: Water Quality Problems and Solutions

4.3 Removal of Turbidity and Particulate Matter

Turbidity is a condition in water caused by the presence of suspended matter. Very fine silt and clay are primarily responsible for turbidity. However, any suspended material, including non-dissolved organics (bits of vegetation for example) and precipitated inorganics, that will not readily settle contributes to turbidity. Some particles are so small they will not settle at all. These tiny, suspended particles are known as **colloids** or colloidal particles. Colloids are generally too small to be removed by passive filtration and generally require complex treatment processes for removal.

In surface water sources larger particles, such as leaves and twigs, must be removed to protect pumps and other equipment. In groundwater, sand may also be a problem.

4.3a Filters

The basic concept behind nearly all filters is similar. The contaminants are physically prevented from moving through a filter either by screening them out with very small pores and/or, in the case of carbon filters, by trapping them within the filter matrix by attracting them to the surface of carbon particles.

Micron or sub-micron filtration refers to a measure of how good the filter is at removing particles from the water. A micron is a unit of measure. One micron is 1/1,000,000 of a meter or about 1/100 the diameter of a human hair. A filter that removes particles down to 5 microns will produce fairly clean-looking water, but most microorganisms, i.e., bacteria, C*ryptosporidium*, *Giardia*, etc. will pass through the pores. A filter must trap particles one micron or smaller to be effective at removing *Cryptosporidium* oocysts or *Giardia* cysts. Viruses cannot be physically removed by any of the water filtration methods.

4.3b Cartridge and Bag Filters

A cartridge filter (Figure 4.1) is made up of a housing (sump and cover) and a removable cartridge (element). The cartridge itself is a disposable item. These devices are suitable for filtering water with small amounts of suspended material or if a small volume of water is required.

In a cartridge filtration system, the replaceable inner element, which is similar to an automobile oil or air filter, consists of a membrane folded in an accordion fashion with a molded retaining device. The package is sealed into a pressure vessel. As the element becomes soiled, raw water will pass further down the pleat until the whole surface is soiled.

An extra filter cartridge or canister is often included with the initial purchase. They also may be available from the same dealer, at a plumbing supply store, or by mail order. Always keep spare filter cartridges on hand. Ensure that the filter unit is NSF/ANSI Standard 61 certified.

When you start to experience low water pressure, the filter is probably full (becoming plugged) and needs replacement. Replace the filter cartridge and, before resealing the filter, remember to put a quarter teaspoon of household bleach into the filter sump to kill any bacteria introduced during filter replacement.

Remember to handle the replacement filter **aseptically** (wash your hands and use clean latex gloves). Do not put the system back online for ten minutes. This gives the bleach sufficient contact time to disinfect the unit and kill potentially harmful pathogens. Flush the system to waste if this option is available. If the filter cartridge has a by-pass valve in the assembly, remember to put it back into the service position after disinfection.

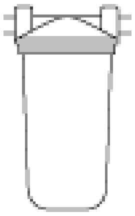


Figure 4.1: Cartridge Filter

Bag filters (Figure 4.2) can be used to filter larger microorganisms such as *Giardia* and certain other types of protozoa. With the bag filter, one or more layers of fabric are formed into a seamless bag that can be sealed into a pressure vessel. The element for this type of filtration may be woven or non-woven, and fibers may be either natural or synthetic.

One type of bag filter made by the 3M Company has many layers of fine fabric interwoven with a more porous fabric. As in sand filtration, particle removal occurs deep in the fabric, leading to longer filter runs and less pressure loss through the filter than with cartridge filters. Where small cartridge filters are available with either stainless steel or plastic housings, bag filters are typically installed using stainless steel housings.

In both the bag and cartridge filter designs, excessive pressure loss indicates that the filter element must be replaced. Unlike traditional filtration technologies, backwashing is usually not used to clean the bag or the cartridge filter. Instead, the whole bag or cartridge is replaced with a new one. The old bag is disposed of along with the accumulated dirt and debris.

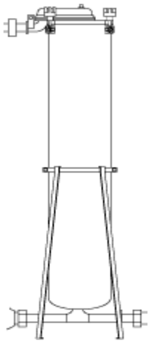


Figure 4.2: Bag Filter

Some cartridge filters can be cleaned by backwashing but will still need periodic replacement. Because operators spend less time cleaning equipment, savings in labor costs offsets the expense of replacing the filter element. Another benefit is not having to dispose of wash water with a high sediment load. Without having to dispose of this waste, costs are cut even further.

The following sequence can be used as a guide for changing the elements in both cartridge and bag filters:

- Shut off the inlet and outlet isolation valves,
- Drain the pressure from the system - this can be accomplished by opening the filter to waste valve,
- Put on latex gloves,
- Remove the housing cover,
- Remove the filter element - place the filter element in a sealed bag for disposal,
- Using a chlorine solution of one to five percent (household bleach is approximately 5% chlorine) disinfect the interior of the housing,
- Install the filter element,
- Inspect the seal on the housing and replace, if damaged,
- Replace and tighten the housing or housing bolts - do not over tighten the housing,
- If not already open, open the filter to waste valve,
- Slowly return flow to ½ of normal,
- After five to ten minutes, close the filter to waste valve and open the inlet and outlet

valves,
- Record initial pressure gauge reading across each stage and flow through the filters; and
- Record the date you change the filter.

Some small systems use a combination cartridge/bag filter design to increase the effectiveness of *Giardia* removal. There is no set standard cartridge/bag filter design, but the design must include an approved *Giardia* barrier filter. Contact the Drinking Water Program at your local ADEC office for names of approved filters providing *Giardia* protection.

Typically, installations include a *Giardia* filter preceded by one or more pre-filters and/or basket strainers. The pre-filters extend the life of the *Giardia* filter by removing excessive debris and they are less expensive to replace than a *Giardia* filter. Typical combinations of filters and pre-filters (Figure 4.3) are:

- 50- and 25-micron pre-filters followed by a 5-micron *Giardia* filter
- 50- and 5-micron pre-filters followed by a 2.5- or 1-micron *Giardia* filter
- 25- and 5-micron pre-filters followed by a 2.5- or 1-micron *Giardia* filter
- Backwashable basket strainers or mixed media filters with 50-, 25-, or 10-micron effective size and 95% removal efficiency, followed by a 5-, 1.5-, or 1-micron *Giardia* filter

Be aware that modifications must be approved by the Drinking Water Program at ADEC. Some typical modifications that must be approved are changing the filter micron size, eliminating or bypassing a component on the system, and replacing or adding new components to the system.

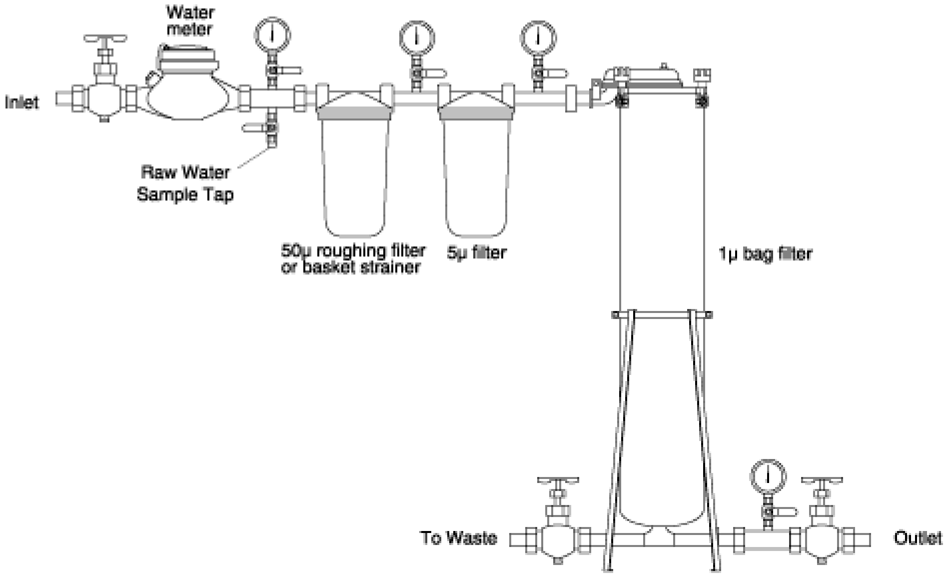


Figure 4.3: Cartridge Bag Filtration

4.3c Sand Filters

Direct sand filtration, filtration without the addition of chemicals will remove a good portion of the larger suspended particles responsible for turbidity. This passive, direct sand filtration is simply a fine, straining process. Very tiny turbidity-causing particles (including colloids) usually will not be adequately removed by direct sand filtration.

In small systems, these types of sand filters are usually installed inline as “pressure filters.” This means that the filtering sand is installed inside a sealed tank that is under the same pressure as the distribution system; not open to the atmosphere like a typical gravity filter. The tanks are usually cylindrical and may be oriented either horizontally or vertically. Water usually flows from top to bottom. In either case, they have the same internal components (Figure 4.4). Inlet piping completes the system.

The exit pipe at the bottom is valved to allow backwash and filter-to-waste flow. Graded gravel provides support for garnet sand, which in turn supports graded silica sand. Anthracite coal, used to adsorb dissolved organic material, is often layered on top of the silica sand (refer to Section 4.6a).

Sand filters must be cleaned periodically using the classic backwash process. Backwashing is the process when the flow of water is reversed through the filter to clean the filter by removing material trapped by the media during the filtration process. The backwash sequence and timing are often automated. The process requires a supply of water and results in a silt-laden backwash waste that must be properly disposed of. These requirements mean that direct sand filters have the disadvantages of requiring frequent operator attention and expensive backwash equipment.

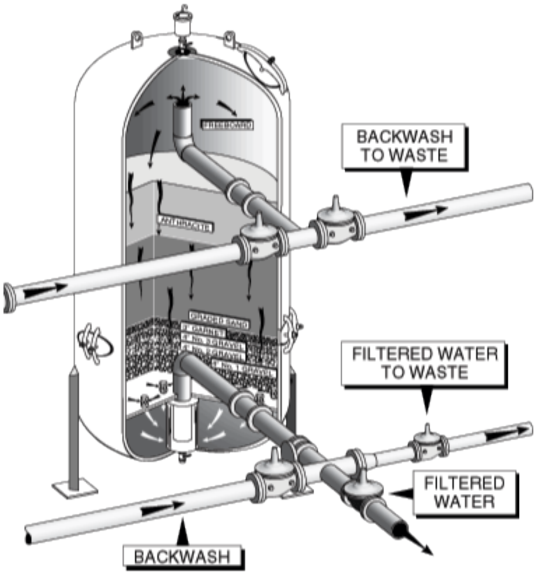


Figure 4.4: Pressure Filter System

Another operational handicap is the fact that the operator cannot directly observe the operation of the filter unless the pressure filter has a viewport. Access to the inside of the vessel is through a sealed hatch.

4.3d Sand Traps

Most wells produce some sand. If sand is excessive, a sand trap can be installed to prevent sand from entering the piping system. Normally, sand traps consist of a large tank with a series of internal baffles or chambers. The baffles or chambers slow the velocity of the water so that gravity will cause the sand and heavier silt particles to settle to the bottom of the tank. Sand and silt are removed from the tank by a blow-off valve located on the bottom of the tank.

4.3e Screens

Screens occasionally are used to remove large chunks of material from surface water sources. Screens protect the pumps, the piping system, and other inline equipment from excessive wear and from plugging. Screens remove such things as leaves, twigs and branches, fish, animals, plastics, fabric, and anything else that may be carried in or on the raw water source. They are placed on the raw water inlet end of piping systems that are used to withdraw water from lakes, reservoirs, rivers, and streams. Screens are also recommended for roof catchment systems. They must be inspected periodically, and material trapped on the screen removed so that inlet flow is not reduced to an unacceptable level.

In groundwater systems, all submersible well pumps and drop pipes for above-ground well pumps have screens to prevent rocks and sand from entering the pump. Even with screens, not all sand can be eliminated from some groundwater sources.

4.4 Removal of Microorganisms

As discussed in detail in Sections 2.6 and 2.7, a variety of microorganisms are responsible for many waterborne diseases. These pathogenic microorganisms include bacteria, protozoa, and viruses.

The waterborne diseases they cause include typhoid fever, cholera, dysentery, hepatitis, and giardiasis among others. Pathogenic microorganisms must be removed or inactivated before water is safe to drink.

One of the very best ways to eliminate pathogenic microorganisms from drinking water is to choose a high-quality raw water source and do everything you can to protect that source from contamination. Unfortunately, that is not always possible, particularly with surface water sources.

Disinfection is the most common method of inactivating pathogenic microorganisms. Disinfection is of such critical importance to water treatment that a separate chapter in this manual is dedicated to the process (refer to Chapter 5).

4.5 Removal of Iron and Manganese

Iron and manganese in drinking water can both be a major nuisance. They will stain laundry, bathroom fixtures, and give an objectionable taste to foods and beverages. Iron leaves a classic “rusty” red stain, whereas manganese leaves a darker, greenish-black stain. Iron and manganese are common water contaminants found in Alaska’s groundwater, but they are not considered health hazards.

Common treatment methods for Small Treated systems include removal by ion exchange and stabilization with sequestering agents. Systems that add oxidizing chemicals to precipitate the iron and manganese, which is then filtered out of the water, are classified by ADEC Operator Certification Program as Water Treatment Class 1 – 4 systems, not as Small Treated systems, and require water treatment certification. Treatment using oxidation is discussed in higher level water treatment courses.

4.5a Ion Exchange

Iron and manganese removal by ion exchange involves passing the water through a column containing a special granular, bead-like ion exchange material. Several different types of ion exchange materials are in use, including natural substances called **zeolites** and synthetic resins. Figure 4.5 illustrates an ion exchange system.

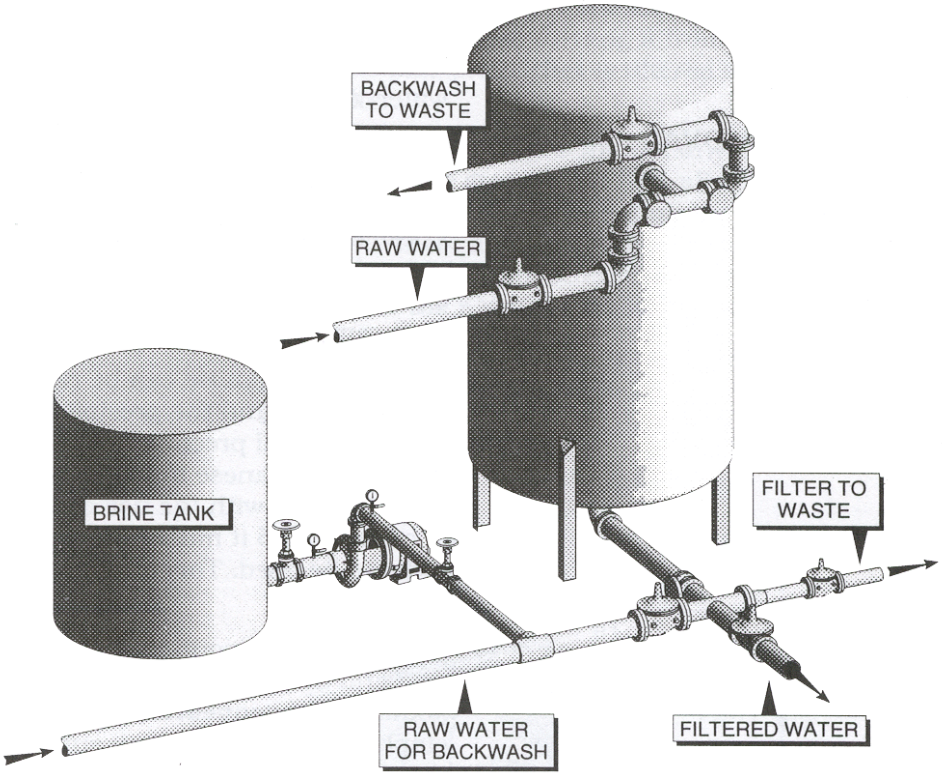


Figure 4.5: Ion Exchange System

The exchange resin is placed in a pressure vessel, and salt brine is flushed through the resin. The sodium ions in the salt brine attach to the resin particles, which are then said to be “charged.” Once “charged,” the raw water, which contains iron and manganese, is passed through the resin and the iron and manganese replace the sodium ions, i.e. the iron and manganese ions are exchanged for the sodium ions. The resulting treated water has no iron and manganese but does contain sodium ions.

The exchange column will continue to remove iron and manganese until all the sodium ions on the exchange resin have been replaced. At this point, it is necessary to regenerate the exchange resin. This is accomplished by passing a strong salt brine through the exchange medium. The extremely concentrated salt brine is capable of reversing the exchange process and replacing the iron and manganese with sodium ions. The waste generated during the recharge process is diverted and disposed of. Then the exchange column is ready to be put back into service.

The ion exchange process is only applicable for waters in which the iron and manganese are in a soluble form and their concentration is less than 0.5 mg/L. Also, this method should only be considered for waters free of dissolved oxygen. If oxygen is present the iron and manganese will be oxidized and come out of solution as a precipitate. A precipitate is a substance that can be dissolved in water but forms into a solid as a result of a chemical reaction or change in conditions. For example, oxygen will combine with iron in water to form iron oxide (oxidation) which will fall out of solution (precipitate) in a form that looks like rust.

The ion exchange process will not work with precipitated materials. Precipitates will plug up an ion exchange column. Water should not be pH corrected prior to ion exchange, because lowering the pH can bring about precipitation of the iron and manganese. This method is used for low flow applications where manganese is the primary metal ion to be removed because the resin exchanges the manganese ion more readily than the iron ion.

4.5b Sequestering

(This section applies to Small Treated Systems only)

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 of iron and manganese that cause the staining. The process also delays the precipitation of **oxidized** iron, thereby greatly reducing the layer of scale that forms on pipes. 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 to maintain water clarity and prevent possible iron staining. This should be before your **hydropneumatic** tank and 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 the water feel slippery.

4.6 Removal of Color, Taste and Odor, and Other Organics

Taste and odors can be caused by a variety of substances in water, one of which is organic compounds. Sources of taste and odor problems include microorganisms, such as algae, decaying vegetation, and gases, such as hydrogen sulfide. Tastes can also be traced to high levels of dissolved minerals in the water. In addition, corrosion of galvanized piping can result in the release of zinc, which imparts a metallic taste to water. And the improper application of chlorine for disinfection can result in chlorine taste and odor.

Organics are also the most frequent cause of color problems in drinking water. In addition to taste, odor, and color-causing organics, there are occasionally other types of undesirable organic compounds present. Some of these can be detrimental to the health of consumers. Consequently, it is impossible to suggest a single treatment that would be universally effective in controlling all taste, odor, and color problems.

This section will discuss the use of aeration, oxidizers, and carbon adsorption for the destruction and removal of organic compounds. We will also discuss, in a general way, options for controlling other causes of taste and odor. A number of taste and odor control methods including oxidation followed by filtration are more complex and systems using these complex treatment methods are classified by ADEC Operator Certification Programs as Water Treatment Class 1 – 4 systems, not as small treated water systems and require water treatment certification.

4.6a Carbon Adsorption

Activated carbon (AC) is used to remove soluble organic compounds. Activated carbon is created by subjecting carbon-based material such as wood, coal, coconut shells or bones to high temperature and high-pressure steam treatment, i.e., activation. This activation process creates carbon particles that have many holes and crevices thus giving it its highly adsorptive properties. It has been estimated that a gram of activated carbon has a surface area equal to the area of a football field.

Organic compounds, including those causing taste and odor, are adsorbed to the extremely porous surface of activated carbon. It is also effective for the removal of color and organic compounds, which may be present in a water system as a result of chlorination or industrial pollution.

AC can be used in two types of filter systems; cartridge and a filter vessel.

Cartridge AC filters are similar to regular cartridge filters, except the filter element is coated with a layer of activated carbon or has an activated carbon core. AC cartridge filters are commonly used in combination with normal cartridge or bag filters.

AC, in the form of anthracite coal, can be used like packed filter media in a pressure filter vessel. The anthracite coal can also be used as the top layer of material in a sand filter vessel. Because AC has a low density it will stay on top when the sand filter is backwashed. Turbidity-causing particles will also be adsorbed but activated carbon should not be used if turbidity is the only problem.

A sediment filter installed ahead of any AC filter will prolong the life of the AC unit. Sediment can easily clog the pores of an AC filter within a short time. A good sediment filter can be purchased for only a fraction of the price of most high-volume AC filters.

Eventually, an AC filter loses its ability to remove contaminants because it becomes clogged with material. In the case of taste and odor, the time to change the filter is easy to detect. However, in the case of other contaminants, it is more difficult to determine when the filter is no longer performing at an adequate level. Most manufacturers recommend a filter change after a certain volume of water has passed through the filter. Some AC units meter the water and automatically shut down after a specific quantity of water has passed through the filter. The only certain way of knowing contaminant levels in the treated water is by testing the water.

4.6b Aeration

Aeration processes can be used to remove many of the substances responsible for taste and odor problems, as well as many other organic compounds.

Aeration mixes air with water to remove the organic impurities. **Volatile** organic compounds, those that escape from the water into the air, and dissolved gases can be removed by the sweeping or scrubbing action that results from the turbulence of the water and air mixing together. Oxidation of certain dissolved gases and minerals such as iron or manganese also occurs.

Aeration using the scrubbing action is also referred to as air stripping. Mixing the air and water volatilizes contaminants (turns them to vapor), which are released directly into the atmosphere. Some small systems use a simple aerator (Figure 4.6) constructed from relatively common materials instead of a designed aerator system.

Aerators include:

- a system that cascades the water or passes it through a slotted container
- a system that runs water over a corrugated surface; or
- an airlift pump that introduces oxygen as water is drawn from the well.

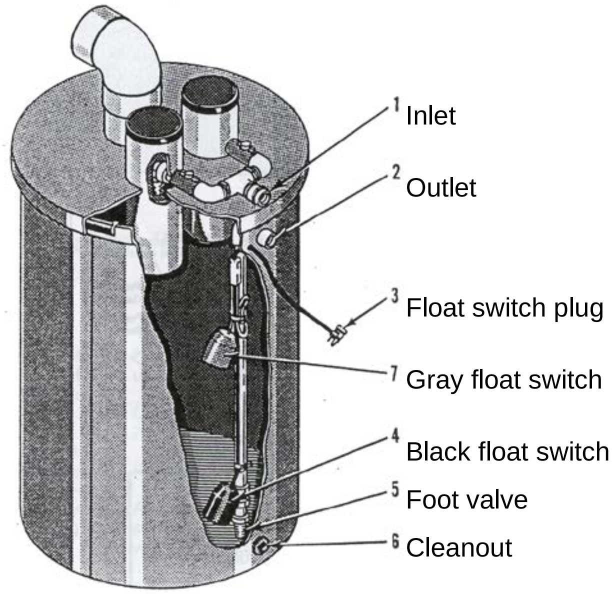


Figure 4.6: Aerator System

Aeration also chemically oxidizes some organic compounds changing the characteristics of the compounds to such an extent that they are no longer offensive or dangerous. Air is a weak oxidizer, however, and not all organic compounds can be destroyed in this way.

4.6c Use of Chlorine and Ozone

(This section applies to Small Treated Systems only)

As just mentioned above in the section on aeration, the chemical characteristics of organic compounds can be changed by a chemical reaction called oxidation. When the chemical characteristics are modified, they often lose their offensive taste and odor.

Chlorine and ozone are both strong oxidizing agents, much stronger than aeration. Of course, chlorine and ozone are both used for disinfection. Therefore, if the application of these disinfectants is designed properly, it is possible to have the added benefit of color, taste, and odor control.

Chlorine and ozone may also have unintended impacts that actually create more problems, such as creating disinfection by-products (refer to Chapter 5), chlorine taste and odor, and precipitation of minerals. For that reason, you should consult an engineering firm that specializes in water treatment to help design a taste and odor control strategy involving these strong oxidizers. Remember that any changes you make to your water system must be approved by the ADEC Drinking Water Program.

4.6d Other Taste and Odor Control Strategies

(This section applies to Small Treated Systems only)

Other significant sources of taste and odor include dissolved minerals, chlorine compounds, and algae growth in raw water supplies.

Reducing the problems associated with dissolved minerals could mean removing them with ion exchange (as with iron and manganese) and reducing the corrosiveness of your water (corrosion of galvanized pipe can release metallic-tasting zinc).

Chlorine taste and odor problems can be minimized by careful disinfection practices. Appropriate design of the chlorine application point and attention to breakpoint chlorination practices are critical factors.

Surface water supplies occasionally support algae growth, especially during the warmer summer months. Algae releases waste and decay products that can cause significant taste and odor problems. Control of algae growth in the reservoir before water is taken into the system (copper sulfate application, for example) will minimize problems later on.

Occasionally, taste and odor problems may be serious and complex enough to warrant seeking a new water source. Remember that poor tasting water often drives consumers to alternate drinking water supplies that may taste better but may not be safe.

4.7 Objectionable Gases

Hydrogen sulfide gas, which causes the classic rotten egg odor, and methane are two objectionable gases occasionally found in water supplies. Sulfur odors may be present in some groundwaters. Although not objectionable themselves, the balance of dissolved oxygen and carbon dioxide affects the pH of the water, which can affect other processes.

The most effective treatment process that small systems can use for the removal of undesirable gases is aeration (Section 4.6b).

4.8 Control of Hardness (Softening)

As discussed earlier, water with high hardness decreases the effectiveness of soaps and detergents and increases scaling in boilers and hot water heaters. For that reason, hardness may need to be reduced to an acceptable level. The removal of hardness is called **softening**.

Hardness is caused by calcium and magnesium. Softening involves the removal of calcium- and magnesium- containing compounds. Two softening processes that are used in water treatment are the lime-soda ash process and ion exchange. Because of the complexity of facilities and equipment required, the lime-soda ash process is not used in small systems.

Softening by ion exchange is very similar to iron and manganese removal by ion exchange (refer to Section 4.5a). The difference lies in the type of exchange resin that is used. In this case, the calcium and magnesium ions are taken up by the resin, and sodium ions are released into the water.

To understand the operation of a water softener, one must first understand the concept of ions. Many chemical elements from compounds dissolved in water separate and form electrically charged particles called ions. Because opposite charges attract each other, these ions move to and attach themselves to objects with opposite charges. A common compound that demonstrates this property is NaCl (sodium chloride or common table salt). The ions formed in water from this compound are Na^+ and Cl^-. The small + and - signs indicate these elements have formed ions and that their charges are either positive (+) or negative (-). Many elements form ions when dissolved in water having undesirable characteristics. Some common ones are listed in Table E.

Ion	**Characteristics**
Ca^{2+} (calcium) Mg^{2+}(magnesium)	Gives water the characteristics we call hard. It causes damage to heating appliances and fixtures because of scaling, excessive soap usage, dry skin and premature deterioration of fabrics washed in water containing it.
Fe^{2+} (iron)	When exposed to air turns red/orange and causes staining.
Mn^{2+} (manganese)	When exposed to air turns black and causes staining.

Table E: Ion Characteristics

Softening by ion exchange involves passing the water through a column containing a special ion exchange material. Several different types of ion exchange materials are in use, including natural substances called zeolites and synthetic resins.

Exchange resins are placed in a pressure vessel, and a salt brine is flushed through the resin. The sodium ions in the salt brine attach to the resin, which become charged. Once charged, water is passed through the resin and the resin exchanges the sodium ions attached to the resin for calcium and magnesium ions, thus removing them from the water. When water containing calcium or magnesium ions is in contact with these materials, an exchange or trade of ions takes place. The calcium and magnesium ions are taken up by the resin, whereas sodium ions, Na^+ are released into the water.

A common water softener consists of two tanks, a resin tank, and a brine (salt) tank. The resin tank is filled with a resin that consists of small plastic beads. The resin is called cation resin. The beads have a permanent negative charge. The negative charge causes the beads to attract positively charged ions. The resin is placed into service with the Na^{+} ions on the beads. When the hardness ions (Ca^{2+} and Mg^{2+}) come into contact with the resin beads, the Ca^{2+} and Mg^{2+} take the Na^{+}’s place on the beads. The Na^{+} is now dissolved in the water. The Na^{+} leaves the resin tank and is delivered to the tap with the water. When most of the Na^{+} is removed from the resin beads the softener head starts the regeneration process (cycle). A control is set that allows raw water into the softener for regeneration. This is done so none of the salt used during regeneration can enter the distribution system. Drawing in a high concentration salt ($NaCl$) solution from the brine tank then regenerates the resin. This salt solution is washed over the depleted resin. The salt solution contains Na^{+} and Cl^{-} ions. The Na^{+} is placed back onto the beads and the Ca^{2+}, $Mg^{2+,}$ and Cl^{-} are washed down the drain. The media is then rinsed with fresh water to remove all the remaining salt.

Softening by ion exchange can produce water with almost zero levels of hardness, but that is not desirable. Very soft water may be aggressive, or corrosive, causing damage to metal pipes and plumbing. Hardness levels of about 100 mg/L are considered optimum for drinking water. Consequently, it may be wise to consider blending water from the softener with raw water before sending the water to the distribution system.

Also, a factor that must be considered is that softened water from an ion exchanger contains sodium, which may be harmful to persons who are on a low-sodium diet. This information should be provided to those who consume the water regularly. However, potassium chloride (KCl) is sometimes used instead of $NaCl$. KCl, a colorless potassium salt, can be used as a regenerate in water softeners. Using potassium chloride will not release sodium into the water but rather potassium ions (K^{+}).

4.9 Nitrate Removal

Nitrate can be a serious health hazard for young children. The MCL for nitrate is 10 mg/L. When nitrate levels exceed the MCL, water system owners often choose to use alternative sources. For very small systems, acceptable water can be purchased, hauled in a tank truck, and stored in the system’s reservoir. Several treatment technologies are available for nitrate removal. The use of ion exchange is probably the most appropriate for small systems. Special exchange resins are available specifically for nitrate removal.

Frequently, the nitrate removal exchange resin is layered on top of calcium and magnesium (hardness removal) exchange resin in a system similar to that described above in Section 4.8

4.10 Corrosion Control

Corrosion is the process where metals are dissolved into the surrounding water. Both internal and external corrosion can destroy piping and other equipment. Corrosion can also lead to taste and odor problems. Section 2.5g explains the corrosion process in more detail.

There are two strategies to reduce or control the corrosive tendencies of water: adjustment of the chemical characteristics of the water (primarily, pH control) and covering the surface of pipes with a protective coating.

4.10a pH Control

Of the five factors that affect corrosivity, pH is the most significant. Low pH contributes to the corrosivity of water. So, raising the pH will reduce corrosivity.

There are several treatment options available for small systems to increase pH.

Aeration

Some waters may have excess dissolved carbon dioxide (CO_2). This is most likely to happen in slow-moving streams or lakes when metabolic activity releases CO_2 and the lack of turbulence allows the dissolved CO_2 to buildup. A buildup of CO_2 results in a low pH because of the CO_2/H_2CO_3 equilibrium. An increase in CO_2 increases the carbonic acid (H_2CO_3), thus lowering the pH. If CO_2 is removed, the process is reversed.

CO_2 is most prevalent in groundwater although it can occur in surface water under ice cover.

The aeration process, as described in Section 4.6b, “scrubs” the CO_2 from the water. The result is a higher pH and a decrease in corrosivity.

Limestone Contactors

A limestone contactor, sometimes called a neutralizing filter, can be used to raise the pH of water. Limestone is calcium carbonate ($CaCO_3$). As low pH water passes through the contactor it dissolves the $CaCO_3$. Through a chemical reaction, similar to that of CO_2/H_2CO_3, a higher pH and a decrease in corrosivity is the result.

A limestone contactor is an inline canister device that is convenient for small system applications. A possible drawback with the use of a limestone contactor is that calcium ions are also released into the water which increases hardness.

Soda Ash – *(This Section Applies to Small Treated Systems only)*
Soda ash (sodium carbonate, Na_2CO_3) can also be used to raise the pH. The chemistry is similar to the use of limestone contactors and causes a higher pH and a decrease in corrosivity results.

Soda ash is normally fed into the water system as a solution using a liquid chemical feed pump. The feed equipment is almost the same as that used to feed hypochlorites as described in Section 5.8.

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

Diluted NaOH is normally fed into the water system using a liquid chemical feed pump. The feed equipment is almost the same as that used to feed hypochlorites as described in Section 5.8.

4.10b Chemical Coatings

(This section applies to Small Treated Systems only)

Corrosion can be inhibited by adding chemicals to the water that adhere directly to the pipe surface or in combination with naturally occurring constituents in the water to form films or coatings on the pipe surface. These coatings prevent contact between the metal pipe surface and the corrosive water, providing a barrier to corrosion reactions.

Phosphates and Silicates
Silicates and orthophosphates are frequently used by small systems to form protective films on pipe surfaces. The protective coating prohibits the corrosive water from contacting the metal pipe. Sodium silicate and phosphate must be continuously added to the systems to be effective.

Carbonate Precipitates
When calcium and magnesium carbonates **precipitate,** they can form a protective coating on the inside of the water pipe. Whether or not the carbonates will precipitate depends on the pH and amount of alkalinity and hardness present in the water. If they all are relatively high, precipitation is enhanced.

Consequently, when limestone ($CaCO_3$) and soda ash (Na_2CO_3) are used to raise the pH there is a side benefit of the protective carbonate coating. Some corrosion control strategies increase pH, alkalinity, and hardness with the expressed goal of forming carbonate precipitates.

4.11 Radon Removal

Radon is found in some groundwater supplies and removal may be required if the MCL is exceeded. Carbon adsorption is recommended as the best available treatment (BAT) for small systems (refer to Section 4.6a).

4.12 Control of Nuisance Growth

Many different organisms can be real nuisances even though they may not be a direct health hazard. Some of these may contribute to taste and odor problems (algae, bacteria, etc.). In addition to taste and odor problems, iron bacteria in wells can cause “red water.” Small aquatic organisms (insect larvae, small snails, and freshwater shrimp) can plug inlet screens and pumps and contribute to taste and odor when they die and decay.

Properly sized and maintained screens can eliminate many larger organisms before they enter the system. Maintaining a trace chlorine residual throughout a treatment system will prevent algae from growing on the walls of open basins and reservoirs. Copper sulfate can be applied to raw water reservoirs to control the growth of algae in surface water sources.

You should consult a water an engineering firm that specializes in water treatment to help design a strategy to control nuisance organisms. Remember that any changes you make to your water system must be approved by the ADEC Drinking Water Program.

4.13 Prevention of Tooth Decay

(This section applies to Small Treated Systems only)

Sodium fluoride (NaF) is added to water in small systems to help prevent tooth decay. Other forms of fluoride are not usually used in small systems.

At the optimum level of 0.7-mg/L, sodium fluoride can reduce tooth decay among children by 65 percent. It is essential that the proper dosage is used because too little is not helpful and too much causes fluorosis (staining or pitting of teeth). **An excessive**

overdose of fluoride can cause death. Fluoride has two regulated limits: the secondary MCL is 2.0 mg/L and the primary MCL is 4.0 mg/L. At no time should the level exceed 4.0 mg/L. The only death attributed to over-fluoridation in a public water system occurred in Hooper Bay, Alaska in May 1992. A study published in *The New England Journal of Medicine* in January 1994 estimated a fluoride concentration of 150 mg/L in the Hooper Bay water system.

Sodium fluoride is fed into the water system using a fluoride **saturator**. The saturator consists of a chemical tank (similar to the hypochlorite feed system), a chemical feed pump, a feedwater line (feedwater must be free of hardness), and automatic water level control. It is called a saturator because a saturated fluoride solution is maintained in the tank. This is accomplished by filling the bottom of the tank with solid sodium fluoride. Feedwater enters the tank at the bottom, under the sodium fluoride crystals, and dissolves the sodium fluoride as it flows upward. The solution in the tank above the sodium fluoride crystals is always saturated under these conditions.

4.14 Common Chemicals Used for Water

Chemical	Common name	Effect	Use
Calcium hypochlorite	HTH	N/A	Disinfection
Calcium Carbonate	Limestone	Increase pH	pH and corrosion control
Potassium chloride	N/A	Ion exchange	Water softener regenerant
Sodium carbonate	Soda ash	Increase pH	Corrosion control
Sodium chloride	Table salt	Ion exchange	Water softener regenerant
Sodium fluoride	Fluoride	N/A	Reduce dental caries
Sodium hexametaphosphate	Polyphosphate	Prevent red water	Sequestering agent
Sodium hydroxide	Caustic soda	Increase pH	Corrosion control
Sodium hypochlorite	Liquid chlorine bleach	N/A	Disinfection
Zinc Orthophosphate	N/A	Protective film	Corrosion control

Table F: Common Chemicals Used for Water Treatment

Chapter 5 – Disinfection

5.1 Background

Disinfection may be defined as the process used to control disease-causing organisms in an effort to prevent waterborne disease. Disinfection is probably the oldest and most widely applied water treatment process used by humans.

Ancient Sanskrit writings indicate that early people boiled and filtered raw water to make it look and taste better. Although no one realized it at the time, these treatments made the water safe. Even today, when drinking water quality is suspect or unknown, public health officials recommend boiling water for eight to ten minutes to ensure the water is safe to drink.

However, boiling large quantities of water is not feasible for even the smallest public water supply systems. Consequently, public water systems have turned to other methods to control disease-causing organisms.

The most common disinfection method for potable water in use today is **chlorination**. Just as water is virtually the universal solvent, chlorine is nearly the universal water treatment chemical.

Chlorination has played a critical role in reducing the threat of waterborne infectious diseases around the world. Many public health officials consider chlorine disinfection the most significant public health protection measure of the 20th century. *Life* magazine once cited filtration of drinking water and chlorination as “probably the most significant public health advance of the millennium.”

Chlorination of drinking water saves lives and prevents the transmission of debilitating diseases such as cholera, hepatitis, typhoid fever, and gastrointestinal disorders to name a few.

The first continuous use of chlorination for disinfection was in Belgium in 1902. The first continuous use of chlorination in the United States was in Jersey City, N.J. in 1908 for disinfecting the Boonton Reservoir which supplied 40 million gallons per day (MGD) of drinking water. Adoption by other cities and towns across the United States soon followed and resulted in the virtual elimination of waterborne diseases such as cholera, typhoid, dysentery, and Hepatitis A. Before the advent of chlorination for drinking water treatment, typhoid fever killed about 25 out of 100,000 people in the U.S. annually, a death rate that is currently associated with automobile accidents.

In more recent times, two protozoan waterborne pathogens caused drinking water professionals to re-evaluate the adequacy of their disinfection procedures. One is *Giardia* also known as “Beaver Fever”, and the other is *Cryptosporidium* which causes intestinal disorders.

Giardia lamblia lives in the small intestine and is transmitted primarily when the infective cysts are ingested along with water. It gained notoriety some years ago when an outbreak occurred in Banff National Park after hikers became ill after drinking water from a stream contaminated with *Giardia* from beavers*.* The media then termed the illness as "Beaver Fever." *Giardia* cysts are resistant to chlorine disinfection. Therefore, a combination of **treatment techniques** is the most effective way in combating *Giardia.* This can take the form of filtration along with disinfection.

Cryptosporidiosis (krip-toe-spo-rid-e-o-sis) is the disease, often called "crypto," caused by the protozoa, *Cryptosporidium parvum*, which is too small to be seen without a microscope. When people get infected with C*ryptosporidium* they can have watery diarrhea, stomach cramps, upset stomach, or a slight fever. In March and April 1993 in Milwaukee, Wisconsin, one of the municipal drinking water treatment systems was contaminated with *Cryptosporidium*. An estimated 403,000 people became ill and 69 people died. The cause of the outbreak was never identified but was believed to be *Cryptosporidium* oocysts breaking through the filtration system of the water treatment plant. The Milwaukee outbreak was a stark reminder of the importance of proper treatment of public water supplies. Due to the ineffectiveness of chlorination to inactivate *Cryptosporidium*, the Surface Water Treatment Rule (SWTR) requires that filtration be used to remove *Cryptosporidium*.

Current drinking water treatment and disinfection practices in the U.S. provide the means to control most pathogenic bacteria, viruses, and protozoa responsible for major outbreaks of waterborne diseases. Some outbreaks still occur, however, and are generally attributed to consumption of untreated water, insufficient or interrupted treatment and/or disinfection, failure to maintain an adequate disinfectant residual in the distribution system, and/or breaches in the water system.

Chlorination is easily the most widely applied method of disinfection for small water systems. No other single chemical finds broader application in the water treatment industry than chlorine. Forms of chlorine commonly used for disinfection by Small Treated water systems include sodium **hypochlorite** (liquid bleach) and calcium hypochlorite granules or tablets. On-site generation of sodium hypochlorite has increased in recent years in Alaska's small systems. Gas chlorine, once the most common disinfection process in the U.S., is rarely used by small systems in Alaska due to safety concerns.

An important characteristic of an effective drinking water disinfectant is the ability to continue to prevent or inhibit microbial growth after the treated water enters the distribution system. Chlorine can provide this desirable lasting disinfecting capacity (residual chlorine) in the distribution system. The presence of this residual will protect against contamination that might occur in the distribution system after the water leaves the treatment plant.

Small Treated water systems may also use passive disinfection treatment methods such as ultraviolet (UV) and ozone disinfection. However, the application of these passive disinfection technologies is infrequent when compared to chlorine disinfection and may be prohibited in certain circumstances.

5.2 Ultraviolet (UV) Light

Ultraviolet (UV) light, or radiation, is used by some small water systems for disinfection. UV radiation, which is generated by a special lamp, effectively destroys bacteria, viruses, and protozoa (Figure 5.1). UV light is not effective against any non-living contaminant, such as lead, asbestos, organic chemicals, chlorine, etc. UV light is generated by a variety of lamps; low-pressure mercury lamps are best suited for use in disinfection systems because they generate a large fraction of UV energy that gets absorbed.

UV radiation systems:

- produce no known toxic residuals,
- require short contact times, and
- are easy to operate and maintain.

Water treated by UV radiation must be relatively clear and colorless to allow the light to penetrate and kill the microorganism. The water should be free of any materials that might build up on the surface of the UV bulb. A film on the bulb could decrease the output from the bulb. Iron, manganese, and hardness are the most common materials that could cause this problem.

It is dangerous to look directly at a source of UV radiation because the UV radiation can seriously and permanently damage your eyes. For this reason, three different levels of safety should be provided with a UV system:

1. UV system with an inspection hole to determine if the light is on.
2. UV system with a photosensor that will automatically determine if the light is on or off. If the light is not on, an alarm will sound and/or the water will be shut off with a solenoid valve.
3. UV system with a transmittance detector that will not only determine if the light is on but will also measure the intensity of the light after it has passed through the water. If the light that is transmitted through the water is not sufficient, the detector will shut the water off to the system until the problem is corrected.

Consult ADEC Drinking Water Program to determine the level of safety that should be provided when using UV radiation for disinfection.

UV radiation does not provide any residual in the distribution system. The lack of residual means that extra care must be taken to make sure the distribution system is thoroughly disinfected during installation. UV lights alone should not be used on any system where there is a potential for contamination in the distribution system, such as leaking underground lines or cross-connections with other supplies.

The combination of chlorination and UV radiation would be a good choice for any situation where residual is needed, or redundancy is required.

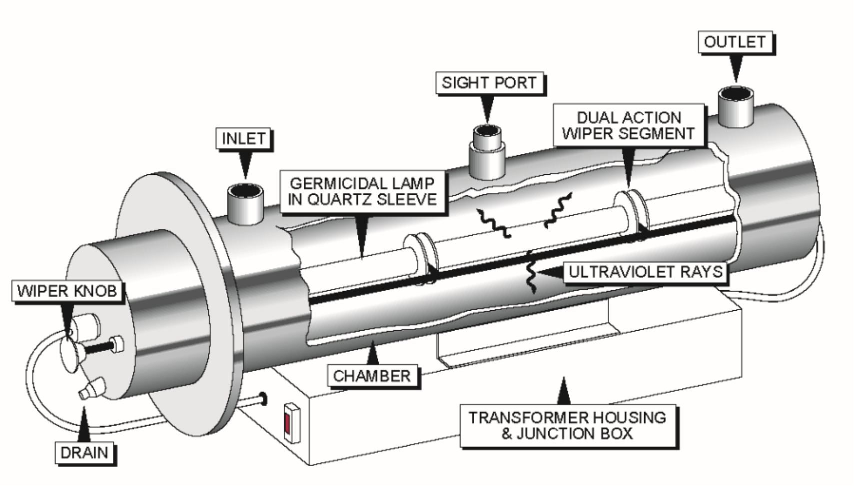


Figure 5.1: UV Disinfection System

5.3 Basic Chlorine Chemistry

(This section applies to Small Treated Systems only)

Chlorine chemistry is quite complex and can be confusing for operators who lack a technical background in chemistry. In this manual, we have simplified the presentation to emphasize the important aspects.

Chlorine readily reacts with water to create an effective disinfectant. It can be applied to water in liquid or gas form. For small systems, liquid hypochlorite disinfection is most common.

If, for example, common bleach (sodium hypochlorite) is used, it reacts with water to form **hypochlorous acid** (HOCl) as follows:

$NaOCl + H_2O \rightleftharpoons HOCl + NaOH$

Hypochlorous acid, in turn, can break down to form **hypochlorite ion** (OCl^-) as follows:

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

It is these two forms of chlorine (HOCl and OCl^-), together referred to as **free chlorine residual**, that make chlorine a powerful disinfectant. However, hypochlorous acid is almost 100 times stronger than the hypochlorite ion. At a pH of 7.5, both are present in almost equal amounts, but hypochlorous acid is more prevalent at lower pH values. Consequently, the disinfection process is more effective at pH values below 7.5.

When chlorine is added to water, it reacts with various contaminants in the water. This reaction between chlorine and the contaminants in water create what is called the **chlorine demand**. The amount of chlorine needed to satisfy this demand depends on the type and quantity of the contaminants present in the water. Once the demand has been satisfied, the remaining chlorine, if any, is called the **chlorine residual**.

Chlorine Dose - Chlorine Demand = Chlorine Residual

There are three types of chlorine residual: free, combined, and total. The chlorine available as hypochlorous acid and hypochlorite ion is termed free chlorine residual. When chlorine combines with nitrogen compounds (ammonia and other organics) in the water, chloramines or **combined chlorine residual** is formed. Combined chlorine residual (chloramines) does have a disinfecting capacity but is much weaker than free chlorine residual.

Total chlorine residual is the sum of the free chlorine residual and the combined chlorine residual. Public water systems generally monitor for free chlorine residual, which is measured in mg/L.

5.4 Breakpoint Chlorination

(This section applies to Small Treated Systems only)

As previously discussed, chlorine combines with many different organic contaminants in water to form combined chlorine compounds. Chlorine is such a powerful oxidizing chemical that as more and more chlorine is added to water already containing combined chlorine compounds, it reacts with and destroys the combined chlorine compounds. As still more chlorine is added, the point at which all the combined chlorine compounds are destroyed is called the **breakpoint**. When additional chlorine is added beyond the breakpoint only free chlorine residual is formed.

Breakpoint chlorination is an important concept, not only from the standpoint of providing a free residual (for maximum disinfection), but also because the presence of combined chlorine residual can result in offensive chlorine taste and odor problems. Adding sufficient chlorine to reach beyond the breakpoint (breakpoint chlorination) will both maximize disinfection and minimize chlorine taste and odor problems.

An important characteristic of an effective drinking water disinfectant is the ability to continue to prevent or inhibit microbial growth after the treated water enters the distribution system. Chlorine can provide a lasting measurable disinfectant residual in the water distribution system to protect against contamination that might occur after the water leaves the treatment plant. For some water systems, free chlorine residual may persist sufficiently long to provide residual protection.

Filtration, or any other water treatment practice that removes chlorine-demanding substances before chlorine is added, lessens the amount of chlorine required for disinfection. Water treatment before chlorine addition may also remove humic acids and other natural organic precursors before chlorination, thereby minimizing the formation of trihalomethanes and other disinfection byproducts (DBPs).

In practice, chlorine may be added at one or more points within the treatment process. Chlorine is typically added as the last step in the water treatment process. Following a period of contact time, disinfected water is pumped into the water distribution system to the customer.

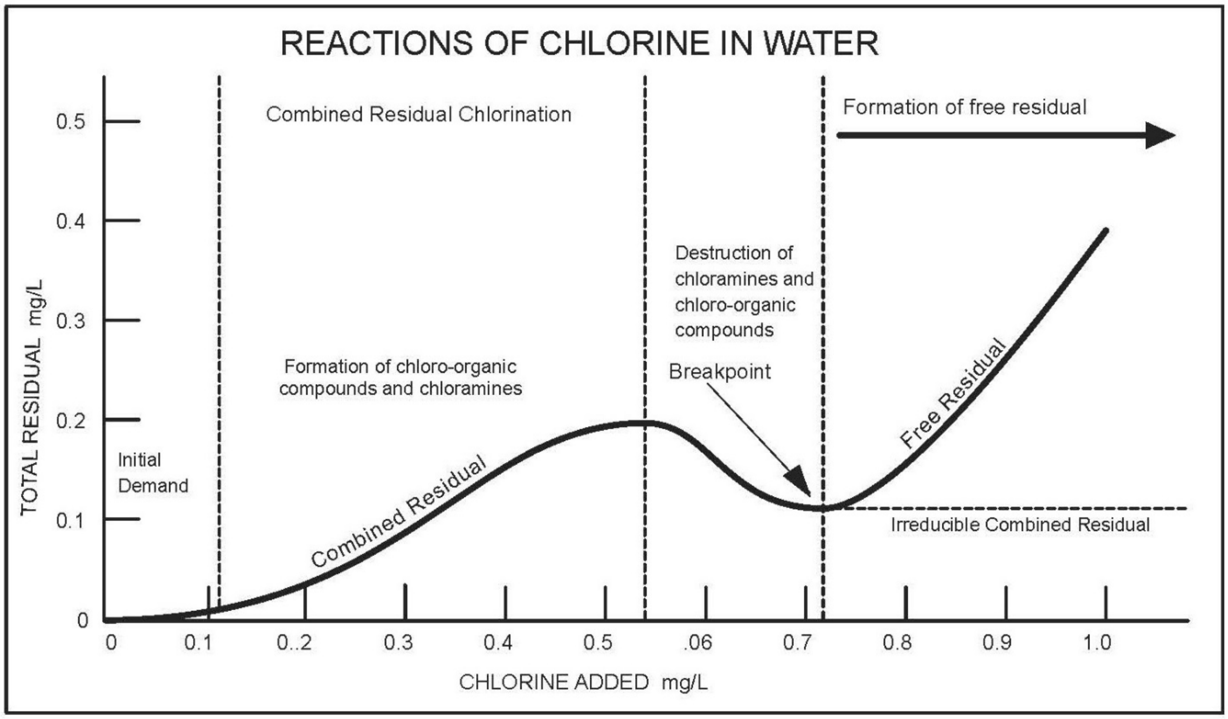


Figure 5.2: Breakpoint Chlorination

5.5 Chlorine Residual

(This section applies to Small Treated Systems only)

Typically, chlorine residual measurements are required daily. Regulations require two separate sample locations in the distribution system. The Surface Water Treatment Rule requires a minimum chlorine residual of 0.2 mg/L entering the distribution system and a trace amount at representative locations within the system is generally required. This means that sufficient chlorine must be added to satisfy the demand and carry out disinfection, and still have some leftover; the 0.2 mg/L free chlorine residual. A 0.2 mg/L free chlorine residual entering the distribution system is considered adequate to maintain a free chlorine residual throughout the distribution system.

Chlorine residual can be determined and expressed in many ways. The most commonly used method for small systems is the colorimetric method. In this procedure, a chemical is used that turns pink in the presence of a chlorine residual. The intensity of the pink color is directly proportional to the concentration of the chlorine residual. The intensity of the pink color is determined using a hand-held color wheel **comparator** or a portable instrument (a **colorimeter**). This method is referred to as the DPD method after the name of the chemical used, N,N-diethyl-p-phenylenediamine.

The DPD colorimetric method can be used to measure both free chlorine residual and combined chlorine residual. The DPD chemicals usually come conveniently packaged for easy use and must be used before the expiration date.

5.6 Effectiveness of Chlorination

(This section applies to Small Treated Systems only)

The two most important factors for the success of chlorination are the chlorine **concentration, C**., and the **contact time, T**., the length of time that the chlorine is in physical contact with the microorganisms. The destruction or inactivation of microorganisms (disinfection) is directly proportional to the concentration times the contact time (C x T), referred to as **CT**. Thus, if the chlorine concentration is decreased, the contact time will have to be increased to achieve the same level of disinfection. Because it is a weaker disinfectant, combined chlorine residual will require a longer contact time than free chlorine.

The temperature and pH of the water are also important considerations for the effectiveness of chlorination. At lower temperatures, the inactivation of bacteria tends to be slower than at higher temperatures. Changes in temperature may necessitate adjustments to the chlorine dosage.

As mentioned earlier, the pH of the water also affects the chlorination process because it determines the relative amounts of HOCl and OCl^-. The pH of the water should be checked regularly. If the pH is being maintained at higher levels in order to control corrosion, the chlorine dosage will have to be adjusted accordingly.

Values of CT can be calculated using a formula or may be determined from a set of tables provided in the ADEC Drinking Water regulations (18 AAC 80). These tables are designed for various temperatures, pHs and chlorine residuals, and for log removals ranging from 0.5 to 3.0. Log removals refer to the percent removal or inactivation of a specific target organism, where 1.0 log removal equals 90% removal, 2.0 log removal equals 99%, and 3.0 log removal equals 99.9%, and so on.

For *Giardia* removal, 3.0 log removal is the required level of treatment. Some removal may occur during filtration, but for surface water systems that do not filter, the disinfection process must provide all 3.0 logs of removal.

5.7 Sodium Hypochlorite (NaOCl)

(This section applies to Small Treated Systems only)

Sodium hypochlorite (NaOCl) is available in a liquid form and comes in 1, 5, or 55 gallon containers. It contains approximately 5% to 15% available chlorine. Common household bleach normally contains 5% chlorine. Sodium hypochlorite will lose strength during prolonged storage.

5.8 Calcium Hypochlorite [$Ca(OCl)_2$]

(This section applies to Small Treated Systems only)

Calcium hypochlorite [$Ca(OCl)_2$] is a solid white substance also known as High Test Hypochlorite (HTH). It is available as a 65% concentration and comes in granular or tablet form. It is a corrosive material with a strong odor that must be kept away from organic materials, such as wood, cloth, and petroleum products because of the dangers of spontaneous fire or explosion. Calcium hypochlorite should be stored in a cool, dry, and dark environment to minimize deterioration. Note carefully the precautions listed on the container label including the use of personal protective equipment such as proper clothing, eye protection, respiratory protection, etc.

5.9 Hypochlorinator System

(This section applies to Small Treated Systems only)

Liquid hypochlorite (sodium hypochlorite) may be fed directly into the water using a **hypochlorinator** system (Figure 5.2). Solid hypochlorite (calcium hypochlorite) must be dissolved in water before feeding with the hypochlorinator system.

When mixing hypochlorites with water, a corrosion-proof container made of plastic is required. The container size depends on the amount of hypochlorite solution that is needed. Most hypochlorinator systems have a 20-to-50-gallon mixing tank with a chemical feed pump mounted on top of the tank. Smaller tanks may be more appropriate for small systems because the smaller volume would mean keeping a fresher chlorine solution. Normally, the tank should hold about a week's supply of hypochlorite.

Some small systems use two tanks for mixing calcium hypochlorite. The calcium hypochlorite is mixed with the water and allowed to sit. The material that does not dissolve settles to the bottom of the tank and the solution is then transferred to the second tank. The hypochlorite solution is pumped from the second tank and injected into the water with a chemical feed pump.

Following is a short description of each of the hypochlorinator system components:

- **Strainer** – protects the pump by screening large pieces of undissolved calcium hypochlorite that might enter the suction line.
- **Foot valve** – a check valve that keeps the pump and suction line primed by opening when the pump is operating and closing when the pump shuts down (not required for peristaltic pumping systems).
- **Weight** – keeps the suction line from curling up and keeps the strainer and foot valve below the hypochlorite solution level.
- **Chemical feed pump** – a positive displacement, diaphragm, or peristaltic pump.
- **4-in-1 valve (Four Function Valve)** – serves four functions:
    1. Anti-siphon (automatic) - the valve prevents backsiphonage when pumping downhill or from the tank should there be a vacuum created in the system.
    2. Back pressure control (automatic) – supplies approximately 25 psi backpressure to prevent over-pumping when little or no system backpressure is present. This constant pressure exists even if the line pressure should drop to zero; also helps maintain the accuracy of the pump.
    3. Pressure relief (automatic) – if the discharge line is over-pressurized the valve opens sending the solution back to the supply tank.
    4. Line depressurization (manual) – by pulling both knobs, the discharge line will drain back to the supply tank to prevent the solution from spraying the operator.
- **Discharge Line** – carries the hypochlorite solution from the pump discharge to the chlorine injection point.
- **Check Valve** – prevents water from being forced back through the discharge line, the pump, and suction line into the hypochlorite solution (backflow).
- **Injector Unit** – a diffuser made of PVC or silver tubing extending one-third the diameter into the water line. The diffuser is inserted into the line to a point that results in maximum mixing of the chlorine solution with the water flow of the plant.
- **Flow switch** – prevents the feed pump from accidentally running when there is no flow of water in the system piping.

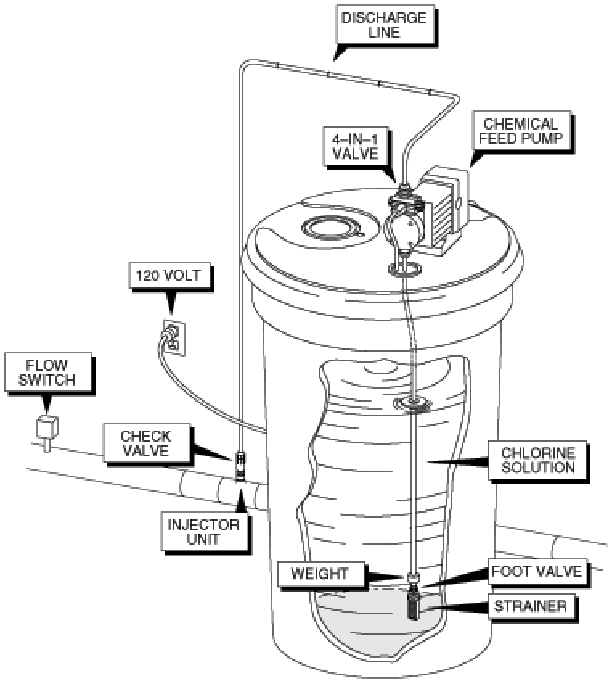


Figure 5.3: Hypochlorinator System

5.10 Chemical Feed Pumps

(This section applies to Small Treated Systems only)

Chemical feed pumps are used to inject chemical solutions into drinking water for various treatment purposes.

When using diaphragm pumps, pump speed and stroke can typically be adjusted to control the feed rate. The frequency of the stroke is adjusted with the speed knob, and the length of the stroke is adjusted with the stroke length knob. The speed knob allows you to adjust the strokes per minute as a percent of the maximum. If the knob is turned clockwise, the stroke frequency is increased. The stroke length knob allows you to adjust the solution discharged during each pump actuation as a percent of the maximum. Turning this knob clockwise increases the amount of solution pumped. Speed and stroke length can be adjusted using buttons or touchscreen displays on newer pumps.

On peristaltic pumps, the pump speed can be adjusted using a knob or buttons.

Chemical feed pumps can be used to inject chemical solutions either at a variable rate or a constant rate. If the plant flow rate varies with time, the chemical feed pump can be set to automatically adjust the pump feed rate in proportion to the changes in plant flow. With the variable rate system, the pumping stroke frequency is controlled by an electrical signal from a flow meter. You can also fine-tune the solution feed rate by manually varying the pump stroke length. When the plant flow rate is constant, the feed pump can be connected electrically to the well pump control system. In this case, when the well pump starts, power is automatically applied to the chemical feed pump and pumping continues until the well pump shuts down.

To prevent the feed pump from running when there is no flow of water in the system, a flow switch is installed in the plant flow line. The chemical feed pump is wired into the control circuit so that the pump cannot start if there is no flow of water.

5.11 Tablet Chlorinators

(This section applies to Small Treated Systems only)

Tablet chlorinator systems use solid calcium hypochlorite tablets instead of liquid sodium hypochlorite. The two main types of calcium hypochlorite chlorinators are called pellet and erosion chlorinators.

Pellet chlorinators are commonly mounted on top of the well and drop chlorine tablets directly into the well. A preset number of tablets are dropped based on the volume of water being pumped. The well casing must be clear of obstructions to ensure that the tablets do not become lodged before reaching the water level.

Erosion chlorinators consist of a canister to hold a supply of chlorine tablets and a chamber to allow water to flow over and slowly erode or dissolve the tablets.

Some systems use larger calcium hypochlorite tablets the size of a hockey puck. These units have the advantage of using chlorine tablets that are easy to handle and store. However, the chlorine dose they deliver tends to fluctuate greatly and is difficult to control. If the tablets get damp in the storage canister they stick together. Tapping the storage canister occasionally will help break them apart.

The storage canister has a sieve plate on the bottom, which allows only the bottom layer of tablets to come into contact with the water. The bottom layer of tablets is eroded as water flows through the sieve plate so that the inlet water flow controls the rate of chlorination. Higher flows result in higher chlorine delivery. The chlorinator itself is not a pressure vessel. It operates under a slight vacuum created by the suction side of the pump or by gravity flow. Typically, the tablets provide 65% available chlorine.

One disadvantage of tablet chlorinators is they are set to deliver specific amounts of chlorine at a given flow rate. Therefore, changes in flow and/or pressure can affect the chlorine dosage. However, these changes can be dealt with by installing flow proportioners and chlorine analyzers.

5.12 Storage and Handling of Hypochlorites

(This section applies to Small Treated Systems only)

Chlorine tablets should be stored in a cool, dry location, and both liquid and solid hypochlorites should be stored in their original labeled container away from children and animals. All chlorine solutions should be stored in a dark place because light reduces the chlorine potency.

Both solid and liquid forms of chlorine are irritating to the skin and are poisonous in their concentrated form. They must be handled carefully and stored properly. Personal protective gear should be worn when handling all water treatment chemicals.
When mixing and working with chemicals wear rubber gloves to protect your skin. A half-face respirator will protect your throat and lungs from the calcium hypochlorite dust that may become airborne when you open or dump a bag. A face shield protects you if the chemical splashes when you are mixing or transferring the chemical solution to another tank and a rubber apron will protect your skin, as well as save your clothes from being ruined if you spill the chemical on your body.

5.13 On-Site Hypochlorite Generation

(This section applies to Small Treated Systems only)

On-site sodium hypochlorite generation has increased in popularity in Alaska over the years both in large utilities and at small systems, such as remote well sites. When sodium hypochlorite is produced on-site, it reduces shipping costs and concerns over safety associated with transporting chlorine solutions.

The on-site generation process is fairly simple requiring only salt, electricity, and water. One pound of equivalent chlorine can be produced from 3.5 pounds of salt, 15 gallons of water, and approximately 2.3 kWh of electricity. The process produces a dilute sodium hypochlorite solution (0.8%) at a pH of 9. The product is very stable at this lower concentration, and with less degradation.

On-site sodium hypochlorite generation is a relatively straightforward process. First, a brine is prepared by adding salt and softened water, which is then diluted to approximately 3% for use. The 3% salt solution is pumped through one or more electrolytic cells to produce $NaOCl$.

Hydrogen gas is generated as a by-product during this process and must be vented to avoid creating an explosive environment. Another factor to consider is the hardness of the water used to produce the brine and process water. To reduce cleaning and maintenance costs, most systems require a softener that prevents the buildup of calcium carbonate scale on the electrolytic cell.

5.14 Mixed-Oxidant (MiOx®) Process

(This section applies to Small Treated Systems only)

The MiOx® process produces a solution of mixed oxidants using 9- to12-volt DC current, NaCl brine, and the patented electrolytic (MiOx®) cell. Electrolysis, or the passing of electric current through a substance to create a chemical change, of chloride solutions using the MiOx® design produces a mixed-oxidant solution consisting of hypochlorite, ozone and other chlor-oxygen species. Since the primary component of the solution is HOCl (the most effective form of chlorine), an effective chlorine residual can be maintained.

The mixed-oxidant solution is collected in a day tank (oxidants tank) and injected into water at rates appropriate to meet treatment objectives.

Since the only items used to generate the mixed oxidants on-site are salt, water, and electricity, no hazardous chemicals are used, transported, or stored. Therefore, on-site generation of mixed oxidants is safer than chlorine gas.

Although, MiOx® generators use brine to produce the mixed-oxidant solution, the addition of salt to the water supply is negligible. In fact, a 12-oz. can of Coke™ contains 140 mg/L of sodium, which is 88 times higher than the level of sodium added to the water by a MiOx® unit at a 1 mg/L dose.

5.15 Chlorine Gas

(This section applies to Small Treated Systems only)

Chlorine gas is less expensive than other disinfectants; however, chlorine gas is dangerous and can be lethal at low concentrations. Chlorine gas has a greenish-yellow color and is visible in high concentrations. Chlorine gas is 2.5 times heavier than air. Since the gas is heavier than air, chlorine gas will settle into low areas if a leak occurs. Because of the dangers associated with storage, handling, and accidental spills, most small water systems disinfect with hypochlorites rather than chlorine gas.

5.16 Ozone

(This section applies to Small Treated Systems only)

Ozone (O_3) is one of the most powerful and effective disinfectants available for use in water treatment. It is very effective against all three types of pathogenic microorganisms (viruses, bacteria, and protozoa) including *Cryptosporidium* and *Giardia.* The main problem with ozone is, like UV radiation, the absence of a persistent residual in the distribution system. Therefore, the use of ozone is often combined with chlorination to maintain a residual in the distribution system.

Ozone has been widely used as a disinfectant in water systems in Europe for nearly as long as chlorine. It is gaining acceptance in the U.S. because of its effectiveness against pathogenic protozoa.

Ozone can produce disinfection by-products, although they are different from those that may be produced by chlorination. Ozone may also be used to control taste, odor, and color because of its strong oxidizing properties.

Ozone is very unstable and must be generated on-site. It is generated by passing a high voltage across an air gap or by using ultraviolet light through which air or purified oxygen is flowing This process is very similar to the formation of ozone by lightning or an arc welder.

The ozone molecule (O_3) is highly reactive, bluish in color, and has a pungent odor. It is highly toxic when inhaled at even low concentrations.

5.17 Disinfection By-Products

(This section applies to Small Treated Systems only)

There is no question that the use of chlorine as the primary disinfectant used for water treatment in the United States has had an enormous impact on the prevention of waterborne diseases. However, when chlorine is added to waters containing naturally occurring organic matter, some undesirable **disinfection by-products (DBPs)** can result. 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 public water supply.

Raw waters containing high levels of organic matter, such as lakes and tundra 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.

The first group of DBPs to be regulated were the total trihalomethanes or TTHMs. In the late 1970s, federal drinking water regulations established a maximum contaminant level (MCL) of 0.10 mg/L for total TTHMs for public water systems serving 10,000 or more persons. Currently, all public water systems, regardless of size, are required to monitor for TTHMs and the MCL for TTHMs is 0.08 mg/L based on a locational running annual average (LRAA) calculated at each monitoring location. LRAA is defined as the average sample analytical results for samples taken at a monitoring location during the previous four calendar quarters.

Five haloacetic acids (HAA5) are the other group of regulated DBPs. The MCL of HAA5 is 0.06 mg/L LRAA.

Additional information regarding the monitoring and reporting requirements for TTHMs and HAA5 can be found in Section 8.12.

The best DBP control strategy is to remove organic matter from the water before it can react with the disinfectant. In some cases, small water systems may be able to effectively control DBP formation by installing activated carbon cartridge filtration or carbon canister filtration systems (see Chapter 4). System owners should contact ADEC drinking water engineers or local water quality consultants to determine the best treatment option for their particular system.

Chapter 6 - Water System Operation & Maintenance

6.1 Record Keeping

The recording of data is an everyday task at a water system. In fact, certain water system records are required by State regulation.

Some records are maintained to assist owner/operators with operational decisions. For example, operational records establish historical data that will indicate when a pump or motor may need to be replaced. Operational decisions based on historical data, through good record-keeping, will save time trying to solve problems, save money through proactive operations rather than reactive (crisis) operating, and free-up time for monitoring and maintenance of the water system.

Records retention should include:

- Monitoring records
- Actions to correct violations
- Bacteriological and other water quality analyses
- Variance of exemptions
- Sanitary survey reports
- Level 1 and 2 Assessments
- Source records:
- Well log
- Total water produced
- Total water used
- Static water level measurements
- Pumping water level measurements
- Raw water temperature
- System Maps
- As-Builts
- Maps of all existing facilities
- Distribution system maps
- Valve locations
- Fire and yard hydrants locations
- Pipe locations and sizes
- Distribution leak locations and dates
- Distribution pipe replacements and dates
- Sampling siting plan

6.2 O&M of Groundwater Systems

A sound maintenance program saves you money by minimizing premature failure of water system components and equipment. Pumps and equipment do not last forever. Every ten to twenty years, well components and equipment may require mechanical service from a qualified pump service company or well pump installer.

However, regular inspection and preventative maintenance will help ensure the continued, reliable operation of the entire water system. Water system maintenance is very important, but it is often delayed because the well, the well components, and the piping system are out-of-sight and, therefore, out-of-mind.

Well Site Visit

Visit your well site regularly to perform routine monitoring and preventative maintenance. Visibly check the above-ground components. The well cap should be secure and watertight. Joints, cracks, or loose connections on the well casing should be sealed to prevent surface contaminants from entering the well. Pumps, pipes, and valves should also be tested regularly, and the cause of any changes in water quantity and quality should be investigated.

The area immediately around the wellhead should slope away from the well casing to prevent surface water from collecting (pooling) near the well. Protecting a well from possible contamination cannot be over-emphasized. Shallow wells draw water near the land surface and may be directly affected by activities around the well.

Well Site Protection

Although it is not a complete list, the sanitary procedures listed below will help you protect your water source:

- Do not store or use hazardous substances, such as gas, oil, pesticides, or paints, in or around the well house.
- Check the sanitary seal and well casing vent monthly to make sure the seal is intact and the screen has not deteriorated. A properly functioning and vented sanitary seal on top of your well casing keeps potential contaminants from entering the well.
- If your well has a pitless adapter (water pipe exiting the well casing below ground level rather than through the top of the well casing), make sure there is an adequate seal present to prevent contaminants from entering the well around the adapter. The pitless adapter may be visually inspected when the well cap is removed by shining a light into the casing. You can also use a mirror to reflect sunlight into the well casing and inspect some of the internal components.
- Keep vegetation from growing around the immediate area of the wellhead and well house.
- Protect the well and distribution system from freezing. Insulate the pipes, place heat tape on the pipes, place a lamp, heat lamp, or heater (with proper electrical connections) in the well house. Be aware that, if lamps burn out, the system may freeze up. Check the lamps frequently.

Each year wells are threatened, damaged, and destroyed by vehicle accidents that occur near the wellhead, for example, a fuel or fertilizer tank leaks or a pesticide truck spill. These are only a few of the types of accidents that threaten the safety of an aquifer on a regular basis. Not allowing these potentially contaminating activities around your well can minimize the threat of possible contamination or destruction. By monitoring all activities and/or moving potential troublesome items from the area, accidents to the well may be avoided or minimized.

Anticipating possible accidents and responding accordingly takes a small amount of time compared to the cost of cleanup or environmental damage. Permanent contamination of a well ultimately means loss of property value and may involve liability.

Local geological conditions determine how long it takes for pollutants to be carried to an aquifer. In some places, the process happens quickly, in weeks, days, or even hours. Areas with thin soil over fractured bedrock or sand and gravel aquifers are particularly vulnerable. Even thick sand over fractured bedrock represents a site vulnerable to contamination. On the other hand, thick clay soils do not allow contaminants to reach the water table and may prevent contamination or delay the day when a well turns bad. If you have a **deep well** (more than several hundred feet below the water table), the well may be less vulnerable to pollutants carried to the aquifer if it is properly sealed and constructed. Once again, be diligent in monitoring the types of activities you allow around your well.

6.3 Well House Inspection

Inspection and maintenance of the well house should be conducted on a regular basis. Keep the well house clean and uncluttered. If the motor is mounted above ground, check the motor temperature by placing the back of your hand on the motor casing. The casing will normally be warm to the touch. If you must remove your hand quickly because the heat is intense, the motor may be overheating, and the cause should be investigated.

Senses

An operator’s senses are the best tools available for detecting abnormal water system conditions. “Look, listen, smell, and touch” are the best tools that can be used to warn operators of potential or existing problems. **Look** for water, air, or lubricant leaks. **Listen** for unusual sounds coming from the pump, motor, valves, or controls. **Smell** the air for burning electric motor insulation. **Touch** the motor casing and pump casing to check for vibration and heat.

Equipment inspection

The well house, pumps, and water system equipment should be inspected daily.

- Check the well house for vandalism or damage.

- Collect a water sample in a clear container and inspect it for sediment. Is the water clear?
- Look at fittings and valves, note any leaks and repair them, if necessary.
- Verify that containers of poisons, pesticides, petroleum products, or other hazardous materials have not been moved into the pump house or near the well.
- Do not use the pump house to shelter animals or as a storage shed.
- Check for exposed and bare electrical wires. All wires should be encased in conduit and wire splices contained within junction boxes. Conduits should be flush against the well cap. The conduit should not be pulled away from the well cap creating an entryway into the well casing for insects and rodents.

Operational log

A daily operational log sheet should be created and tailored to record data for the specific well house and water system being operated.

- Record the date and time you visit the well house and any maintenance done or operational changes made.
- Record pressure gauge and water meter readings.
- Pay special attention to the pump discharge pressure gauge. This reading is used to monitor the efficiency of the well pump.
- Similarly, the suction and discharge pressure gauge readings are useful for monitoring performance on end-suction centrifugal booster pumps.
- Observe the on and off pressures for the hydropneumatic tank.
- Record the pump hour meter reading. The pump hour meter is normally located in the control panel and records the amount of time that power was delivered to the pump (the length of time water was pumped).
- Check the well pump to ensure it is not short cycling. Record the pump cycles-counter reading. The pump cycles-counter tallies the number of times the pump motor cycles (turns) on and off. If cycles are too frequent, the storage tank level controls are improperly set or the hydropneumatic tank may have lost its air cushion and is waterlogged.

Well house inspection

- Make certain the well house access door is locked after completing the routine maintenance and inspection visit.
- Review water monitoring data and analyses, and compare to past results, on a regular basis.
- Find and fix the cause of any change in water color, taste, or odor. Shock-chlorinate the well only when necessary.
- Keep a permanent record of the static water level from a reference point such as the top of the well casing. These measurements provide early warning of pump and well capacity problems.
- Measure the static water level at least twice per year and record the measurement, time, and date. Measurements should be made on approximately the same dates each year, usually in the spring and fall. The well should be

allowed to sit without pumping for one to two hours before measuring the static water level.

Records

Records should be accurate and consistent. Good record keeping will provide you with a historical log that can be a very helpful resource when troubleshooting problems. Start a file specifically for the records of your water system. The records file does not have to be fancy or elaborate. For small systems a three-ring binder is sufficient. Keep records in the system office or your home, if you do not have a system office. Do not keep permanent records in the well house. Records kept in the well house are subject to moisture damage and may easily fade or be completely ruined.

Record file

Keep the following records in your file:

- The well log
- Pump data that includes the date the pump was installed, the brand and model number
- A record of yield and drawdown
- Dates pump was replaced or pulled for maintenance
- Water quality monitoring records
- Copy of your last sanitary survey
- Name and phone number of your local pump maintenance technician
- Local ADEC office phone number

6.4 Chemical System Inspection

- Check the level of chemical solution in the tank. Note the amount of solution used since the last visit and replenish, if necessary. As a general rule of thumb, if the solution is thirty days old or older, replace it with a fresh solution. Try not to mix more than a seven-day supply.
- Record the date the solution was made on the vat or other readily visible structure and in the logbook.
- Inspect all the chemical feed pump fittings for leaks.
- As you observe the discharge line, can you see the solution being pumped?
- Make sure the foot valve is below the surface of the liquid.
- Does the pump sound normal, like it has in the past, or is it louder?
- Feel the pump with the back of your hand to make sure it is not running hot.
- Inspect the electrical connections and note any corrosion or looseness.
- Calculate and record the dosage of chemical you are feeding.

6.5 Operation and Maintenance of Pumps

Service manuals

When performing pump installation or maintenance procedures, always refer to the manufacturer’s service manual provided with your pump. Manufacturer’s service manuals should be available for all water system equipment. Service manuals provide detailed instructions for the replacement of impellers, seals, and bearings. Be sure to follow the manufacturer’s instructions for the particular pump being serviced. Service manuals should be read carefully, filed in a convenient place, and consulted whenever servicing is required.

Consult with a reputable pump manufacturer or local pump service company before purchasing a pump. Purchasing a pump that is oversized in anticipation of future system requirements can lead to problems and waste electricity.

When pumps are operated against a throttled (partially closed) discharge valve, the pump operates under capacity. This arrangement not only wastes horsepower, but it also creates internal vibration and pressure surges that can damage your pump.

Pump problems

Pumps will last longer and provide reliable service if a regular maintenance schedule is followed. Periodically check the following:

- Pump discharge – The operation of the pump should be checked regularly, i.e., at least every six months. The discharge of a pump will decrease if abrasive materials such as sand have worn the impeller, if the impeller is jammed, or if the system is air locked. Replacing a worn impeller and wear rings may restore a pumps performance to nearly its original output.
- Vibration – Excessive vibration can be caused by loose mounting bolts, a broken impeller, worn bearings, or a misaligned shaft. A centrifugal pump should run smoothly. If it vibrates, shut it down and determine the cause. Vibration may also be the result of cavitation. Cavitation occurs when the inlet pressure falls below the design inlet pressure or when the pump is operating at a flow rate higher than the design flow rate. When the inlet pressure in the flowing liquid falls below its vapor pressure, bubbles begin to form in the eye of the impeller. Once the bubbles move to an area where the pressure of the liquid increases to above its vapor pressure, the bubbles collapse thereby emitting a “shock wave.” These shock waves can pit the surface of the impeller and shorten its service life. The collapse of the bubbles also emits a pinging or crackling noise that can alert you that cavitation is occurring.
- Debris – Is there sand and sediment in the water? Submersible pumps often pump sand. If the screen is missing or damaged, the sand may reach the pump. Sand will damage the impeller and impede the flow. Reduced pump discharge or unusual noise may indicate debris in the pump.

Pressure gauge and electric meter

Submersible pumps are inspected infrequently. Therefore, recording the amount of water produced by the well, recording the pressure gauge reading on the pump discharge pipe, and recording the electrical meter reading (submersible pump usage) are crucial to determining when a submersible pump should be pulled for service or replacement.

Incrustation

Declining well yield may indicate that the pump needs to be serviced or replaced. A declining well yield may also indicate an incrustation problem. The main materials causing incrustation are calcium carbonate and iron. Incrustation occurs when the well screen and the water-bearing formation around the intake become clogged by calcium carbonate or iron precipitates.

Correcting an incrustation problem involves pulling the screen and either removing the incrusted material or installing a new screen. However, removing well screens is not an easy process and may not be practical. Incrustation can be dissolved with the screen still in the well. By treating the screen and water-bearing formation with acid.

If incrustation is severe enough, the well may have to be completely redeveloped. You should consult with a reputable pump manufacturer or local pump service company for the proper procedure to correct incrustation problems.

Iron bacteria

Iron bacteria occur naturally in the soil and may be introduced into the groundwater during the well drilling process. These bacteria metabolize soluble iron and, as a by-product, form a gelatinous slime or mat. This mat may appear as a reddish, slippery substance on the inside surfaces of pipes, parts of a toilet tank, and clog the well screen.

Sulfur bacteria

Once this mat of iron bacteria is established on steel pipes, such as the well casing, it may provide a haven for sulfur bacteria, another troublesome microorganism. Some sulfur bacteria convert sulfides to elemental sulfur, which combines with bacterial filaments to clog pipes. Another group of sulfur bacteria generates hydrogen sulfide gas, which is corrosive to pipes and has a foul smell like rotten eggs. Certain sulfur bacteria may produce sulfuric acid that can also cause the corrosion of pipes.

As mentioned above, the slime mat produced by the iron bacteria provides a favorable environment for the sulfur bacteria. This slime mat also encloses and supports sites of corrosion, which may be the cause of the odor, taste, and staining problems commonly encountered with well water.

Static and pumping water levels

Declining well yield may be the result of a declining static water level. The static water level and pumping water level should be compared to previous records. Records will reveal past static water levels and help identify the cause of the declining yield.

Above ground pumps

Lineshaft turbine pumps and above surface pumps and motors require more maintenance, but they are also much easier to access. Operators should check daily for irregularities in motor and pump performance. Irregularities that must be noted include:

- Changes in the sound of a running pump
- Unexplained temperature changes on bearings
- Seal chamber leakage
- Sudden pressure gauge drops
- Increased motor or pump vibration or heat

Any irregularities should be investigated and corrected**.** Pressure gauges should be observed, and readings recorded daily. Also, the well house flow meter and electrical meter readings should be observed and recorded.

Bearings and sleeves

Pump bearings and sleeves that require lubrication should be checked to make sure they contain the correct amount of grease. Grease should be added as needed. Old grease should be flushed out by pumping new grease into the bearing.

Pump bearings are designed to have a minimum service life of more than thirty years when properly installed, operated, and maintained. Contamination of bearing lubricant is a far greater danger to bearing life than overloading, overuse, or fatigue. Grease according to the manufacturer’s recommendations, which will be approximately twice per year (semiannually). Do not over-grease bearings. **More grease is not better and may cause the bearing to overheat.**

Seals

Pumps have seals on the shaft that stop air from getting into the pump and prevent water from leaking out between the volute and the shaft. Seals may be mechanical or packing type.

Packing is designed to allow leakage of a small amount of water. This helps cool the pump shaft. Packing glands should be tightened until water barely drips from the packing. One or two drips about every five seconds are adequate. Mechanical seals should not normally leak water.

Semi-annual maintenance should include:

- Inspect shaft packing
- Replace packing, if necessary

- Observe mechanical seals for signs of leaking
- Check stuffing box packing glands for free movement
- Clean and lubricate packing gland bolts
- Check pump and driver alignment

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

Spare parts inventory
A spare parts inventory should be maintained as insurance against delays in receiving parts. Delays may result in serious downtime. Pump usage, past repairs, and maintenance records will determine the minimum number of spare parts that should be stocked. Spare parts should be stocked when the pump is purchased. Consult with the pump installer or pump manufacturer to determine what critical spare parts should be kept on hand.

Remote water systems in Alaska must factor shipping time into the creation of a spare parts inventory. Delivery may take five to seven days or more in many parts of the state. It is probably wise for small water systems to have a spare pump on hand and ready to run, rather than wait for the pump to fail and then start overhauling it.

6.6 Well Pumps

The two most common well pumps in use today are the centrifugal pump and jet pump. Use extra precautions when working on pumps or other water system equipment. Contamination may enter the water system through the transmission of bacteria from your hands, the ground, or tools.

A centrifugal pump is the simplest of all pumps. It consists of one moving part (a rotary impeller) and a stationary casing (the volute or diffuser). The volute (case) captures the water that is thrown from the impeller (Figure 6.1) and directs it in a single direction. The operation of a centrifugal pump is very simple. The pump body is filled with liquid and the impeller is rotated, causing the liquid to flow outward by centrifugal force, creating a high velocity to the water. The outward flow of the liquid through the impeller reduces the pressure at the eye of the impeller, causing more liquid to be forced into the impeller eye by external or atmospheric pressure.

The liquid is collected in the volute, or diffuser, and converted to pressure. The pressure a centrifugal pump develops is in direct relation to the velocity created by the impeller. The larger the diameter of the impeller or the faster the impeller is rotated the more pressure the pump will develop. The width of the impeller vanes will determine how much liquid the pump will deliver. Pump speed and impeller size both affect the horsepower size of the motor. The more water you pump, or the higher pressures you develop, the more horsepower you will need. Horsepower is defined as a measurement of work. One foot-pound of work is the amount of energy required to lift one pound of water one foot in elevation. One horsepower is 33,000 foot-pounds per minute of work.

Figure 6.1: Semi-open Impeller

Jet pumps are seldom used in Alaska public water systems because of their low efficiency. However, they are commonly used for private wells because of their initial low cost and low maintenance. Jet pumps are used successfully in shallow wells and small diameter domestic wells. A jet pump includes a jet. A jet is a nozzle that receives water at high pressure. As water passes through the jet, water speed (velocity) increases, and the pressure drops. The action is comparable to the squirting action achieved through a garden hose when the nozzle starts to be closed. The velocity of the water coupled with the pressure drop allows water around the jet to be sucked in along with the suction flow of the pump.

6.7 Motor Maintenance (Non-Submersible Pump)

Lineshaft motor inspection

The motor for a lineshaft turbine pump is usually located above ground on a cement base. The motor can and should be visually inspected regularly.

- Check the oil quantity and condition on oil-filled motors.
- Check the color of the oil in the motor housing through the oil inspection sight window or inspection plug. Oil should be a light rich bronze color. If it is solid black or you see sediment in the oil, change it.
- The oil may be emulsified (cream-like appearance), which indicates that water has entered the cavity.

- If there has been leakage or other problems, correct it and make certain that the oil is refilled to the proper level using the correct grade of oil.

Temperature, moisture, altitude, power source, and wire size are all factors that could impact the performance and longevity of the motor and pump.

6.8 Operation and Maintenance of Valves

Valves

Valves are used to regulate water flows, reduce pressure, provide air and vacuum relief, and blow off or drain water from the system. Valves are also used to prevent **backflow** and to isolate sections of the piping system for repair and maintenance. Many types of valves are used in the water industry, but all have basically the same function, i.e., to control or stop the flow of water in pipes.

Valve inspection program

A well-organized valve inspection program is essential for proper system maintenance. Valves normally suffer from a lack of operation, not wear. Valves four inches and larger should be **exercised** semi-annually. Exercising valves means opening and closing the valve manually to assure they operate properly and easily. When exercising valves, they must be opened and closed slowly. If they are closed quickly **water hammer** may occur. The rise and fall in pressures, or water hammer, can cause serious damage to the distribution pipes and components.

Valves in a distribution system allow small sections of the distribution lines to be isolated for emergency maintenance.

Inspection items

A good valve inspection program includes:

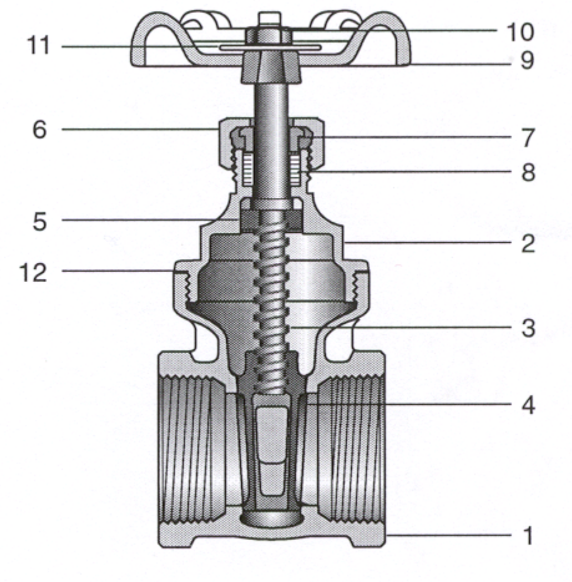
- Check the location of each valve as well as the measurements to established reference points, such as poles, trees, hydrants, or buildings.
- Exercise valves in both directions; fully closed and fully open. Record the number of turns required to close the valve. Any valves that operate in the opposite direction from normal (normal: “righty-tighty; lefty-loosey”) should be noted. Leave valves in a position one-half turn from the fully opened or fully closed position.
- Most valves should be left in the open position, but valves that normally remain closed should be noted.
- Valve boxes should be checked, debris removed, raised or lowered to grade, or replaced as necessary to accommodate current local conditions.

Small valves should be inspected annually and checked to make sure the handle and valve stem move freely. Tightening the packing nut, located on the top of valves, one-half to one full turn to stop leakage around the valve stem.

Gate Valves

The most common type of valve used in the water distribution system is the gate valve (Figure 6.2). It receives its name because of its gate-like operation. The most common gate valve is one with a non-rising stem; a valve in which the stem does not rise as the valve is opened.

This type of valve is reasonably dependable, has an almost unobstructed waterway when open, is very economical in smaller sizes and can be installed underground with a minimum cost. A gate valve should not be used for throttling flow or for infrequent operation. It should be operated in the full-open position or left in a full-closed position.

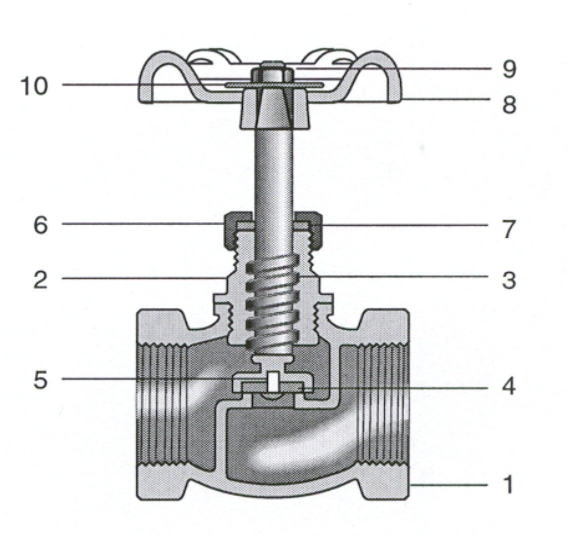


1 – Body	7 – Gland
2 – Bonnet	8 – Gland packing
3 – Stem	9 – Handwheel
4 – Disc	10 – Wheel nut
5 – Lock nut	11 – Name plate
6 – Packing nut	12 – Bonnet gasket

Figure 6.2: Gate Valve

Globe Valve

Globe valves are installed where there is to be a frequent change of operation. It receives its name because the main body is globelike in shape (Figure 6.3). Because of its design, this type of valve offers significant resistance to the flow of liquids but does provide a more positive shutoff. Globe-type valves would not be used if the flow rates are important to the installation. The design of the valve is such that it must be installed in the correct position with the flow of liquid. Oftentimes, this direction is indicated by an arrow on the valve itself. Globe valves are ideal for throttling or regulating flow.



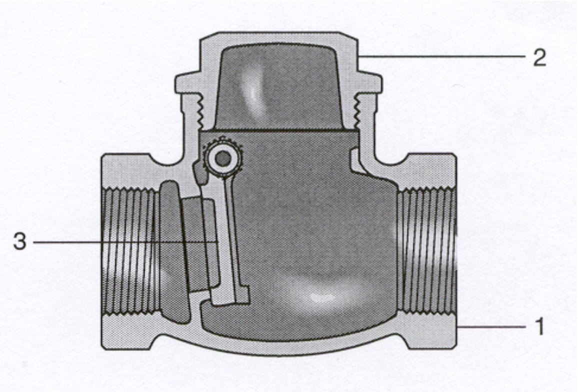
1 – Body	6 – Packing nut
2 – Bonnet	7 – Gland packing
3 – Stem	8 – Handwheel
4 – Disc	9 – Wheel nut
5 – Disc bolt	10 – Nameplate

Figure 6.3: Globe Valve

Check Valve

A check valve is designed to allow flow in only one direction. The most common use of check valves in a water system is on the discharge side of pumps to prevent backflow when pumps shut down. A foot valve is a special type of check valve installed at the bottom of the pump suction so the pump will not lose its prime when power is shut off.

The most common type of check valve is a swing check (Figure 6.4). Installed in the correct position, the flow of the liquid opens the disc allowing the fluid to pass. Should the flow reverse, the pressure and the disc’s weight close the disc against the seat, stopping backflow.

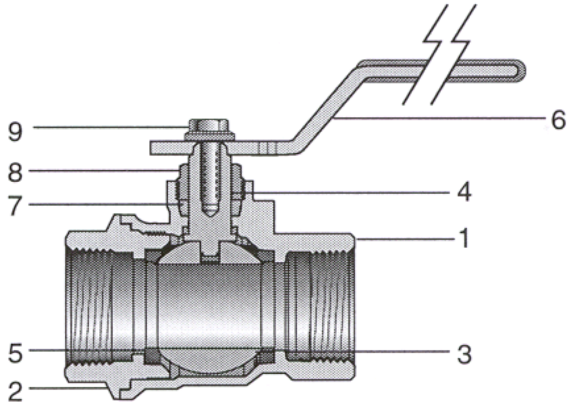


1 – Body	
2 – Cap	
3 – Disc	

Figure 6.4: Check Valve

Ball Valve

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 (Figure 6.5). Ball valves can be used to throttle flow in low pressure applications.



1 – Body	6 – Lever handle
2 – Body end piece	7 – Gland packing
3 – Ball	8 – Packing nut
4 – Stem	9 – Handle bolt
5 – Seat	

Figure 6.5: Ball Valve

6.9 Operation and Maintenance of Pressure Tanks

Hydropneumatic tanks

Hydropneumatic or pressure tanks (Figure 6.6) are frequently used in small Alaska water systems. They maintain distribution system pressure. Generally, when service to more than fifty houses is anticipated, storage, other than a pressure tank, should be provided.

Tank types

Tanks are constructed of steel or fiberglass. The most common types of pressure tanks in use are the diaphragm, the bladder, and plain galvanized pressure tanks. They are not a good storage vessel for fire protection purposes due to the small volume of water within the tank.

Pressure tank system

The typical hydropneumatic system is made up of the following:

- Tank – stores the water.
- Air volume control – controls the air volume.
- Relief valve – prevents excessively high pressure.
- Inlet pipe – allows the flow of water into the system.
- Pressure gauge – monitors pressure.
- High/low water level controls – regulates water level.
- Discharge piping/air – discharges water from the tank; forces additional air into the tank to increase pressure.

Pump cycle

The water supply pump in hydropneumatic tank systems starts when the pressure drops to a predetermined low pressure (cut-in pressure). As the tank fills the energy from the pump pressurizes the pocket of air at the top of the tank. When the pressure builds to a predetermined high pressure (cut-out pressure), the pump stops, and compressed air forces the water out of the tank and into the distribution system. When the pressure falls to the cut-in pressure (often 30 to 40 psi), the pump starts up again, and the cycle is repeated.

The pressure tank prevents frequent start/stop cycling that can be extremely hard on the pump. The cycle rate is the number of times the pump starts and stops in one hour. Six to eight pump cycles/hour with a minimum pump run time of one minute is the recommended standard.

A pressurized storage tank must have provisions to replenish the air since water tends to absorb air. The tanks are pressurized with an air compressor that pumps air into the tank. Bladder tanks or tanks with optimum air volume controls generally are set up for one-third air and two-thirds water. Off-the-shelf galvanized tanks have an equal volume of water and air.

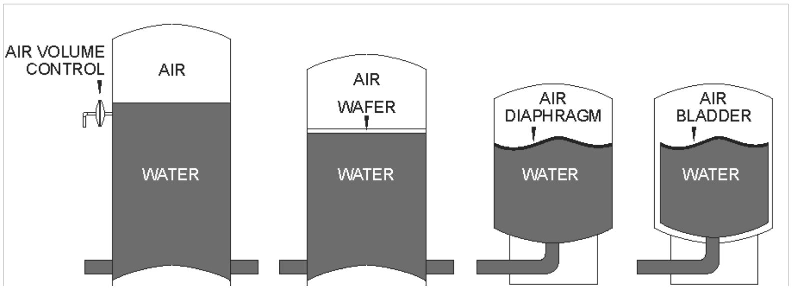


Figure 6.6: Hydropneumatic Tanks

6.9a Diaphragm and Bladder Pressure Tanks

Diaphragm and Bladder Tanks

Diaphragm and bladder type tanks use a flexible separator that completely isolates the air from the water. The tank is pre-charged at the factory and has an air charging valve installed on the top of the tank to allow the installer to change the tank pressure in the field to accommodate different system pressures. If the pressure switch is set to start the pump when the pressure drops to 30 psi, the air pre-charge pressure in the tank should be 28 psi.

Table G lists the recommended recharge pressure for different systems.

Pressure switch setting	Tank discharge (psi)
20 – 40 psi	18
30 – 50 psi	28
40 – 60 psi	38

Table G: Recommended Recharge Pressures

Waterlogged tanks

A water system may use pump cycle counters to tally the times that the pump cycles on and off. If cycles are too frequent, it is an indication that the storage tank level controls are improperly adjusted or that the hydropneumatic tank has lost its air cushion and is **waterlogged**. This cycle will continue over and over, eventually causing damage to the pump. To confirm a waterlogged tank, install a pressure gauge on the system. If the gauge shows a steady drop in pressure, even though no water is leaving, the tank will need to be drained and refilled.

Recharging a waterlogged tank

- Shut off electrical power to pump.
- Lockout/tagout the breaker box.

- Locate and remove the 1½" or 2" pipe plug that is located about 1/3 of the way down from the top of the tank.
- Water will drain from the tank when the pipe plug is removed.
- Drain the tank completely, if possible
- When the water stops draining out, replace the pipe plug, using Teflon tape or thread sealer.
- Remember to disinfect before putting the system back in service after cleaning or repairs are complete.
- Reconnect electrical power to the pump and run through a normal cycle.
- Check for leaks.
- Determine the reason for the air-add system failure and correct it.

The air-add system used by a submersible pump/galvanized tank setup has 3 critical parts:

1. Air volume control (air release type)
2. Check valve with snifter valve at the tank
3. Bleed-back valve in the well

Note that failure of any one of the listed critical parts will cause the tank to become waterlogged.

To check pressure tank air charge:

- Disconnect electrical power to pump.
- Lockout/tagout the breaker box. (Lock/Tagout procedures are described in Section 9.4.)
- Open the nearest faucet and completely drain the tank.
- Check pressure with a regular tire gauge using the air charging valve located on the top of the tank.
- If air pressure is more than 2 psi below pump cut-in pressure, add air with a tire pump or air compressor.
- Use a soap solution to ensure the air charging valve is not leaking before replacing the cap.

Note: If the pre-charge pressure is low, you will generally find that the tank feels heavier than it should when you rock it, indicating water remains inside the tank on top of the bladder. Seldom does adding air successfully restore proper operation. If air pressure is too high, remove air as necessary.

To test for bladder leakage:

- Disconnect power to pump.
- Lockout/tagout the breaker box.
- Drain all water from the tank bladder by opening a faucet closest to the tank.

- Remove the valve cap from the air charging valve and release all pressure possible by depressing the valve core.
- When air stops coming out of the valve, remove the valve core to release the remaining air.
- Disconnect all piping to the tank.
- Carefully turn the tank upside down or lay the tank on its side.
- Retained water in the tank may cause a sudden weight shift when lowering. Support tank so the tank cannot fall when being lowered or inverted.
- Water will run out of the air charge valve if the bladder has a leak.
- Some bladders can be replaced, but it may be cheaper to replace the tank. If you decide to replace the bladder yourself, be sure to follow the manufacturer's instructions and recommendations.

Air charge valve replacement

- Disconnect power to pump.
- Lockout/tagout the breaker box.
- Drain all water in the system by opening the faucet closest to the tank.
- Depress valve core to release all air pressure in the tank. When air stops coming out of the valve, remove the core from the inside of the valve to release the remaining air.
- Remove air charge valve.
- Use Teflon tape on the new valve. Thread valve into the tank and tighten.
- Do not overtighten!
- Recharge the tank with air pressure according to Table E above.

6.9b Galvanized Pressure Tanks

Galvanized Pressure Tanks

Galvanized pressure tanks can be mounted in either a horizontal or vertical position. The tank discharge should always be near the bottom of the tank. This tank operates similarly to the diaphragm and bladder tanks, with the exception that these tanks have no barrier between the water and the air cushion (air-water interface).

Maintaining Air Pressure

To maintain the proper air pressure inside the tank, a special valve known as an air volume control valve is mounted on the tank at the level where the water will be when the pump starts. When the pump starts, the diaphragm in the valve is drawn toward the outside by pump suction. Air enters through the snifter valve if the water level in the tank is above the air control. When the pump shuts off, the pressure equalizes, and the diaphragm moves back by spring pressure and forces air into the tank.

Leaky Tanks

Galvanized pressure tanks are usually low maintenance; however, occasionally the air volume control valve will fail. Water will start dripping from the valve and this indicates that the valve should be replaced. Over time, galvanized tanks will rust and may begin to leak. It is not a good idea to weld the tank to stop the leak. Welding on the tank will accelerate the corrosion and cause the tank to deteriorate within a short period of time and the tank may become waterlogged.

Excessive Air in Water

If customers complain about milky water or air bubbles, check to see that the air-volume control valve on the pressure tank is working properly. In most cases, the air-volume control valve is the cause and should be replaced.

Air Volume Control Replacement

- Shut off electrical power to pump.
- Lockout/tagout the breaker box.
- Partially drain the tank until the water level is below the air volume control connection.
- Remove the small line from the pump suction line to the air control valve.
- Remove the old air control valve with a wrench.
- Use Teflon tape on the pipe nipple.
- Install the new air volume control.
- Do not overtighten!
- Install small line from pump suction to new air control valve.
- Reconnect electrical power to pump and run through a normal cycle.
- Check for leaks.

Pump Cycles

Most pumps and systems come from the manufacturer with the pressure switch preset. Many small water systems deliver about 40 psi to each house. Pressure switches are set to start the pump when the pressure drops close to 20 psi and shut off the pump near 40 psi. Due to **backsiphonage** concerns, some systems may be preset at 30 psi cut-in pressure and 50 psi cut-out pressure.

Keep a good operational pressure gauge on the pump and check it periodically as the pump goes through its cycle. A pump cycle check will confirm that the system is operating at the preset pressures and at its most efficient cycle.

Tank Size

To determine if the size of the pressure tank is adequate refer to Table H. Example: If the pump puts out 18 gpm, and the water system pressure is between 30-50 psi, a 315-gallon pressure tank is recommended.

Pump Capacity (gpm)	Pressure-Switch Range Setting (psi)				
	20-40 psi	30-50 psi	40-60 psi	50-70 psi	60-80 psi
4	*42	82	82	120	120
8	82	120	180	220	315
12	120	180	220	315	315
15	144	220	315	525	525
18	180	315	315	525	525
24	220	315	525	525	1000
32	315	525	525	1000	1000

Table H: Pressure Tank Selection Chart

***** Number denotes pressure tank size in gallons

6.10 Storage Facilities Operation and Maintenance

Function of Storage Tanks

Water storage facilities located on water distribution systems are used to average out or equalize flow rate demands on the water supply system. Maintenance of adequate pressure throughout the system is critical. Low pressure might result in system contamination due to backsiphonage. Low pressure can indicate improper connections and too high a pressure can stress system components, cause high leakage rates, and can force air out of water. Other functions of water storage facilities include increasing operating convenience, leveling pumping requirements (to keep pumps from running 24 hours a day), decreasing power costs, providing water during power source or pump failure, providing large quantities of water to meet fire demands, providing surge relief (to reduce the surge associated with stopping and starting pumps), and providing chlorine contact time.

Type of Storage Tanks

Besides hydropneumatic tanks, there are five types of storage tanks in common use:

1. Ground-level tanks – constructed at ground level and located above a service area to maintain pressure throughout that area
2. Elevated tanks – elevated above the ground and located above a service zone to maintain adequate and uniform pressure throughout that area
3. Clear wells – constructed partially or totally below ground to store finished water from a treatment plant and in many cases used to achieve the required contact time
4. Standpipes – constructed at ground level having a height greater than its diameter
5. Surge tanks – constructed at ground level and often used to control water hammer or regulate the flow of water

Storage Tank Inspection

Regardless of the type of storage tank installed they should be inspected regularly. The storage facility is a critical part of the water system. A basic storage tank operation and maintenance plan helps ensure the water remains safe to drink and aesthetically pleasing for customers.

- Check the tank regularly to make sure no contamination can get into the tank.
- When was the last time your tank was cleaned or inspected? Storage tanks can be a haven for microorganisms if not kept clean and maintained.
- Storage tanks should be inspected annually, and a regular cleaning schedule established based on those inspections.
- Visually check around the base or foundation of the tank to make sure no erosion has occurred that may result in a tank collapse and failure.
- Are there any signs of rust or serious corrosion?
- If you have to shut down the tank for repairs, can you shut the valves (isolate) or does the whole system have to be shut down to repair the tank?
- Do you have access to some calcium hypochlorite or sodium hypochlorite to disinfect the tank after it is repaired?

6.11 Leak Detection

Leak detection inspection should be routinely conducted throughout the entire distribution system. The distribution system consists of a network of pipes, valves, fire hydrants, service lines, meters, and well house plumbing. Water can be lost from any of these components.

Small leaks never get smaller. Early detection and leak repair will help keep operating and maintenance costs down. Lost water equals lost revenue. Inspect the distribution system regularly and look for obvious leaks. Look for wet spots on the ground that may indicate a leak. Some systems pay a professional to perform an annual leak inspection on the system.

Check and record the master flow meter readings daily. If customers have individual meters, residential water use can be compared to the master flow meter reading.

Also, water pooled around a leak in the pipe is an indirect cross-connection. Non-potable water may back siphon into the water pipe if a pressure drop caused by a leaking line or power failure occurs and creates a vacuum.

6.12 Cross-Connection

The greatest potential hazard in the piping or distribution system is associated with **cross-connections** to non-potable waters. It is the system owner's responsibility to ensure that their system is safe from cross-connections. If you have any questions about potential cross-connection situations, a cross-connection control specialist should be consulted.

A cross-connection is defined as any direct or indirect connection between a public water supply and any other source of non-potable liquid. A direct connection is a physical connection between the piping arrangements of a potable and non-potable system. An indirect connection occurs when the water completes the connection, such as a hose from a potable supply submerged in contaminated water, or a leaking pipeline that pools water around the break.

Backflow

One of the greatest hazards that exists in a small water system can occur as a result of backflow from the customers' premises into the distribution system. Backflow is defined as an undesired, reversed flow of liquid in a piping system. Backflow due to cross-connections are serious plumbing problems that can cause sickness or death.

Backsiphonage

Backflow can be caused by backsiphonage (Figure 6.7), backpressure, or a combination of the two. Backsiphonage results from pressure in the distribution system falling below atmospheric pressure (14.7 psi at sea level). Contaminated water from the customer's pipelines is sucked into the distribution system because the supply pressure is less than atmospheric pressure.

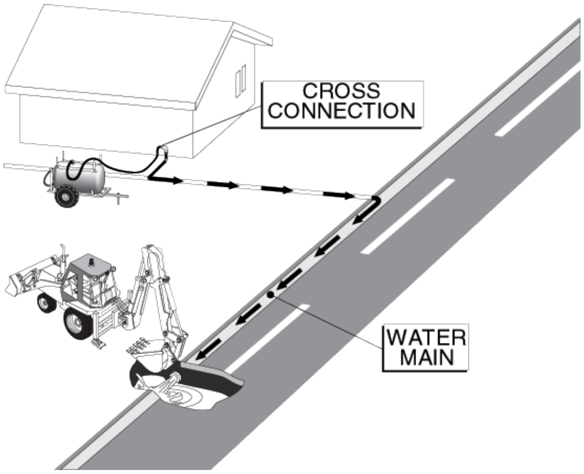


Figure 6.7: Backsiphonage Condition

Backpressure

Backflow due to backpressure happens when a customer's water pressure is greater than your water system's pressure. When this occurs, potentially contaminated water from the higher pressure in the customer’s pipelines flows into the distribution system’s pipelines.

The minimum pressure that should be maintained in the distribution system is 20 psi. At 20 psi, a positive pressure is maintained in the distribution system, and the chance of backsiphonage is reduced.

Occurrence
Cross-connections can occur in a variety of locations, including the pump house, hospitals, farms, houses, and apartment complexes. The following are examples of cross-connections:

- A prevalent type of cross-connection is made when a hose is connected to a sink faucet with the other end of the hose lying in a pool or sink full of polluted or contaminated water. In this case, backflow occurs by backsiphonage. If a partial vacuum is set up in the distribution system, water can be drawn from the sink by suction when the faucet is opened.
- Direct cross-connections to a pressurized system, such as a hot water boiler, are not uncommon. In this case, backflow can occur by backpressure and by backsiphonage. Backpressure backflow can occur when the water pressure in the boiler or pressurized tank exceeds the positive pressure in the water distribution lines.
- A cross-connection to an elevated tank containing a non-potable substance can cause backflow by backpressure. Backflow can occur if the valve is left open and the pressure caused by the water elevation in the tank exceeds the line pressure.
- A cross-connection to a pressurized pipe carrying contaminated water can cause backflow. When the valve is opened, backflow by backpressure can occur if the pressure in the non-potable lines is higher than the positive pressure in the potable system.
- A cross-connection can be created when a hose connection from a water line is used to fill a tanker truck. Backflow can occur by backsiphonage if a partial vacuum is developed in the water system.
- A cross-connection can be created when a hose connection from a water line is used to operate a paint sprayer or a herbicide applicator.

6.13 Backflow Preventers

There are five basic devices or methods used to prevent or reduce the possibility of backflow in cross-connections. Each device must be installed properly and tested annually by a certified backflow device tester to ensure satisfactory performance. If you have any questions regarding the suitability of a particular device in a specific application, an experienced backflow device technician should be consulted.

1. Air Gap

An air gap (Figure 6.8) is a physical separation of the potable and non-potable water system by an air space. The air gap is the most reliable backflow prevention measure. The vertical distance between the supply pipe and the flood-level rim should be at least two times the diameter of the supply pipe, but never less than two inches. This type of backflow prevention technique can be used in situations in which potable water runs into a tank, sink, or any source that is under atmospheric pressure.

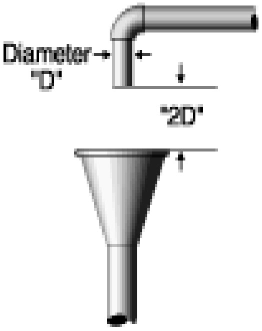


Figure 6.8: Air Gap

2. Atmospheric Vacuum Breaker (AVB)

Atmospheric vacuum breaker devices (Figure 6.9) do not prevent backflow due to backpressure, but they can control backsiphonage. They must be installed on the discharge side of the last control valve. In addition, they cannot be used under continuous pressure for eight hours or more.

AVBs are usually used with hose bibs or spigots in situations in which a hose is attached to a sprinkler system or is draining into a tank.

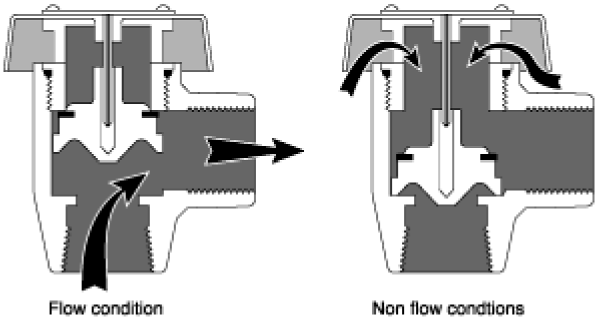


Figure 6.9: Atmospheric Vacuum Breaker

3. Pressure Vacuum Breaker Assembly (PVB)

Pressure vacuum breaker assemblies are similar to atmospheric vacuum breakers except that these devices can be used under continuous pressure. They cannot prevent backflow due to backpressure and must be installed above the usage point to prevent backsiphonage.

The PVB is spring-loaded to allow air to enter the device. Under normal conditions, water pressure compresses the spring, closing the air opening with the plunger. If a partial vacuum in the assembly is obtained, air is allowed to enter the assembly, forming an air gap.

4. Double Check Valve Assembly

Double check valve assemblies (Figure 6.10) are used for a direct connection between two potable water systems. Under continuous pressure, they cannot be used to connect a potable water supply to a contaminated or high-hazard water system. They offer only a partial degree of protection because particles can prevent proper seating of the valves causing them to leak.

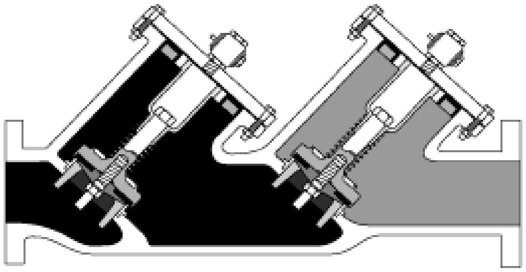


Figure 6.10: Double Check Valve

5. Reduced Pressure Zone (RPZ) Assembly

Of all these devices, the reduced pressure zone assembly (Figure 6.11) provides the greatest protection against backpressure and backsiphonage. The RPZ can be used under continuous pressure and in high-hazard conditions. It is composed of two independent, internally weighted check valves separated by a reduced pressure zone valved to the atmosphere. The assembly also has an isolation valve on each end, as well as test ports to determine the proper operation of the assembly. The valve is designed so that the valve on the reduced pressure zone will open when the pressure in the zone gets to within two psi of the supply pressure. For backflow to occur through this valve, the two check valves, as well as the reduced pressure zone valve, would all have to fail at the same time.

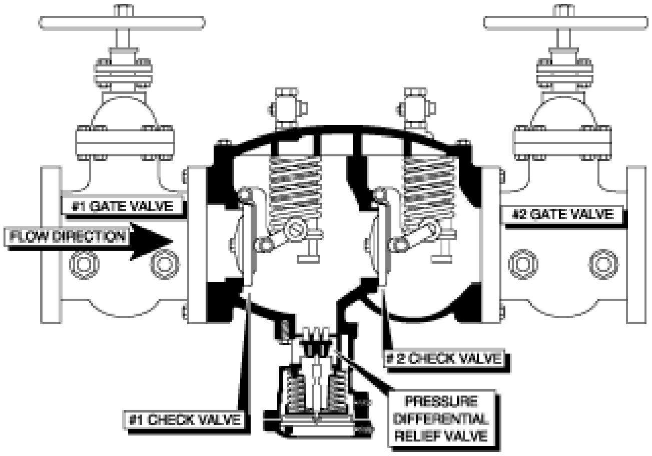


Figure 6.11: Reduced Pressure Zone Assembly

Only approved assemblies may be installed in a water system. For an assembly to be approved, it must undergo extensive testing by a private testing laboratory. ADEC Drinking Water Program maintains a listing of approved assemblies. A certified backflow prevention device tester must test the assemblies once each year. To obtain a certification as a backflow prevention assembly tester, you must attend a course and pass a written and practical exam. To maintain your certification, some states require an annual refresher course, proof that you have tested devices in the past year, and a certificate indicating that your test instruments have been tested within the past year.

6.14 Cross-Connection Control Program

The main function of a cross-connection control program is to eliminate the risk of cross-connections in the water system. Creating an effective cross-connection control program is an important and challenging responsibility.

Developing a program
Establishing a cross-connection control program for a small water system can be a daunting task. Small water systems in Alaska may be more susceptible to backflow and backpressure problems than larger water systems. As a water system owner or operator, the last thing you want is someone getting sick or possibly dying due to a cross-connection in your system.

To prevent this from happening, you need to survey your system for cross-connections. Every time a new connection is made to the potable water system, you must ask yourself if you are creating a cross-connection. If the answer is yes, the proper backflow device must be installed and maintained.

If you have backflow devices already installed in your system, you must make sure a qualified tester inspects them annually and records of the tests are retained.

Water system operators must be able to recognize cross-connections and take the appropriate actions to remove indirect cross-connections if possible or install approved backflow prevention devices on direct cross-connections.

6.15 Water System Security

Though the threat of contamination of drinking water through vandalism is remote, small water systems must be prepared. Take a few moments and decide how you would handle an unknown threat to your water source. If there are signs of unauthorized activity near your source or unauthorized entry to your plant, the threat should be taken seriously by water system owners, operators, and managers. Emergency response plans should be in place or written immediately, and small water system personnel should review and have formal safety plans in place. It does not have to be elaborate, but a common-sense plan should be developed.

If there are signs of unauthorized activity, you should increase source water and water system facilities inspections. Look for any changes that may have occurred at any of the facilities since the last visit: signs of unauthorized entry to the facilities, water tanks, or changes in water color, smell, or appearance. A water supply may appear clear, have no odors, and taste fine, yet may have a high level of dissolved substances or microorganisms that are not visible to the naked eye. Since it is impossible to judge the quality of the water with the eye, it is critical to analyze the water for physical and chemical properties.

The location of your system and its vulnerability to vandalism will determine the level of surveillance and security needed. If you are located in a residential area or near a school, the incidence of vandalism will likely be higher than if you are in a secluded, remote location.

Do not take any changes for granted. Report unauthorized entry to facilities to the manager and owner. Notify the proper legal authorities immediately if you suspect illegal entry to any of your facilities. Surveillance, vigilance, and common sense will help protect your system from vandalism.

6.16 Basic Electricity

Small water system owners/operators may fit the definition of being a “Jack of all Trades.” They are expected to have knowledge of microbiology, chemistry, mathematics, hydraulics, supervisory skills, administrative ability, accounting experience, mechanics, and serve as a part-time electrician in some instances. All the knowledge is then tailored to keep their water system running and provide safe water on a daily basis.

Seventy-five percent of well pumps and control problems are reported to be electrical-related. Therefore, an owner/operator will likely encounter an electrical problem at some point. The following basic electrical information will help an operator prepare for the certification exam and provide an understanding of electrical fundamentals.

NOTE: Electricity is dangerous and can kill you. The information contained in this manual covers electrical theory in very basic terms and ***does not*** attempt to prepare an owner/operator for troubleshooting electrical problems, electrical circuits, wiring water system instrumentation or machinery. An owner/operator should not attempt servicing or troubleshooting water system electrical components unless they have received appropriate training. In most cases, an electrical professional should be contacted to assist in troubleshooting or conducting electrical repairs.

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.

Most electricity used in the United States is produced at power plants. Various energy sources are used to turn turbines. The spinning turbine shafts turn electromagnets that are surrounded by heavy coils of copper wire inside generators. This creates a magnetic field, which causes the electrons in the copper wire to flow.

Electricity travels fast at 186,000 miles per second. If you traveled that fast, you could travel around the world eight times in the time it takes to turn on a light! And if you had a lamp on the moon wired to a switch in your bedroom, it would take only 1.26 seconds after you flipped the switch for electricity to light the lamp 238,857 miles away!

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 that 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.

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 (Figure 6.12) include the following:

Source
The part that provides the electric force to move the electrons as pressure, such as a battery or generator.

Load
The part that does the work, or part that uses the electricity, such as a light bulb, heater, or motor.

Conductor
The part that carries the electricity around the circuit such as a wire, cable, or power line.

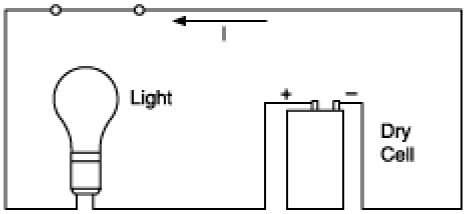


Figure 6.12: Simple Circuit

The battery pushes electrons through the metal wire, through the light bulb, and back to the other terminal of the battery, completing the circuit.

6.16a Current Flow

The following section lists electrical terms and gives a brief discussion of electrical theory.

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:

1. Direct Current (DC). The electrons flow in only one direction. Batteries and solar power are examples of systems that use DC.

2. Alternating Current (AC). The AC you use at home changes direction 60 times per second. This means it moves 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 (Hz) means 60 of these cycles occur each second.

6.16b Electrical Pressure

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. 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. The voltage difference between the two prongs of the outlet is 120 V or 240 V.

6.16c Resistance

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** (Ω) and is measured by a test instrument called an **ohmmeter**. Factors that determine amount of resistance are:

Type of material
- A conductor has low resistance permitting the flow of electrons, such as copper or aluminum.
- An insulator has high resistance restricting the flow of electrons, such as rubber or glass.

Size (diameter)
- Large diameter; less resistance
- Small diameter; higher resistance

Length
- The longer the length, the more resistance

Temperature
- The higher the temperature, the more resistance

If something has a high resistance, it takes a lot of voltage (pressure) to get the current to flow.

6.16d 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 measures 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. Electrical circuit

Source
- Water circuit – a water pump produces water pressure (psi) to cause water to flow (gpm)
- Electrical circuit – a generator produces an electrical force (volts) to cause electrons to flow (amps)

Conductor
- Water circuit – a pipe that carries the flow of water
- Electrical circuit – wire that carries the electrons

Flow measurement
- Water circuit – a flow meter measures water flow in gpm
- Electrical circuit – an ammeter measure current in amperes (amps)

Load
- Water circuit – a water wheel does work by rotating
- Electrical circuit – a light bulb does work by producing light and heat

Pressure loss
- Water circuit - to determine the loss of energy, pressure gauges installed before and after a water wheel can measure the loss of water pressure
- Electrical circuit – a voltmeter measures voltage drop as the current goes through a light bulb (conversion of electrical energy to light and heat energy)

6.16e Ohms Law

You have learned that the flow of electrons (current) is measured in amperes or amps. Also, electrical pressure, measured in volts, is required to cause current to flow. In addition, there is always resistance to this flow and the unit of resistance is the ohm.

The relationship between these electrical terms can be expressed very simply as Ohm's Law. Known as Ohm's Law because German physicist Georg Simon Ohm discovered the relationship between voltage, current, and resistance. It is one of the basic laws of electricity and can be expressed by the following equation:

$$Amps = \frac{Volts}{Ohms}$$

Or,

$$Volts = Amps \times Ohms$$

Or,

$$Ohms = \frac{Volts}{Amps}$$

6.16f Electric Power

When a charge moves in a circuit, *the rate* at which work is done is called electric power. Electric power is equal to the product of current and voltage:

Power = Voltage x Current
You must have voltage and current to generate power. Power is *the rate* at which electrical work is done, measured in Watts (W).

Watts (Power) = Volts x Amperes
A more powerful pump motor can pump water faster than a less powerful one. Many electrical devices (heater, light bulbs, etc.) are rated in watts, but electric motors used to drive pumps are usually rated in horsepower (hp).

Although theoretically, one horsepower equals 746 watts, this does not include the loss of energy in the motor through heat and friction. Consequently, for practical purposes, if a motor is ½ hp or larger each hp is equivalent to approximately 1000 watts. Motors smaller than ½ hp, use 1200 watts per hp. A 5-hp motor will use about 5,000 watts at full load and a ¼ hp motor will use about 300 watts at full load. However, watts and horsepower do not tell you how much electrical energy a piece of equipment is using. Remember, since power is a rate, you need to include the time that the equipment is running. The unit most commonly used to measure power is the kilowatt-hour or Kw-h.

If we can figure out how much energy an electrical device uses and we know how long the equipment is in operation each day, we should be able to figure out how much it costs to operate that device. For instance, let us calculate the cost of running a 1 ½ hp pump for 10 hours a day if electricity costs 15 cents per kilowatt-hour:

1. Since a horsepower is roughly equivalent to 1000 watts for this size pump, the power consumed by the pump would be 1,500 watts or 1.5 kilowatts.

2. Next find the energy consumed:

   $Energy = Power \times Time$ = 1.5 Kw x 10 hours

   a. = 15 Kw-hours

3. Next find cost:
   Cost = 15 Kw-hours x $0.15/Kw-hour = $2.25

The cost is about $2.25 to run this pump for 10 hours a day.

6.17 Emergency Generator (Power)

An extended power outage may shut off the pump, as well as other electricity needed to run the water system. To prevent this problem, a water system owner/operator may want to purchase an emergency generator to keep the pump operating and maintain minimal electrical service to the system. The generator should be powerful enough to operate the pump. Also, because of the electrical hazard, a qualified electrician should make the installation.

Chapter 7 – Troubleshooting

7.1 Introduction

During water system operations, various problems may develop that cause trouble. Finding the cause of the problem or trouble is called “troubleshooting.” Troubleshooting involves a series of steps leading from an assessment of what you know about current conditions and what you know about the normal operation of the system through a systematic investigation of the status of the components involved to ideas about the possible causes and solutions.

Problems may be hydraulic, mechanical, and/or electrical. Hydraulic problems may include a pump that will not deliver water at all, delivers an insufficient amount of water, or loses prime after start-up. Mechanical problems may include excessive use of power to operate the pump, excessive vibration or noise, or bearings failure. Electrical problems may be interrupted power supply, burned-out components, faulty wiring and grounds, or improperly designed and/or installed equipment.

Many problems are caused by a combination of mechanical, hydraulic, and electrical problems. For example, a well may pump sand or mud. When this occurs, the well screen may have collapsed or corroded, causing the screen’s slot openings to become enlarged allowing debris, sand, and mud to enter. If the well screen is not the problem, the pumping rate should be checked. The pumping rate may be too high. Excessive sand may require the installation of a sand trap. Or there may be an electrical problem, such as a faulty switch or starter.

Seventy-five percent of pump and control problems are reported to be electrical. Therefore, an owner/operator will likely encounter an electrical problem at some point.

Operators should have a good working knowledge of electrical circuits and circuit-testing instruments before attempting to service or troubleshoot the electrical circuits and components commonly used in well pump operations.

Small water systems operators unfamiliar with well pump or electrical circuit troubleshooting should arrange with a local, licensed electrical firm or pump service company to perform this service.

Chapter 6 of this manual provides an overview of electrical fundamentals.

NOTE: Never attempt to service, troubleshoot, or repair a motor without disconnecting the motor breaker from the main power source. Many motors also use capacitors which maintain an electrical charge until they are properly discharged!! Do not attempt to service electrical equipment without appropriate training and licensing.

7.2 Troubleshooting Guide

This troubleshooting guide is not intended to be all-inclusive, but rather a starting point for recognizing and identifying well problems. A list of well problems, probable causes, and possible solutions are listed in Table I. Also refer to Appendix 3, Troubleshooting Guide for Submersible Pumps.

Troubleshooting Guide:

Symptom	Probable Cause	Corrective Action
Pump Will Not Start	Circuit breaker or overload relay tripped, motor cold	Reset breaker or reset manual overload relay.
	Fuses burned out	Check for cause and correct, replace fuses.
	No power to switch box	Confirm with voltmeter by checking incoming power source, notify power company.
	Motor is hot and overload relay has tripped	Allow motor to cool. Check supply voltage. If low, notify power company. If normal, reset overload relay, start motor, check amperage; if above normal, call electrician.
	Loose or broken wire, or short	Tighten wiring terminal, replace any broken wires, check for shorts and correct.
	Low line voltage	Check incoming power, use voltmeter; if low, notify power company.
	Defective motor	*MEG* out motor; if bad, replace.
	Defective pressure switch	With contact points closed, check for voltage through switch; if no voltage, replace switch; if low voltage, clean contact points; if full voltage, proceed to next item.
	Line to pressure switch is plugged or valve in line has accidentally been shut off	Open valve if closed. Clean or replace line.
	Pump control valve malfunctioning	Check limit switch for proper travel and contact. Adjust or replace as required.
	Defective time delay relay or pump start timer	Check for voltage through relay or timer – replace as necessary – check for loose linkage.

	Float switch or transducer malfunctioning	If pump is activated by float switch or pressure transducer on storage tank, check for incoming signal; if no signal, check out switch or transducer with voltmeter. If okay, look for broken cable between storage tank and pump station.
Pump Will Not Shut Off	Defective pressure switch	Points in switch stuck or mechanical linkage broken, replace switch.
	Line to pressure switch is plugged or valve in line has been accidentally shut off	Open valve if closed. Clean or replace plugged line.
	Cutoff pressure setting too high	Adjust setting.
	Pump control valve malfunctioning	Check limit switch for proper travel and contact. Adjust or replace as required.
	Float switch or transducer malfunctioning	Defective incoming signal, check and replace components as required. Check cable.
	Defective timer in pump stop mode	Check for voltage through pump stop timer, replace if defective.
Pump Starts Too Frequently	Pressure switch cut-in and cutoff settings too close	Adjust settings, maintain minimum 20 psi (138 kPa or 1.4 kg/sq cm) differential.
	Waterlogged tank	Add air to tank. Check air charging system and air release valve. Also check tank and connections for air leaks.
	Leaking foot valve	Check for backflow into well; if excessive or if pump shaft is turning backward, correct problem as soon as possible.
	Time delay relay or pump start/stop timers are malfunctioning	Check relay or timers for proper operation, replace defective components.

MEG: A procedure used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring

Symptom	Probable Cause	Corrective Action
Fuses Blow, Circuit Breaker or Overload Relays Trip When Pump is in Operation	Switch box or control not properly vented, or in full sunshine or dead air location, overload relay may be tripping due to external heat	Provide adequate ventilation (may require small fan). Provide shelter from sun. Paint box or panel with heat reflective paint, preferably white.
	Incorrect voltage	Check incoming power source. If not within prescribed limits, notify power company.
	Overload relays tripped	Check motor running amperage; verify that thermal relay components are correctly sized to operating conditions. Repeated tripping will weaken units, replace if necessary.
	Motor overloaded and running very hot	Modern motors are designed to run hot and if the hand can be held on the motor for 10 seconds without extreme discomfort, the temperature is not damaging. Motor current should not exceed *NAMEPLATE* rating. Fifteen percent overload reduces motor life by 50 percent.
Pump Will Not Deliver Normal Amount of Water	Pump breaking suction	Check water level to be certain water is above pump bowls when operating. If not, lower bowls.
	Pump impeller improperly adjusted	Check adjustment and lower impellers (qualified personnel only).
	Rotation incorrect	Check rotation.
	Impellers worn	If well pumps sand, impeller could be excessively worn thus reducing amount of water pump can deliver. Evaluate and recondition pump bowls if required.
	Pump control valve malfunctioning	Check limit switch for proper travel and contact. Adjust or replace as required.
	Impeller or bowls partially plugged	Wash down pump by forcing water back through discharge pipe. Evaluate sand production from well.

	Drawdown more than anticipated	Check pumping water level. Reduce production from pump or lower bowls.
	Pump motor speed too slow	Check speed and compare with performance curves. Also check lift and discharge pressure for power requirements.
Pump Takes Too Much Power	Impellers not properly adjusted	Refer to manufacturer’s bulletin for adjustment of open or closed impellers.
	Well is pumping sand	Check water being pumped for presence of sand. Restrict discharge until water is clean. Care should be taken not to shut down pump if it is pumping very much sand.
	Crooked well, pump shaft binding	Reshim between pump base and pump head to center shaft in motor quill. Never shim between pump head and motor.
	Worn bearing or bent shaft	Check and replace as necessary.
Excessive Operating Noise	Motor bearing worn	Replace as necessary.
	Bent line shaft or head shaft	Check and replace.
	Line shaft bearings not receiving oil	Make sure there is oil in the oil reservoir and the oiler solenoid is opening. Check sight gage drip rate, adjust drip feed oiler for 5 drops per minute plus 1 drop per minute for each 40 feet (12 m) of column.

NAMEPLATE: A durable metal plate found on equipment which lists critical installation and operating conditions for the equipment.

Table I: Troubleshooting Guide

7.3 Emergency Well Disinfection

Disease-causing organisms can enter wells, tanks, and distribution piping during the construction process, or during maintenance or repair. Special care must be taken to prevent contaminated soils or water from getting into the water source or distribution system resulting in a positive coliform test.

Poorly constructed wells may also allow contaminated ground water or surface water runoff to enter the well. The State of Alaska Drinking Water Regulations (18 AAC 80) require that before use, a newly constructed or reworked well must be flushed of sediment and disinfected as specified in ANSI/AWWA Standard C654-03. A copy of the ANSI/AWWA Standard may be purchased from AWWA.

Water supply wells must be disinfected and sampled after their initial construction to assure that the water produced is safe for human consumption. Additionally, wells should be disinfected and sampled after repairs are made to the well or well equipment. Whenever periodic or emergency disinfection is required, only chlorine products approved by the National Sanitation Foundation (NSF) or AWWA for use in potable water should be used. When system disinfection is performed with non-NSF approved products, such as household bleach, it is critical to flush all chlorine from the system prior to human consumption. NSF approved sodium hypochlorite is preferred.

High-test hypochlorite (HTH), or calcium hypochlorite, is used to disinfect swimming pools and is readily found at hardware stores and outlets for swimming pool equipment. HTH is NSF approved at a maximum dosage of only 4.0 mg/L. Since it is used at a much higher dosage for disinfection, it must be thoroughly flushed from the system before human consumption.

When working with chlorine, the operator must be in a well-ventilated place. The powder or strong liquid should not come in contact with skin or clothing. Chlorine solutions are best handled in plastic or glass containers because metals are corroded by strong chlorine solutions.

7.4 Disinfection Procedure for Shock Chlorinating Systems

If coliform tests indicate that bacterial contamination is occurring, shock chlorination is the most widely used method for initial treatment. Shock chlorination is a one-time introduction of a strong chlorine solution into the entire water system; well, pump, distribution pipeline. Groundwater systems may need to shock chlorinate the well:

- If lab results indicate the presence of bacteria.
- Upon completion of a new well or after pump replacement or repair.
- If the piping system is opened for repairs or maintenance; or
- To control iron and sulfur bacteria.

Appendix 4 shows the required amount of liquid household bleach or calcium hypochlorite to be added to five or ten gallons of water to achieve the proper chlorine concentration in the well (approximately 100 mg/L).

The procedure involves calculating the volume of water standing in the well and then applying enough chlorine powder, tablets or liquid to achieve a 100 mg/L chlorine concentration (50 mg/L for new wells). The chlorine is mixed with five to ten gallons of water and then poured down the well.

As a rule of thumb, wells of six inches in diameter require 0.5 ounces of sodium hypochlorite (household bleach) or 0.033 ounces of calcium hypochlorite per foot of water for disinfection.

Remember that chlorine is very volatile and is dangerous to work with in confined areas. Make sure the work area is well ventilated. Chlorine products must be handled in accordance with the manufacturer's directions. Failure to follow instructions could cause injury. Wear eye protection, gloves, and clothes that cover the body for protection.

. When creating the concentrated chlorine solution follow all the safety precautions. If concentrated chlorine accidentally comes into contact with your eyes or skin, use this fresh water to flush for ten to fifteen minutes. If you get some of the chlorine solution in your eyes, see your doctor after thoroughly flushing the affected eye.

Once the chlorine solution has been added to the well, a hose is then connected to the discharge side of the pump with the outlet of the hose pointed back down into the well casing or access pipe. The well pump is started so that water from the well is circulated back down into the casing. Circulation should continue until a strong chlorine odor is detected coming from the hose. A chlorine colorimeter may also be used to measure chlorine residual.

Another method of shock chlorinating a large diameter well is to place calcium hypochlorite tablets or powder in a weighted porous sack (tightly woven burlap works well). Raise and lower the sack in the well water. Remember that only the portions of the well coming in contact with the chlorine will be disinfected. Be sure to allow the sack to touch the bottom of the well during the process.

For small diameter wells (4-6 inch diameter) there is not enough room in the well casing to use a sack. Instead, dissolve the tablets or powder in a bucket of water and introduce into the well casing as described for using liquid a chlorine solution. Again, use a nearby hydrant and hose to circulate water through a portion of the distribution system to assure that the chlorine material is thoroughly mixed with well water.

Regardless of how you introduce the chlorine material into your well, start and stop the pump several times to ensure that the chlorine is thoroughly mixed with well water. Recirculate the water until a strong chlorine smell has been noted for at least five minutes. The following list summarizes the steps used to shock chlorinate a well and distribution system.

Steps to shock chlorinate a well:

1. Calculate the depth of water in the well by subtracting the non-pumping (static) water level in the well from the well depth. Then calculate the volume of water in the well.
2. A solution of approximately 100 mg/L chlorine is recommended for the disinfection of wells containing coliform or non-coliform bacteria. Using Appendix 4 determine the amount of sodium hypochlorite (or bleach) or calcium hypochlorite needed to disinfect the well. Be sure the bucket is plastic and thoroughly washed. Mix this calculated dosage with five to ten gallons of water. Make sure to always add the

chlorine to the water and NOT add water to the chlorine.

3. Remove the well cap. Carefully pour the chlorine solution down the well. Try to splash the solution on the sidewalls of the well casing as much as possible. Replace the cap securely. Attach a hose to a hydrant or faucet near the well and start the well pump. Circulate the well water through the hydrant and back into the well. This will thoroughly mix the chlorine solution and well water until the chlorine odor is present.
4. Turn on each service tap and allow the water to run until the chlorine odor is present at each tap. Shut the tap off. Do this at each tap if possible. *Customers must not be allowed to drink the superchlorinated water*.
5. Leave the chlorine in the well and system for at least twelve to twenty-four hours to allow contact time with the bacteria. Do not use the water during this time. Never drink well water containing high levels of chlorine.
6. After 12 - 24 hours, pump the chlorinated water out of the system until its odor is no longer detected, or the residual measures 0.5 mg/L or below with the colorimeter. Water with a chlorine residual above 1 mg/L should not be discharged to any lake, stream, or other surface water body because chlorine is extremely toxic to fish and other aquatic life. Complete removal of the chlorinated water may take several hours depending on the capacity of the pump. Flush all taps inside the buildings. Drain as much water from the system as possible. Hydropneumatic tanks containing a bladder, the rubber air-water separator inside the tank, could be damaged by the chlorine solution. Check manufacturers' recommendations to determine if the pressure tank should be bypassed. For pressure tanks without bladders, release the air so that the tank can be filled with chlorinated water. Drain water from the water heaters so that chlorinated water can be circulated through the hot water pipelines.
7. Backwash and clean water softeners, sand filters, and iron removal filters with a strong chlorine solution. *Do not* chlorinate activated carbon filters since these filters will remove the chlorine until they become overloaded. Activated carbon filters should be removed from the distribution system until after chlorine has been flushed from the system.
8. Wait 72 hours and then collect a water sample to test for coliform bacteria. The sample should be taken to determine if the disinfection process was effective and should be labeled a special sample when submitted to the laboratory. It will not be used for compliance purposes.

7.5 Well Disinfection Evaluation

Try to determine the cause of the positive coliform samples if you had to shock chlorinate to correct the problem. If the repeat samples are satisfactory after disinfection, attempt to determine if the contamination was due to operator error or caused by a bacteriological growth in the distribution system due to a distribution repair or plumbing change. If so, disinfecting probably corrected the problem.

If the contamination was caused by a persistent source of contamination, disinfection treatment can appear to correct the problem by temporarily killing off bacteria, but the problem can and probably will reoccur.

If the contamination is from a major source, with a high bacteria count, repeated disinfection and testing of the well may yield inconsistent results, sometimes satisfactory results, and sometimes not. If shock disinfection due to positive samples is necessary more than twice per year, serious well contamination or distribution system problems may be indicated.

If repeat samples are unsatisfactory after disinfecting, there is likely a persistent source of contamination. Common sources of contamination include a loose or damaged sanitary seal, a loose or damaged pitless adapter (where the buried water line enters the well casing), a bad plumbing connection in piping between the well and the building, a cross-connection, spiders living in the wellhead, or a dead animal in the well. Rodents can gain entry into a well that was not properly capped or has a damaged well casing.

Bacteria can be filtered out of water that passes through several feet of soil. Therefore, coliform test results may start to be intermittently satisfactory and then unsatisfactory. A detergent test may determine if the well is being influenced by a septic system. Any water that reaches a well from a septic system will have detergent present. Have your testing lab run a test for the presence of detergent if a septic system is suspected as the source of contamination.

Correcting the source of contamination is naturally preferred but installing continuous disinfecting equipment such as a chlorinator or ultraviolet light system may be required to protect the health of water system customers. The disinfecting equipment will depend on the type of chemical to be used.

In addition to required tests, well water should be tested immediately if there is any change in its clarity, color, odor, or taste, or if there has been a change in the surrounding land use. Through regular assessment and testing of drinking water, the microbial and chemical safety of well water can be verified so that it will be both safe to drink and aesthetically pleasing.

Chapter 8 – Public Water Supply Regulations & Monitoring

8.1 Introduction

People have different water quality concerns, depending on the use for which the water is intended. Farmers are interested in the effects irrigation waters have on the chemical and physical properties of soils. Fisheries biologists are concerned about turbidity, dissolved oxygen, and contaminants that are toxic to fish. We, as water suppliers, are mainly concerned with protecting the health of our customers. However, we must also be concerned with the taste and appearance of the water and such things as providing water that does not stain clothes and fixtures, does not consume large amounts of soaps and detergents, and does not destroy the customers' piping or appliances.

Most harmful contaminants cannot be seen, smelled, or tasted. Pathogenic microorganisms can only be observed with a microscope. Lead, arsenic, cyanide, and other harmful inorganic chemicals can be dissolved in water without making the water look or taste unsatisfactory. Even fuel or oil contamination cannot be detected at low levels. The only way to detect the presence of harmful contaminants is to routinely sample and test the water.

The State and federal governments establish sampling and monitoring requirements for public water supply systems to protect the health of the public. Standards, establishing safe levels for various contaminants, must be set and public water systems are required to monitor their water for compliance with these standards at a frequency established by the regulatory agency.

At the federal level, the Safe Drinking Water Act (SDWA) sets minimum standards to be met by all public water systems. Alaska, and most other states, has established through primacy its own drinking water regulations using federal regulations as guidelines.

8.2 Safe Drinking Water Act (SDWA)

The law regulating all public water systems in the United States is the SDWA. The act which was originally passed by Congress in 1974 authorized the USEPA to establish a cooperative program among local, state, and federal agencies for the regulation of drinking water. Under the SDWA, the primary role of the federal government was to develop national drinking water regulations that protect public health and welfare.
The states could request the responsibility of implementing the regulations and monitoring the performance of public water systems. The term primacy is used to describe this process. ADEC obtained primacy in 1978 and has administered and enforced the State Drinking Water Regulations since then. To maintain primacy, Alaska was required to adopt regulations no less stringent than federal requirements. Public water systems themselves are responsible for testing their drinking water to ensure that

it meets the standards established by the regulations.

A **Public Water System** is a system that delivers to the public piped water for human consumption. To be defined as a public water system the system must have at least 15 service connections or regularly serve at least 25 individuals daily at least 60 days out of the year.

In Alaska, public water systems are divided into three classifications: Community Water Systems (CWS), Non-Transient Non-Community Water Systems (NTNCWS), and Transient Non-Community Water Systems (TNCWS).

A **Community Water System** is a public water system that expects to serve, year-round at least 25 individuals or 15 residential service connections.

A **Non-Transient Non-Community Water System** is a public water system that is not a community water system and that regularly serves at least 25 of the same individuals over six months per year. Examples include schools, office buildings, and hospitals.

A **Transient Non-Community Water System** is a public water system that serves in the normal course of events, at least 25 persons each day for at least 60 days of the year and is not a Community or Non-Transient Non-Community System, i.e., it does not serve the same people on a regular basis. Examples include lodges, campgrounds, and restaurants.

For purposes of contaminant monitoring, the distinction between CWS, NTNCWS, and TNCWS is important. The important distinction is that CWS and NTNCWS serve residential/nontransient populations and TNCWS serve transient populations. For example, a campground, which would be a TNCWS, may serve hundreds of people daily, but they are probably different people each day so no one individual drinks the campground's water on a regular basis. Since certain contaminants have adverse health effects only when consumed regularly, over a long period, the distinction between CWS/NTNCWS (residential/nontransient) and TNCWS (transient) is important in determining which contaminants must be monitored and the frequency.

The SDWA has been amended several times over the years, significantly increasing the number of contaminants for which public water supply systems must monitor from 18 in 1975 to over 80 in 1996. The most recent, 1996 SDWA amendments, also added the certified operator requirements among other requirements.

8.3 Health Effects of Drinking Water Contaminants

Contaminants in drinking water may cause either **acute** or **chronic** health effects. An acute effect usually follows ingestion of a pathogenic microorganism or a large dose of a chemical and occurs almost immediately. Examples of acute health effects are nausea, diarrhea, skin rash, vomiting, dizziness, and, in extreme cases, death.

Although pathogenic microorganisms can cause an acute health effect, the levels of chemicals commonly found in drinking water are seldom high enough to cause acute health effects. With the exception of nitrate, chemicals are more likely to cause chronic health effects. Chronic health effects occur after exposure to small amounts of a chemical over a long period of time. Examples of chronic health effects include cancer, birth defects, organ damage, disorders of the nervous system, and damage to the immune system. Lead and trihalomethanes are examples of contaminants that can cause chronic health effects.

The possible health effects of a contaminant in drinking water differ widely, depending on the nature of the contaminant and whether a person consumes the water over a long period, briefly, or intermittently. Thus, allowable levels and monitoring requirements for systems serving residential populations (CWS and NTNC) may be more stringent than those for systems serving transient or intermittent users (TNC).

8.4 Drinking Water Standards

There are two types of standards: primary and secondary. **Primary standards** are health-based and enforceable. **Secondary standards** are set more for aesthetic reasons (how the water looks and tastes) but can also have public health consequences at elevated levels. Secondary standards can be enforceable if significant levels are present.

8.4a Primary Standards

Primary standards are designed to protect public health by setting maximum permissible levels of potentially harmful substances in the drinking water. Primary standards may be either **Maximum Contaminant Levels (MCLs)** or **Treatment Technique Requirements (TTRs)**. The MCL is the number against which the water samples from your system are judged for compliance with the regulations.

MCLs for potentially toxic or harmful substances reflect levels that can be safely consumed in water, taking into account exposure to the substance from other sources. The MCLs are based on the consumption of approximately 2 quarts of water every day for a 70-year lifetime. The State of Alaska must establish MCLs that are at least as stringent as those set by the USEPA.

Setting drinking water standards is an imperfect process, based on health risks and effects, as well as limits of detection and treatment technology effectiveness. It is important to understand that primary standards or MCLs for drinking water contaminants do not guarantee that water with a contaminant level below the standard is risk-free; nor do they mean that water with a higher level is unsafe.

The process of setting primary standards (MCLs) for drinking water contaminants is based on three criteria:

- The contaminant may have adverse health effects.
- The contaminant is known to occur or there is a high chance that the contaminant will occur in public water system often enough and at levels of public health concern; and
- Regulation of the contaminant presents a meaningful opportunity for health risk reductions for persons served by public water systems.

The primary contaminant monitoring requirements vary depending upon the raw water source (groundwater, surface water, or GWUDISW) and the system classification (CWS, NTNC, or TNC). Your system's monitoring requirements can be downloaded from Drinking Water Watch which is accessed from the ADEC Drinking Water Program's webpage. Alternatively, you can contact your local office of the ADEC Drinking Water Program for a copy of your monitoring summary. With the exception of nitrate and microorganisms, water that exceeds the MCL for inorganic and organic chemicals and radionuclides poses no immediate or acute risk to consumers. The substances are monitored for and controlled because drinking water that exceeds the standards for long periods of time may be harmful to consumers.

Where the USEPA is unable to establish an MCL for a regulated contaminant due to a lack of reliable methods to economically and feasibly measure the contaminant, it must establish a Treatment Techniques Requirement (TTR) instead of an MCL. Public water systems (PWS) must comply with these treatment requirements. Currently, there are surface water filtration, corrosion control, and purity of treatment chemicals requirements instead MCLs for several microorganisms, lead and copper, and acrylamide, and epichlorohydrin respectively.

An MCL may be expressed in milligrams per liter (mg/L) or micrograms per liter (µg/L), which is the same for the purposes of water quality analysis as parts per million (ppm) and parts per billion (ppb), respectively.

8.4b Secondary Standards

Secondary standards and the SMCLs apply to the aesthetic qualities of the water, such as taste, odor, or color. Water with contaminant levels above the SMCL may not be pleasant to drink but will generally not cause health problems. Yet, secondary standards can be important from a customer acceptability standpoint. Perfectly safe drinking water may be rejected based upon how it looks, tastes, or smells.

8.5 Public Water System Monitoring

Since the majority of harmful contaminants cannot be seen, smelled, or tasted, you are required to monitor the water system, by sampling and testing the water at routine intervals. Most analyses must be performed by a state-certified lab, although some routine tests, such as chlorine residual, can be performed on-site by the system operator. Reports documenting this monitoring must be sent to the ADEC Drinking Water Program.

Alaska's Drinking Water Regulations establish rules for all Public Water Systems in Alaska. Monitoring requirements, MCLs, public notice requirements, and plan review for all public water systems, large and small, are described in the State's Drinking Water Regulations (18 AAC 80). Monitoring by public water systems is on a nine-year compliance cycle. The types and frequency of required monitoring depend on the classification of your system and the source of raw water used. System owners/operators are encouraged to obtain the most recent version of the State Drinking Water Regulations from their local ADEC office or online on the ADEC website.

Under certain circumstances the ADEC may grant to a public water system a variance from a requirement or an exemption from an MCL or treatment technique requirement. Variances and/or exemptions (sometimes referred to as waivers) may be granted, upon application to ADEC, for circumstances that are unique or where compliance is technically or economically impossible. Variances and exemptions will not be granted if ADEC determines that doing so would jeopardize consumer health. System owners/operators should consult with ADEC Drinking Water Program representatives for advice and assistance.

8.6 Inorganic Contaminants

When ingested with drinking water several inorganic substances, particularly heavy metals, can be detrimental to human health. Some of these inorganic substances have been shown to damage the brain, lungs, kidneys, heart, and intestines of mammals. Sources of inorganic contaminants include natural mineral deposits, runoff from mining operations, and industrial waste discharge.

Monitoring for most of the regulated inorganic contaminants is required every three years. However, nitrate, nitrite, lead, copper, and asbestos monitoring are exceptions.

For these contaminants, the monitoring frequency may be reduced or increased depending on contaminant levels. A limited number of inorganic substances are discussed in this section. For a complete list of inorganic substances and monitoring requirements refer to your system's monitoring summary available from the ADEC Drinking Water Program website or contact your local ADEC Drinking Water Program representative.

Nitrate

Nitrates are inorganic chemicals found in both surface and ground water. They originate from many sources including animal waste, human wastes from leaching from septic tanks or sewage, soil, fertilizers, and crop residues. Nitrates enter the water either by direct runoff or by percolation through the soil. Therefore, elevated levels of nitrates could indicate either a point or non-point pollution source.

Nitrate must be monitored annually (one sample per year) for both surface water and groundwater sources. The MCL is 10 mg/L (as N). If the nitrate level exceeds 5.0 mg/L (as N), quarterly testing is required.

Surface water systems and GWUDISW systems can return to annual monitoring after 4 consecutive quarters of samples that are less than 5 mg/L (as N). Groundwater systems can return to annual monitoring after 4 consecutive quarters of samples that are reliably and consistently below the MCL.

Nitrate is considered an acute contaminant. Nitrate levels above the MCL of 10 mg/L pose an immediate threat to children less than six months of age because their digestive systems are more likely to convert nitrates to nitrite. The nitrite is absorbed into the bloodstream and prevents the blood from carrying oxygen. This condition is called methemoglobinemia or "blue baby" syndrome and can be fatal.

Nitrite

The health effect of nitrite is explained in the paragraph above. The MCL for nitrite is 1.0 mg/L (as N). If the result of the nitrite sample is below 0.5 mg/L (as N) only one sample is required. If the nitrite result is greater than 0.5 mg/L (as N), the water system must monitor quarterly until the results are reliably and consistently less than the nitrite MCL. Monitoring requirements are the same for surface water, GWUDISW, and groundwater sources. Surface water and GWUDISW systems that chlorinate on a continuous basis are not required to sample for nitrite. The combination of nitrate and nitrite levels cannot exceed 10 mg/L (as N).

Lead & Copper

Lead and copper are inorganic contaminants that have very specific sampling and monitoring requirements. A small number of natural waters contain significant levels of lead or copper. Most incidences of lead and copper contamination are a result of the corrosion of pipe and fixtures containing lead and copper or alloys such as bronze. Consequently, lead and copper samples are taken at the customer's tap.

Lead can interfere with normal body functions. It can change the way the blood-forming cells work, alter the way nerve cells signal each other, and can disturb or destroy thought processes. Lead exposure is of special concern for children because their bodies are still developing. Their future health and well-being are at risk if they are exposed to lead. The use of lead pipe and lead solder for installation or repair of public water system piping is no longer allowed.

The Lead and Copper Rule (LCR) specifies sampling procedures, numbers of samples required based on population, actions to be taken if an **action level** is exceeded and acceptable treatment techniques that may be used to correct distribution system corrosion problems.

Treatment techniques, rather than finished water contaminant levels, have been established for lead and copper because the corrosion, which results in high levels of lead and copper, occurs in the piping system. Whereas most inorganic samples are taken before the water enters the distribution system, samples for lead and copper analysis are taken directly from the consumers' taps.

The "action level" for lead is 0.015 mg/L, and for copper it is 1.3 mg/L. Systems that do not meet the "action level" at the tap are required to install corrosion control treatment and/or perform actions such as public education and service line replacement to reduce the levels of lead and copper. The LCR requires "first draw samples" to be taken from customers' taps. "First draw samples" are samples taken after the water has stood in the house piping for at least 6 hours. A "first draw sample" assures that the sample of water that has been exposed to the maximum potential corrosive action in the consumer's piping. If the "first draw sample" is below action levels, it is safe to assume that water spending less time in contact with the piping system is also below the action level.

The population served by the system determines the number of samples required. The lead and copper results determine what, if any, further action is required.

Lead and copper monitoring is required for all community and non-transient non-community water systems for two initial (consecutive) six-month monitoring periods. If the results of the two monitoring periods are below the "action level," the water system may reduce the number of samples collected and perform the monitoring annually. After two consecutive years of annual monitoring with results below the action levels, monitoring may be reduced (with ADEC Drinking Water Program approval) to a three-year cycle.

Asbestos

Asbestos is a naturally occurring mineral more prevalent is surface water than groundwater. It is also a component of asbestos-cement pipe. Because there is a risk of developing stomach cancer from ingesting water that contains asbestos, an MCL of 7 million fibers per liter (MFL) has been established.

Asbestos monitoring is required once during the first three years after the system begins to provide potable water, after which a waiver may be obtained allowing monitoring every nine years.

Arsenic

Arsenic is an element that occurs naturally in rocks, soil, water, air, plants, and animals. The erosion of rocks and minerals, volcanic activity and forest fires are natural events that can release arsenic into the environment. Another source of arsenic is human activities, such as mining or smelting ores that contain arsenic. Arsenic in drinking water causes bladder, lung and skin cancer, and may cause kidney and liver cancer, serious skin problems, and harm the central and peripheral nervous systems, as well as heart and blood vessels. It also may cause birth defects and reproductive problems.

Currently, only community and non-transient non-community systems, using either surface water, GWUDISW, or groundwater sources, are required to monitor for arsenic. The USEPA MCL for arsenic in drinking water is 10µg/L or 10 ppb with a Maximum Contaminant Level Goal (MCLG) of zero. MCLGs represent an aspirational health goal at which no known or anticipated adverse health effects would occur, allowing an adequate margin of safety. Initially, monitoring must occur every three years. After three test results are below the MCL, a waiver is available to reduce monitoring to once every nine years.

Radium and Radon

Groundwater may have a long enough residence time in the ground to pick up radioactive contaminants. Consequently, some groundwater aquifers in the United States have naturally occurring radioactive contaminants. Radium and radon are the main radioactive elements in groundwater that are potential health threats. Only community and non-transient non-community systems using groundwater sources are required to sample for gross alpha radioactivity and at a frequency of at least once every four years. The MCL for radium is 5 picocuries per liter (pCi/L) and for radon (gross alpha particle) is 15 pCi/L. A curie (Ci) is a measure of intensity of radioactivity in a sample material. One Ci is equal to 2.2 trillion disintegrations per minute. A pCi is one trillionth of a Ci or 2.2 disintegrations per minute.

8.7 Organic Chemicals

Many **synthetic organic chemicals (SOCs)** are included in the primary regulations. Organic contaminants originate from domestic, commercial, and industrial activities. They can enter surface water and/or groundwater by direct runoff from illegal dumping or waste storage, industrial and sewage treatment plant discharge, and agriculture application of herbicides and pesticides. Some of these (for example, benzene and carbon tetrachloride) readily become airborne and are known as **volatile organic compounds (VOCs)**.

Public drinking water supplies must be sampled and analyzed for organic chemicals at least every three years. Both SOCs and VOCs must be monitored quarterly for one year. If sample results show Non-Detects (NDs), the monitoring frequency may be reduced to once every three years.

TTHMs and HAA5s are of concern when water treatment includes chlorination. Chlorination of water containing either natural or artificial organics can result in the formation of a group of chlorinated by-products. TTHMs and HAA5s are considered to potentially pose a health hazard. The MCL for TTHM is 0.08 mg/L LRAA and for HAA5 is 0.06 mg/L LRAA.

Community and non-transient non-community surface water systems and community and non-transient non-community GWUDISW serving populations under 500 people are required to monitor for TTHM and HAA5 once per year. Those systems serving populations over 500 people are required to monitor for TTHM and HAA5 quarterly.

Community and non-transient non-community groundwater systems (excluding GWUDISW systems) that use chlorine disinfection and serve fewer than 10,000 people are required to monitor for TTHM and HAA5 once per year. Those systems serving populations over 10,000 people are required to monitor for TTHM and HAA5 quarterly.

Waivers to reduce the frequency of monitoring may be granted under certain conditions. Consult with the ADEC Drinking Water Program for details.

8.8 Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)

PFOS and PFOA are part of a larger group of chemicals called per- and polyfluoroalkyl substances (PFASs). PFASs, which are human-made highly fluorinated aliphatic molecules, have been released into the environment through industrial manufacturing and the use and disposal of PFAS-containing products since the 1940s. Many common consumer products have contained PFASs because of their water and oil-repelling properties, including carpets, clothing, fabrics, leather, food packaging, and cookware. Additionally, PFAS can be found in aqueous film-forming foams (or AFFFs) which has been used in fighting fires, specifically at airports, shipyards, military bases, firefighting training facilities, chemical plants, and refineries.

PFOS and PFOA are persistent in the environment, resistant to typical environmental degradation processes, and are known to bioaccumulate in humans and wildlife. As a result of these factors, PFOS and PFOA are widely distributed across all ecological levels and are found in soil, air, and groundwater at sites across the United States. Studies have found PFOS and PFOA in the blood samples of the general human population and wildlife, indicating that exposure to the chemicals is widespread. The toxicity, mobility, and bioaccumulation potential of PFOS and PFOA result in potential adverse effects on the environment and human health. There is some evidence that PFOA is likely carcinogenic to humans and suggestive evidence of a carcinogenic potential for PFOS.

Most uses of PFOA and PFOS were phased out by US manufacturers in the mid-2000s. However, PFAS with fewer carbon atoms, such as hexafluoropropylene oxide (HFPO) dimer acid and its ammonium salt (together referred to as ‘‘GenX chemicals’’) and perfluorobutane sulfonic acid and its related compound potassium perfluorobutane sulfonate (together referred to as ‘‘PFBS’’), were developed to replace PFOA and PFOS due to similar characteristics and the ability to be more quickly eliminated from the human body.

Due to studies based on oral exposure to animals, GenX chemicals have been linked to health effects on the liver, kidneys, immune system, and developmental effects, as well as cancer and PFBS have shown health effects on the thyroid, reproductive organs and tissues, developing fetus, and kidney.

EPA has established interim health advisories in November 2021 for PFOA of 0.004 parts per trillion (ppt) and for PFOS of 0.02 ppt. EPA’s health advisories are non-enforceable and non-regulatory and provide technical information to agencies and public health officials. EPA has established final health advisories for GenX chemicals as 10 ppt and for PFBS as 2,000 ppt. Contact the ADEC Drinking Water Program or visit the US EPA website for more information on PFAS.

8.8 Microorganisms

The presence or absence of living organisms, especially microscopic organisms (microorganisms) can be one of the most useful **indicators** of water contamination. The microorganism group of contaminants includes bacteria, viruses, and protozoa. The total coliform group of bacteria is used to indicate the possible presence of pathogenic organisms.

A group of bacteria, called coliforms, are perhaps the most important biological indicator of water quality. Coliforms are a broadly defined group of bacteria. They occur naturally in the soil and on vegetation as well as in the digestive tract of warm-blooded animals, including humans. It is necessary to make a distinction between two groups of coliforms: total coliforms and **fecal coliforms**.

Total coliforms refer to all the members of the coliform group regardless of origin. The total coliform group has been used for since the early 1900s as the indicator of the possible presence of disease-causing microorganisms. These organisms are used as indicators because the analytical methods available to detect them are inexpensive, they are present in large numbers in the fecal matter of humans and other warm-blooded animals, and they survive outside the body longer than most pathogenic bacteria.

The presence of fecal coliforms provides stronger evidence of fecal contamination, thereby increasing the probability of the presence of pathogens than do total coliforms. Fecal coliforms do not include coliforms found naturally in the soil and on vegetation. The presence of one particular bacteria, *Escherichia coli (E. coli),* confirms that the fecal coliforms are from humans or animals.

The microbiological quality of water is determined by looking for the presence of bacteria indicative of contamination - namely, total coliforms*.* Fecal coliforms or *E. coli* will appear in water samples that may have been contaminated recently by fecal matter; thus, they indicate the possible presence of disease-causing bacteria, viruses, or protozoa. Water containing *E. coli* or fecal coliforms is not safe to drink.

8.8a Revised Total Coliform Rule (RTCR)

The Revised Total Coliform Rule (RTCR) was implemented in February 2013 to increase the protection of public health by reducing the number of ways fecal contamination could enter the distribution system.

Under the RTCR, owners of all community and non-transient non-community and transient non-community public water systems are required to routinely collect total coliform samples and deliver them to an ADEC approved certified laboratory (contact ADEC for a list of laboratorys) for bacteriological examination at least monthly.

Under certain conditions a waiver may be granted to small systems, reducing the sampling requirement to once per quarter. The Drinking Water Program grants waivers only after a thorough system review.

The exact number of routine coliform monitoring samples a water system is required to collect is mandated by federal standards. Every regulated system must complete a Sample Siting Plan to specify where in the distribution system, and when, routine coliform monitoring samples must be taken to ensure they are representative of the system. Small water systems serving less than 1,000 people are required to take a minimum of one sample per month unless **repeat samples** are required.

The RTCR requires:
- Routine total coliform monitoring
- Repeat sample collection in the event of a positive sample
- Fecal coliform testing of positive total coliform samples
- A **sample siting plan**, and if necessary
- Public notification

A coliform monitoring sample siting plan must be filed with and approved by ADEC Drinking Water Program.

Routine coliform samples are collected monthly unless a quarterly waiver is granted by the Drinking Water Program. Routine samples should be collected early in the month to provide enough time to collect **replacement samples** if the original samples are damaged in transit or cannot be analyzed by the lab. Collection sites for bacteriologic samples must be designated on the sample siting plan. Sample collection sites are rotated monthly so that samples are representative of the entire distribution system.

The sample siting plan should include:

- Contact information
- Water system type, population served and number of service connections
- Number of routine samples required and the frequency of sampling
- Source water types
- Routine sample sites and rotation schedule
- Repeat sample sites
- Reasons for choosing routine sample locations
- System map

Repeat samples must be collected if coliform bacteria are detected in the routine sample. Repeat samples must be collected within 24 hours after being notified by the lab that the routine sample was unsatisfactory. Do not disinfect or change any treatment process prior to taking repeat samples.

If coliform organisms were detected in a routine sample, the owner/operator of a Small Treated water system must collect three repeat samples for each routine coliform-positive sample found. One repeat sample shall be taken from the site of the original positive, one repeat sample within five service connections upstream, and one within five service connections downstream (systems with wells must also collect a raw source water sample from each active well).

Small systems with few service connections may need to adjust the location of repeat samples per instructions from the ADEC Drinking Water Program. Any routine or repeat sample that is total coliform positive must also be analyzed for fecal coliforms or *E. coli.*

If any of the three repeat samples are positive, there is more than one routine sample that is positive, or the owner/operator failed to collect all three repeat samples, a Level 1 Assessment must be completed and submitted to the ADEC Drinking Water Program within 30 days. The Level 1 Assessment will require water systems to identify a possible cause to the total coliform positive samples and any corrective actions taken/needed.

Under the RTCR, if a water system violates an E. coli MCL, or two Level 1 Assessments are triggered in a rolling 12-month period, a Level 2 Assessment must be completed by the ADEC Drinking Water Program. E. coli MCLs are given in Table J.

When an E. coli MCL is exceeded, the water owner/operator must issue a Tier 1 Public Notice to all customers served by the water system within 24 hours and also notify the ADEC Drinking Water Program.

A Tier 1 Public Notice includes a Boil Water Notice. A Boil Water Notice notifies customers that water should be boiled vigorously prior to drinking and that boiled or bottled water should be used for drinking, making ice, brushing teeth, washing dishes, and food preparation until further notice. Refer to Appendix 5 for Boil Water Notice instructions and a template.

Water systems are required to issue a Tier 2 Public Notice to all customers within 30 days for the following violations of the Coliform Treatment Technique requirements:

- Failure to conduct or submit a required Level 1 or Level 2 Assessment within 30 days.
- Failure to complete any corrective action identified in a Level 1 or Level 2 Assessment by the deadlines given in the assessment.
- For seasonal systems only, failure to complete a State Board-approved start-up procedure prior to serving water to the public.

The method of notification and the form and content of the message is very specific. Contact the ADEC Drinking Water Program for help in developing an adequate public notice.

Routine	Repeat
Total Coliform + and E. coli -	E. coli +
Total Coliform + and E. coli -	Total Coliform + but not analyzed for E. coli
Total Coliform + and E. coli +	Total Coliform +
Total Coliform + and E. coli +	One or more samples is missing

Table J: E. coli MCLs

8.8b Significance of the Coliform Test

Coliform bacteria detected in any water sample warn of possible contamination. One test does not prove that contamination exists; more tests must be taken. Samples may have been contaminated from external sources or there may have been other problems such as non-sterile bottles, contamination of the sample bottle during sampling, or laboratory error. Another common problem, however, involves errors in sampling. The current regulations require that if a sample is positive (shows the presence of coliforms), the water supplier must take repeat samples. Consequently, proper sampling techniques and sampling precautions are critical.

8.8c Collecting a Coliform Sample

- Obtain sterile bottles from the lab.
- Do not open a sample bottle until ready to fill.
- Do not rinse the bottle before filling! The tablet or white powder inside the sample bottle is **sodium thiosulfate**, which neutralizes any chlorine in the water.
- Select a sample tap. Always collect the sample from the cold-water tap. Select a faucet that is not leaking, non-swivel, and non-mixing.
- Do not sample from drinking fountains or outside hydrants.
- Avoid sample points located after water softeners, carbon filters, or cisterns serving single homes.
- Wash your hands.
- Remove any faucet attachments (aeration screens, hoses, etc.).
- Remove the screen from the faucet and disinfect the mouth the of faucet with a chlorine bleach solution. If rubbing alcohol is used, remember alcohol requires contact time.
- Do not use a butane lighter to flame the faucet.
- Open tap fully. Let water run to waste for two or three minutes (sufficient time to allow complete flushing of the service line).
- If you must use a mixing faucet, run the hot water tap for two minutes and then run the cold water tap for two or three minutes (always collect a cold-water sample).
- Reduce the flow (to about the diameter of a pencil) and fill the bottle. If the water dribbles to the faucet edge and contacts the metal (lips) before entering the bottle, the sample may be contaminated; readjust the flow or locate a different sampling tap.
- Carefully remove the lid. Do not lay it down or touch the inside. Do not take the pill out of the bottle. Fill the bottle to the fill line.
- Replace the lid. Be sure to complete the information on the sample bottle label and fill out the paperwork.

The sample should be shipped to the lab using the shortest transit possible. Keep the sample cool by placing it in a cooler with ice packs. Do not allow the sample to freeze. Regulations require that analysis for coliform bacteria begin within 30 hours of collection and completed no later than 48 hours from the time the sample is drawn.

8.8d Invalid Sample

Owners/operators are primarily concerned with bacterial pathogens responsible for disease. However, not every bacterial organism causes disease. Bacteria are found on our skin, in our intestines, on plants, and animals, as well as in soil. Some harmless bacteria can interfere with the coliform test and make the results invalid. This happens when there are numerous non-coliform bacteria in the water, and they interfere with the test method. This prevents coliforms from growing and is often reported in the sample result as:

- Too numerous to count non-coliforms (TNTC)
- Heavy growth non-coliforms

When non-coliform bacteria interference occurs, a replacement sample is required. It must be collected during the same calendar month in which the routine sample was due.

8.9 Interpreting Laboratory Analyses

As a public water system owner or operator, you are required to monitor the quality of your drinking water on a routine basis. The frequency of the required monitoring is established by the State Drinking Water Regulations (18 AAC 80). Most test procedures must conform to strict analytical standards and be performed according to approved standards or methods. Most frequently a certified laboratory performs this testing.

Test results are transmitted to both the system owner and to the ADEC Drinking Water Program. If an MCL is exceeded or another problem is noted with the water analysis, an ADEC Drinking Water Program representative will contact the system owner.

However, in order to communicate effectively with Drinking Water Program staff and your customers, you need to know some basic information in order to understand the reports you receive from the laboratory.

Comments on Sampling
Virtually every contaminant or contaminant group has different sampling procedures and handling requirements. The bottles may be plastic or glass and of a specific size depending on the analysis to be performed. Some analyses require that a preservative or other chemical be added to the sample. This is often done at the laboratory before they send you the sample bottles. Using an empty pickle jar or beer bottle, regardless of its cleanliness, will most likely invalidate the sample results.

When you request bottles from the lab for a specific analysis, the bottles will be prepared by the lab for that analysis. Generally, the bottles should not be rinsed. Very specific sampling instructions will accompany the sample bottles. *Read these instructions carefully!*

Once the samples have been taken, fill out the paperwork that accompanied the bottles and take the samples directly to the laboratory. If you cannot get them directly to the lab, the samples should be chilled or placed on ice in special coolers provided by the laboratories. Do not leave them on the dash of the car in the hot sun.

Bacteriological Reports

Bacteriological lab reports are generally straightforward. The format may change depending on the laboratory you are using, but the same information will be on the report form.

Information completed by the water supplier:

- The information to be completed by water supplier is specific to your water system and is generally straightforward. *It is important to include your PWSID*.
- Sample Type: It is important that you designate whether this is a routine sample, check sample or special purpose sample. Routine samples are used to calculate compliance and should be differentiated from “other” samples. Also designate the sample as “Treated water” or “Untreated water”
- It is critical that the sample number on the bottle matches the sample location, *especially if multiple samples are taken at the same time*. Sample time and date will be used to determine the “age” of the samples. If samples are too old, they may be rejected or invalidated.

Information completed by the laboratory:

- Results: The box will be checked accordingly – “Satisfactory”, “Unsatisfactory” or “Sample too long in transit” or “Invalid Sample”.
- Analytical Method: The box checked will denote which method was used to analyze the sample: “Fermentation tube” or “Membrane Filter”. Most laboratories in Alaska are using the membrane filter method, but the fermentation tube or Most Probable Number (MPN) method is also an approved method.
- Test Result: For the membrane filter technique, this is the number of colonies; for the fermentation tube method, this is the number of positive tubes, and for the presence/absence method, this is either a “P” or an “A”.
- Notes written by the analyst: An example can be, there was “Confluent growth TNTC with coliforms”. NOTE: TNTC = Too Numerous To Count.

Chemical Analyses Reports

Typically, most Small Treated water systems test their water for total coliforms on a monthly basis. Chemical analyses are run far less frequently. Consequently, small system owners likely will have much less experience reading the laboratory reports for chemical analyses.

Units

Before you can understand the lab reports, a basic understanding of the units used to report concentrations is needed. Since the Drinking Water regulations list the MCLs for various contaminants in milligrams per liter (mg/L), most laboratories report results as milligrams per liter or mg/L. However, some results may be reported in micrograms per liter. A milligram is 1/1,000th of a gram and a microgram is 1/1,000th of a milligram. Since there are 28 grams in an ounce, you can see that a milligram is quite a small amount, and a microgram is a thousand-fold smaller. A liter is slightly more than a quart.

So, as you can see, we are concerned about increasingly smaller and smaller amounts of contaminants in our drinking water.

Although the MCLs are typically listed in mg/L, not all analysts or drinking water professionals you interact with may use the same units when discussing your lab results. Some may use mg/L and others may use parts per million (ppm) to refer to the same result. Similarly, some may use micrograms per liter while others use parts per billion (ppb), when referring to the same analytical result. In the drinking water industry, these terms are used interchangeably and mean essentially the same thing; 100 micrograms/liter (µg/L) is the same as 100 ppb, which is the same as 0.1 mg/L or 0.1 ppm.

The relationship between mg/L and µg/L comes in handy when discussing concentrations when the number of mg/L is a decimal. For example, since 1 mg equals 1,000 µg, it is often less cumbersome to discuss very small concentrations in µg instead of mg. For example, the current MCL for total trihalomethanes is 0.08 mg/L. This is the same as 80 ppb. Instead of saying the concentration is "zero-point–zero-eight" mg/L, analysts and drinking water professionals often say the concentration is 80 parts per billion. Similarly, the current MCL for arsenic is 0.01 mg/L; this is commonly referred to as 10 ppb, instead of saying "zero-point-zero-one mg/L.

Another unit that is less frequently used but is still used occasionally among technicians who have worked with water softeners for a long time, is grains per gallon or gpg. Although it is rarely, if ever, used by laboratories today, hardness concentration was once listed in grains per gallon. One grain per gallon is equivalent to 17.1 mg/L. So, a hardness of 15 grains is equivalent to 256.5 mg/L.

Typical Chemical Analysis Lab Report

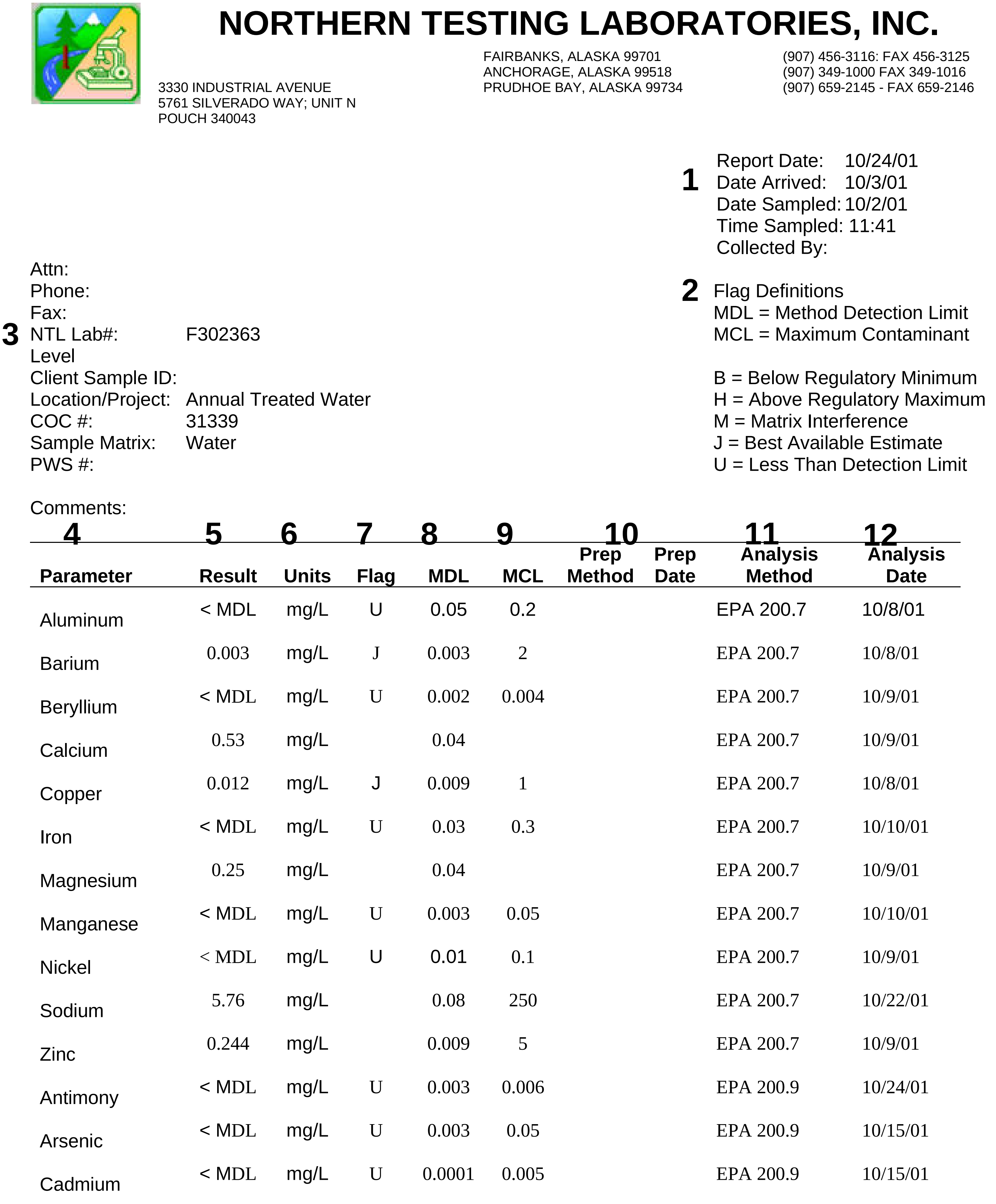
A typical lab report for inorganic chemical analyses on Figure 8.1. Most laboratories are providing a "key" on their forms to help explain what various abbreviations and acronyms represent, but if you do not understand what something on the report form means, you will not be able to respond appropriately to questions regarding the analyses. *If you do not understand what something on the report means or the significance of it, ask the laboratory to explain it to you. You are paying for this service; it is your report.* An explanation of the "numbered items" is on the sample report following this section.

1. The time between sampling and analysis can be critical to the validity of the test. This data should be checked for accuracy, especially if the sample is rejected due to holding time problems related to sample preservation.
2. Flag Definitions: This section is provided as a courtesy by the laboratory. It defines the abbreviations and acronyms that appear on the form and the designations found under the "Flag" heading (# 7).
3. Your name, address, etc. *Double check the PWSID # to make sure the sample "belongs to you". It is also a good idea to give each sample a "client sample ID" that is unique to your system to ensure that the results are definitely for your sample and*

there was no mix up at the laboratory. The labs handle hundreds of samples each day and also run samples in groups. They are very careful about tracking samples and maintaining sample integrity, but you should always check this information to make sure sample identification is consistent with your records and PWSID.

4. Parameter: This is the chemical that was analyzed. In this case, several of the primary inorganics were analyzed, as well as sodium, zinc, iron and manganese - secondary contaminants and calcium and magnesium - the metals that contribute to hardness.
5. Result: The result is the concentration that was detected. Note that several do not have a numerical value listed. Instead "<MDL" is listed – this means that for that particular parameter "less than the Method Detection Limit" was present.
6. Units: Note that the units are all mg/L (milligrams per liter or parts per million) for this particular analysis.
7. Flag: Where appropriate a "flag" is listed. See flag definitions (#2). Flags alert you to instances where the actual concentration cannot be accurately determined, but a result may be listed based on acceptable analytical procedures.
8. MDL = Method Detection Limit. This refers to the test method. All methods have a limit below which the actual concentration cannot be accurately determined. The number in this column lists the detection limit for each parameter using that particular method. If another method had been used (other than USEPA 200.7) a higher or lower MDL might be expected.
9. MCL = Maximum Contaminant Level. This column lists the MCL that is listed in the Alaska State Drinking Water Regulations. If the number in the Result column exceeds the number in the MCL column, your sample has exceeded the concentration allowed under the regulations for that parameter. An "H" would appear in the Flag column if that were the case.
10. Prep Method and Prep Date: If a sample required special preparation before analysis, it would be described here.
11. Analysis Method: This column lists the analytical method used. This is important from a regulatory standpoint, because specific methods are called out in the Drinking Water Regulations. If the method used is not an "approved method", the sample results will not be valid for compliance purposes. The laboratories in Alaska are very good about making sure the correct method is used if the sample is to be used for compliance purposes. In this case, most of the parameters could be analyzed using one method (EPA 200.7). However, the last three parameters listed were analyzed using EPA 200.9.
12. Analysis Date: This is the day the sample was analyzed.

These are your analyses; you pay for them. If you have any questions or need clarification, you should talk to the laboratory. Your assigned ADEC Drinking Water Program specialist may also be able to help.



NORTHERN TESTING LABORATORIES, INC.

3330 INDUSTRIAL AVENUE
5761 SILVERADO WAY; UNIT N
POUCH 340043

FAIRBANKS, ALASKA 99701
ANCHORAGE, ALASKA 99518
PRUDHOE BAY, ALASKA 99734

(907) 456-3116: FAX 456-3125
(907) 349-1000 FAX 349-1016
(907) 659-2145 - FAX 659-2146

1
Report Date: 10/24/01
Date Arrived: 10/3/01
Date Sampled: 10/2/01
Time Sampled: 11:41
Collected By:

Attn:
Phone:
Fax:
3 NTL Lab#: F302363
Level
Client Sample ID:
Location/Project: Annual Treated Water
COC #: 31339
Sample Matrix: Water
PWS #:

2 Flag Definitions
MDL = Method Detection Limit
MCL = Maximum Contaminant

B = Below Regulatory Minimum
H = Above Regulatory Maximum
M = Matrix Interference
J = Best Available Estimate
U = Less Than Detection Limit

Comments:

4	5	6	7	8	9	10		11	12
Parameter	**Result**	**Units**	**Flag**	**MDL**	**MCL**	**Prep Method**	**Prep Date**	**Analysis Method**	**Analysis Date**
Aluminum	< MDL	mg/L	U	0.05	0.2			EPA 200.7	10/8/01
Barium	0.003	mg/L	J	0.003	2			EPA 200.7	10/8/01
Beryllium	< MDL	mg/L	U	0.002	0.004			EPA 200.7	10/9/01
Calcium	0.53	mg/L		0.04				EPA 200.7	10/9/01
Copper	0.012	mg/L	J	0.009	1			EPA 200.7	10/8/01
Iron	< MDL	mg/L	U	0.03	0.3			EPA 200.7	10/10/01
Magnesium	0.25	mg/L		0.04				EPA 200.7	10/9/01
Manganese	< MDL	mg/L	U	0.003	0.05			EPA 200.7	10/10/01
Nickel	< MDL	mg/L	U	0.01	0.1			EPA 200.7	10/9/01
Sodium	5.76	mg/L		0.08	250			EPA 200.7	10/22/01
Zinc	0.244	mg/L		0.009	5			EPA 200.7	10/9/01
Antimony	< MDL	mg/L	U	0.003	0.006			EPA 200.9	10/24/01
Arsenic	< MDL	mg/L	U	0.003	0.05			EPA 200.9	10/15/01
Cadmium	< MDL	mg/L	U	0.0001	0.005			EPA 200.9	10/15/01

Figure 8.1: Sample Laboratory Inorganic Chemical Analysis Report

8.10 Consumer Confidence Reports

A **Consumer Confidence Report (CCR)** is an annual drinking water quality report issued to consumers of all community water systems, summarizing information regarding source water, detected contaminants, compliance, and educational information. The reports are to be available to consumers by July 1 each year. Additionally, October 1st or 90 days after distribution of CCR to customers, whichever is first, is the deadline for annual submission of proof of distribution of the CCR to the Drinking Water Program that Alaska's small water systems, systems serving less than 500 people per day and less than 100 service connections, must mail or otherwise directly deliver one copy of the CCR to each customer. Also, the report must be available upon request.

Public water systems are free to enhance their reports in any useful way, but each report must provide consumers with the following fundamental information about their drinking water:

- Water System Information – Name/phone number of a contact person; information on public participation opportunities.
- Source(s) of Water – Type; commonly used names.
- Definitions – Maximum Contaminant Level (MCL); MCL Goal (MCLG); Treatment Technique (TT); Action Level (AL); Maximum Residual Disinfectant Level (MRDL); MRDL Goal (MRDLG).
- Detected Contaminants – A table summarizing reported concentrations and relevant MCLs and MCLGs or MRDLs and MRDLGs; known source of detected contaminants; health effects language.
- Information on Monitoring for Cryptosporidium, Radon, and Other Contaminants (if detected).
- Compliance with Other Drinking Water Regulations (any violations and Ground Water Rule [GWR] special notices).
- Variances and Exemptions (if applicable).
- Required Educational Information – Explanation of contaminants in drinking water and bottled water; information to vulnerable populations about Cryptosporidium; statements on nitrate, arsenic, and lead.

CCRs are the centerpiece of the right-to-know provisions in the 1996 Amendments to the SDWA. The Amendments contain several other provisions aimed at improving public information about drinking water, including the annual public water system compliance report and improved public notification in cases where a water supplier is not meeting a contaminant standard. The Amendments also call for increased public participation in the protection and delivery of safe drinking water. For example, citizen advisory committees are helping states to implement their source water assessment activities and are involved in decisions about allocating the state revolving loan fund that provides funding for drinking water infrastructure improvements.

8.11 Surface Water Treatment Regulations

(This section applies to Small Treated Systems only)

Bacteria and other microbes in public water supplies may pose immediate and serious health risks. Since these contaminants are often difficult to detect through traditional testing, the **Surface Water Treatment Rule (SWTR)** requires most surface water sources to be treated through a system of disinfection and/or filtration.

Remember from Chapter 5 that disinfection is a process that kills or inactivates disease-causing organisms in drinking water through the use of chemical oxidants such as chlorine, ozone, and ultra-violet light. Also, keep in mind those Groundwater Systems Under the Influence of Surface Water (GWUDISW) must meet the requirements of the SWTR. GWUDISW as defined by 40 CFR 141.2 and adopted by 18 AAC 80 is any water beneath the surface of the ground with:

- Significant occurrence of insects or other macroorganisms, algae, or large-diameter pathogens such as *Giardia lamblia*, or
- Significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH, which closely correlate to weather or surface water conditions.

ADEC is responsible for determining whether groundwater is under the direct influence of surface water.

The SWTR is based on the “multiple barrier” approach to surface water treatment. Disinfection is required for <u>all</u> surface water systems. Filtration is required for all surface water systems and for groundwater systems under the direct influence of surface water that fail certain SWTR standards including those for coliforms, turbidity, *Giardia lamblia*, and residual disinfectants. The SWTR requirements that apply to your water system will depend on the type of water source you use.

If you are a transient non-community surface water system, you must be sure to disinfect and filter the water. In addition, you must send reports to the state documenting compliance with all treatment and monitoring requirements.

If your system uses a groundwater source that is under the direct influence of surface waters (as determined by ADEC) and if it exceeds applicable limits for coliform bacteria, turbidity, disinfectant residuals, or other criteria (collectively called "filtration avoidance criteria"), then you must install filtration.

Generally, filtration is not required for systems using groundwater under the direct influence of surface water that are able to meet all of the filtration avoidance criteria. For more information regarding the SWTR, contact your local ADEC Drinking Water Program office.

8.11a Long Term 1 Enhanced Surface Water Treatment Rule

(This section applies to Small Treated Systems only)

The **Long Term 1 (LT1) Enhanced Surface Water Treatment Rule** applies to surface water and groundwater under the direct influence of surface water systems serving fewer than 10,000 people. The LT1 Enhanced Surface Water Treatment Rule introduced the requirement that systems serving fewer than 10,000 people must comply with federal **Disinfectant/Disinfection By-Product (D/DBP)** standards. The 1979 total trihalomethane (TTHM) regulation was only applicable to systems serving greater than 10,000 people.

The intent of LT1 provisions is to maintain microbial protection, particularly Cryptosporidium while complying with the new D/DBPR standards.

The LT1 provisions include:

- Maximum contaminant level goal (MCLG) of zero for Cryptosporidium.
- A treatment technique for filtered systems requiring a 2-log (99%) Cryptosporidium removal requirement.
- Strengthened combined filter effluent turbidity performance standards and individual filter provisions.
- Disinfection benchmarking provisions to ensure continued microbial protection.
- Inclusion of *Cryptosporidium* in the definition of GWUDISW and in the watershed control requirements for unfiltered systems; and
- Requirements for covers on new finished water reservoirs.

8.11b Long Term 2 Enhanced Surface Water Treatment Rule

(This section applies to Small Treated Systems only)

The **Long Term 2 (LT2) Enhanced Surface Water Treatment Rule** addresses the health effects associated with *Cryptosporidium* in surface water used as a drinking water supply.

Under LT2, all public water systems that use surface water or groundwater under the direct influence of surface water must:

- Monitor their water sources to determine treatment requirements.
- Implement treatment requirements based on their monitoring results.

Monitoring involved an initial two years of monthly sampling for *Cryptosporidium.* Small filtered systems can first monitor for *E. coli* and then only monitor for *Cryptosporidium* if *E. coli* results exceed specified levels. A second round of monitoring must have been completed six years after the completion of the initial round. Systems are not required to monitor if they provide the maximum level of treatment required under the rule.

Systems that are classified as high risk based on monitoring results, must provide 1.0 to 2.5-log additional *Cryptosporidium* treatment. All unfiltered water systems must provide 2 to 3-log removal depending on their monitoring results.

LT2 also introduced requirements for systems with open treated water storage reservoirs to either cover the reservoir or treat it to inactivate 4-log virus, 3-log *Giardia lamblia* and 2-log *Cryptosporidium*.

8.12 Stage 1 and Stage 2 Disinfectants/Disinfection Byproducts Rule (DBPR)

(This section applies to Small Treated Systems only)

Many water systems treat their water with a chemical disinfectant to inactivate pathogens that cause disease. The public health benefits of common disinfection practices are significant and well recognized. However, disinfection poses risks of its own.

Chlorine can react with naturally occurring organic material in water to form **Disinfection Byproducts (DBPs). DBPs** are also formed during disinfection with alternate oxidants such as ozone. Some disinfectants and disinfection byproducts (DBPs) have been shown to cause cancer and reproductive effects in lab animals and suggested bladder cancer and reproductive effects in humans.

The DBPR applies to all sizes of community water systems (CWSs) and Non-Transient Non-Community water systems (NTNCs) that add a disinfectant other than ultraviolet (UV) light or deliver disinfected water, and Transient Non-Community water systems (TNCs) that add chlorine dioxide.

Surface water systems or groundwater systems under the direct influence of surface water must conduct routine monitoring for total trihalomethanes (TTHMs) and the total of **five haloacetic acids (HAA5s)**.

The Stage 1 DBPR lowered the current TTHM MCL to 0.08 mg/L and sets an MCL for the total of HAA5 at 0.06 mg/L. Compliance with these MCLs is based on running annual averages of monitoring data because the health effects of concern are based on a lifetime of exposure. These MCLs are intended to limit the presence of known DBPs.

In addition, the Stage 1 DBP rule includes a maximum residual disinfectant level (MRDL) for chlorine at 4.0 mg/L (based on free chlorine). Compliance is based on a running annual average of monthly averages of samples taken in the distribution system. A running annual average is used as the basis for compliance because suspected health effects are long-term. These levels are thought to be the lowest feasible MRDLs for some systems that would not compromise microbial protection.

The Stage 2 DBP Rule increases compliance monitoring requirements for public water systems with high risk. Stage 2 DBP requires some systems to complete an Initial Distribution System Evaluation to determine DBP levels in their distribution systems and identify locations to monitor DBPs.

For additional information on the DBP rules, contact ADEC.

8.13 Ground Water Rule

The Ground Water Rule specifies the appropriate use of disinfection in groundwater and addresses other components of groundwater systems to assure public health protection. The rule applies to all public water systems (PWSs) that use groundwater or systems that mix surface and groundwater where the groundwater is added to the distribution system without treatment.
This regulation requires:

- Routine sanitary surveys of systems:
    - Every three years for community water systems
    - Every five years for noncommunity water systems
- Triggered source water monitoring for a system that identifies a positive sample during regular Total Coliform monitoring.
- Compliance monitoring requirements apply to systems that provide 4- log treatment of viruses and are not subject to triggered source water monitoring requirements; and
- Corrective action for any system with a significant deficiency or source water fecal contamination

8.14 Specific Monitoring Information

For specific monitoring information and variances that may apply to the water system you own/operate, call your local ADEC Drinking Water Program representative.

8.15 Public Notification Rule

The primary purpose of Public Notification (PN) Rule is to notify the public of drinking water violations or situations that may pose a risk to public health. Public notification serves to advise consumers of the potential health hazards and to educate them about the importance of adequate financing and support for drinking water systems.

Public water systems (PWSs) must notify their customers when they violate state drinking water regulations. Please immediately consult with your local ADEC local drinking water program representative if your system:

- Violates a maximum contaminant level or treatment technique,
- Fails to report or monitor a contaminant,
- Fails to comply with the requirements of a compliance schedule prescribed under a variance or exemption .

The ten required elements of a public notice are:

1. Description of the violation or situation, including the contaminant(s) of concern, and (as applicable) the contaminant level(s).
2. When the violation or situation occurred (i.e., date the sample was collected or was supposed to be collected).
3. Any potential adverse health effects from drinking the water and standard language regarding the violation or situation. (For MCL, MRDL, treatment technique violations, or violations of the conditions of a variance or exemption, use health effects language from Appendix B of the PN Rule. For monitoring and testing procedure violations, use the standard monitoring language below.)
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 the PWS is doing to correct the violation or situation.
8. When the PWS expects to return to compliance or resolve the situation.
9. The name, business address, and phone number or those of a designee of the PWS as a source of additional information concerning the notice.
10. A statement (see standard distribution language below) encouraging notice recipients to distribute the notice to others, where applicable.

There are three different tiers of notification:

- Tier 1, Immediate notice within 24 hours:
    - Distribution system sample violation when fecal coliform or *E. coli* are present; failure to test for fecal coliform *or E. coli* after initial total coliform distribution system sample tests positive.
    - Nitrate, nitrite, or total nitrate and nitrite MCL violation; failure to take confirmation sample.
    - Special notice for noncommunity water systems (NCWSs) with nitrate exceedances between 10 mg/L and 20 mg/L, where system is allowed to exceed 10 mg/L by the Drinking Water Program.
    - Chlorine dioxide maximum residual disinfectant level (MRDL) violation when one or more of the samples taken in the distribution system exceeds

    the MRDL on the day after a chlorine dioxide measurement taken at the entrance to the distribution system exceeds the MRDL, or when required samples are not taken in the distribution system.
  - Exceedance of maximum allowable turbidity level, if elevated to a Tier 1 notice by the Drinking Water Program.
  - Waterborne disease outbreak or other waterborne emergency.
  - Detection of *E. coli*, enterococci, or coliphage in a groundwater source sample.
  - Other violations or situations determined by the Drinking Water Program.

- Tier 2, Notice as soon as practical within 30 days:
  - All MCL, MRDL, and treatment technique violations, except where Tier 1 notice is required.
  - Monitoring violations, if elevated to Tier 2 notice by the Drinking Water Program.
  - Failure to comply with variance and exemption conditions.
  - For groundwater systems providing 4-log treatment and conducting Ground Water Rule compliance monitoring, failure to maintain required treatment for more than 4 hours.
  - Failure to take any required corrective action or be in compliance with a corrective action plan for a fecal indicator-positive groundwater source sample.
  - Failure to take any required corrective action or be in compliance with a corrective action plan for a significant deficiency under the Ground Water Rule.
  - Special public notice for repeated failure to conduct monitoring for *Cryptosporidium*.
- Tier 3, annual notice
  - All monitoring or testing procedure violations, unless primacy agency elevates to Tier 2, including failure to conduct benchmarking and profiling (surface water systems) and failure to develop a monitoring plan (disinfecting systems).
  - Operating under a variance and exemption.
  - Special public notice for availability of unregulated contaminant monitoring results.
  - Special public notice for fluoride secondary maximum contaminant level (SMCL) exceedance.

Tier 1 PNs must be issued via radio, TV, hand delivery, or posting. PWSs must also initiate consultation with the Drinking Water Program within 24 hours.

The Tier 2 and Tier 3 PNs must be issued by Community Water Systems via mail or direct delivery and by NCWSs via posting, direct delivery, or mail.

Chapter 9 – Safety

This section will introduce you to 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 our 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.

9.1 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 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 five-minute task that causes many injuries. Quick fixes usually promote unsafe acts. Do not let five-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 the foresight to correct a hazardous situation before an accident occurs. Together materials handling, falls, falling objects and machinery cause more than two-thirds of all workplace injuries.

9.2 Lifting

Operators are routinely required to lift and move various objects and materials. One-third of all injuries result from improper lifting and handling of heavy objects. Nearly a half-million disabling job injuries are reported annually and most are back injuries. Of every one-hundred injuries, thirty-three are injured because of improper lifting.

You should know the proper methods for lifting heavy objects (Figure 9.1). Here are the steps for safe lifting:

- Get a good footing
- Place feet about shoulder-width apart
- Bend at the knees to grasp the weight
- Keep the back straight and vertical
- Get a firm hold
- Keep the load close to the body
- Keep the back as straight and vertical as possible
- Lift gradually by straightening the legs
- Do not twist your body while lifting
- Get help when the load is too heavy or bulky for you to lift comfortably
- Reverse the procedure when putting the load down

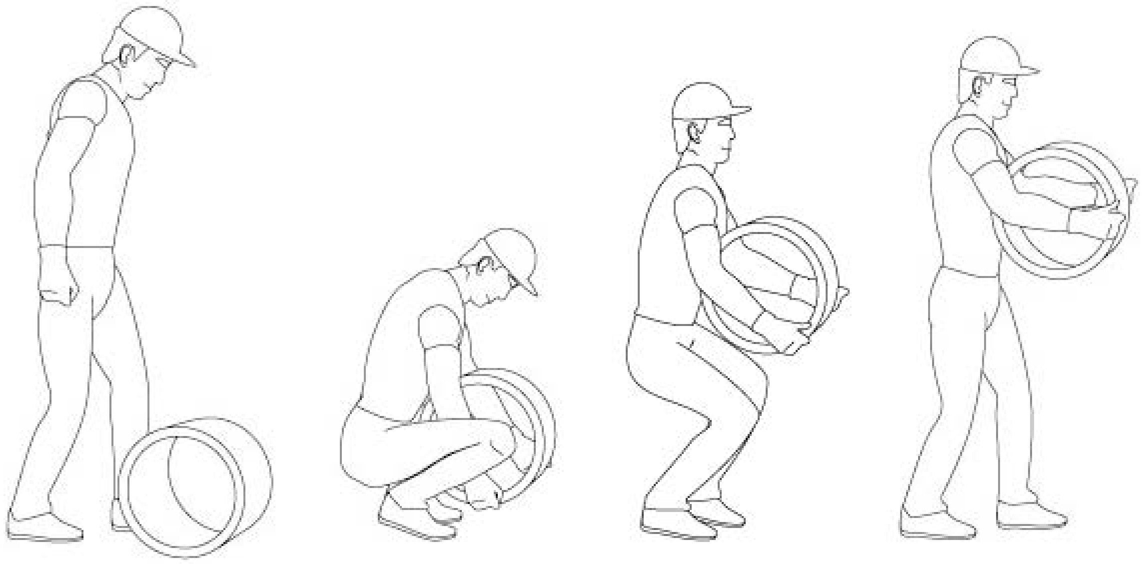


Figure 9.1: Safe Lifting Procedures

Carrying heavy, bulky, or long objects may result in a fall. Check your path beforehand and pick up or avoid slipping or tripping hazards. In Alaska, we have a lot of snow and ice in the wintertime, so take a few extra minutes to clean off icy stairs and clear a safe pathway. Make sure the object is balanced and your grasp secure before walking. Take your time, particularly on steps and through tight places. Make sure large objects do not bump or catch on anything and throw you off balance. Carry objects so you can see where you are going. Get help if you need it or save the job until help is available. Do not risk straining your back or falling. Wear steel-toed boots to protect your feet in case you drop a heavy load.

9.3 Electrical Safety

Operators work around electrically powered equipment all the time. Consequently, they are exposed to dangerous situations involving electricity. Electrical measurements should be taken be a licensed electrician. In an emergency, when one is not available, follow these safety precautions:

- Remove all jewelry, including earrings, rings, watches, necklace, metal-rimmed glasses and large belt buckles
- Wear shirts with tight-fitting sleeves
- Fasten the panel door open
- Wear safety goggles
- Wear electrical safety gloves
- Have a second person standing by when making the measurement
- Make the measurements with one hand, keep the second hand in your pocket

Of course, high voltage can cause serious injury. But even low voltage can cause serious injury if the current is sufficiently high. Figure 9.2 and Table K show the amperage flow through various parts of the human body and the effect the regular 60 Hz current has on the average human.

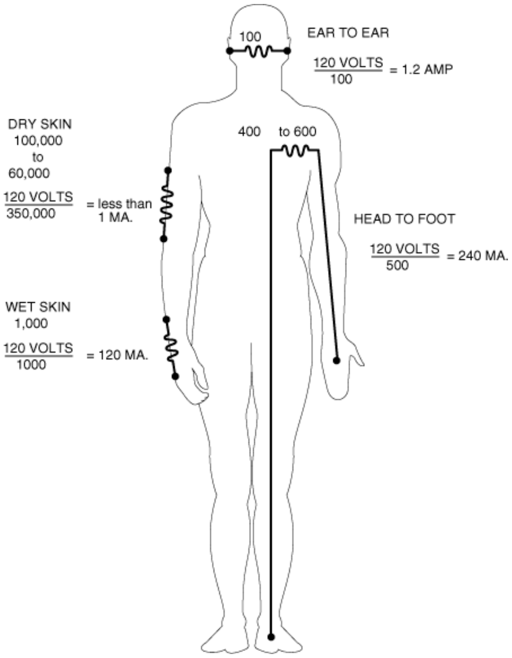


Figure 9.2: Body Resistance

Effects of 60 hz Current on an Average Human

	Current Values Through Body Trunk	**Effect**
Safe Current Values	1 Milliamp, or less……………………….	Causes no sensation – not felt. Is at threshold of perception
	1 to 8 Milliamps………………………………….	Sensation of shock. Not painful. Individual can let goat will, as muscular control is not lost. (5ma is accepted as maximum harmless current intensity).
Unsafe Current Values	8 to 15 Milliamps………………………...	Painful shock. Individual **can let go** at will, as muscular control is not lost
	15 to 20 Milliamps……………………….	Painful shock. Muscular control of adjacent muscles lost. **Cannot let go.**
	20 to 50 Milliamps……………………...	Painful. Severe muscular contraction. Breathing is difficult
	100 to 200 Milliamps…………………...	Ventricular Fibrillation (A heart condition that results in death – **no known remedy**).
	200 and over Milliamps………………....	Sever burns. Severe muscular contractions, so severe that chest muscles clamp heart and stop it during duration of shock. (This prevents Ventricular Fibrillation.)

Table K: Effects of 60 hz Current on an Average Human

9.4 Lockout/Tagout

Plant machinery and equipment powered by electricity must be de-energized and isolated before maintaining or servicing. Isolation and de-energizing equipment is required to protect yourself and other workers from unexpected start-up of the equipment or machinery or from release of energy (grounding).

OSHA standards require each facility to have a **lockout/tagout** plan. The most effective way to protect operators or maintenance personnel is to use a lockout device (Figure 9.3) or an energy-isolating device.

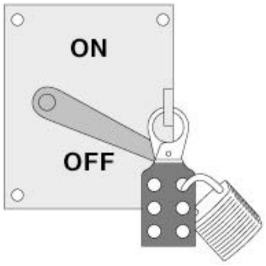


Figure 9.3: Lockout Device

Tagout means to place a warning tag on or near the lockout or energy-isolating device. The tag (Figure 9.4) must include the name of the person applying the tag, the date, and the reason that the equipment is being locked out.

Figure 9.4: Warning Tag

9.5 Chemical Handling and Storage

Operators work with or around chemicals and chemical products every day. Many of these materials have properties that make them hazardous: they can create physical (fire, explosion) and/or health hazards (toxicity, chemical burns.) There are ways to work with chemicals that can reduce to a negligible level, the probability, and consequences of an accident. Chemical safety is inherently linked to other safety issues including laboratory procedures, personal protective equipment, electrical safety, fire safety, and hazardous waste disposal.

The following sections provide general guidelines for chemical safety. Follow these basic guidelines when working with chemicals:

- Assume that any unfamiliar chemical is hazardous
- Know all the hazards of the chemicals you use; refer to the Safety Data Sheet (SDS)
- Consider any mixture to be at least as hazardous as its most hazardous component
- Never use any substance that is not properly labeled
- Follow all chemical safety instructions precisely
- Minimize your exposure to any chemical, regardless of its hazard rating
- Use appropriate personal protective equipment
- Use common sense at all times

9.5a Sodium Hypochlorite

As you have learned, sodium hypochlorite is a liquid sold with varying strengths. Common household laundry bleach is 5.25% available chlorine. Solutions of approximately two and three times this concentration are also available.

Since sodium hypochlorite is a liquid, the hazards of fire and chlorine fumes are often underestimated. Some basic safety precautions should be followed when using sodium hypochlorite.

- Store containers in a cool, dark area away from possible falling objects or physical damage
- Avoid contact with the eyes or with the skin
- Wear personal protective equipment at all times
- Keep the container tightly closed and away from combustible materials. If spilled, wash down thoroughly and do not allow spills to remain in contact with cloth, paper, oil products or other organic matter.
- Keep containers away from heat and fire
- Never use in combination with acids, vinegar, toilet bowl cleaners or any other cleaning agents

Fires have occurred spontaneously where rags and other combustible organic materials soaked with sodium hypochlorite have been allowed to stand where a heat source may have been present.

9.5b Calcium Hypochlorite

Calcium hypochlorite is supplied as a powder, in small granular form, or compressed into tablets. As such it can more easily be packaged in small quantities, transported, and, if simple precautions are taken, handled safely. Contrary to popular belief, this “safe” form of chlorine causes a great number of accidents. The appearance and packaging can be very misleading. Failure to adhere strictly to the rules of safe handling of calcium hypochlorite can prove disastrous.

Examine closely these care and handling rules that are summarized from the information published by the manufacturers:

- Never mix calcium hypochlorite with anything but water.
- Store in a cool, clean, dry area in the original container and always keep covered. Most safe containers have a plastic bag liner that should not be removed and should also be carefully closed and sealed. A separate storage area is recommended for storage, away from any other treatment chemicals.
- The storage area should be clean and located away from any combustible material and should not be located where chlorine fumes will cause corrosion to equipment.
- Metal drums should be kept upright and should not be dropped, rolled or skidded.
- When measuring calcium hypochlorite to make up solutions, use only a plastic, glass, or enameled measuring cup that is completely clean and dry.
- Calcium hypochlorite is a strong oxidizing agent. It ***must not*** be allowed to come in contact with heat, acids, or any combustible materials. Combustible organic

materials include paper, rags, beverages, tobacco, oil base products, etc. Calcium hypochlorite must be kept away from heat sources, such as matches, open flames, lit cigarettes and other forms of heat.

- Never permit calcium hypochlorite to contact the eyes. If you get calcium hypochlorite in your eyes, flush immediately and thoroughly with water.
- Always fill mixing vat halfway with water, then add the calcium hypochlorite. Never add water to calcium hypochlorite because a violent chemical reaction may occur. Rinse empty containers thoroughly with water.

In case of a fire or hypochlorite spill, contact your local fire department.

9.5c Chlorine Gas

The use and handling of chlorine gas presents some serious safety challenges. Consequently, *operators who use gas chlorine must be thoroughly trained*. Such training is beyond the scope of this manual.

Pure chlorine is shipped in steel containers. To protect the valve, keep the cap on the cylinder when the cylinder it not in use. Since chlorine in the cylinders is under pressure, and pressure increases when temperature increases, cylinders have a special safety feature to prevent explosion. This feature is a soft metal plug that is designed to melt at between 158^{o}F and 165^{o}F. In the case of fire, this plug will melt allowing the chlorine gas to escape, rather than allowing pressure to build up to the point where the cylinder might eventually rupture.

Small leaks can be detected by using a spray bottle filled with strong ammonia. Chlorine gas will react with ammonia to form a “white cloud.” Leak detectors are also recommended in chorine gas rooms.

Below are the more common safety rules for handling and storing gas chlorine cylinders.

- Due to chlorine gas being heavier than air, storage areas for chlorine cylinders should have ventilation to outside air located near the floor,
- When moving cylinders, the valve protection hood should be in place at all times.
- Cylinders must not be dropped or struck.
- A safety chain or strap should be placed around the cylinder and affixed to a wall, pipe, etc. to prevent the cylinder from tipping over in the event it is accidentally hit or pushed.
- Cylinders should be stored in an upright position.
- Cylinders should not be stored near a ventilating system, passageways, or below ground in unventilated rooms.
- Grease or oil should never be on, or around, chlorine fittings or connections.

- If there is any indication of the presence of chlorine in the air, immediate action should be taken to correct the leaking condition. Chlorine leaks that are left alone will always get worse. In such cases, repairs should only be attempted by individuals wearing appropriate PPE, including a Self Contained Breathing Apparatus (SCBA) unit.
- If an extensive chlorine leak is found, all persons should be kept away from the area to prevent exposure to the toxic gas – preferably upwind and at a higher elevation.

9.6 Safety Data Sheets (SDS)

A **Safety Data Sheet (SDS)** is a compilation of the information known about a chemical that relates to assessing the hazards of that chemical. The SDA was previously known as the Material Safety Data Sheet (MSDS). Chemical manufacturers are required by OSHA to provide SDS for all hazardous chemicals. The SDS can tell you what Personal Protective Equipment (PPE) is needed when handling that specific chemical, what to do in case of a spill, and first aid procedures.

Before using any chemical, read the container label and the appropriate SDS. Container labels and SDSs are good sources of information for chemical safety. The SDS contains 16 sections.

1. Identification: Identifies the chemical on the SDS as well as its recommended uses.
2. Hazard(s) Identification: Identifies the hazards of the chemical presented on the SDS and the appropriate warning information associated with those hazards.
3. Composition/Information on Ingredients: Identifies the ingredient(s) contained in the product indicated on the SDS, including impurities and stabilizing additives.
4. First-Aid Measures: Describes the initial care that should be given by untrained responders to an individual who has been exposed to the chemical.
5. Fire-Fighting Measures: Provides recommendations for fighting a fire caused by the chemical.
6. Accidental Release Measures: Provides recommendations on the appropriate response to spills, leaks, or releases, including containment and cleanup practices to prevent or minimize exposure to people, properties, or the environment.
7. Handling and Storage: Provides guidance on the safe handling practices and conditions for safe storage of chemicals.
8. Exposure Controls/Personal Protection: Indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker exposure.
9. Physical and Chemical Properties: Identifies physical and chemical properties associated with the substance or mixture.
10. Stability and Reactivity: Describes the reactivity hazards of the chemical and the chemical stability information.

11. Toxicological Information: Identifies toxicological and health effects information or indicates that such data are not available.
12. Ecological Information (non-mandatory): Provides information to evaluate the environmental impact of the chemical(s) if it were released to the environment.
13. Disposal Considerations (non-mandatory): Provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices.
14. Transport Information (non-mandatory): Provides guidance on classification information for shipping and transporting of hazardous chemical(s) by road, air, rail, or sea.
15. Regulatory Information (non-mandatory): Identifies the safety, health, and environmental regulations specific for the product that is not indicated anywhere else on the SDS.
16. Other Information: Indicates when the SDS was prepared or when the last known revision was made.

Chemical manufacturers should provide SDSs, and buyers should receive an SDS with the shipment. If an SDS is not with the shipment, you should request one from the vendor. SDSs can also be found on the web by searching under the manufacturer’s name.

Refer to Appendix 6 for an example of an SDS.

9.7 Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) includes steel-toed boots, safety glasses or goggles, face shields, earplugs, gloves or chemical protective clothing. 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. The employer is responsible for providing PPE for their employees.

Respiratory protection equipment is commonly used because of the danger of inhalation, which can provide a route of entry into the bloodstream for dangerous volatile chemicals. There are two 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.

A respirator with its own air source is called a supplied-air respirator or SCBA (Self Contained Breathing Apparatus). It consists of either a self-contained unit that the worker wears or a hose connecting a worker to a remote air source. The SCBA provides continuous positive air pressure into a facemask.

9.8 Confined Spaces

A **confined space** means a space that:

- is large enough and configured such that an employee can enter and perform assigned work.
- has limited or restricted means for entry or exit.
- was not designed for continuous occupancy.

Some examples of confined spaces include manholes, sewers, boilers, pipelines, dug wells, fuel tanks, storage tanks, tanks on haul-trucks, septic tanks, sewage lift stations, and valve vaults. Tanks and underground vaults are the types of confined spaces most frequently encountered by the water operator.

Air monitoring should be conducted before entering a confined space and while workers remain in the space. A confined space may have an oxygen-deficient atmosphere or an explosive atmosphere. The buddy system should be used when working in a confined space, with one person *always* remaining outside the confined space. In the event of an accident, the person on the outside of the confined space should *never* enter the space to attempt a rescue. That person should immediately call for help.

In the event that the confined space is oxygen-deficient, under no circumstances should an air-purifying respirator be used. Always use a SCBA. If you are required to enter confined spaces on a regular basis, it is recommended that you attend a confined space entry class for a more in-depth look at the subject.

Chapter 10 – Math

10.1 Introduction

This math section will be very basic. The certification exam does not require an operator of a small treated or small untreated water system to be a mathematician. This chapter deals with basic math that is required for you to accomplish tasks associated with operating your water system.

Someone once asked Albert Einstein how many feet were in a mile. "I don't know," he replied, "Why should I fill my head with information I can look up in a reference guide within two minutes?" That reasoning is why a math formula sheet is included when you take the certification exam. A copy of the formula sheet is also available as Appendix 7. Use the formula sheet as your reference guide. Do not cram your head full of formulas preparing for your certification exam since you'll have a formula sheet in front of you.

Learn to identify what a math problem is asking, then use the formula sheet to plug in the numbers to solve the math problem. Using Albert Einstein's logic, why try to memorize mathematical formulas when you can look them up on the formula sheet during the exam?

Also, an approved nonprogrammable calculator can be used during certification exams. Practice and be familiar with the calculator you will use when taking the certification exam.

Once again, this section is very basic. However, to pass the operator certification examination, you must know how to do certain calculations.
Calculating and adding the correct chemical dosage to drinking water can be the difference between life and death.

Solving math problems is not any different than solving other types of problems. It requires practice in manipulation and knowledge of what manipulations to make. Below is an approach to solving math problems:

- Understand the problem,
- Decide what the problem is asking,
- List the information given,
- Make a drawing of the information in the problem, if appropriate,
- Pay attention to the units given and required,
- If the calculation calls for an equation, write it down,
- Pick the appropriate formula,
- Refer to the formula sheet, and fill in the data in the equation,
- Look to see what is missing in the equation - what to solve for,
- Perform the calculations necessary to solve the problem,

- Review your work,
- Record your answer.

10.2 Averages

An average is a way of representing several different measurements as a single number. An average is the sum of all the numbers in a set divided by the total number in the set.

Problem:
Find the average of the following set of numbers:
90, 120, 75, 250, 150

Solution:
Add the five numbers together.

90 + 120 + 75 + 250 + 150 = 685

Next, divide the total from above by the number in the set

685 ÷ 5 = 137

The average is 137.

Problem:
Flow measurements were taken twice a week for a month. Find the average daily flow for the month:
1,200 gpd; 2,250 gpd; 2,600 gpd; 1,800 gpd; 1,900 gpd; 2,200 gpd; 2,500 gpd; 1,100 gpd.

Solution:
Add the eight numbers together.

1,200 gpd + 2,250 gpd + 2,600 gpd
+ 1,800 gpd + 1,900 gpd + 2,200 gpd
+ 2,500 gpd + 1,100 gpd = 15,550 gpd

Next, divide by the number in the set.

15,550 gpd ÷ 8 = 1,943.75 gpd

The average for the month is 1,973.75 gpd

Problem:
Find the average chlorine residual for the week given the following:

Monday’s residual: 0.8 ppm
Tuesday’s residual: 0.9 ppm
Wednesday’s residual: 1.2 ppm
Thursday’s residual: 0.9 ppm
Friday’s residual: 1.0 ppm
Saturday’s residual: 0.6 ppm
Sunday’s residual: 0.7 ppm.

Solution:
Add the seven residual readings together.

0.8 ppm + 0.9 ppm + 1.2 ppm + 0.9 ppm
+ 1.0 ppm + 0.6 ppm + 0.7 ppm = 6.1 ppm

Next, divide the total by the number in the set.

6.1 ppm ÷ 7 = 0.87 ppm

The average chlorine residual is 0.87 ppm

10.3 Fractions

You will often face routine situations that require working with fractions. Fractions are used when you want to express a portion of the whole. The number 12 divided by 3 gives an exact quotient of 4 (12/3 = 4). But, if you try to divide 4 by 5, you will not get an exact quotient. The division may be written 4/5. This is read four-fifths. The bar (—) or slash (/) in the fraction separates the two numbers and is read "divided by".

Divided by means the top number (numerator) is divided by the bottom number (denominator). This means that another way to say 4/5 is to say 4 divided by 5.

If you have a pizza that is cut into five pieces and you eat one, you have eaten one-fifth (1/5) of the pizza (1 divided by 5). If you eat two pieces, you have eaten two-fifth (2/5) of the pizza (two divided by five). Since you took a part of the whole pizza, you took a fraction of it. Remember that a fraction consists of a numerator and a denominator. The two (2) is the numerator; the five (5) is the denominator. You might remember which is which by thinking 'd' stands for down.

10.3a Adding or Subtracting Fractions with the Same Denominator

Now that you understand the basics, try adding and subtracting fractions with the same denominator.

Problem:

$\frac{1}{5} + \frac{3}{5}$

Solution:

Add the numerators together.

$\frac{1}{5} + \frac{3}{5} = \frac{4}{5}$

Problem:

$\frac{5}{52} + \frac{45}{52}$

Solution:

Add the numerators together

$\frac{5}{52} + \frac{45}{52} = \frac{50}{52}$

Problem:

$\frac{5}{8} - \frac{3}{8}$

Solution:

Subtract the numerators.

$\frac{5}{8} - \frac{3}{8} = \frac{2}{8}$

10.3b Multiplying Fractions

To multiply factions, first multiply the two numerators, then the two denominators. If necessary, simplify the resulting fraction.

Problem:

$\frac{1}{3} \times \frac{2}{5}$

Solution:

$\frac{1}{3} \times \frac{2}{5} = \frac{1 \times 2}{3 \times 5} = \frac{2}{15}$

Can this fraction be reduced?

No, the answer is 2/15.

Problem:

$\frac{3}{5} \times \frac{8}{12}$

Solution:

$\frac{3}{5} \times \frac{8}{12} = \frac{3 \times 8}{5 \times 12} = \frac{24}{60}$

Can this fraction be reduced?

Yes, both the numerator and denominator are divisible by 12.

$$\frac{{}^{24}/_{12}}{{}^{60}/_{12}} = \frac{2}{5}$$

10.3c Adding and Subtracting Fractions with Different Denominators

To add or subtract fractions with different denominators, you must first find the least common denominator (LCD). The LCD is the smallest number that can be a common denominator for a set of fractions.

The LCD can be the product of the denominators.
For example,

$\frac{2}{3} + \frac{3}{5}$

The LCD is 15, i.e., $3 \times 5 = 15$.

Convert 2/3 to have 15 in the denominator; multiply the numerator and denominator by 5.

$\frac{2}{3} \times \frac{5}{5} = \frac{10}{15}$

Convert 3/5 to have 15 in the denominator; multiply the numerator and denominator by 3.

$$\frac{3}{5} \times \frac{3}{3} = \frac{9}{15}$$

Add:

$$\frac{10}{15} + \frac{9}{15} = \frac{19}{15}$$

Alternatively, instead of having an LCD that is the product of the denominators, you can find the lowest common multiple to each of the denominators.

For example,

$$\frac{1}{2} + \frac{1}{3} + \frac{1}{5}$$

Find the lowest common multiple.

X	2	3	5
1	2	3	5
2	4	6	10
3	6	9	15
4	8	12	20
5	10	15	25
6	12	18	30
7	14	21	
8	16	24	
9	18	27	
10	20	30	
11	22		
12	24		
13	26		
14	28		
15	30		

In this case the lowest common multiple is 30. To convert to the LCD:
For 1/2, multiply the numerator and denominator by 15

$$\frac{1}{2} \times \frac{15}{15} = \frac{15}{30}$$

For 1/3, multiply the numerator and denominator by 10

$$\frac{1}{3} \times \frac{10}{10} = \frac{10}{30}$$

For 1/5, multiply the numerator and denominator by 6

$$\frac{1}{5} \times \frac{6}{6} = \frac{6}{30}$$

Add:

$$\frac{15}{30} + \frac{10}{30} + \frac{6}{30} = \frac{31}{30}$$

Problem:

$$\frac{8}{9} - \frac{2}{5}$$

Solution:

Find the LCD. In this case, you can just multiply the denominators.

$$9 \times 5 = 45$$

Convert 8/9 to the LCD.

$$\frac{8}{9} \times \frac{5}{5} = \frac{40}{45}$$

Convert 2/5 to the LCD.

$$\frac{2}{5} \times \frac{9}{9} = \frac{18}{45}$$

Subtract:

$$\frac{40}{45} - \frac{18}{45} = \frac{22}{45}$$

10.3d Dividing Fractions

To divide fractions, turn the second fraction (the one you want to divide by) upside down, then multiply and simplify, if necessary.

For example,

$$\frac{5}{8} \div \frac{2}{3}$$

Flip the second fraction and multiply.

$$\frac{5}{8} \times \frac{3}{2} = \frac{15}{16}$$

Problem:

$$\frac{12}{13} \div \frac{1}{2}$$

Solution:

Flip the second fraction and multiply.

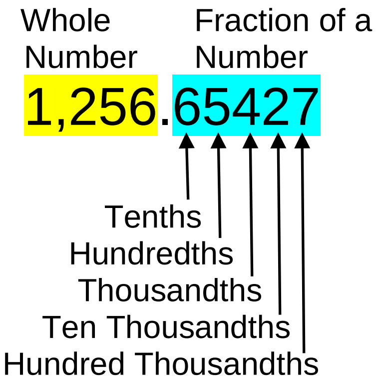
$$\frac{12}{13} \times \frac{2}{1} = \frac{24}{13}$$

Simplify:

$$\frac{24}{13} = 1\ \frac{11}{13}$$

10.4 Decimals

Another method of representing a fraction is by using decimals of tenths, hundredths, etc. This is a much better method to use with a calculator. If you have a fraction, and need to express the fraction as a decimal, you can convert the fraction to a decimal by dividing the numerator by the denominator. A decimal is composed of two sets of numbers. The numbers to the left of the decimal are whole numbers and numbers to the right of the decimal are parts of whole numbers, or a fraction of a whole number.



You can convert a fraction to a decimal by dividing the numerator by the denominator. Using a calculator to divide the fraction, simplifies the process. For example, to convert 3/4 to a decimal, we divide 3 by 4. Using a calculator, enter the following keystrokes:

$$\frac{3}{4} = 3 \div 4 = 0.75$$

The display will show 0.75

10.4a Adding and Subtracting Decimals

When adding or subtracting decimals with a calculator, make sure to line up the decimal points.

Addition example,

Add 236.45 and 784.11

Line up the decimals and then add.

$$\begin{array}{r} 236.45 \\ \underline{+784.11} \\ 1{,}020.56 \end{array}$$

Subtraction example,

Subtract 145.36 from 687.93

Line up the decimals and then subtract.

$$\begin{array}{r} 687.93 \\ \underline{-145.36} \\ 542.57 \end{array}$$

10.4b Multiplying Decimals

When multiplying two or more numbers, follow these basic rules:

- Multiply the numbers as if they are whole numbers. Don’t worry about the decimal point for now.
- Write down the answer.
- Count the total number of digits (numbers) to the right of the decimal point in all

the numbers multiplied.
- Place the decimal point that many places from the right of your answer.

Problem:
Multiply 23.58 x 2.3

Solution:

Multiply as whole numbers
$2358 \times 23 = 54234$

Count the total number of digits to the right of the decimal point in each number.
23.58 has two
2.3 has one
Therefore, a total of three digits to the right of the decimal point.

Place the decimal point three places from the right.
54.234

Therefore,
$23.58 \times 2.3 = 54.234$

10.4c Dividing Decimals

To divide a number by a number containing a decimal, the divisor must be made into a whole number by moving the decimal point to the right until a whole number remains. Follow these basic rules:

- Count the number of places the decimal needed to be moved
- Move the decimal in the dividend by the same number of places

Problem:
Divide 288.8 by 21.6

Solution:

$21.6\overline{)288.8}$

Divisor
Dividend

Move the decimal in the divisor 1 place to the right, changing the divisor to the whole number 216. Moving the dividend decimal 1 place to the right changes the dividend to 2888.

The equation becomes:

$216\overline{)2888}$

Note the sum of decimal places moved equals two. Place the decimal two places from the right of the 1; (13.37037). Answer rounded to two decimal places for convenience.

However, it's much simpler using a calculator. You would enter the following:
$288.8 \div 21.6 =$

The answer is 13.37037

10.5 Rounding Numbers

Rounding is the process of taking a number and reducing the number to one with fewer digits. Digits are rounded for convenience, not accuracy.

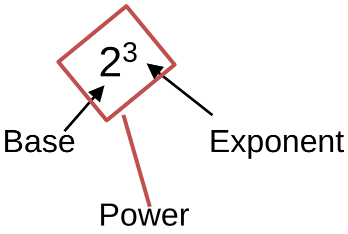
If you have a number like the decimal example above (13.37037) and you wanted to round to two significant digits, you look at the third number to the right of the decimal (13.37037). If the number is greater than 5 raise the second digit up one, if the number is less than 5 leave the number as is. The solution to rounding the above number would be 13.37.

Most the time, rounding is used because it makes numbers easier to work with in your head. Rounding can get an answer that is close but that does not have to be exact. In general, round numbers by making numbers that end in 1 through 4 into the next lower number that ends in 0. For example, 63 rounded to the nearest ten would be 60.

Numbers that end in a digit of 5 or more should be rounded up to the nearest ten. The number 88 rounded to the nearest ten would be 90. As a rule of thumb, if the number you are rounding is followed by 5, 6, 7, 8, or 9, round the number up. For example; 48 rounded to the nearest ten is 50. If the number you are rounding is followed by 0, 1, 2, 3, or 4, round the number down. For example; 43 rounded to the nearest ten is 40.

10.6 Exponents

The exponent of a mathematical expression indicates the number of times it should be multiplied by itself. A power is expressed as a base number and an exponent.



Some examples are 2^3, ft^2 (squared feet or feet x feet), or ft^3 (cubic feet or feet x feet x feet)

Rather than writing 5 x 5 x 5 x 5, it is convenient to use an exponent to indicate that the factor 5 is used as a factor four times. Specifically, when several numbers are multiplied together as above, 5 x 5 x 5 x 5 = 625, the 5s are the factors; 625 is the product. Since the factors are alike, the product is called a power. Thus, 625 is the power of 4, and 5 is the base of the power (5^4). A power is a product obtained by using a base a certain number of times as a factor.

The exponent is a small number placed above and to the right of the base number and indicates how many times the base is to be used as a factor. Using this system of notation, the multiplication 5 x 5 x 5 x 5 is written 54.

Problem:

Rewrite $4 \times 4 \times 4 \times 4 \times 4$ and calculate the product.

Solution: $4 \times 4 \times 4 \times 4 \times 4 = 4^5 = 1{,}024$

10.7 Ratios

A ration compares two numbers with the same units, i.e. how many times one number is contained in another. For example, if there are 5 marbles and six rocks on the ground, then the ration of marbles to rocks is 5:6. Similarly, the ratio of rocks to marbles is 6:5 and the ratio of marbles to the total number of rocks and marbles is 5:11.

10.8 Unit Conversions

Unit conversion represents a method of converting from one unit to another, such as cubic feet (ft^3) to gallons. Conversions are a process of changing the units of a number to make the number usable in a specific instance. Conversions are accomplished by multiplying or dividing into another number to change the units of the number. If the units are incorrect the number that you calculate is incorrect as well.

Most calculations used for water related problems have units connected with them. Unit conversions appear to be one of the most difficult tasks for water system operators. You must always write the units down with each number. The number tell us how many, the units tell us what we have. All units must be checked prior to your calculations to make sure your answer will be in the correct units.

When converting one unit to another, the following method determines units (but it does not solve the equation):

- Write down the number and units you wish to convert from on the left
- Write down the unit you wish to convert to on the right
- Draw a line under both of these (this line means “divided by” and allows you to use a conversion factor)
- Below the division line (on the right) write down the same unit as you wrote on the left
- Write the appropriate conversion number associated with the two units on the right
- Cancel out the same units (this will leave you with the units you wish to convert to)
- Perform the appropriate multiplication and division

Example A:
How many gallons is in 200 cubic feet (ft^3)? There are 7.48 gallons in one cubic foot.

$$\frac{200\ ft^3 \times 7.48\ gallons}{1\ ft^3} = 1{,}486\ gallons$$

Example B:
How many cubic feet are in 7,667 gallons?

$$\frac{7{,}667\ gallons \times 1\ ft^3}{7.48\ gallons} = 1{,}025\ ft^3$$

Units must be the same to make calculations. For instance, when numbers are added or subtracted, the units must be the same. For example, 6 feet + 6 feet = 12 feet

Now, add 4 feet to 6 yards. The answer cannot be determined unless yards are converted to feet or feet are converted to yards. Converting the larger units is easiest, when possible, but the conversion may depend on the answer desired.

There are 3 feet in one yard. Convert 6 yards to feet.

$$\frac{6\ yards\ \times 3\ feet}{1\ yard} = 18\ feet$$

Complete the problem:

$$18\ feet + 3\ feet\ = 22\ feet$$

Another way to do this is:

$$\frac{6\ yards\ \times 3\ feet}{1\ yard} + 3\ feet = 22\ feet$$

When taking your certification exam refer to the formula sheet (Appendix 7) for conversion factors.

Problem:
If your pressure tanks holds 100 gallons of water, how many cubic feet of water does the tank contain?

$$\frac{100\ gallons\ \times 1\ ft^3}{7.48\ gallon} = 13.4\ ft^3$$

10.9 Solving Word Problems

1. Read the problem,
2. Circle what is being asked for, underline pertinent information, draw a picture and label with information given in the question,
3. Stop and think about what the question asks for,
4. Check the units; often the units of the item being asked for will tell you how to do the problem,
5. Do not proceed until you understand what is being asked and you know how to proceed,
6. Select the proper formula from the formula sheet,
7. Write down the formula,
8. Plug numbers from the question into the formula; if you don’t have enough numbers to plug into the formula or too many numbers for the formula you probably are trying to use the wrong formula,
9. Solve the formula,

10. Check if the answer is reasonable (makes sense). If not, go back and check your work and the formula you used.

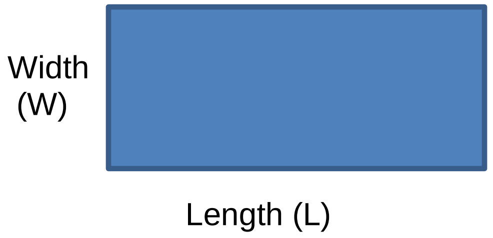
10.10 Area

Area represents the size of the surface of an object. Area of any figure is measured in the two dimensions or in square units. The units in the English system are usually square inches (in^2), square feet (ft^2), etc. Once again, remember units must be the same to solve math problem.

Area is typically determined by multiplying the length times the width, resulting in a square measurement.

10.10a Area of a Rectangle

The area of a rectangle is equal to the length multiplied by the width.



Problem:
Find the area of a rectangle with a length of 8 feet and a width of 4.5 feet.

Solution:
$Area = length \times width$

$Area = 4.5\,feet \times 8\,feet = 36\,ft^2$

Remember: The units must be the same, i.e. both in feet, inches, etc.

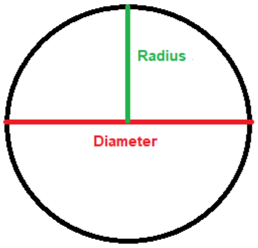
Problem:
What is the area of a sand filter that is 32 feet wide and 46 feet long?

Solution:
$Area = length \times width$

$$Area = 46\,feet \times 32\,feet = 1{,}472\,ft^2$$

10.10b Area of a Circle

The area of a circle is found in a different manner because a circle does not have length and width measurements. A circle is defined as a figure that has an arc that is equidistant in all areas from a center point. A line drawn from the center point to any point on the arc is called the radius (r). A straight line drawn through the center from arc to arc is called the diameter (D) of the circle. The distance around the outside of the circle is called the circumference (C).



When making calculations involving circular objects, a special number is required, referred to as the Greek letter pi (pronounced pie), the symbol for pi is π. Pi (π) always has the value 3.1416 (many calculators include a button for π, since it is used so often). Pi is usually rounded to 3.14.

The area of a circle is found by using the following formula.

$\boldsymbol{Area = \pi \times radius^2}$ **or**
$\boldsymbol{Area = \pi r^2}$

Alternatively, using the diameter the formula can be rewritten as:

$\boldsymbol{Area = \pi \times \left(\frac{diameter}{2}\right)^2}$ **or**

$Area = \pi\left(\frac{d}{2}\right)^2$ or

$Area = \frac{\pi}{4}d^2 = 0.785 \times d^2$

Problem:
What is the area of a circle with a diameter of 25 feet?

Solution:
$Area = 0.785 \times d^2$
$Area = 0.785 \times (5\ feet)^2$
$Area = 0.785 \times 25\ feet^2$
$Area = 19.625\ ft^2$

Practice Problems:

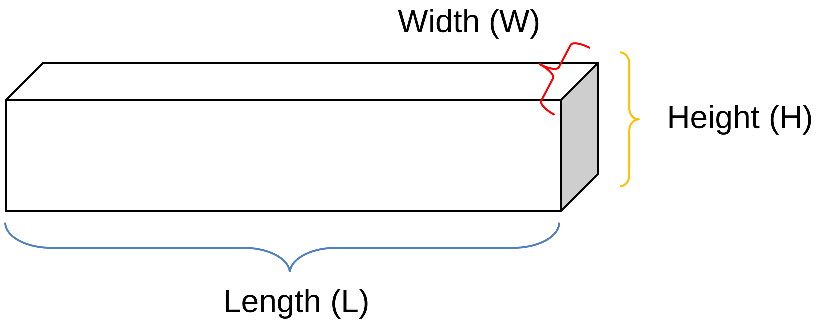
1. What is the area of the top of a circular tank with a diameter of 40 feet? (Answer: 1,256 ft^2)
2. How many gallons of paint will be needed to paint the top of a circular storage tank that is 20 feet in diameter? A gallon of paint covers 110 square feet. (Answer: 2.85 gallons)
3. A sheet of drywall is 4 feet wide and 8 feet tall. What is its surface area? (Answer: 32 ft^2)
4. You decide to install drywall in your house on a wall that measures 14 feet long by 8 feet high? How many sheets of drywall do you need? (Answer: 3.5 sheets)

10.11 Volume

As an operator, you will be usually interested in how many gallons a container, tank, or pipe can hold. Volume is measured in the three dimensions where a depth or height of the figure, width, and length are known. Units are generally in cubic feet (ft^3), cubic inches (in^3), acre-feet, or gallons. In the water field, the volumes of most tanks are measured in gallons.

10.11a Volume of a Rectangle

The volume of a rectangular object like a clear well is calculated by multiplying together the length, width, and the depth. When calculating volume, remember the length times the width is the surface area. Then, surface area is multiplied by the depth to find the volume.



$$\boldsymbol{Volume} = \boldsymbol{L} \times \boldsymbol{W} \times \boldsymbol{H},$$

Where,
L = Length
W = Width
H = Height

Problem:
What is the volume in cubic feet of a storage tank 45 feet long, 20 feet wide, and 10 feet deep?

Solution:
$\boldsymbol{Volume} = \boldsymbol{L} \times \boldsymbol{W} \times \boldsymbol{H}$
$\mathrm{V} = 45\ \mathrm{ft} \times 20\ \mathrm{ft} \times 10\ \mathrm{ft}$
$V = 9{,}000\ ft^3$

Most problems involving storage tanks require the volume to be in gallons instead of cubic feet. To convert cubic feet to gallons use the following conversion factor:

$1\ ft^3 = 7.48\ gallons$

Now, convert the answer in the previous problem into gallons.

$$V = 9{,}000\ ft^3 \times \frac{7.48\ gallons}{1\ ft^3}$$

$$V = 67{,}320\ gallons$$

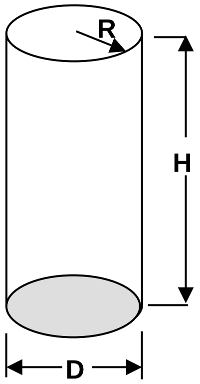
Practice Problems:

1. What is the volume, in gallons, of a storage tank that is 50 feet long, 32 feet wide, and 15 feet deep? (179,520 gallons)
2. A storage tank holds 251,328 gallons and is 160 feet long and 35 feet wide. What is the depth of the tank? (6 feet deep)

10.11b Volume of a Cylinder

The volume of a cylinder is equal to the surface area of the circular base times the height of the cylinder.

$Volume = \pi \times r^2 \times H$
$Volume = 0.785 \times D^2 \times H$



Problem:
A cylindrical tank has a diameter of 10 feet and contains water to the 30 foot level. How many gallons of water are in the tank?

Solution:

$$Volume = 0.785 \times (10\ ft)^2 \times 30\ ft$$
$$Volume = 2{,}355\ ft^3$$

Convert to gallons:

$$Volume = 2{,}355\ ft^3 \times 7.48\ {}^{gal}\!/_{ft^3}$$
$$Volume = 17{,}615.4\ gallons$$

Practice Problems:

1. How many gallons will a cylindrical tank that measures 60 feet in diameter and 40 feet deep hold? (Answer 845,539.2 gallons)
2. If a cylindrical tank holds 40,000 gallons of liquid, what is the depth of the container when the radius is 12 feet? (Answer 11.8 feet)
3. The static water level is measured to be 40 feet below ground level. The well casing is 6-inch diameter and 250 feet long. How many gallons of water are in the casing? (Answer 308 gallons)

10.12 Pressure

Pressure is expressed as pounds per square inch (psi), but it can be expressed as feet of water or feet of head. Pressure in the water system makes the system work. It is caused by the weight of water above a given point in the system.

To convert from feet of head to psi multiply the head times 0.433 psi/foot of water. When you know the pressure on a given point you can calculate the head in feet by multiplying the pressure times 2.31 feet/psi.

$$1.0\ foot\ of\ water = 0.433\ psi$$
$$1.0\ psi = 2.31\ feet\ of\ water$$

Problem:
Find the pressure on a gauge when the water level above a point is 35 feet.

Solution:

$$35\ ft \times \frac{0.433\ psi}{1\ ft} = 15.2 \text{ psi}$$

Problem:
Find the feet of head when a pressure gauge reads 30 psi.

Solution:
$$30\,psi \times \frac{2.31\,ft}{1\,psi} = 69.3\,ft$$

Practice Problems:
1. A pressure gauge at the base of a water tank reads 29 psi. What is the elevation of the water above the gauge? (Answer 67 feet)
2. A water tank is 35 feet high but is filled to the 30-foot level? What is the pressure at the base of the tank? (Answer 13 psi)

10.13 Dosage Calculations

As an operator, you must understand the importance of calculating the amount of chemical that needs to be added to the water. Calculating the amount of chemical needed is called dosage. Dosage is typically expressed in pounds. The concentration of the chemical being added is expressed as either parts per million (ppm) or milligrams per liter(mg/L). Milligrams per liter and parts per million are considered to be equal, i.e. mg/L = ppm.

To calculate dosage we use a formula called “Pounds” formula.

$$Pounds = \ Concentration\left(\frac{mg}{L}\ or\ ppm\right) \times Volume(MG) \times 8.34\ {}^{lbs}/_{gal}$$

Where,
Dosage is the amount of chemical added in pounds (lbs),
Concentration is the strength of the chemical in milligrams per liter (mg/L),
Volume is the amount of water in million gallons (MG), and
8.34 is a conversion factor converting the water of one gallon of water into pounds, i.e. one gallon of water equals 8.34 pounds.

The Pounds formula assumes that the chemical being added is 100% pure. However, often when adding chlorine the purity maybe 65% available chlorine. In such a case, you will need to divide your answer by 0.65 (65%) when calculating the dosage to account for the chlorine not being 100% pure. You will often find 65% available chlorine called High Test Hypochlorite (HTH) which is a powered form of calcium hypochlorite.

$$Pounds = \frac{mg/l \times MG \times 8.34}{Percent\ Purity\ (as\ a\ decimal)}$$

To convert gallons to million gallons (MG), divide the gallons by 1,000,000 gallons.

$$MG = \frac{gallons}{1{,}000{,}000}$$

Problem:
How many million gallons (MG) is 750,000 gallons?

Solution:
$\frac{750{,}000\ gallons}{1{,}000{,}000}$ =0.75 MG

Problem:
How many pounds of chlorine (assume 100% pure) must be added to 1.5 million gallons of water to obtain a 2.5 ppm chlorine dosage?

Solution:

$$Pounds\ = 2.5\ ppm \times 1.5\ MG \times 8.34\frac{lbs}{gallon} = 31.3\ pounds$$

Problem:
How many pounds of HTH (65% available chorine) must be added to 3.5 million gallons of water to obtain a 2.0 mg/L chlorine dosage?

Solution:

$$Pounds = 2.0\ ppm \times 3.5\ MG \times 8.34\frac{lbs}{gallon} = 58.4\ pounds$$

However, you’re not done yet. The chlorine is only 65% pure.

$$Pounds = \frac{58.4\ pounds}{0.65} = 89.8\ pounds\ of\ 65\%\ chlorine$$

Note: To calculate pounds per day replace MG with million gallons per day (MGD).

10.14 Proportion Problems

How many gallons of a 15% solution are needed to be mixed with water to fill a 50-gallon barrel with 2% solution? Sounds complicated? Not really, if you follow some simple steps setting up a proportion problem.

You can use the following equation to solve dilution problems.

$C_1 \times V_1 = C_2 \times V_2$
Where,

C_1 = beginning concentration
V_1 = beginning volume
C_2 = diluted concentration
V_2 = diluted volume

The units for C_1 and C_2 must be the same and V_1 and V_2 must be the same.

Using the example in the first paragraph of this section. How many gallons of a 15% solution are needed to be mixed with water to fill a 50 gallon barrel with 2% solution? Solve for the needed volume of the 15% solution.

$C_1 \times V_1 = C_2 \times V_2$
$15\% \times V_1 = 2\% \times 50\ gal$
$V_1 = \frac{2\% \times 50\ gal}{15\%} = 6.67$ gal

Problem:
You have 10 gallons of a 25% solution and need a 15% solution. How much water do you need to add?

$$25\% \times 10\ gallons = 15\% \times V_2$$

$$V_2 = \frac{25\% \times 10\ gal}{15\%}$$

$$V_2 = 16.67\ gallons\ of\ water$$

10.15 Detention Time

The detention time of a tank or piping system is the time that it would take to fill or empty the tank or pipe. Detention time is a theoretical time since it will not determine if the tank is short-circuiting or not. Detention time is found by calculating the volume of the vessel and dividing it by the flow to the vessel.

$$Detention\ Time = \frac{Volume}{Flow}\ or\ \frac{Tank\ Capacity}{Flow\ Rate}$$

Problem:
Find the detention time of a tank that measures 30 feet long 20 feet wide and 10 feet deep with a flow into the tank of 500 gpm?

Solution:

1. Calculate the volume of the tank:
   $Volume = L \times W \times H$

$$Volume = 30\ ft \times 20\ ft \times 10ft$$

$$Volume = 6{,}000\ ft^3$$

2. Convert to gallons:
   $Volume = 6{,}000\ ft^3 \times \frac{7.48\ gallon}{1ft^3}$ = 44,880 gallons

3. Calculate detention time:

$$Detention\ Time = \frac{Tank\ Capacity}{Flow\ Rate}$$

$$Detention\ Time = \frac{44{,}880\ gallons}{500\ gpm}$$

$$Detention\ Time = 89.76\ or\ 90\ minutes$$

Problem:

Find the detention time of a cylindrical tank that has a diameter of 35 feet and is 15 feet deep with a flow into the tank of 150 gpm.

Solution:

1. Calculate the volume of the tank:
   $Volume = 0.785 \times d^2 \times H$

$$Volume = 0.785 \times (35\ ft)^2 \times 15ft$$

$$Volume = 14{,}424.375\ ft^3$$

2. Convert to gallons:
   $Volume = 14{,}424.375\ ft^3 \times \frac{7.48\ gallon}{1ft^3}$ = 107,894.325 gallons

3. Calculate detention time

$$Detention\ Time = \frac{Tank\ Capacity}{Flow\ Rate}$$

$$Detention\ Time = \frac{107{,}894.632\ gallons}{150\ gpm}$$

$$Detention\ Time = 719.3\ minutes\ or\ 12\ hours$$

Glossary

A

Action level - The concentration of lead or copper in water that determines, in some cases, the treatment requirements for source water or corrosion control.

Acute - Pertaining to an intense effect of a chemical or infectious agent. Acute effects are generally closely associated with high doses of the causative agent. They are not necessarily confined to brief exposure to the agent.

Algae - Simple, aquatic plants. They contain chlorophyll and require sunlight. They vary from microscopic single cells organisms to giant seaweed. In drinking water sources, blooms of microscopic algae cause taste and odor problems.

Alkalinity - A measure of the capacity of a water to neutralize strong acids; in natural waters this capacity is usually attributed to bases such as bicarbonate (HCO3-1), carbonate (CO3-2), and hydroxide (OH-1). Alkalinity is expressed in mg/L as Ca CO3.

Ammeter - A test instrument for measuring electrical current in amps. Often part of an instrument, called a VOM (volt, ohm, amp meter), have capacity to measure, voltage, current, and resistance.

Ampere - The unit of measurement of electrical current.

Anaerobic - In reference to microorganisms, organisms that can grow in the absence of free oxygen. In reference to the environment, the condition in which free oxygen is absent.

Annular Space - The space between the outside of a well casing and the drilled hole.

Appurtenance - Machinery, appliances, structures and other parts of a main structure that are necessary to allow it to operate as intended, but not considered part of the main structure. Example: Valves are appurtenances of the distribution piping system.

Aquifers - Underground formations where groundwater exists in sufficient quantities to supply wells or springs. These saturated underground formations will yield water to a well or spring. The water in an aquifer is called groundwater and the two terms often are used interchangeably. A saturated formation that will not yield water in usable quantities is not considered an aquifer.

Artesian - Water held under pressure in porous rock or soil confined by impermeable geologic formations.

Aseptically - Performing an operation in a manner that is free from disease-causing organisms.

B

Backflow - An undesired, reversed flow of liquid into a piping system.

Backpressure - Backpressure occurs when normal flow in the distribution system is reversed due to an increase in the downstream pressure above the supply pressure.

Backsiphonage - Backsiphonage can occur when a negative pressure (below atmospheric pressure, or a vacuum) develops in the distribution system that can allow pollutants or contaminants to be siphoned into the water system.

BacT - Abbreviation for bacteriological, as in BacT sample (microbiological sample).

Bacteria - Microscopic unicellular organisms having a rigid cell wall. They lack a nuclear membrane, amitotic system and mitochondria. They possess a single chromosome and divide by binary fission. Most are nonphotosynthetic (except cyanobacteria, the group formerly referred to a blue-green algae).

Boil Water Notice - A public notice issued by a public water system that advises users that their water is, or potentially is, unsafe microbiologically and that the water should be boiled before use. To kill waterborne pathogens, water at sea level should be brought to a rolling boil for 1 minute and then allowed to cool before consumption.

Bored Wells - A well that is excavated by means of an auger (hand or powered), as distinguished from dug, drilled or driven.

Borehole - A hole for well made by the boring excavation process.

Breakpoint - The point on a breakpoint curve (graphic representation of the relationship that exists as increasing amounts of chlorine are added to water containing ammonia-nitrogen and nitrogen-containing organics compounds) at which the chlorine dosage has satisfied the demand exerted by the ammonia nitrogen and nitrogen-containing organic compounds and beyond which addition chlorine is measured as free, rather than combined, residual.

C

Capacitor - An electrical device consisting of two conductive plates separated by a non-conductor used to store an electrical charge (capacitance).

Carcinogenic - Having the capacity to induce cancer.

Chlorination - An oxidation process initiated through the addition of chlorine. In chlorination, oxidation oxidizes microbiological material, organic compounds and inorganic compounds. Chlorination is the principal form of disinfection of water supplies in the U.S.

Chlorine Demand - The quantity of chlorine consumed in a specified time period by the oxidative reaction with microbiological material, organic compounds and inorganic compounds.

Chlorine Residual - The concentration of chlorine compounds present in water after the oxidation (chlorine) demand has been satisfied. Chlorine residual is expressed in terms of free chlorine residual, combined chlorine residual, and total chlorine residual.

Chronic - Pertaining to symptoms that continue for a long time as a result of a single exposure or repeated exposure over a long period of time.

Close-Coupled - In reference to pump configuration, where the pump is connected directly to its power source by a common shaft without any reduction gearing or shafting.

Colloid - A small, discrete solid particle in water that is suspended (not dissolved) and will not settle by gravity; usually considered to be less that one micrometer in diameter.

Color - A physical characteristics describing the appearance of water (different from turbidity, which is the cloudiness of water).

Colorimeter - A device used to measure the absorption of light at a specific wavelength.

Combined Chlorine Residual - Chlorine residual resulting from the sum of the residual chlorine that is combined with ammonia and organic nitrogen.

Community Water System - In the system used in Alaska to classify public water systems; those public water systems that are expected to serve year-round a population of at least 25 of the same individuals.

Comparator - In reference to chemical analysis, a device to determine the intensity of color that has developed as part of a colorimetric chemical analysis. The color intensity is compared visually to a set of color standards. The intensity of the color is proportional to the concentration of the material being analyzed. Typically used by operators to determine chlorine residual concentration.

Concentration, C. - In reference to the product C x T (concentration times time), used to evaluate microorganism inactivation by a disinfectant, “C” is the concentration of the disinfectant expressed in mg/L.

Conductivity - A measure of the ability of a solution to conduct electrical current. Its value is commonly used to estimate the total dissolved solids concentration of the solution.

Conductor - A substance that permits the flow of electricity.

Cone of Depression - A depression in the water table around a well or group of wells in response to groundwater withdrawal.

Confined Aquifer - Bounded on the top by materials (clay, shale, etc.) through which water moves very slowly. Groundwater in a confined aquifer is under pressure and rises in a well above the top of the aquifer.

Confined Space - A space that is configured so that an employee can bodily enter and perform assigned work but that has limited or restricted means of entry and exit and is not designed for continuous employee occupancy. A legal definition related to OSHA’s requirements for certain specific restrictions and employee training.

Consumer Confidence Reports (CCR) - An annual report to consumers of each Class A community public water supply system on the source of their water and the levels of contaminants found in the drinking water.

Contact Time, T. - In reference to the product C x T (concentration times time), used to evaluate microorganism inactivation by a disinfectant, “T” is the time, in minutes, that the disinfectant is in contact with the water being disinfected.

Corrosion - The gradual deterioration of a substance (usually a metal) as a result of a reaction with its surroundings.

Corrosivity - An indication of the corrosiveness of a water. Often expressed by the Langelier Saturation Index.

Cross-connection - A physical arrangement by which a public water system is connected, directly or indirectly, with an unapproved water system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture, or other device that contains, or might contain, wastewater or other substances of unknown or unsafe quality that might be capable of contaminating the water supply through backflow; “cross-connection” includes a bypass arrangement, jumper connection, removable section, swivel or change-over device, and other temporary, permanent, or potential connection through which, or because of which, backflow or back-pressure could occur.

Current - The speed of electrical charge movement or the “flow rate” of electricity, measured in amperes.

Cycle - In reference to alternating current (AC) electrical systems, one complete change in direction of current flow.

D

Decommissioned - In reference to wells, a decommissioned is a well that has been abandoned and sealed according to specific standard procedures.

Discharge Pipe - The piping system through which water flows from the outlet side of a pump, pump station, or reservoir.

Disinfection - The process designed to inactivate most microorganisms in water, including all pathogenic bacteria and viruses.

Disinfection/Disinfection By-Product (D/DBP) - A group of disinfectants and the chemical by-products resulting from the application of those disinfectants and regulated as a primary drinking water regulation.

Disinfection By-Products (DBPs) - A chemical by -product of the disinfection process. DBPs are formed by the reaction of the disinfectant, natural organic matter and the bromide ion (Br-1).

Drainage Basin - Also called a watershed. The land area, usually expressed in square miles, from which water flows into a stream or river above a specified point.

Drilled Well - A well that is excavated by cable tool or rotary method, as distinguished from dug, bored or driven.

Drinking Water Protection Program (DWPP) - An Alaskan program intended to help protect the water sources of public water systems.

Driven Wells - A well that is constructed by driving a series of pipes into unconsolidated material to water-bearing stratum, as distinguished from bored dug, or drilled.

Dug Well - A shallow, large-diameter well that is excavated by hand or with power machinery, as distinguished from bored, drilled or driven.

E

Evaporation - A process in which a liquid is changed to a gaseous state by volatilization at a set temperature and pressure.

Exercised - In reference to water system valves, the process of opening and closing the value to ensure that the mechanism operates smoothly.

F

Fecal Coliform – Members of the total coliform group of bacteria that area characterized by their ability to ferment lactose at 112.1o F (44.5o C). Fecal coliforms provide stronger evidence of the possible presence of pathogens than do total coliform. This group indicates the presence of fecal matter, which could be of human or animal origin since fecal coliforms come from the intestines of all warm-blooded animals. Fecal coliforms do not include coliforms found naturally in the soil and on vegetation. Eschericia coli (E. coli) are fecal coliforms from humans.

Filtration - In reference to water treatment, the removal of suspended material from the water by passage through a filtering medium, such as sand.

Finished Water - Water that has passes through a water system plant, such that all the treatment process are completed or finished, and the water is ready for delivery to consumers.

Free Chlorine Residual - Chlorine residual resulting from the sum of gaseous chlorine (Cl_2), Hypochlorous acid (HOCl), and Hypochlorite ion (OCl^{-1}).

G

Groundwater - Water that occupies voids, cracks or other pore spaces in clay, silt, sand, gravel, or rock beneath the surface of the earth.

Grouting - The placement of grout in the subsurface by drilling and injection to prevent the movement of groundwater along the outside of a well casing.

H

Haloacetic Acids (HAAs) - A class of disinfectant by-products formed primarily during the chlorination of water containing natural organic matter and bromide ions. Chemical compounds resembling acetic acid where halogens (chlorine and/or bromine) replace one or more hydrogen atoms.

Hardness - A quality of water caused by divalent cations (Ca^{+2} and Mg^{+2}) and resulting in increased consumption of soaps and detergents, hindrance to some industrial processes and sometimes, taste and odor problems.

Hazard - In reference to a chemical hazard, the chemicals capacity to do harm by virtue of its toxicity, flammability, explosiveness or corrosiveness.

Horsepower - A measurement of work. One foot-pound of work is the amount of energy required to lift one pound of water one foot in elevation. In pumping situations, the amount of work done will be in the thousands of foot-pounds. Because we do not like to use large numbers, we have defined another term for work. When 33,000 foot-pounds of work is performed in one minute we call it one horsepower.

Hydrologic Cycle - Describes the constant movement of water above, on, or below the earth's surface. Water changes states between liquid, solid, and gas during the cycle. Condensation, evaporation, and freezing of water occur in the cycle in response to the earth and its climactic conditions.

Hydrological Event - The occurrence of any form of precipitation; rain, snow, sleet or hail.

Hydropneumatic - In reference to water storage tanks, pressurized tanks containing water and an air cushion that maintains system water pressure within a pre-determined range.

Hypochlorinator - A chemical feed system used to feed hypochlorite solutions into a water system. Usually consists of a chemical tank, positive displacement chemical feed pump and associated control components.

I

Impeller - A rotating device in a pump for forcing water in a given direction under pressure.

Impoundment - A pond, lake, tank, basin, reservoir or other space, either natural or artificial, used to store, regulate and control the flow of water.

Indicators - Bacteria that serve as a surrogate indicator for the potential presence of pathogens in drinking water.

Indicator Organism - An organism that can be detected with relative ease and specificity and whose presence or absence has been shown to be correlated with a specific condition of interest. In reference to drinking water quality the coliform bacteria are used as indicators of the potential presence of enteric pathogenic microbes.

Infectious Disease - A clinically apparent disease resulting from an infectious agent such as a pathogenic bacteria, protozoa, or virus.

Infiltration - the flow or movement downward through the soil.

Insulator - Any material that resists the flow of electricity and can be forced to carry electricity only by the application of very string electrical force.

Intake Structure - The works or structure at the head of a conduit into which water is diverted, usually referring to the structure designed to divert untreated, raw water into system for treatment and distribution.

Iron Bacteria - Microorganisms that metabolize iron. This specialized group of bacteria is capable of using iron for metabolic processes and commonly causes red-water, slime, or encrustation in well water systems.

K

Kilowatt-hour (Kw-h) - A unit of energy or work. The electrical work is a combination of watts (electrical power) used over a period of times (hours).

L

Lineshaft Turbine - A vertical turbine pump used in wells in which the submerged pump bowls are connected to the above ground motor by a vertically oriented drive shaft.

Lockout/Tagout - The safety procedure whereby the power source for electrical equipment and machinery is isolated, de-energized, locked and labeled to avoid accidental startup of equipment and machinery.

Long Term 1 (LT1) Enhanced Surface Water Treatment Rule - Federal regulation that applies to surface water systems and groundwater under the influence of surface water serving fewer than 10,000 people intended to maintain microbial protection. Generally, parallels the Interim Enhanced Surface Water Treatment Rule that has applied only to larger systems.

M

Maximum Contaminant Level - The maximum permissible level of a contaminant in a public water supply system.

Micron - A unit of length equal to one millionth (10-6) of a meter.

Microorganism - An animal or plant of microscopic size that includes bacteria, viruses, and protozoa.

N

Non-Transient Non-Community System - In the system used in Alaska to classify public water systems; those public water systems that are expected to serve, in the normal course of events, at least 25 of the same persons each day for at least 6 months of the year, i.e., schools, office buildings.

O

Ohmmeter - A test instrument that measures the resistance of a conductor in Ohms.

Ohm - 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.

Organic Material - Material originating from living matter; chemical substances containing the element carbon.

OSHA Standards - Safety and health standards established by the federal Occupational Safety and Health Administration.

Oxidize - A chemical reaction that alters the structure, characteristics, and properties of the reactants. Oxidized substances loss electrons to the oxidizing agent. Example: Chlorine oxidized soluble ferrous iron to insoluble ferric iron, the ferrous iron losing an electron to the chlorine.

P

Palatable - In reference to drinking water, water that is agreeable or pleasant, especially to the sense of taste.

Parameter - A water quality attribute. Examples: the presence of certain bacteria, the hardness and the level of sodium are all parameters.

Pathogen - An organism that is capable of causing disease.

Pathogenic Organisms - An organism that can cause a disease in a host.

Permafrost – Ground that is below freezing for 2 or more years.

Personal Protective Equipment (PPE) - Equipment such as hard hats, gloves, goggles, and steel-toed shoes used by workers to prevent potential injuries from workplace hazards.

Percolate - The flow or movement of water through a porous medium such as an aquifer.

pH - The power of Hydrogen. The numerical measure of hydrogen ion activity with a scale of 0 -14. Neutral is pH 7; values below 7 are acid, and values above 7 are alkaline (basic).

Pitless Adapter - A tube with a waterproof cap that is attached to a well casing below the frost line to protect the well discharge pipe and pump from freezing.

Primacy - Primary enforcement authority granted to states for implementation and enforcement of federal regulations.

Primary Standard - Designed to protect public health by setting maximum permissible levels of potentially harmful substances in the drinking water. An enforceable drinking water standard.

Prime - To prepare for operation by or pouring water into a pump.

Potable - Safely drinkable.

Precipitate - In reference to the chemical process, material in solution that converts to an insoluble form and will settle out and/or can be remove by filtration.

Protozoa - Small, one-celled organisms, including amoeba, ciliates, and flagellates.

Public Water System (PWS) - A system for conveying drinking water to the public that serves at least 15 service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

R

Radioactive - Material capable of giving off radiant energy in the form of particles or rays (alpha, beta and gamma radiation).
Raw Water - Water from the supply source prior to treatment.
Recharge Area - The land surface through which water percolates downward as a renew source for groundwater in aquifers.
Repeat Sample - A sample taken to confirm the presence of a contaminant that was detected in a previous sample.
Replacement Sample - A sample used to replace an original sample that may have been damaged in transit or cannot be analyzed by the lab.
Resistance - A measure of a material’s ability to impede the flow of electricity. Resistance is measured in ohms.
Revised Total Coliform Rule (RTCR) - A USEPA rule regulating total coliforms, fecal coliforms and Escherichia coli.
Risk - The probability that a particular adverse event will occur.
Routine Sample - A sample taken at regular intervals to determine compliance with maximum contaminant levels.

S

Safe Drinking Water Act - The Safe Drinking Water Act (SDWA) was enacted by Congress in 1974 and amended several times since then, establishes minimum drinking water standards in the United States.
Safety Data Sheets (SDS) - Information on the use, handling, and storage of specific chemicals or products.

Sample site plan - Bacteriological sample collection location plans required of all community public water supply systems identifying locations for routine monitoring and repeat monitoring.
Sanitary Seal - In reference to a well, the device that provides a protective seal between the inside of the well casing and the external environment.
Saturator - A piece of equipment that feeds a sodium fluoride solution into water for fluoridation.
Secondary Maximum Contaminant Level (SMCL) - A non-enforceable numerical limit set by the USEPA on the basis of aesthetic effects to prevent undesirable taste, odor, or appearance.
Secondary Standard - A non-enforceable regulation set by the USEPA on the basis of aesthetic effects to prevent undesirable taste, odor, or appearance.
Sequester - To keep a substance in solution through the addition of a chemical agent that forms chemical complexes with the substance. Example: Sodium hexametaphosphate is used to sequester iron.
Sodium Hypochlorite - One of several liquid forms of chlorine commonly used to disinfect public water supply systems. Sodium hypochlorite is usually available in 5%, 12%, and 35% chlorine solution.
Softening - The removal of calcium and magnesium ions, which are the principal causes of hardness in water.
Specific Capacity - A measurement of well yield per unit length of drawdown.

Spring - A concentrated discharge of groundwater appearing at the ground surface as a current of flowing water; usually occurs where a water-bearing strata (aquifer) intersects with the earth's surface.

Static Water Level - The level where water stands when the well is not being pumped. It is generally expressed as the distance in feet from the top of the well casing down to the water level in the well.

Submersible Pump - A pump designed to fit inside the well casing and to operate below the water level. A sealed electrical motor is mounted below the pump impeller stages.

Surface Water - All water on the surface (lakes, ponds, streams, rivers, etc.) as distinguished from subsurface or groundwater.

Surface Water Treatment Rule (SWTR) - Name for the USEPA regulation established in 1989 that sets maximum contaminant level goals for Giardia lamblia, viruses as well as other regulations for public water systems using surface water sources or surface water under the direct influence of surface water. Includes requirements for filtration and disinfection.

Synthetic Organic Chemicals (SOCs) - An organic chemical that is commercially made, some of which are regulated contaminants in drinking water.

T

Top terminal Height - The casing head must extend twelve inches above the finished ground surface or pump house floor, and twelve inches minimum above the local surface runoff level.

Total Chlorine Residual - The sum of free and combined chlorine residuals. Total Coliform Bacteria - A group of indicator bacteria used to detect the possible contamination of water by pathogenic organisms.

Total Dissolved Solids (TDS) - The weight per unit volume (usually mg/L) of solids remaining after a sample has been filtered to remove suspended and colloidal solids.

Toxicology - The study of the quantitative effects of chemicals on biological tissue.

Transient Non-Community System - In the system used in Alaska to classify public water systems; those public water systems that provides water to at least 25 individuals per day in a place such as a gas station or campground where people do not remain for long periods of time.

Treatment Technique – A process used to improve the quality of water for human consumption.

Treatment Technique Requirements (TTRs) - A requirement of specific regulations that specifies, for a specific contaminant, one or more treatment techniques that lead to a reduction of that contaminant sufficient to achieve compliance.

Trihalomethanes (THMs) - A group of organic compounds that are derivatives of methane in which three atoms of a halogen (chlorine, bromine, iodine) are substitutes for hydrogen atoms on the methane molecule; THMs are formed during chlorination and are regulated because of their potential carcinogenicity.

Turbidimeter - An instrument that measures the amount of light scattered by suspended particles in a water sample.

Turbidity - The cloudy appearance of water caused by the presence of suspended and colloidal matter.

U

Unconfined aquifer - The uppermost aquifer located immediately beneath the unsaturated zone. Groundwater in this aquifer is not pressurized. Because the unconfined aquifer is nearest to the surface, it is generally more susceptible to contamination than a confined aquifer.

V

Viruses - Pathogens responsible for many human diseases such as viral gastroenteritis, smallpox, poliomyelitis (polio) and infectious hepatitis. They are intracellular parasitic particles considered to be the smallest living infectious materials known.

Volatile - Capable of turning to vapor (evaporating).

Volatile Organic Compounds (VOCs) - Organic chemicals capable of turning to a vapor; some of which are regulated contaminants in drinking water.

Voltage - The electrical pressure available to cause the flow of current when an electrical circuit is closed.

Voltmeter - An instrument used to measure the potential difference, in volts, between two points. Often part of an instrument, called a VOM (volt, ohm, amp meter), have capacity to measure, voltage, current, and resistance.

Volt - Unit of measurement of electromotive force.

W

Water Hammer - Opening or closing a valve rapidly may cause a quick rise and fall of water pressure throughout the distribution piping system. The sound, like someone hammering on the pipe, occurs because the pressure in the pipe will increase and decrease back and forth very quickly.

Water Table - The level in the geologic formation below which all voids or cracks are saturated. The water table also can be thought of as the upper surface of the groundwater and top of the saturated zone for an unconfined aquifer.

Waterborne Disease - A disease transmitted through the ingestion of contaminated water.

Waterlogged - Saturated with water. In reference to hydropneumatic tanks, when the air cushion is replaced by water and the normal pressure cycle is disrupted.

Watershed - The land area, usually expressed in square miles, from which water flows into a stream or river above a specified point. Also see discharge area.

Watts (W) - The unit of electrical power.

Well Capacity (yield) - The volume of water per unit of time discharged from the well usually recorded as gallons per minute (gpm) or gallons per day (gpd).

Well Casing - A non-perforated riser pipe connecting the well intake in the aquifer to the surface.

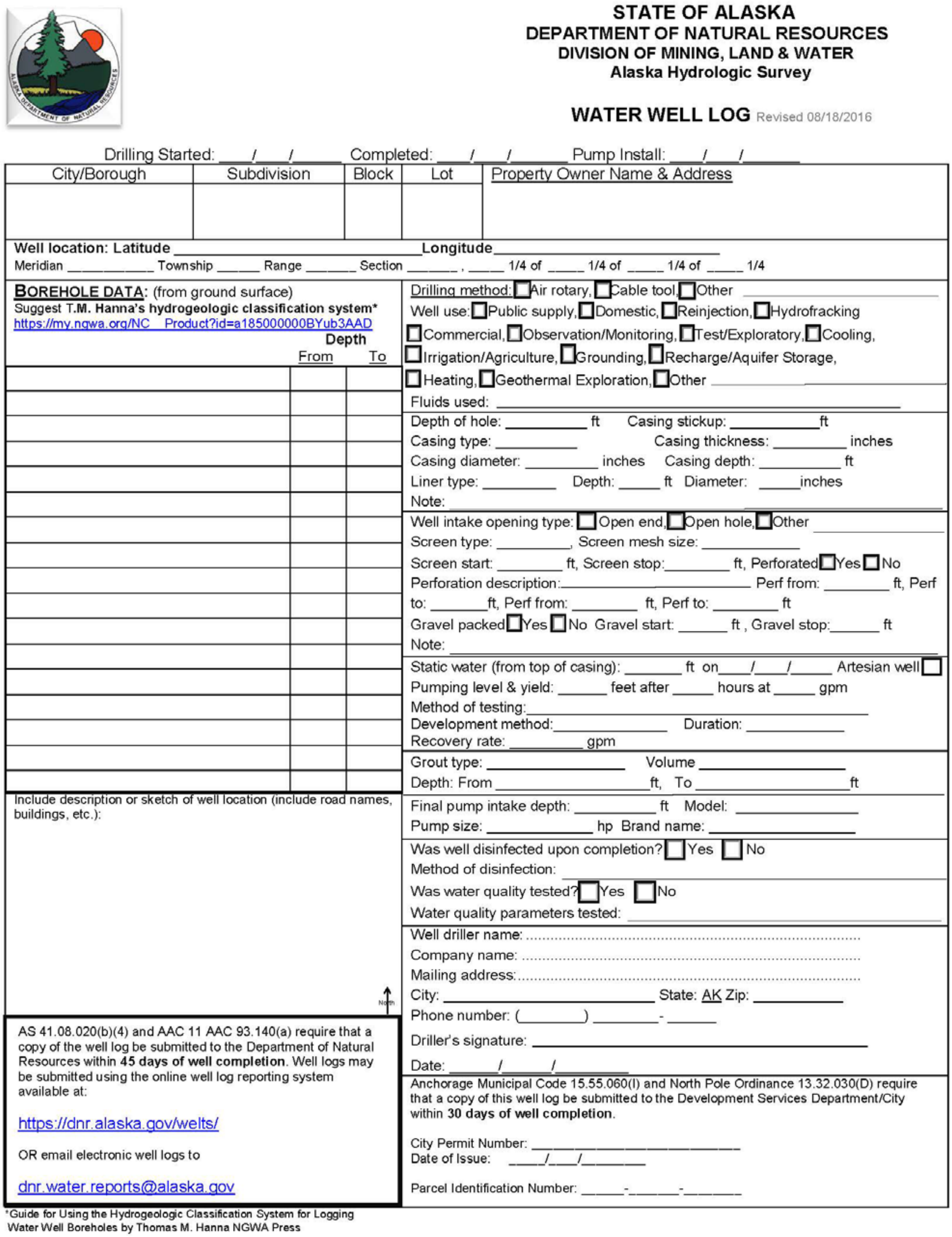
Well Development - Involves vigorously pumping the well to help clean out drill cuttings and to maximize production of the well. Development should result in a well that produces sand-free water when operated properly.

Well Log - A written report produced by the well driller that includes a description of the material (soil, rock, or ice) that was encountered during drilling, the depths at which they occurred, the depth to groundwater, and the well depth.
Well Yield - The quantity of water produced by a well, expressed in flow rate.

Z

Zeolite - Any of a group of hydrated sodium alumina silicates, either naturally occurring or synthetically produced, with ion exchange properties.
Zone Of Influence - The area around a well that experience a measurable drawdown during pumping of the well.
Zone Of Saturation - That part of an aquifer that has all the available pore spaces filled with water

Appendix 1 – Water Well Log Example



STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINING, LAND & WATER
Alaska Hydrologic Survey

WATER WELL LOG Revised 08/18/2016

Drilling Started: ___/___/_____ Completed: ___/___/_____ Pump Install: ___/___/_____

City/Borough	Subdivision	Block	Lot	Property Owner Name & Address

Well location: Latitude ____________________ **Longitude** ____________________

Meridian __________ Township _____ Range ______ Section ______ , ____ 1/4 of ____ 1/4 of ____ 1/4 of ____ 1/4

BOREHOLE DATA: (from ground surface)
Suggest T.**M. Hanna's hydrogeologic classification system***
https://my.ngwa.org/NC__Product?id=a185000000BYub3AAD

	Depth	
	From	To

Include description or sketch of well location (include road names, buildings, etc.):

North

AS 41.08.020(b)(4) and AAC 11 AAC 93.140(a) require that a copy of the well log be submitted to the Department of Natural Resources within **45 days of well completion**. Well logs may be submitted using the online well log reporting system available at:

https://dnr.alaska.gov/welts/

OR email electronic well logs to

dnr.water.reports@alaska.gov

Drilling method: ☐ Air rotary, ☐ Cable tool, ☐ Other ____________

Well use: ☐ Public supply, ☐ Domestic, ☐ Reinjection, ☐ Hydrofracking
☐ Commercial, ☐ Observation/Monitoring, ☐ Test/Exploratory, ☐ Cooling,
☐ Irrigation/Agriculture, ☐ Grounding, ☐ Recharge/Aquifer Storage,
☐ Heating, ☐ Geothermal Exploration, ☐ Other ____________

Fluids used: ____________________

Depth of hole: ________ ft Casing stickup: _________ ft
Casing type: ________ Casing thickness: _______ inches
Casing diameter: _______ inches Casing depth: ________ ft
Liner type: _______ Depth: ____ ft Diameter: ____ inches
Note: ____________________

Well intake opening type: ☐ Open end, ☐ Open hole, ☐ Other __________
Screen type: _______, Screen mesh size: ________
Screen start: ______ ft, Screen stop: ______ ft, Perforated ☐ Yes ☐ No
Perforation description: ______________ Perf from: ______ ft, Perf to: _____ ft, Perf from: ______ ft, Perf to: ______ ft
Gravel packed ☐ Yes ☐ No Gravel start: _____ ft , Gravel stop: _____ ft
Note: ____________________

Static water (from top of casing): _____ ft on ___/___/____ Artesian well ☐
Pumping level & yield: _____ feet after ____ hours at ____ gpm
Method of testing: ____________________
Development method: __________ Duration: _________
Recovery rate: _______ gpm

Grout type: ____________ Volume ____________
Depth: From ____________ ft, To ____________ ft

Final pump intake depth: _______ ft Model: __________
Pump size: ________ hp Brand name: ____________

Was well disinfected upon completion? ☐ Yes ☐ No
Method of disinfection: ____________________
Was water quality tested? ☐ Yes ☐ No
Water quality parameters tested: ____________________

Well driller name: ....
Company name: ....
Mailing address: ....
City: __________________ State: AK Zip: ________
Phone number: (______) ______ - _____

Driller's signature: ______________________________

Date: ____/____/______

Anchorage Municipal Code 15.55.060(I) and North Pole Ordinance 13.32.030(D) require that a copy of this well log be submitted to the Development Services Department/City within **30 days of well completion**.

City Permit Number: __________________
Date of Issue: ____/____/______

Parcel Identification Number: _____-______-______

*Guide for Using the Hydrogeologic Classification System for Logging Water Well Boreholes by Thomas M. Hanna NGWA Press

Appendix 2 – Health Effects of Contaminants

The specific ADEC requirements for your system may be different than the EPA MCLs referenced in this appendix.

For more information about treatment and sampling requirements for your water system please contact the ADEC Drinking Water Program: https://dec.alaska.gov/eh/dw/.

The most updated information about EPA Drinking Water Regulations can be found online at: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

Microorganisms

Contaminant	Sources of Contaminant in Drinking Water	Potential Health Effects from Long-Term Exposure Above the MCL	EPA MCL
Cryptosporidium	Human and animal fecal waste.	Gastrointestinal illness (such as diarrhea, vomiting, and cramps).	Water systems are required to follow Treatment Techniques to reduce the level of these contaminants. Please contact the ADEC Drinking Water Program for details.
Giardia lamblia	Human and animal fecal waste.	Gastrointestinal illness (such as diarrhea, vomiting, and cramps).	
Heterotrophic plate count (HPC)	HPC measures a range of bacteria that are naturally present in the environment.	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	
Legionella	Found naturally in water; multiplies in heating systems.	Legionnaire's Disease, a type of pneumonia.	
Total Coliforms (including fecal coliform and *E. Coli*)	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.	
Turbidity	Soil runoff	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (such as whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	
Viruses (enteric)	Human and animal fecal waste.	Gastrointestinal illness (such as diarrhea, vomiting, and cramps).	

Inorganic Chemicals

Contaminant	Sources of Contaminant in Drinking Water	Potential Health Effects from Long-Term Exposure Above the MCL	EPA MCL
Antimony (Sb)	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder.	Increase in blood cholesterol; decrease in blood sugar.	0.006 mg/L
Arsenic (As)	Normally found in groundwater as a natural occurrence or in surface water as an industrial pollutant of a product of agricultural runoff.	Arsenic builds up in the body over time with effects including fatigue, skin damage, problems with circulatory system, and increased cancer risk.	0.01 mg/L
Barium (Ba)	May be found in groundwater as a natural occurrence or as an industrial pollutant.	Barium has toxic effects on the heart, blood vessels, nerves, and kidneys.	2 mg/L
Beryllium (Be)	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries.	Intestinal lesions.	0.004 mg/L
Cadmium (Cd)	Primarily found in surface water as a pollutant from industries such as electroplating.	Potential damage from cadmium may take the form of anemia, retarded growth, and increased blood pressure.	0.005 mg/L
Chromium (Cr)	To be found in groundwater as a natural occurrence or in surface water as an industrial pollutant commonly from the plating industry.	Chromium can be toxic and can produce skin irritations when external exposure occurs or liver damage from internal exposure.	0.1 mg/L
Copper (Cu)	Corrosion of household plumbing systems; erosion of natural deposits.	Short term exposure can cause gastrointestinal distress. Long term exposure can cause live or kidney damage.	1.3 mg/L
Cyanide (CN-)	Discharge from steel/metal factories; discharge from plastic and fertilizer factories. Runoff from historic mining sites.	Nerve damage or thyroid problems.	0.2 mg/L
Fluoride (F)	Dissolved in small quantities from rock and soil; fluoride may in some cases be added to drinking water supplies to aid in dental health.	May cause mottling of the teeth in children depending on quantity and temperature average per year; in proper amounts, may reduce dental cavities.	4.0 mg/L
Lead (Pb)	Corrosion of household plumbing systems. Found in surface waters from industrial pollution and erosion of natural deposits.	Lead symptoms range from gastrointestinal disturbances to inflammation of the brain and spinal cord; toxic to infants and pregnant women.	0.015 mg/L
Mercury (Hg)	Increased concentrations in recent years have been caused by industrial and agricultural pollution.	Mercury poisoning attacks the central nervoussystem and may be transmitted to children as congenital disease.	0.002 mg/L
Nitrate (NO_3)	Runoff from fertilizer use; leaking from septic tanks or sewage systems; erosion of natural deposits; runoff containing animal waste or decaying plant matter.	High concentrations may suggest pollution; water with high nitrate content may cause blue baby syndrome and should not be used for infant feeding; some animals such as cattle can be poisoned by high concentrations of nitrate; nitrate encourages the growth of algae and other organisms which may produce undesirable taste and odors.	10 mg/L
Nitrite (N)			1.0 mg/L

Selenium (Se)	Obtained as a by-product of copper mining, it is normally found in groundwater and occasionally surface water as a natural occurrence.	Selenium attacks the central nervous system and can be fatal in extreme cases; minor amounts may, however, be beneficial to health.	0.05 mg/L
Thallium (Tl)	Normally appearing in surface water as an industrial pollutant.	Hair loss; changes in blood; kidney, intestine, or liver problems.	0.002 mg/L

Disinfection Byproducts

Contaminant	Sources of Contaminant in Drinking Water	Potential Health Effects from Long-Term Exposure Above the MCL	EPA MCL
Bromate	Byproduct of drinking water disinfection.	Increased risk of cancer.	0.010 mg/L
Chlorite	Byproduct of drinking water disinfection.	Anemia; infants and young children: nervous system effects	1.0 mg/L
Haloacetic acids	Byproduct of drinking water disinfection.	Increased risk of cancer	0.060 mg/L
Total Trihalomethanes (TTHMs)	Byproduct of drinking water disinfection.	Liver, kidney or central nervous system problems; increased risk of cancer.	0.08 mg/L

Radionulides

Contaminant	Sources of Contaminant in Drinking Water	Potential Health Effects from Long-Term Exposure Above the MCL	EPA MCL
Alpha Particles	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation.	Increased risk of cancer.	15 pCi/L
Beta Particles	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation.	Increased risk of cancer.	4 mrem/year
Radium 226 and Radium 228	Erosion of natural deposits.	Increased risk of cancer.	5 pCi/L
Uranium	Erosion of natural deposits.	Increased risk of cancer.	30 ug/L

Organic Chemicals

Please see https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations for a full list of regulated organic chemicals.

Other Considerations

Contaminant	Source or Cause	Significance	Limits
Alkalinity, as $CaCO_3$	Indicates the presence of bicarbonates, carbonates,and hydroxides (see pH).	Information on alkalinity is useful in water treatment, softening, and control of corrosion.	No standards established.
Calcium (CA) and Magnesium (Mg)	Dissolved from soil and rock, especially from limestone, dolomite, gypsum; calcium and magnesium are found in large quantities in seawater.	Cause most of the hardness and scale-forming properties of water which, for example, consume soap. Water low in calcium and magnesium is desirable for boiler use.	No standards established.
Carbonate (CO_3) and Bicarbonate (HCO_3)	Formed from carbonated rock such as limestone and dolomite.	Produces alkalinity and forms scale in hot water facilities as a result of hardness in combination with calcium and magnesium.	No standards established.
Dilutes Conductance	Based on dissolved solids content of water.	Measurement of the capacity of the water to conduct an electric current.	No standards established.
Foaming agents	Chemical surfactants that can be found in household detergents, consumer products, domestic sewage, pesticides, drilling fluids, and some industrial discharges.	Foaming agents in water can cause the water to create a foam when aerated. Very high dosages, i.e., over 50 mg/L, can cause gastrointestinal problems.	0.5 mg/L
Hydrogen sulfide	Anaerobic decay of organic matter.	Rotten egg odor and discoloration.	No standards established.
Sodium (Na)	Dissolved from rock and soil; found also in oil-field brine, seawater, etc.	Moderate amounts have little effect but persons on low-sodium diets should consult a physician.	20 mg/L
Total Hardness as $CaCO_3$	Caused by the presence of calcium and magnesium. Can be removed by lime and soda ash.	Hard water consumes soap before a lather will form and creates scale in boilers, water heaters, and pipes.	0 – 60 mg/L = soft, 61 – 120 mg/L = moderate, 121 – 180 mg/L = hard, 181 mg/L up = very hard

Appendix 3 – Troubleshooting Guide for Submersible Pumps

A. Circuit Breaker Trips and Fuses Blow When Motor is Started

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Incorrect line voltage	Check line voltage terminals in the control box(or connection box in the case of the 2-wire models) with a voltmeter. Make sure that the voltage is within the minimum-maximum range prescribed by the manufacturer.	If the voltage is incorrect, contact the power company to have it corrected.
2. Defective control box: 2a. Defective wiring	Check out all motor and power line wiring in the control box, following the wiring diagram in the control box. See that all connections are tight and that no short circuits exist because of worn insulation, crossed wires, etc.	Rewire any incorrect circuits. Tighten looseconnections. Replace worn wires.
2b. Incorrect components	Check all control box components to see that they are the type and size specified for the pump in the manufacturer's literature. In previous service work, the wrong components may have been installed.	Replace any incorrect component with the size and type recommended by the manufacturer.
2c. Defective starting capacitor (skip for 2-wire models)	Using an ohmmeter, determine the resistance across the starting capacitor. When contact is made, the ohmmeter needle should jump at once, then move up more slowly. No movement indicates an open capacitor (or defective relay points); no resistance means that the capacitor is shorted.	Replace defective starting capacitor.
2d. Defective relay (skip for 2-wire models)	Using ohmmeter, check the relay coil. Its resistance should be as shown in the manufacturer's literature. Recheck ohmmeter reading across starting capacitor. With a good capacitor, no movement of the needleindicates defective relay points.	If coil resistance is incorrect or points defective, replace relay,
3. Defective pressure switch	Check the voltage across the pressure switch point. If less than the line voltage determined in “1” above, the switch points are causing low voltage by making imperfect contact.	Clean points with a mild abrasive cloth or replace pressure switch.
4. Defective motor winding or cable: 4a. Shorted or open motor winding	Check the resistance of the motor winding by using an ohmmeter on the proper terminals in the control box (see manufacturers wiring diagram). The resistance should match the ohms specified in the manufacturer’s data sheet. If too low, the motor winding may be shorted. If the ohmmeter needle does not move, indicating high or infinite resistance, there is an open circuit in the motor winding.	It the motor winding is defective - shorted or open - the pump must be pulled, and the motor repaired.
4b. Grounded cable or winding	Ground one lead of the ohmmeter onto the drop pipe or shell casing, then touch the other lead to each motor terminal. If the ohmmeter needle moves appreciably when this is done, there is a ground in either the cable or the motor winding.	Pull the pump and inspect the cable for damage. Replace damaged cable. If cablechecks OK, the motor winding is grounded.
5. Pump sand locked	Make pump run backwards by interchanging main and start winding (black and red) motorleads at control box.	Pull pump, disassemble, and clean. Before replacing, make sure that sand has settled in the well. If well Is always sandy, a submersible pump should not be used.

B. Pump Operates but Too Little Water

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Pump may be airlocked	Stop and start pump several times, waiting about one minute between cycles. If pump then resumes normal deliver, air lock was the trouble.	If this test falls to correct the trouble, proceed as below.
2. Water level in well too low	Well production may be too low for pump capacity. Restrict flow of pump output, wait for well to recover, and start pump.	If partial restriction corrects trouble, leave valve at restricted setting. Otherwise, lower pump in the well if depth is sufficient. Do not lower if sand clogging might occur.
3. Discharge line check valve installed backward	Examine check valve on discharge line to make sure that arrow indicating flow direction points in right direction.	Reverse valve if necessary.
4. Leak in drop pipe	Raise pipe and examine for leaks.	Replace damaged section of drop pipe.
5. Pump check valve jammed by drop pipe	When pump is pulled after completing "4" above, examine connection of drop pipe outlet. If threaded section of drop pipe has been screwed in too far, it may be jamming the pump's check valve in the closed position.	Unscrew drop pipe and cut off portion of threads.
6. Pump intake screen blocked	The intake screen on the pump may be blocked by sand or mud. Examine the screen	Clean screen and, when reinstalling pump, make sure that it is located several feet above the well bottom – preferably 10 feet or more.
7. Pump parts worn	The presence of abrasives in the water may result in excessive wear on the impeller, casing, and other close-clearance parts. Before pulling pump, reduce setting on pressure switch to see if pump shuts off. If it does, worn parts are probably at fault.	Pull pump and replace worn components.
8. Motor shaft loose	Coupling between motor and pump shaft may have worked loose. Inspect for this after pulling pump and looking for worn components, as in “7” above.	Tighten all connections, set-screw, etc.

C. Pump Starts Too Often

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Pressure switch defective or out of adjustment	Check setting on pressure switch and examine for defects.	Reduce pressure setting or replace switch.
2. Leak in pressure tank	Apply soap solution to entire surface of tank and look for bubbles indicating air escaping.	Repair or replace tank.
3. Leak in plumbing system	Examine service lines to each house and distribution branches for leaks.	Repair leaks.

4. Discharge line check valve leaks	Remove and examine check valves.	Clean or replace valves.
5. Air volume control plugged	Remove and inspect air volume control.	Clean or replace air volume control.
6. Snifter valve plugged	Remove and inspect snifter valve.	Clean or replace snifter valve.
7. Pressure tank waterlogged	Check sight glass.	Drain out some of the water and charge with air.

D. Pump Won’t Shut Off

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Defective pressure switch	Arcing may have caused pressure switch points to “weld” in closed position. Examine points and other parts of switch for defects.	Clean points with fine sandpaper or replace switch.
2. Pump cannot keep up with demand 2a. Leaks in the system	Well production may be too low for system demand. Temporarily restrict flow to system and start pump.	If partial restriction of flow to system corrects trouble, the pump is not producing enough water. Look for leaks in the system.
2b. Leak in drop line	Raise pipe and examine for leaks.	Replace damaged section of drop pipe.
2c. Pump parts worn	The pressure of abrasives in the water may result in excessive wear on the impeller, casing, and other close-clearance parts. Before pulling pump, reduce setting on pressure switch to see if pump shuts off. If it does, worn parts are probably at fault.	Pull pump and replace worn components.
3. High water shut-off defective	If float switches are used move the float switch in the tank by hand to see if the switch is working.	If a float switch is not working, replace it. If the switch is okay, make sure the float switch is hanging free with enough room to float into the off position.
	If pressure switches are used, manually adjust the off pressure until pump shuts off.	If switch will not shut pump off, replace switch. Readjust off-pressure until pump shuts off at desired pressure. The hand lever must be hold in by hand until about 20 psi of pressure is on the line.

E. Circuit Breaker Trips, or Fuses Blow When Motor is Running

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Incorrect voltage	Check line terminals in the control box (or connection box in the case of 2-wire models)with a voltmeter. Make sure that the voltage is within the minimum-maximum range prescribed by the manufacturer.	If voltage is incorrect, contact power company for service.
2. Overheated overload protection	If sunlight or other source of heat has made box too hot, circuit breakers may trip or fuses blow. If box is hot to the touch, this may be the problem.	Ventilate or shade control box, or remove from source of heat. Check manufacturer’s literature and make sure

		the correctly sized overload heaters are installed.
3. Defective control box components	Using an ohmmeter, determine the resistance across the running capacitor. When contact is made, the ohmmeter needle should jump at once. Then move up more slowly. No movement indicates an open capacitor (or defective relay points); no resistance means that the capacitor is shorted. Using an ohmmeter, check the relay coil. Its resistance should be shown in the manufacturer's literature. Recheck ohmmeter reading across running capacitor. With a good capacitor, no movement of the needle indicates relay points.	Replace defective components.
4. Defective motor winding or cable	Check the resistance of the motor winding by using an ohmmeter on the proper terminals in the control box (see manufacturer's wiring diagram). The resistance should match the ohms specified in the manufacturer's data sheet. If too low, the motor winding may be shorted. If the ohmmeter needle does not move, indicating high or infinite resistance, there is an open circuit in the motor winding. Ground one lead of the ohmmeters to the drop pipe or shell casing, then touch the other lead to each motor wire-terminal. If the ohmmeter needle moves appreciably when this is done, there is ground in either the cable or the motor winding.	It neither cable or winding is defective - shorted, grounded, or open – pump must be pulled and serviced.
5. Pump becomes sand-locked	If the fuses blow while the pump is operating,sand or grit may have become wedged in the impeller, causing the motor to lock. To check this, pull the pump.	Pull pump, disassemble, and clean. Before replacing, make sure that sand has settled in the well. If well is always sandy, a submersible pump should not be used.

F. Your Circuit Breaker Does Not Trip – Motor Does Not Start but Fuses Do Not Blow

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Overload protection out	Check fuses or circuit breaker to see that they are operable.	If fuses are blown, replace, if breaker is tripped, reset.
2. No power	Check power supply to control box (overload protection box) by placing a voltmeter across incoming power lines. Voltage should approximate normal line voltage.	If no power is reaching box, contact power company for service.
3. Defective control box	Examine wiring in control box to make sure all contacts are tight. With a voltmeter check voltage at motor wire terminals. If no voltage is shown at terminals, wiring is defective in control box.	Correct faulty wiring or tighten loose contacts.
4. Defective pressure switch	With a voltmeter, check voltage across pressure switch while the switch is closed. If the voltage drop is equal to the line voltage the switch is not making contact.	Clean points or replace switch.

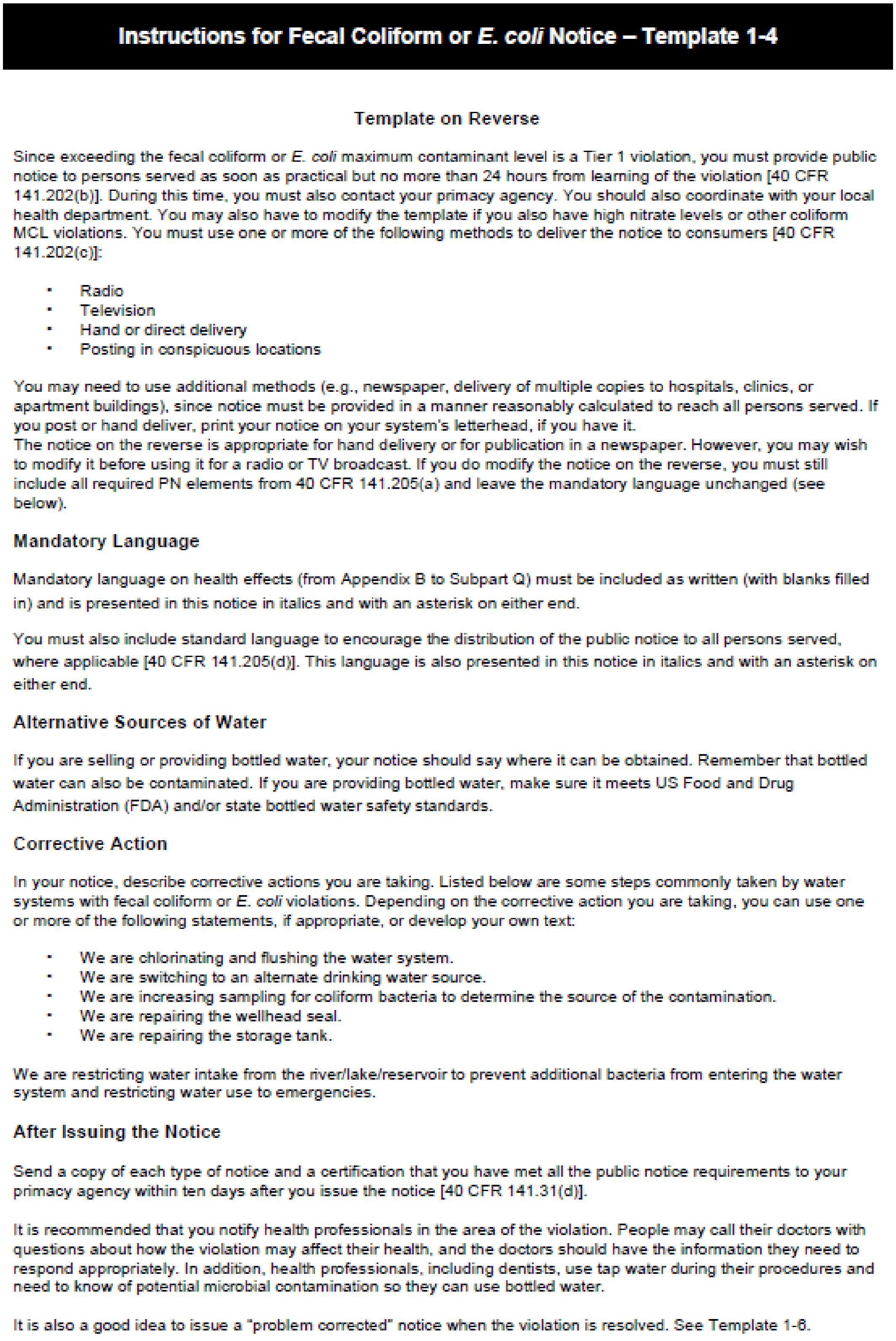
Appendix 4 – Quantities of Calcium Hypochlorite for Well Disinfection

65% hypochlorite (rows A) and liquid household bleach, 5.25 hypochlorite (rows B) required for water well disinfection.

Depth of Water in Well (ft.)		Well Diameter (In.)															
		2	3	4	5	6	8	10	12	16	20	24	28	32	36	42	48
5	A	1T	1T	1T	1T	1T	1T	2T	3T	5T	6T	3 oz	4 oz	5 oz	7 oz	9 oz	12 oz
	B	1C	1C	1C	1C	1C	1C	1C	1C	2C	4C	1 Q	2 Q	3 Q	3 Q	4 Q	5 Q
10	A	1T	1T	1T	1T	1T	2 T	3 T	5 T	8 T	4 oz	6 oz	8 oz	10 oz	13 oz	1 1/2 lb	1 1/2 lb
	B	1C	1C	1C	1C	1C	1 C	2 C	2 C	1 Q	2 Q	3 Q	4 Q	4 Q	6 Q	8 Q	2 1/2 G
15	A	1T	1T	1T	1T	2 T	3 T	5 T	8 T	4 oz	6 oz	9 oz	12 oz	1 lb	1 1/2 lb	1 1/2 lb	2 lb
	B	1C	1C	1C	1C	1 C	2 C	3 C	4 C	2 Q	2 1/2 Q	4 Q	5 Q	6 Q	2 G	3G	4 G
20	A	1T	1T	1T	2 T	3 T	4 T	6 T	3 oz	5 oz	8 oz						
	B	1C	1C	1C	1 C	1 C	2 C	4 C	1 Q	2 1/2 Q	3 1/2 Q						
30	A	1T	1T	2 T	3 T	4 T	6 T	3 oz	4 oz	8 oz	12 oz						
	B	1C	1C	1 C	1 C	2 C	4 C	1 1/2 Q	2 Q	4 Q	5 Q						
40	A	1T	1T	2 T	4 T	6 T	8 T	4 oz	6 oz	10 oz	1 lb						
	B	1C	1C	1 C	2 C	2 C	1 Q	2 Q	2 1/2 Q	4 1/2 Q	7 Q						
60	A	1T	2 T	3 T	5 T	8 T	4 oz	6 oz	9 oz								
	B	1C	1 C	2 C	3 C	4 C	2 Q	3 Q	4 Q								
80	A	1T	3 T	4 T	7 T	9 T	5 oz	8 oz	12 oz								
	B	1C	1 C	2 C	4 C	1 Q	2 Q	3 1/2 Q	5 Q								
100	A	2 T	3 T	5 T	8 T	4 oz	7 oz	10 oz	1 lb								
	B	1 C	2 C	3 C	1 Q	1 1/2 Q	2 1/2 Q	4 Q	6 Q								
150	A	3 T	5 T	8 T	4 oz	6 oz	10 oz	1 lb	1 1/2 lb								
	B	2 C	2 C	4 C	2 Q	2 1/2 Q	4 Q	6 Q	2 1/2 G								

Quantities are indicated as: T = tablespoon; oz = ounces (by weight); C = cups; lb = pounds; Q = quarts; G = gallons
NOTE: Figures corresponding to rows A are amount of solid calcium hypochlorite required; those corresponding to rows B are amounts of liquid household bleach. For shock chlorination of iron bacteria, the amounts of either compound should by multiplied by 10 to obtain the necessary chlorine concentration. For cases lying to the left of the dark line, add 5gallons of chlorinated water as final step. For those cases to the right of the dark line, add 10 gallons of chlorinated water as final step.

Appendix 5 – Tier 1 Boil Water Notice Example



Instructions for Fecal Coliform or *E. coli* Notice – Template 1-4

Template on Reverse

Since exceeding the fecal coliform or *E. coli* maximum contaminant level is a Tier 1 violation, you must provide public notice to persons served as soon as practical but no more than 24 hours from learning of the violation [40 CFR 141.202(b)]. During this time, you must also contact your primacy agency. You should also coordinate with your local health department. You may also have to modify the template if you also have high nitrate levels or other coliform MCL violations. You must use one or more of the following methods to deliver the notice to consumers [40 CFR 141.202(c)]:

- Radio
- Television
- Hand or direct delivery
- Posting in conspicuous locations

You may need to use additional methods (e.g., newspaper, delivery of multiple copies to hospitals, clinics, or apartment buildings), since notice must be provided in a manner reasonably calculated to reach all persons served. If you post or hand deliver, print your notice on your system's letterhead, if you have it.
The notice on the reverse is appropriate for hand delivery or for publication in a newspaper. However, you may wish to modify it before using it for a radio or TV broadcast. If you do modify the notice on the reverse, you must still include all required PN elements from 40 CFR 141.205(a) and leave the mandatory language unchanged (see below).

Mandatory Language

Mandatory language on health effects (from Appendix B to Subpart Q) must be included as written (with blanks filled in) and is presented in this notice in italics and with an asterisk on either end.

You must also include standard language to encourage the distribution of the public notice to all persons served, where applicable [40 CFR 141.205(d)]. This language is also presented in this notice in italics and with an asterisk on either end.

Alternative Sources of Water

If you are selling or providing bottled water, your notice should say where it can be obtained. Remember that bottled water can also be contaminated. If you are providing bottled water, make sure it meets US Food and Drug Administration (FDA) and/or state bottled water safety standards.

Corrective Action

In your notice, describe corrective actions you are taking. Listed below are some steps commonly taken by water systems with fecal coliform or *E. coli* violations. Depending on the corrective action you are taking, you can use one or more of the following statements, if appropriate, or develop your own text:

- We are chlorinating and flushing the water system.
- We are switching to an alternate drinking water source.
- We are increasing sampling for coliform bacteria to determine the source of the contamination.
- We are repairing the wellhead seal.
- We are repairing the storage tank.

We are restricting water intake from the river/lake/reservoir to prevent additional bacteria from entering the water system and restricting water use to emergencies.

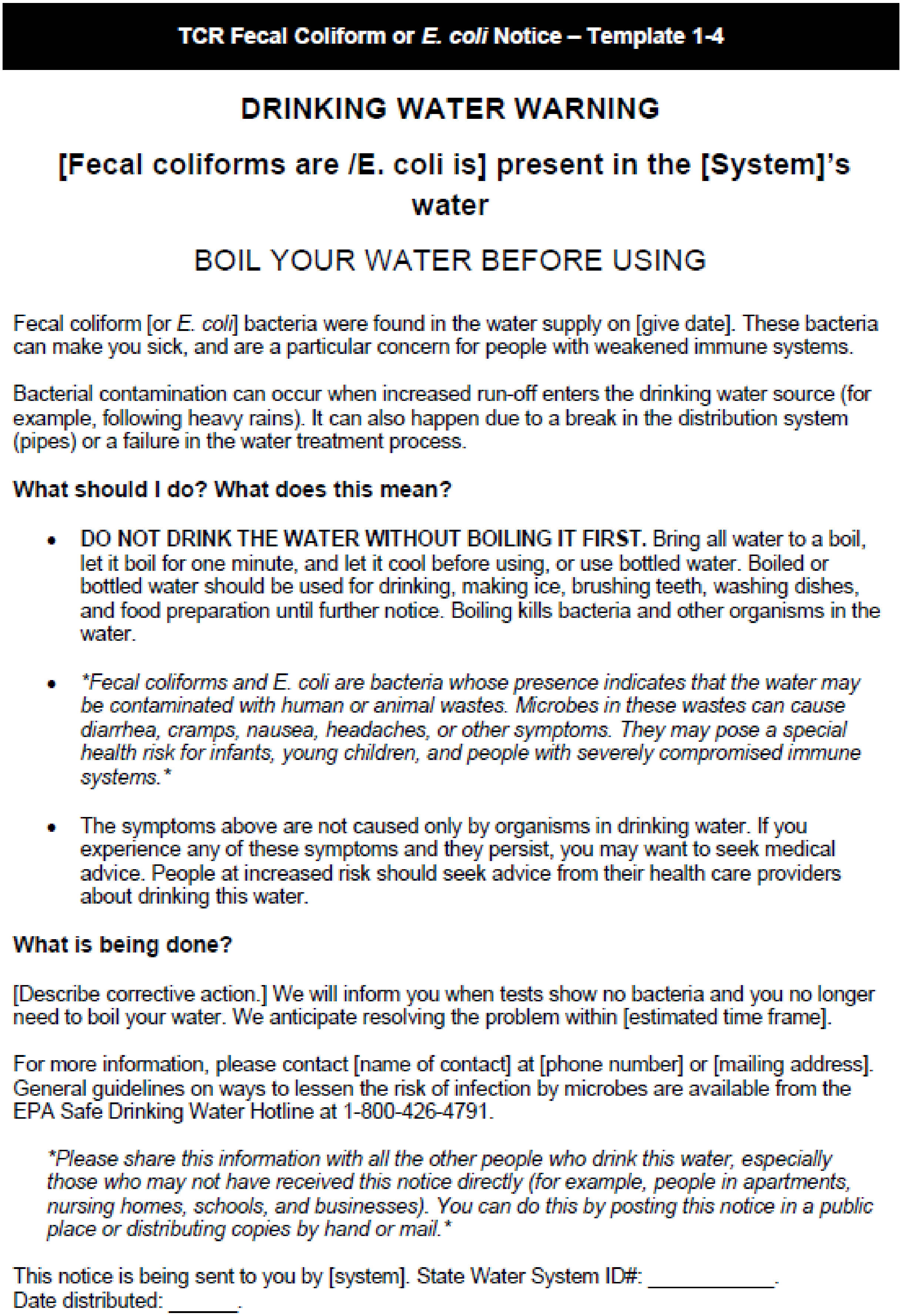
After Issuing the Notice

Send a copy of each type of notice and a certification that you have met all the public notice requirements to your primacy agency within ten days after you issue the notice [40 CFR 141.31(d)].

It is recommended that you notify health professionals in the area of the violation. People may call their doctors with questions about how the violation may affect their health, and the doctors should have the information they need to respond appropriately. In addition, health professionals, including dentists, use tap water during their procedures and need to know of potential microbial contamination so they can use bottled water.

It is also a good idea to issue a "problem corrected" notice when the violation is resolved. See Template 1-6.

Appendix 5 – Tier 1 Boil Water Notice Example



TCR Fecal Coliform or *E. coli* Notice – Template 1-4

DRINKING WATER WARNING

[Fecal coliforms are /E. coli is] present in the [System]'s water

BOIL YOUR WATER BEFORE USING

Fecal coliform [or *E. coli*] bacteria were found in the water supply on [give date]. These bacteria can make you sick, and are a particular concern for people with weakened immune systems.

Bacterial contamination can occur when increased run-off enters the drinking water source (for example, following heavy rains). It can also happen due to a break in the distribution system (pipes) or a failure in the water treatment process.

What should I do? What does this mean?

- **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, and food preparation until further notice. Boiling kills bacteria and other organisms in the water.
- **Fecal coliforms and E. coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems.*
- The symptoms above are not caused only by organisms in drinking water. If you experience any of these symptoms and they persist, you may want to seek medical advice. People at increased risk should seek advice from their health care providers about drinking this water.

What is being done?

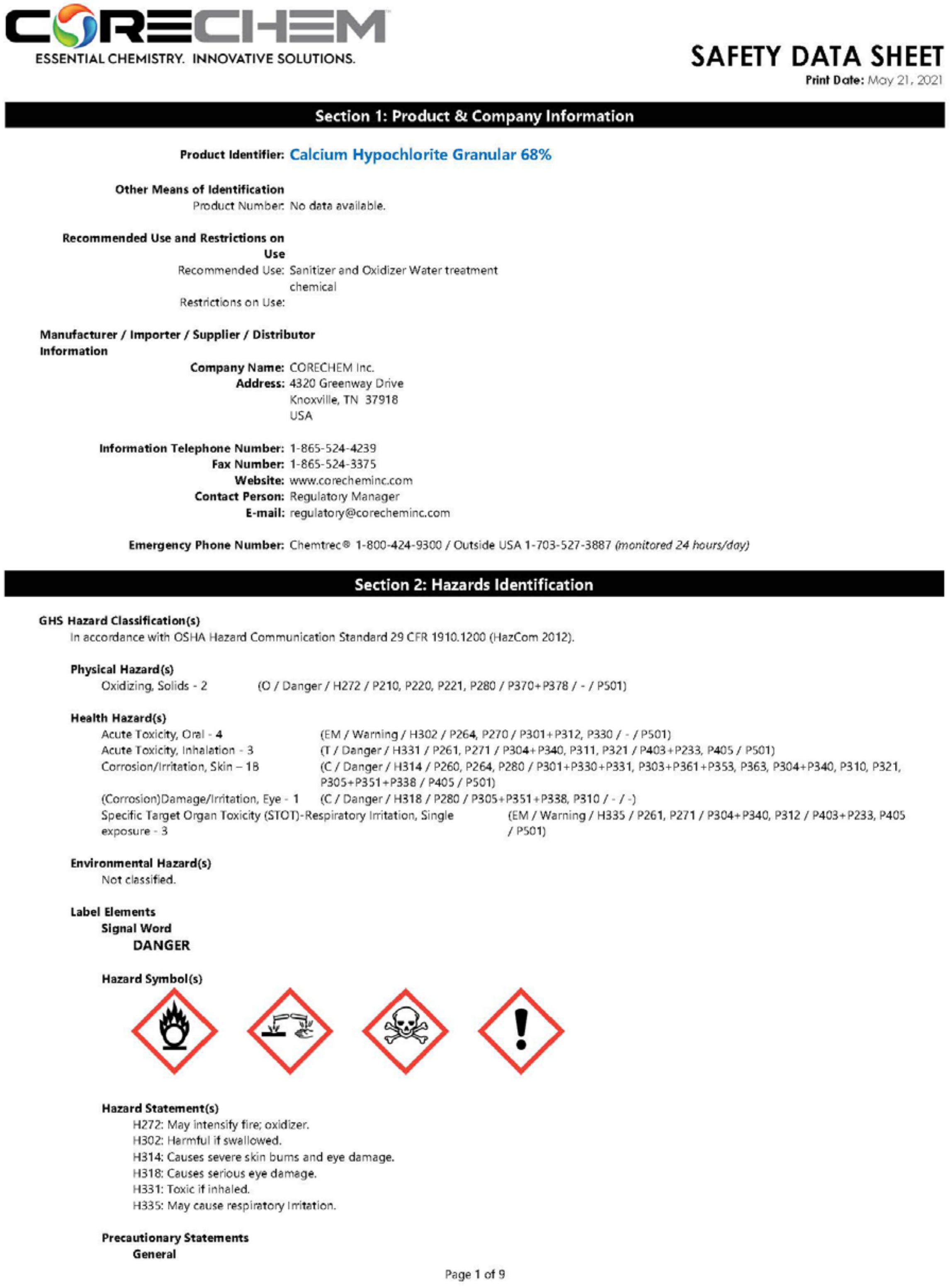
[Describe corrective action.] We will inform you when tests show no bacteria and you no longer need to boil your water. We anticipate resolving the problem within [estimated time frame].

For more information, please contact [name of contact] at [phone number] or [mailing address]. General guidelines on ways to lessen the risk of infection by microbes are available from the EPA Safe Drinking Water Hotline at 1-800-426-4791.

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

This notice is being sent to you by [system]. State Water System ID#: ___________.
Date distributed: ______.

Appendix 6 – Safety Data Sheet (SDS) Example



CORECHEM
ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET

Print Date: May 21, 2021

Section 1: Product & Company Information

Product Identifier: **Calcium Hypochlorite Granular 68%**

Other Means of Identification
Product Number: No data available.

Recommended Use and Restrictions on Use
Recommended Use: Sanitizer and Oxidizer Water treatment chemical
Restrictions on Use:

Manufacturer / Importer / Supplier / Distributor Information
Company Name: CORECHEM Inc.
Address: 4320 Greenway Drive
Knoxville, TN 37918
USA

Information Telephone Number: 1-865-524-4239
Fax Number: 1-865-524-3375
Website: www.corecheminc.com
Contact Person: Regulatory Manager
E-mail: regulatory@corecheminc.com

Emergency Phone Number: Chemtrec® 1-800-424-9300 / Outside USA 1-703-527-3887 *(monitored 24 hours/day)*

Section 2: Hazards Identification

GHS Hazard Classification(s)
In accordance with OSHA Hazard Communication Standard 29 CFR 1910.1200 (HazCom 2012).

Physical Hazard(s)

Oxidizing, Solids - 2	(O / Danger / H272 / P210, P220, P221, P280 / P370+P378 / - / P501)

Health Hazard(s)

Acute Toxicity, Oral - 4	(EM / Warning / H302 / P264, P270 / P301+P312, P330 / - / P501)
Acute Toxicity, Inhalation - 3	(T / Danger / H331 / P261, P271 / P304+P340, P311, P321 / P403+P233, P405 / P501)
Corrosion/Irritation, Skin – 1B	(C / Danger / H314 / P260, P264, P280 / P301+P330+P331, P303+P361+P353, P363, P304+P340, P310, P321, P305+P351+P338 / P405 / P501)
(Corrosion)Damage/Irritation, Eye - 1	(C / Danger / H318 / P280 / P305+P351+P338, P310 / - / -)
Specific Target Organ Toxicity (STOT)-Respiratory Irritation, Single exposure - 3	(EM / Warning / H335 / P261, P271 / P304+P340, P312 / P403+P233, P405 / P501)

Environmental Hazard(s)
Not classified.

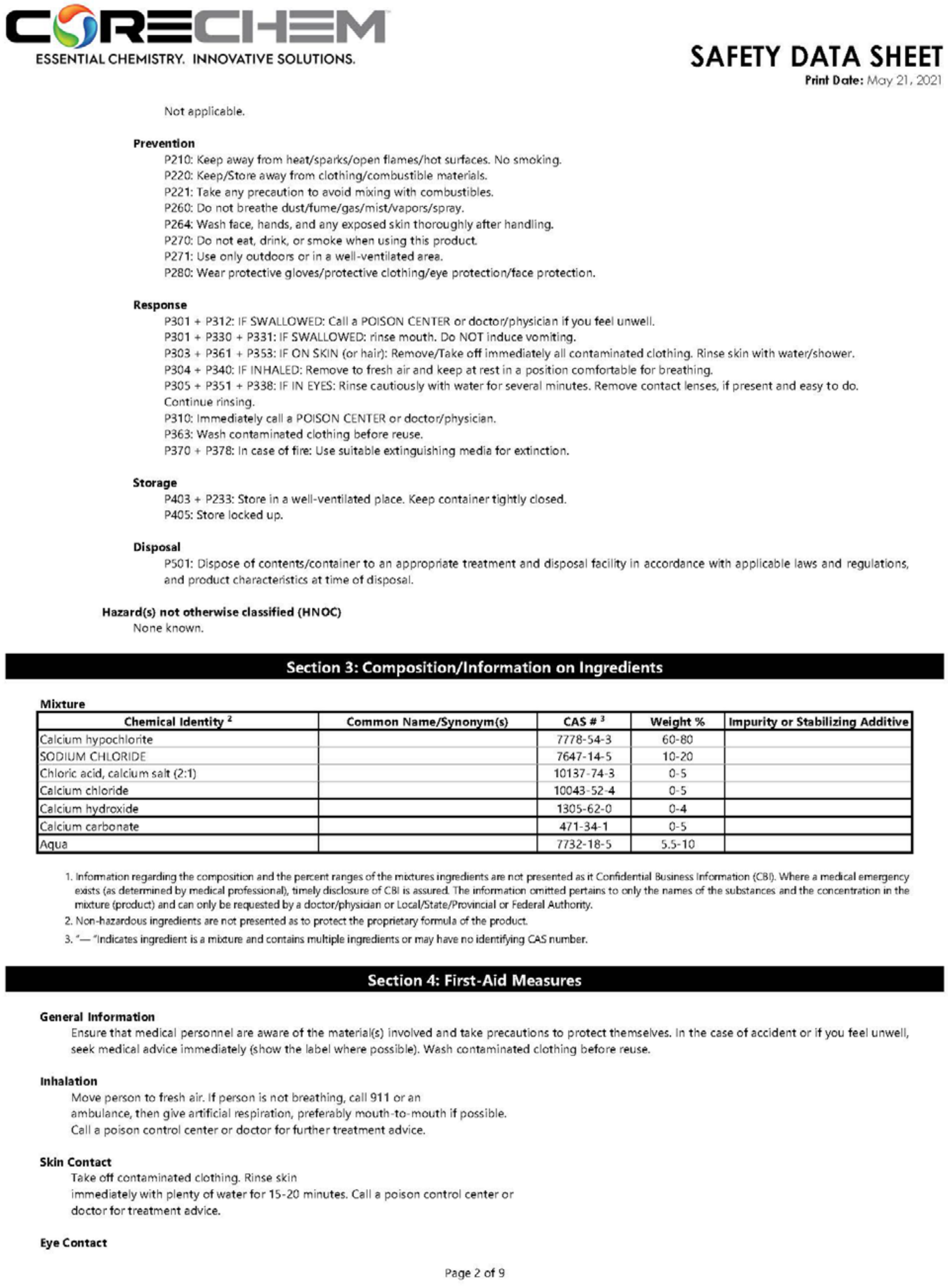
Label Elements
Signal Word
DANGER

Hazard Symbol(s)

Hazard Statement(s)
H272: May intensify fire; oxidizer.
H302: Harmful if swallowed.
H314: Causes severe skin burns and eye damage.
H318: Causes serious eye damage.
H331: Toxic if inhaled.
H335: May cause respiratory irritation.

Precautionary Statements
General

Page 1 of 9



CORECHEM
ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET
Print Date: May 21, 2021

Not applicable.

Prevention

P210: Keep away from heat/sparks/open flames/hot surfaces. No smoking.
P220: Keep/Store away from clothing/combustible materials.
P221: Take any precaution to avoid mixing with combustibles.
P260: Do not breathe dust/fume/gas/mist/vapors/spray.
P264: Wash face, hands, and any exposed skin thoroughly after handling.
P270: Do not eat, drink, or smoke when using this product.
P271: Use only outdoors or in a well-ventilated area.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Response

P301 + P312: IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P301 + P330 + P331: IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303 + P361 + P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304 + P340: IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing.
P305 + P351 + P338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310: Immediately call a POISON CENTER or doctor/physician.
P363: Wash contaminated clothing before reuse.
P370 + P378: In case of fire: Use suitable extinguishing media for extinction.

Storage

P403 + P233: Store in a well-ventilated place. Keep container tightly closed.
P405: Store locked up.

Disposal

P501: Dispose of contents/container to an appropriate treatment and disposal facility in accordance with applicable laws and regulations, and product characteristics at time of disposal.

Hazard(s) not otherwise classified (HNOC)

None known.

Section 3: Composition/Information on Ingredients

Mixture

Chemical Identity [2]	Common Name/Synonym(s)	CAS # [3]	Weight %	Impurity or Stabilizing Additive
Calcium hypochlorite		7778-54-3	60-80	
SODIUM CHLORIDE		7647-14-5	10-20	
Chloric acid, calcium salt (2:1)		10137-74-3	0-5	
Calcium chloride		10043-52-4	0-5	
Calcium hydroxide		1305-62-0	0-4	
Calcium carbonate		471-34-1	0-5	
Aqua		7732-18-5	5.5-10	

1. Information regarding the composition and the percent ranges of the mixtures ingredients are not presented as it Confidential Business Information (CBI). Where a medical emergency exists (as determined by medical professional), timely disclosure of CBI is assured. The information omitted pertains to only the names of the substances and the concentration in the mixture (product) and can only be requested by a doctor/physician or Local/State/Provincial or Federal Authority.
2. Non-hazardous ingredients are not presented as to protect the proprietary formula of the product.
3. "— "Indicates ingredient is a mixture and contains multiple ingredients or may have no identifying CAS number.

Section 4: First-Aid Measures

General Information

Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves. In the case of accident or if you feel unwell, seek medical advice immediately (show the label where possible). Wash contaminated clothing before reuse.

Inhalation

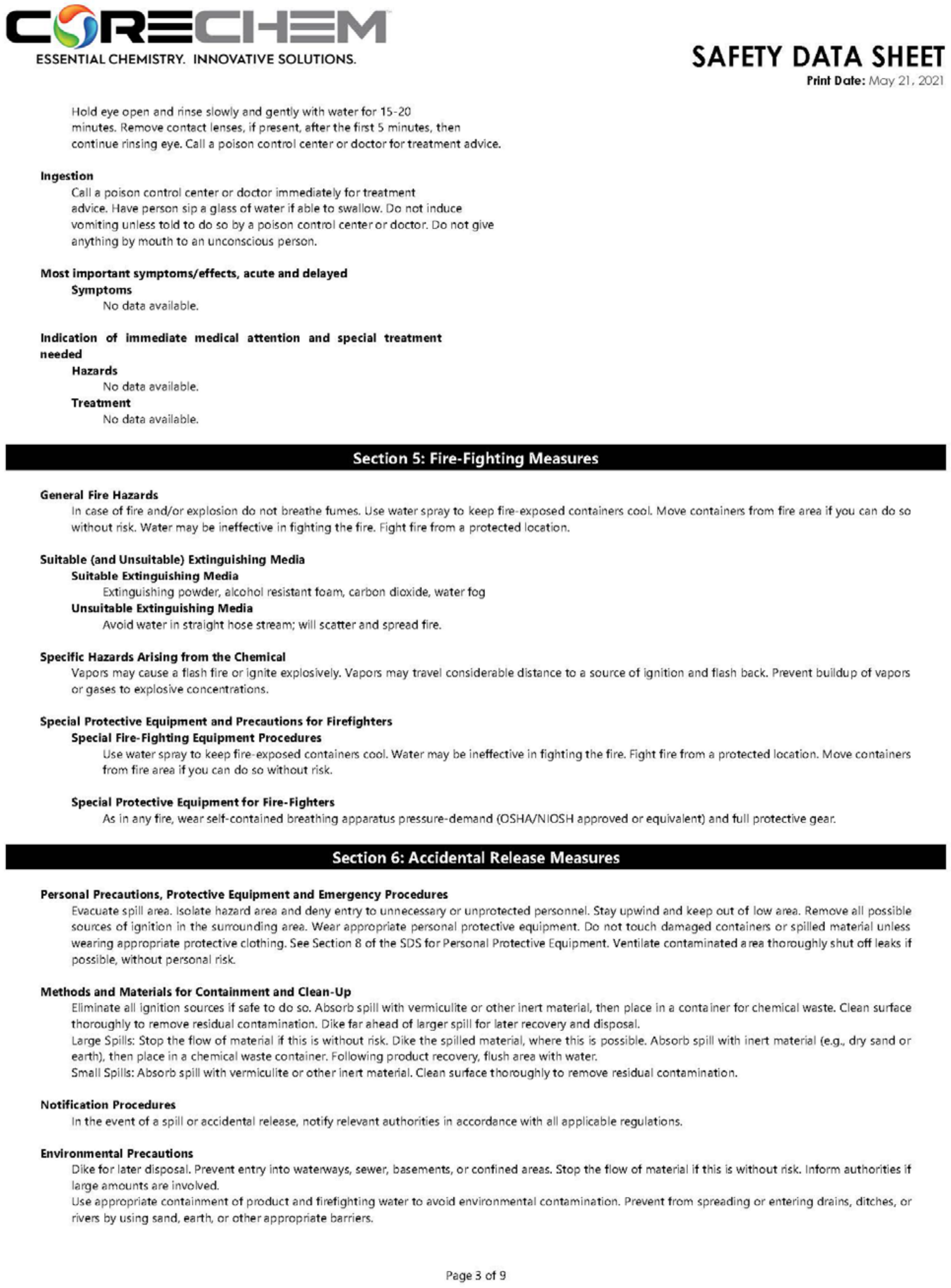
Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. Call a poison control center or doctor for further treatment advice.

Skin Contact

Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for treatment advice.

Eye Contact

Page 2 of 9



Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a poison control center or doctor for treatment advice.

Ingestion

Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give anything by mouth to an unconscious person.

Most important symptoms/effects, acute and delayed

Symptoms

No data available.

Indication of immediate medical attention and special treatment needed

Hazards

No data available.

Treatment

No data available.

Section 5: Fire-Fighting Measures

General Fire Hazards

In case of fire and/or explosion do not breathe fumes. Use water spray to keep fire-exposed containers cool. Move containers from fire area if you can do so without risk. Water may be ineffective in fighting the fire. Fight fire from a protected location.

Suitable (and Unsuitable) Extinguishing Media

Suitable Extinguishing Media

Extinguishing powder, alcohol resistant foam, carbon dioxide, water fog

Unsuitable Extinguishing Media

Avoid water in straight hose stream; will scatter and spread fire.

Specific Hazards Arising from the Chemical

Vapors may cause a flash fire or ignite explosively. Vapors may travel considerable distance to a source of ignition and flash back. Prevent buildup of vapors or gases to explosive concentrations.

Special Protective Equipment and Precautions for Firefighters

Special Fire-Fighting Equipment Procedures

Use water spray to keep fire-exposed containers cool. Water may be ineffective in fighting the fire. Fight fire from a protected location. Move containers from fire area if you can do so without risk.

Special Protective Equipment for Fire-Fighters

As in any fire, wear self-contained breathing apparatus pressure-demand (OSHA/NIOSH approved or equivalent) and full protective gear.

Section 6: Accidental Release Measures

Personal Precautions, Protective Equipment and Emergency Procedures

Evacuate spill area. Isolate hazard area and deny entry to unnecessary or unprotected personnel. Stay upwind and keep out of low area. Remove all possible sources of ignition in the surrounding area. Wear appropriate personal protective equipment. Do not touch damaged containers or spilled material unless wearing appropriate protective clothing. See Section 8 of the SDS for Personal Protective Equipment. Ventilate contaminated area thoroughly shut off leaks if possible, without personal risk.

Methods and Materials for Containment and Clean-Up

Eliminate all ignition sources if safe to do so. Absorb spill with vermiculite or other inert material, then place in a container for chemical waste. Clean surface thoroughly to remove residual contamination. Dike far ahead of larger spill for later recovery and disposal.

Large Spills: Stop the flow of material if this is without risk. Dike the spilled material, where this is possible. Absorb spill with inert material (e.g., dry sand or earth), then place in a chemical waste container. Following product recovery, flush area with water.

Small Spills: Absorb spill with vermiculite or other inert material. Clean surface thoroughly to remove residual contamination.

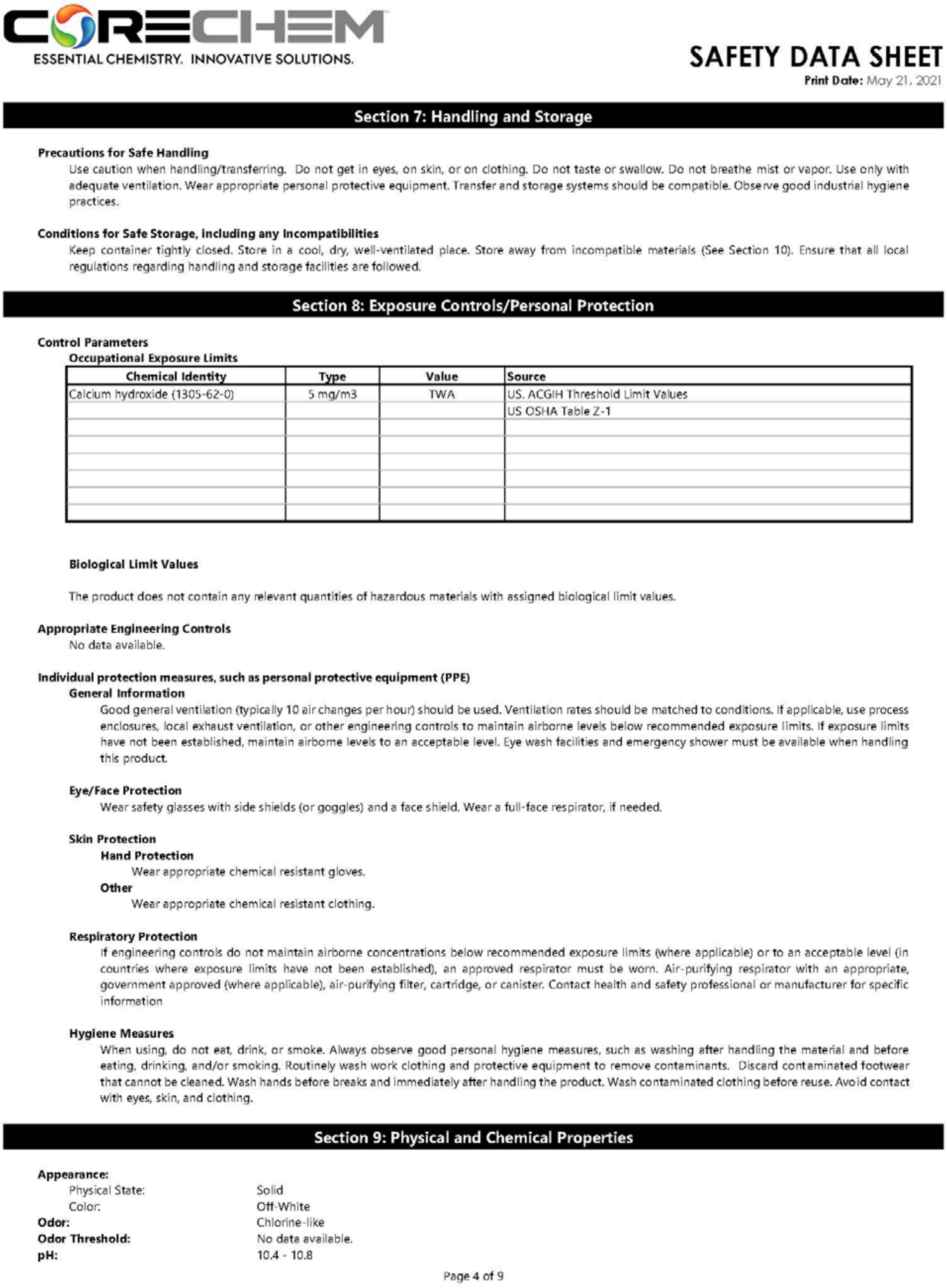
Notification Procedures

In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations.

Environmental Precautions

Dike for later disposal. Prevent entry into waterways, sewer, basements, or confined areas. Stop the flow of material if this is without risk. Inform authorities if large amounts are involved.

Use appropriate containment of product and firefighting water to avoid environmental contamination. Prevent from spreading or entering drains, ditches, or rivers by using sand, earth, or other appropriate barriers.



ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET

Print Date: May 21, 2021

Section 7: Handling and Storage

Precautions for Safe Handling

Use caution when handling/transferring. Do not get in eyes, on skin, or on clothing. Do not taste or swallow. Do not breathe mist or vapor. Use only with adequate ventilation. Wear appropriate personal protective equipment. Transfer and storage systems should be compatible. Observe good industrial hygiene practices.

Conditions for Safe Storage, including any Incompatibilities

Keep container tightly closed. Store in a cool, dry, well-ventilated place. Store away from incompatible materials (See Section 10). Ensure that all local regulations regarding handling and storage facilities are followed.

Section 8: Exposure Controls/Personal Protection

Control Parameters

Occupational Exposure Limits

Chemical Identity	Type	Value	Source
Calcium hydroxide (1305-62-0)	5 mg/m3	TWA	US. ACGIH Threshold Limit Values
			US OSHA Table Z-1

Biological Limit Values

The product does not contain any relevant quantities of hazardous materials with assigned biological limit values.

Appropriate Engineering Controls

No data available.

Individual protection measures, such as personal protective equipment (PPE)

General Information

Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level. Eye wash facilities and emergency shower must be available when handling this product.

Eye/Face Protection

Wear safety glasses with side shields (or goggles) and a face shield. Wear a full-face respirator, if needed.

Skin Protection

Hand Protection

Wear appropriate chemical resistant gloves.

Other

Wear appropriate chemical resistant clothing.

Respiratory Protection

If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn. Air-purifying respirator with an appropriate, government approved (where applicable), air-purifying filter, cartridge, or canister. Contact health and safety professional or manufacturer for specific information

Hygiene Measures

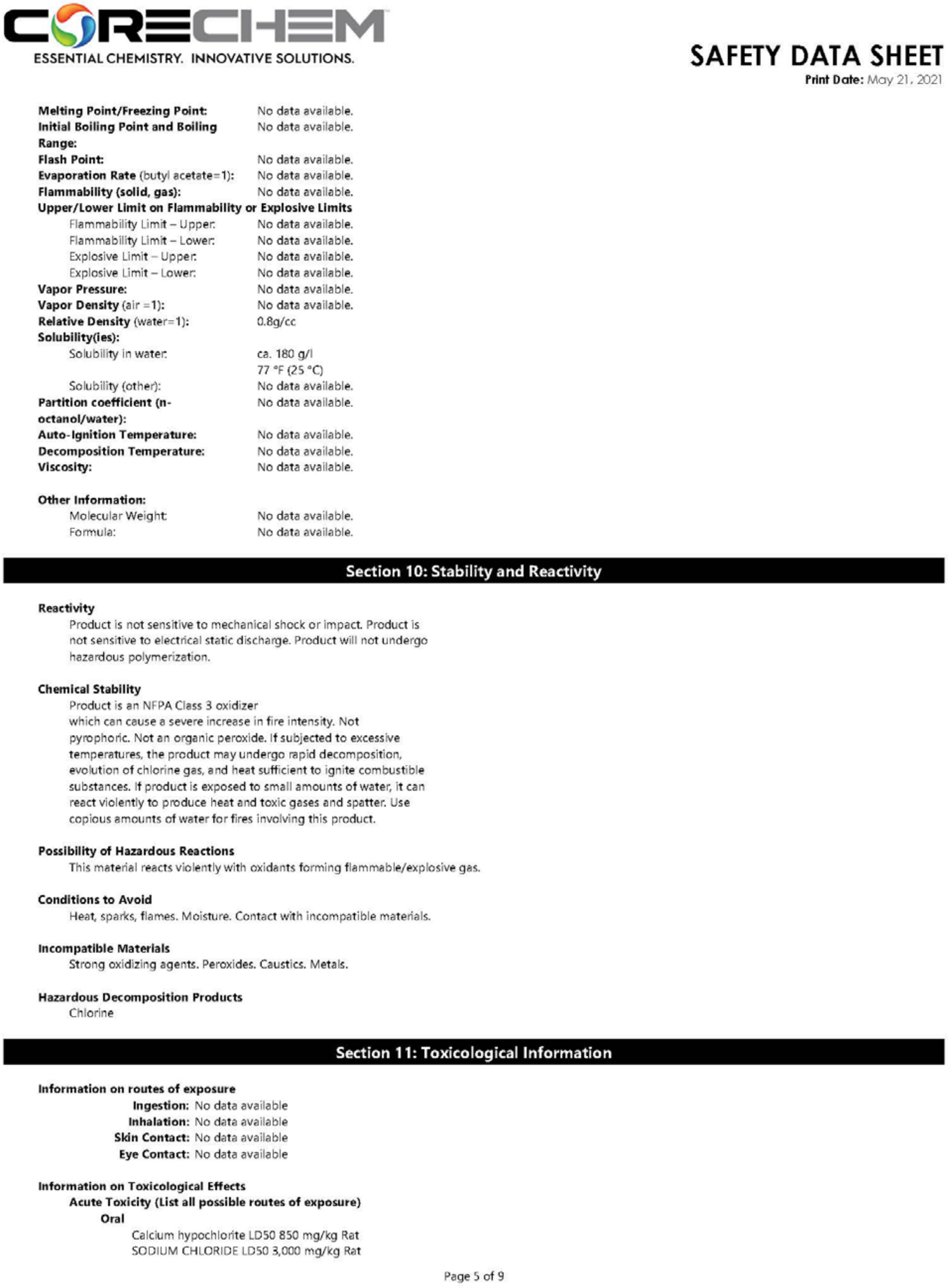
When using, do not eat, drink, or smoke. Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated footwear that cannot be cleaned. Wash hands before breaks and immediately after handling the product. Wash contaminated clothing before reuse. Avoid contact with eyes, skin, and clothing.

Section 9: Physical and Chemical Properties

Appearance:	
Physical State:	Solid
Color:	Off-White
Odor:	Chlorine-like
Odor Threshold:	No data available.
pH:	10.4 - 10.8

Page 4 of 9

Appendix 6 – Safety Data Sheet (SDS) Example



ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET

Print Date: May 21, 2021

Melting Point/Freezing Point:	No data available.
Initial Boiling Point and Boiling Range:	No data available.
Flash Point:	No data available.
Evaporation Rate (butyl acetate=1):	No data available.
Flammability (solid, gas):	No data available.
Upper/Lower Limit on Flammability or Explosive Limits	
Flammability Limit – Upper:	No data available.
Flammability Limit – Lower:	No data available.
Explosive Limit – Upper:	No data available.
Explosive Limit – Lower:	No data available.
Vapor Pressure:	No data available.
Vapor Density (air =1):	No data available.
Relative Density (water=1):	0.8g/cc
Solubility(ies):	
Solubility in water:	ca. 180 g/l 77 °F (25 °C)
Solubility (other):	No data available.
Partition coefficient (n-octanol/water):	No data available.
Auto-Ignition Temperature:	No data available.
Decomposition Temperature:	No data available.
Viscosity:	No data available.
Other Information:	
Molecular Weight:	No data available.
Formula:	No data available.

Section 10: Stability and Reactivity

Reactivity

Product is not sensitive to mechanical shock or impact. Product is not sensitive to electrical static discharge. Product will not undergo hazardous polymerization.

Chemical Stability

Product is an NFPA Class 3 oxidizer which can cause a severe increase in fire intensity. Not pyrophoric. Not an organic peroxide. If subjected to excessive temperatures, the product may undergo rapid decomposition, evolution of chlorine gas, and heat sufficient to ignite combustible substances. If product is exposed to small amounts of water, it can react violently to produce heat and toxic gases and spatter. Use copious amounts of water for fires involving this product.

Possibility of Hazardous Reactions

This material reacts violently with oxidants forming flammable/explosive gas.

Conditions to Avoid

Heat, sparks, flames. Moisture. Contact with incompatible materials.

Incompatible Materials

Strong oxidizing agents. Peroxides. Caustics. Metals.

Hazardous Decomposition Products

Chlorine

Section 11: Toxicological Information

Information on routes of exposure

Ingestion: No data available
Inhalation: No data available
Skin Contact: No data available
Eye Contact: No data available

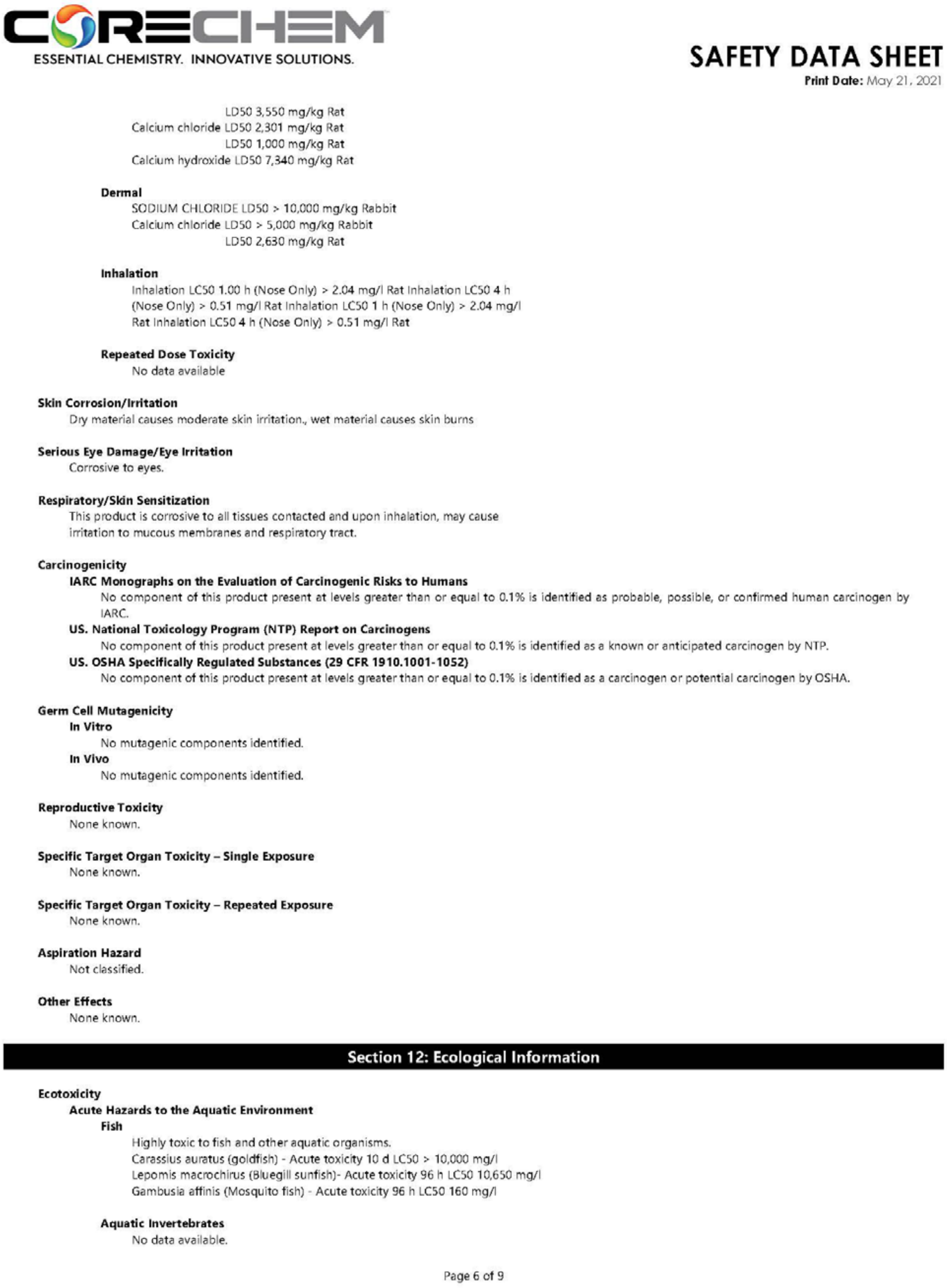
Information on Toxicological Effects

Acute Toxicity (List all possible routes of exposure)

Oral

Calcium hypochlorite LD50 850 mg/kg Rat
SODIUM CHLORIDE LD50 3,000 mg/kg Rat

Page 5 of 9



CORECHEM

ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET

Print Date: May 21, 2021

LD50 3,550 mg/kg Rat
Calcium chloride LD50 2,301 mg/kg Rat
LD50 1,000 mg/kg Rat
Calcium hydroxide LD50 7,340 mg/kg Rat

Dermal

SODIUM CHLORIDE LD50 > 10,000 mg/kg Rabbit
Calcium chloride LD50 > 5,000 mg/kg Rabbit
LD50 2,630 mg/kg Rat

Inhalation

Inhalation LC50 1.00 h (Nose Only) > 2.04 mg/l Rat Inhalation LC50 4 h (Nose Only) > 0.51 mg/l Rat Inhalation LC50 1 h (Nose Only) > 2.04 mg/l Rat Inhalation LC50 4 h (Nose Only) > 0.51 mg/l Rat

Repeated Dose Toxicity

No data available

Skin Corrosion/Irritation

Dry material causes moderate skin irritation., wet material causes skin burns

Serious Eye Damage/Eye Irritation

Corrosive to eyes.

Respiratory/Skin Sensitization

This product is corrosive to all tissues contacted and upon inhalation, may cause irritation to mucous membranes and respiratory tract.

Carcinogenicity

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans

No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible, or confirmed human carcinogen by IARC.

US. National Toxicology Program (NTP) Report on Carcinogens

No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

US. OSHA Specifically Regulated Substances (29 CFR 1910.1001-1052)

No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Germ Cell Mutagenicity

In Vitro

No mutagenic components identified.

In Vivo

No mutagenic components identified.

Reproductive Toxicity

None known.

Specific Target Organ Toxicity – Single Exposure

None known.

Specific Target Organ Toxicity – Repeated Exposure

None known.

Aspiration Hazard

Not classified.

Other Effects

None known.

Section 12: Ecological Information

Ecotoxicity

Acute Hazards to the Aquatic Environment

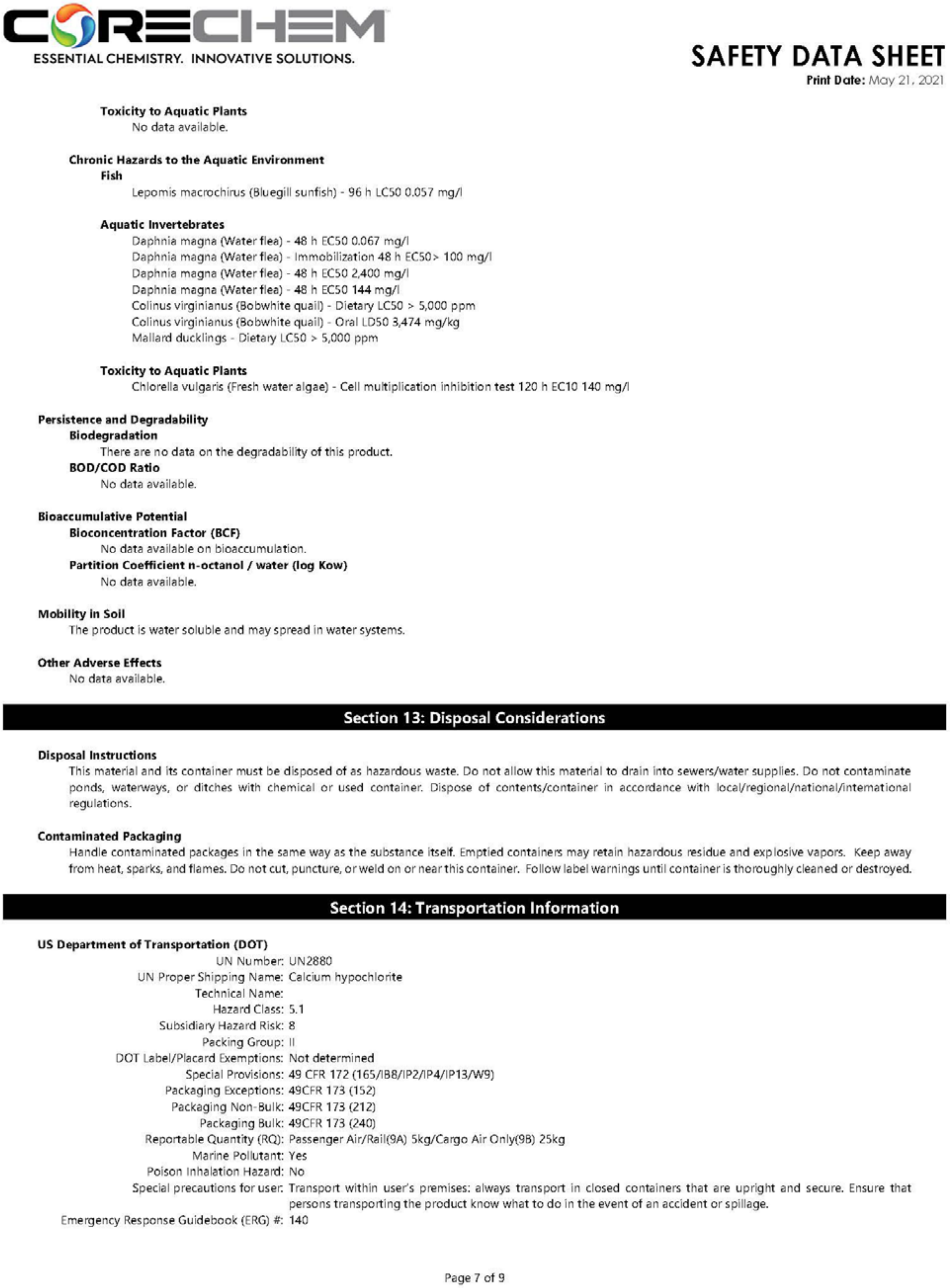
Fish

Highly toxic to fish and other aquatic organisms.
Carassius auratus (goldfish) - Acute toxicity 10 d LC50 > 10,000 mg/l
Lepomis macrochirus (Bluegill sunfish)- Acute toxicity 96 h LC50 10,650 mg/l
Gambusia affinis (Mosquito fish) - Acute toxicity 96 h LC50 160 mg/l

Aquatic Invertebrates

No data available.

Page 6 of 9



CORECHEM
ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET
Print Date: May 21, 2021

Toxicity to Aquatic Plants
No data available.

Chronic Hazards to the Aquatic Environment
Fish
Lepomis macrochirus (Bluegill sunfish) - 96 h LC50 0.057 mg/l

Aquatic Invertebrates
Daphnia magna (Water flea) - 48 h EC50 0.067 mg/l
Daphnia magna (Water flea) - Immobilization 48 h EC50> 100 mg/l
Daphnia magna (Water flea) - 48 h EC50 2,400 mg/l
Daphnia magna (Water flea) - 48 h EC50 144 mg/l
Colinus virginianus (Bobwhite quail) - Dietary LC50 > 5,000 ppm
Colinus virginianus (Bobwhite quail) - Oral LD50 3,474 mg/kg
Mallard ducklings - Dietary LC50 > 5,000 ppm

Toxicity to Aquatic Plants
Chlorella vulgaris (Fresh water algae) - Cell multiplication inhibition test 120 h EC10 140 mg/l

Persistence and Degradability
Biodegradation
There are no data on the degradability of this product.
BOD/COD Ratio
No data available.

Bioaccumulative Potential
Bioconcentration Factor (BCF)
No data available on bioaccumulation.
Partition Coefficient n-octanol / water (log Kow)
No data available.

Mobility in Soil
The product is water soluble and may spread in water systems.

Other Adverse Effects
No data available.

Section 13: Disposal Considerations

Disposal Instructions
This material and its container must be disposed of as hazardous waste. Do not allow this material to drain into sewers/water supplies. Do not contaminate ponds, waterways, or ditches with chemical or used container. Dispose of contents/container in accordance with local/regional/national/international regulations.

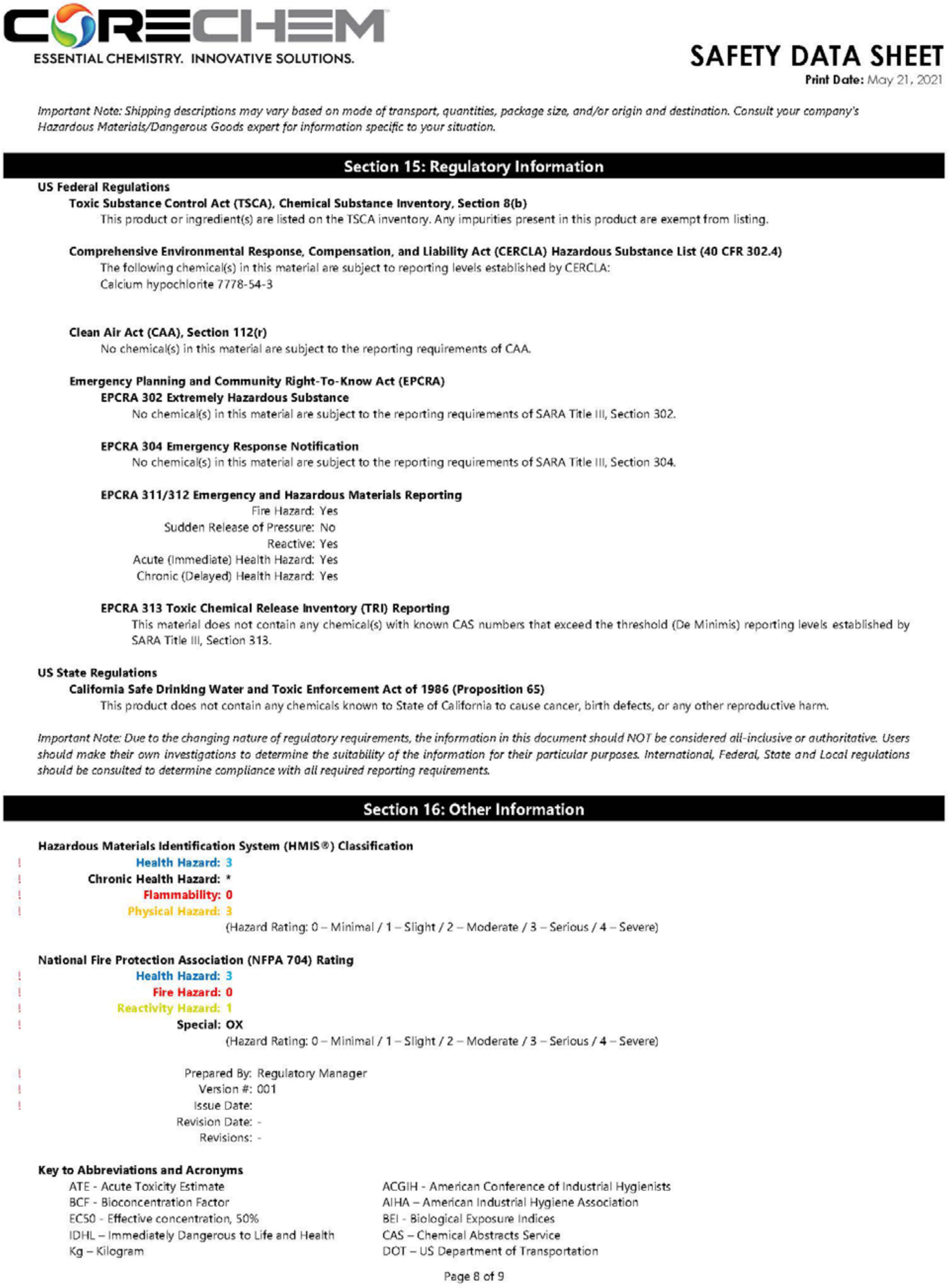
Contaminated Packaging
Handle contaminated packages in the same way as the substance itself. Emptied containers may retain hazardous residue and explosive vapors. Keep away from heat, sparks, and flames. Do not cut, puncture, or weld on or near this container. Follow label warnings until container is thoroughly cleaned or destroyed.

Section 14: Transportation Information

US Department of Transportation (DOT)
UN Number: UN2880
UN Proper Shipping Name: Calcium hypochlorite
Technical Name:
Hazard Class: 5.1
Subsidiary Hazard Risk: 8
Packing Group: II
DOT Label/Placard Exemptions: Not determined
Special Provisions: 49 CFR 172 (165/IB8/IP2/IP4/IP13/W9)
Packaging Exceptions: 49CFR 173 (152)
Packaging Non-Bulk: 49CFR 173 (212)
Packaging Bulk: 49CFR 173 (240)
Reportable Quantity (RQ): Passenger Air/Rail(9A) 5kg/Cargo Air Only(9B) 25kg
Marine Pollutant: Yes
Poison Inhalation Hazard: No
Special precautions for user: Transport within user's premises: always transport in closed containers that are upright and secure. Ensure that persons transporting the product know what to do in the event of an accident or spillage.
Emergency Response Guidebook (ERG) #: 140

Page 7 of 9

Appendix 6 – Safety Data Sheet (SDS) Example



ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET

Print Date: May 21, 2021

Important Note: Shipping descriptions may vary based on mode of transport, quantities, package size, and/or origin and destination. Consult your company's Hazardous Materials/Dangerous Goods expert for information specific to your situation.

Section 15: Regulatory Information

US Federal Regulations

Toxic Substance Control Act (TSCA), Chemical Substance Inventory, Section 8(b)

This product or ingredient(s) are listed on the TSCA inventory. Any impurities present in this product are exempt from listing.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Hazardous Substance List (40 CFR 302.4)

The following chemical(s) in this material are subject to reporting levels established by CERCLA:
Calcium hypochlorite 7778-54-3

Clean Air Act (CAA), Section 112(r)

No chemical(s) in this material are subject to the reporting requirements of CAA.

Emergency Planning and Community Right-To-Know Act (EPCRA)

EPCRA 302 Extremely Hazardous Substance

No chemical(s) in this material are subject to the reporting requirements of SARA Title III, Section 302.

EPCRA 304 Emergency Response Notification

No chemical(s) in this material are subject to the reporting requirements of SARA Title III, Section 304.

EPCRA 311/312 Emergency and Hazardous Materials Reporting

Fire Hazard: Yes
Sudden Release of Pressure: No
Reactive: Yes
Acute (Immediate) Health Hazard: Yes
Chronic (Delayed) Health Hazard: Yes

EPCRA 313 Toxic Chemical Release Inventory (TRI) Reporting

This material does not contain any chemical(s) with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

US State Regulations

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65)

This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

Important Note: Due to the changing nature of regulatory requirements, the information in this document should NOT be considered all-inclusive or authoritative. Users should make their own investigations to determine the suitability of the information for their particular purposes. International, Federal, State and Local regulations should be consulted to determine compliance with all required reporting requirements.

Section 16: Other Information

Hazardous Materials Identification System (HMIS®) Classification

! **Health Hazard: 3**
! **Chronic Health Hazard: ***
! **Flammability: 0**
! **Physical Hazard: 3**
(Hazard Rating: 0 – Minimal / 1 – Slight / 2 – Moderate / 3 – Serious / 4 – Severe)

National Fire Protection Association (NFPA 704) Rating

! **Health Hazard: 3**
! **Fire Hazard: 0**
! **Reactivity Hazard: 1**
! **Special: OX**
(Hazard Rating: 0 – Minimal / 1 – Slight / 2 – Moderate / 3 – Serious / 4 – Severe)

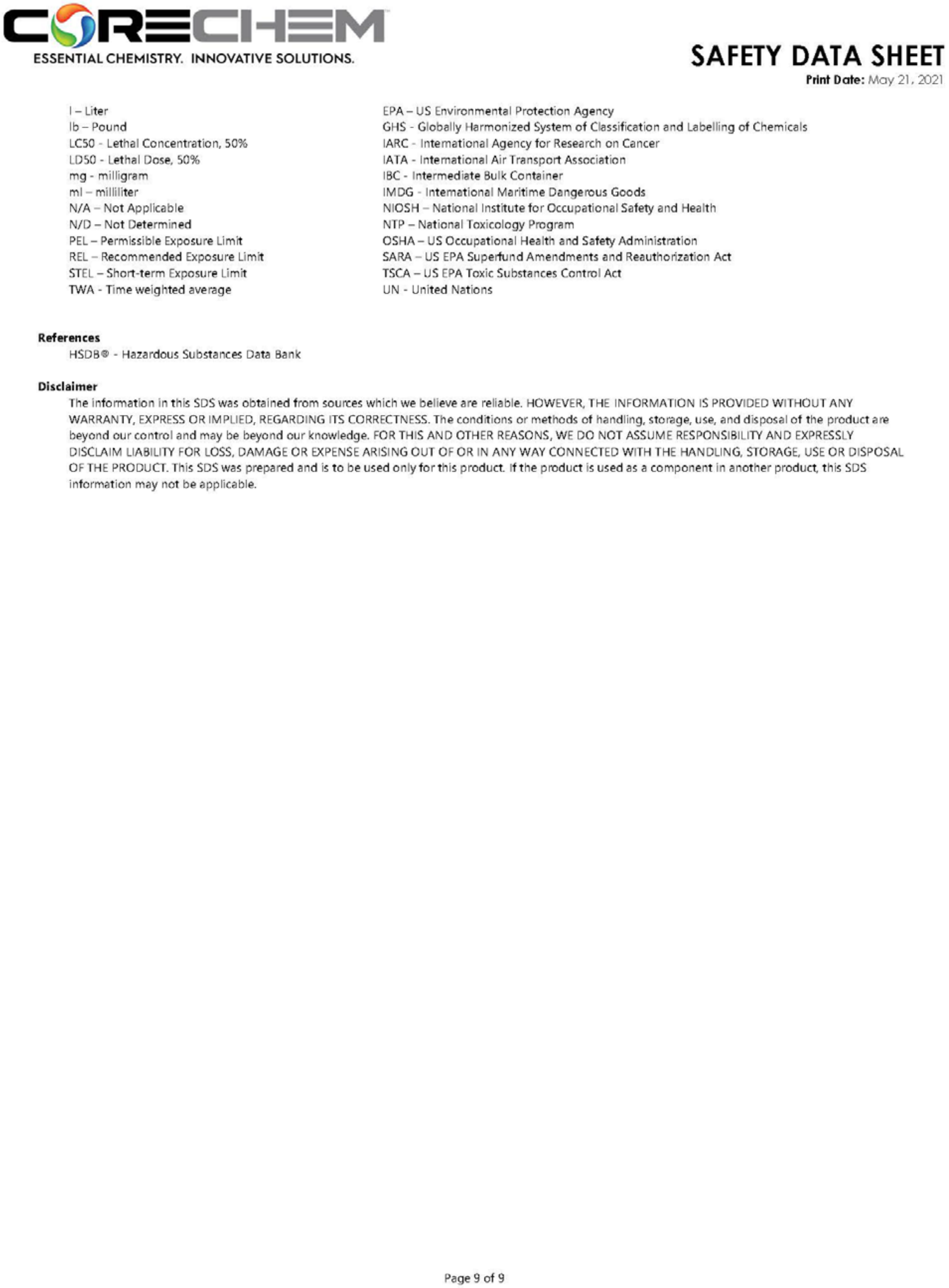
! Prepared By: Regulatory Manager
! Version #: 001
! Issue Date:
Revision Date: -
Revisions: -

Key to Abbreviations and Acronyms

ATE - Acute Toxicity Estimate
BCF - Bioconcentration Factor
EC50 - Effective concentration, 50%
IDHL – Immediately Dangerous to Life and Health
Kg – Kilogram
ACGIH - American Conference of Industrial Hygienists
AIHA – American Industrial Hygiene Association
BEI - Biological Exposure Indices
CAS – Chemical Abstracts Service
DOT – US Department of Transportation

Page 8 of 9

Appendix 6 – Safety Data Sheet (SDS) Example



CORECHEM
ESSENTIAL CHEMISTRY. INNOVATIVE SOLUTIONS.

SAFETY DATA SHEET
Print Date: May 21, 2021

l – Liter
lb – Pound
LC50 - Lethal Concentration, 50%
LD50 - Lethal Dose, 50%
mg - milligram
ml – milliliter
N/A – Not Applicable
N/D – Not Determined
PEL – Permissible Exposure Limit
REL – Recommended Exposure Limit
STEL – Short-term Exposure Limit
TWA - Time weighted average

EPA – US Environmental Protection Agency
GHS - Globally Harmonized System of Classification and Labelling of Chemicals
IARC - International Agency for Research on Cancer
IATA - International Air Transport Association
IBC - Intermediate Bulk Container
IMDG - International Maritime Dangerous Goods
NIOSH – National Institute for Occupational Safety and Health
NTP – National Toxicology Program
OSHA – US Occupational Health and Safety Administration
SARA – US EPA Superfund Amendments and Reauthorization Act
TSCA – US EPA Toxic Substances Control Act
UN - United Nations

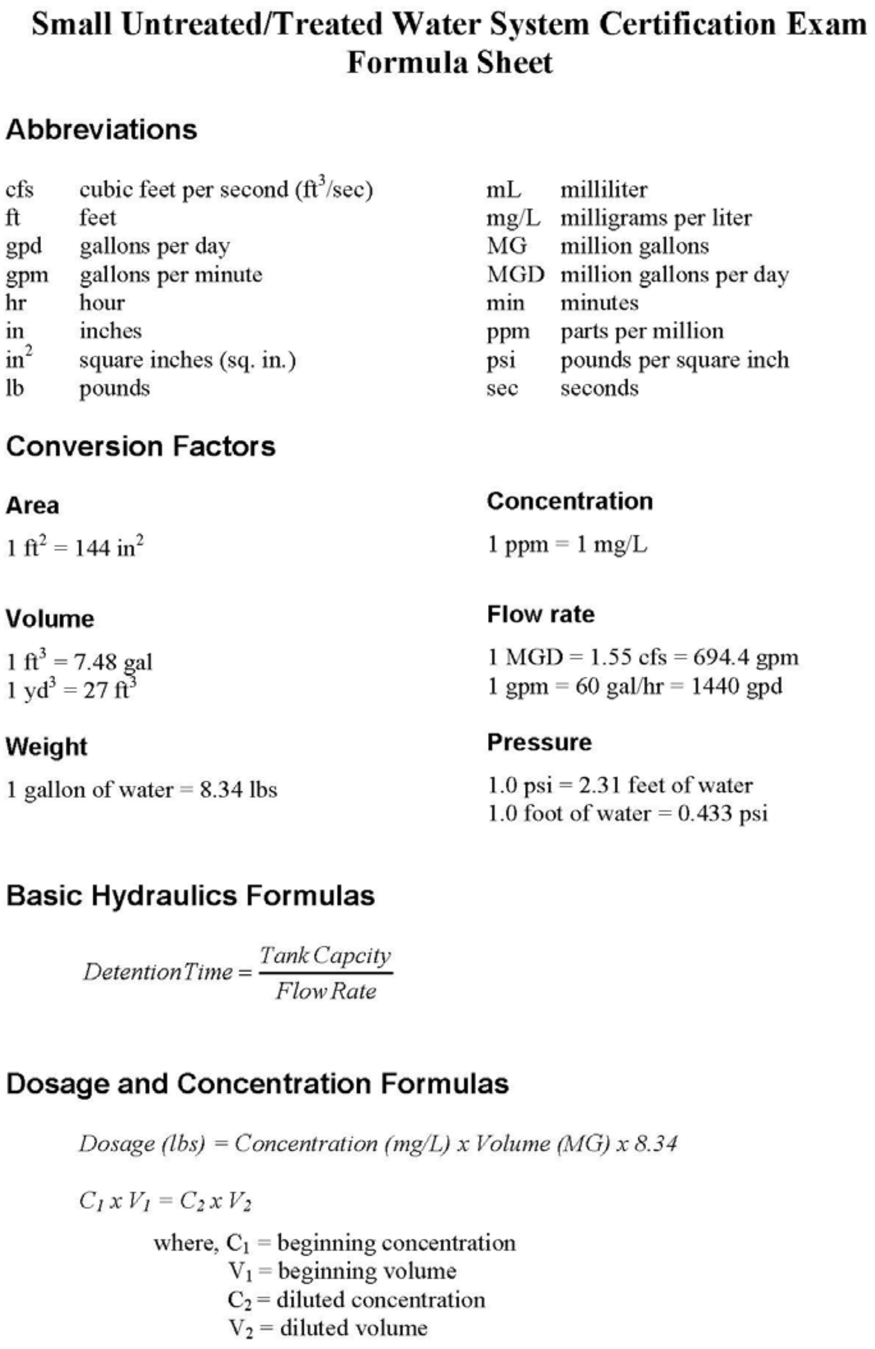
References

HSDB® - Hazardous Substances Data Bank

Disclaimer

The information in this SDS was obtained from sources which we believe are reliable. HOWEVER, THE INFORMATION IS PROVIDED WITHOUT ANY WARRANTY, EXPRESS OR IMPLIED, REGARDING ITS CORRECTNESS. The conditions or methods of handling, storage, use, and disposal of the product are beyond our control and may be beyond our knowledge. FOR THIS AND OTHER REASONS, WE DO NOT ASSUME RESPONSIBILITY AND EXPRESSLY DISCLAIM LIABILITY FOR LOSS, DAMAGE OR EXPENSE ARISING OUT OF OR IN ANY WAY CONNECTED WITH THE HANDLING, STORAGE, USE OR DISPOSAL OF THE PRODUCT. This SDS was prepared and is to be used only for this product. If the product is used as a component in another product, this SDS information may not be applicable.

Appendix 7 – Small Water Systems Exam Formula Sheets



Small Untreated/Treated Water System Certification Exam Formula Sheet

Abbreviations

cfs	cubic feet per second (ft^3/sec)	mL	milliliter
ft	feet	mg/L	milligrams per liter
gpd	gallons per day	MG	million gallons
gpm	gallons per minute	MGD	million gallons per day
hr	hour	min	minutes
in	inches	ppm	parts per million
in^2	square inches (sq. in.)	psi	pounds per square inch
lb	pounds	sec	seconds

Conversion Factors

Area

$1\ ft^2 = 144\ in^2$

Concentration

1 ppm = 1 mg/L

Volume

$1\ ft^3 = 7.48$ gal
$1\ yd^3 = 27\ ft^3$

Flow rate

1 MGD = 1.55 cfs = 694.4 gpm
1 gpm = 60 gal/hr = 1440 gpd

Weight

1 gallon of water = 8.34 lbs

Pressure

1.0 psi = 2.31 feet of water
1.0 foot of water = 0.433 psi

Basic Hydraulics Formulas

$$Detention\,Time = \frac{Tank\,Capcity}{Flow\,Rate}$$

Dosage and Concentration Formulas

Dosage (lbs) = Concentration (mg/L) x Volume (MG) x 8.34

$C_1 \times V_1 = C_2 \times V_2$

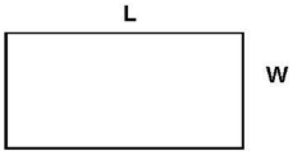
where, C_1 = beginning concentration
V_1 = beginning volume
C_2 = diluted concentration
V_2 = diluted volume

Small Untreated/Treated Water System Certification Exam Formula Sheet

Area

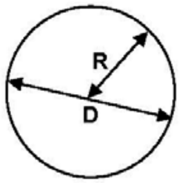
Square or Rectangle

$A = L \times W$



Circle

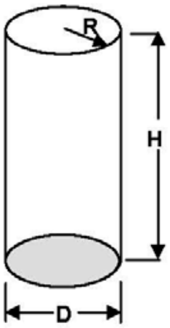
$A = \pi R^2$ **or** $A = 0.785\ D^2$



Where $\pi = 3.14$

Volume

Cylinder



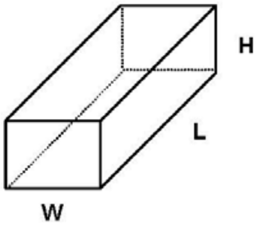
$V = 0.785\ D^2H$

or

$V = \pi R^2H$

Where $\pi = 3.14$

Cube



$V = L \times W \times H$

References and Credits

Arasmith, Skeet. Introduction to Small Water Systems – Student Manual, 3rd Edition. Albany, OR: ACR Publications, 1999.

Arasmith Consulting Resources; Arasmith, Skeet. Operation and Maintenance of Hypochlorite Systems. Albany, OR: ACR Publications, 1993.

“EPA Proposes Lower Arsenic Limit.” On Tap Drinking Water News for America’s Small Communities. Spring 1994; Volume 3, Issue 2.

Groundwater Manual for Small Water Systems. Drinking Water Assistance Program,The Montana Water Center. Montana State University. January 1999.

Holden, W., S., et. al. Water Treatment and Examination; The Society for Water Treatment Examination. London: J. & A. Churchill. 1970.

Karassik, Igor J., et. al. Pump Handbook 3rd Edition. New York: McGraw-Hill, 2001.

Manual of Instruction for Water Treatment Plant Operators. New York State Department of Health, Office of Environmental Health Manpower. New York. NY.

Math Preparation for Certification: http://nrwa./OM-Chap%204.htm

McKay, FS. Mottled enamel: the prevention of its further production through a change of the water supply at Oakley, Idaho. J Am Dent Assoc. 1933; 20: 1137-49.

Recommended Standards for Water Works. New York: Health Education Services, 1997.

Removal of the Pump; UCLA Department of Epidemiology; http://www.ph.uclaa.edu/epi/snow/removal.html

Small Water System Operation and Maintenance, 6th Edition. California: California State University Sacramento, 2018.

State of Alaska Department of Environmental Conservation. 18 AAC 80 Drinking Water. As amended through May 3, 2019.

Symons, James M., et. al. The Drinking Water Dictionary Colorado: American Water Works Association, 2000.

The Groundwater Foundation: http://www.groundwater.org/GWB Basics/ wells.htm

USEPA Region 8 Small Community Work Group. Everything You Wanted to Know About Environmental Regulations But Were Afraid to Ask! A Guide for Small Communities. January 1999 Revised Edition.

USEPA Region 9. The Safe Drinking Water Act; A Pocket Guide to the Requirements for the Operators of Small Water Systems. June 1993.

USEPA, Office of Water Programs, Water Supply Division. Manual of Individual Water Supply Systems. First printed 1973, Revised 1974, Reprinted 1975.

USEPA. A Pocket Sampling Guide for Operators of Small Water Systems: Phases II and V. July 1994.

Webster's II New College Dictionary. 1999.

The valve figures in Chapter 6 were used by permission from the Red-White Valve Corp., 20600 Regency Lane, Lake Forest, CA 92630.