

INTRODUCTION TO WATER SYSTEMS

Water systems today are finding themselves with ever increasing responsibilities in the area of proper treatment and protection of the water supply. The impact on small systems can be substantial. It is more important than ever to make sure the people that run these systems have better understanding of their system's operation.

The basic responsibility of the system is to provide each individual with an adequate supply of safe, potable drinking water. This responsibility extends to all employees, whether on a managerial, supervisory, operational, or clerical level, in some direct or indirect manner. Each employee should be aware of their duties and call to the attention of their supervisors any condition that might impair the quality of the water or which may cause an interruption of service to any part of the system. These responsibilities can be broken down into three major areas of concern:

- 1. Providing enough water to meet the total demands of the system.**
- 2. Providing water that is both safe and palatable to the customers.**
- 3. Providing that water to the customer when it is needed.**

MEETING WATER SYSTEM DEMANDS

The amount of water used by the entire system is known as the demand placed on that system. This demand may come from several different sources.

DOMESTIC WATER USAGE

Domestic water usage is any water that is used directly by people in their daily activities. These activities include bathing, drinking, cooking, sanitation and other miscellaneous activities like watering lawns, washing the car and laundry. Two major factors that determine the domestic water demands placed on a system are one, the number of individuals the system serves and secondly the amount of water each person on the system will need per day. On a nationwide basis, the average daily consumption of water (total gallons used divided by the total population) is about 130 gallons per person per day. However, this figure will vary depending on the geographic location involved and the population density of that area. Rural areas tend to have a daily consumption rate lower than the national average, while urban areas may have a higher rate.

INDUSTRIAL WATER USAGE

Industrial usage of water is considered to be water used for production of goods for marketing. The primary sources of industrial demands in rural areas for dairies, food processing, wood products and textiles. A single industrial user may require as much water as the entire domestic demand on the system.

AGRICULTURAL WATER USAGE

Agricultural usage of water is considered to be water used in irrigation of crops, watering livestock, and in cooling and cleanup of dairies and farm equipment. Agricultural demand will generally represent a larger portion of the total water usage than the industries in rural areas.

PUBLIC WATER USAGE

Public water usage may be defined as any community service that requires potable water. Services may include fire protection, recreation (swimming pools, golf courses, etc.) and street maintenance. In rural communities where these services are limited, public water usage may not be a consideration.

Present conditions and future increases in water production should be considered when designing the system. Operators may not be concerned with the original design of the system but should be aware of the impact of new additions and extensions to the system. This is especially true in areas where present water mains are handling maximum capacities.

SOURCES OF SUPPLY

Finding enough water to satisfy the demand on the system is certainly a major concern for the water supplier. The legal and financial considerations that arise when trying to procure water rights or finance the capital funding required to construct treatment facilities can limit the options available in many cases.

Systems are faces with essentially two choices when selecting a source of supply. They can drill wells and use ground water or, if a suitable river or lake is present, they may choose to use a surface water supply. Some groundwater sources are classified as GWUDI systems, or GroundWater Under Direct Influence of surface water. A GWUDI system is one where flows or source water characteristics change when weather conditions change. Water characteristics like temperature, pH, and alkalinity can change in a GWUDI system when it rains or during spring runoff.

WATER QUALITY

All drinking water needs some type of treatment to meet the standards required by the Safe Drinking Water Act. The kind of treatment that is required is determined by the contaminants that are present in the water. These contaminants are grouped into five general categories. They are minerals, turbidity, waterborne pathogens, tastes and odors, and color. Temperature, pH, and alkalinity are other characteristics of the source water that are important.

MINERALS

The mineral problems in water are caused by inorganic contaminants. These are usually dissolved metals and dissolved gases. Some of the more common mineral problems include iron and manganese, famous for causing "red water" problems, and hardness. Carbon dioxide gas can cause corrosion problems and hydrogen sulfide gas is noted for the "rotten egg" odor that is sometimes found in water. All of the inorganic chemicals that are listed under the SDWA Primary and Secondary standards are also included in this category. Primary standards are those that can cause immediate harm. Secondary standards are usually aesthetic concerns (taste and smell).

TURBIDITY

Silt and clay are primarily responsible for the turbidity in water. However, any suspended material that will not readily settle is considered to be turbidity. Some clay particles are so small that they will not settle at all. These particles in suspension are known as "colloids." Most turbidity particles carry a slight negative electrical charge that causes them to repel each other. This is why some surface water will remain cloudy even after it has been sitting still for hours. Turbidity should not be present in groundwater supplies.

WATERBORNE PATHOGENS

There are disease-causing organisms that can be transmitted through the water supply. Most of these organisms are bacteria. But some are viruses and small water animals called protozoa. They are known collectively as waterborne pathogens. These bacteriological contaminants can be found in the raw water supply and they can also be introduced into the distribution systems through line breaks and cross-connections. When this occurs, it is called secondary contamination.

TASTES AND ODORS

The main source of taste and odor problems in surface supplies is algae. Algae are small floating water plants. These are organic compounds that impart a mossy or fishy odor. The most common source of taste and odors in ground water supplies are inorganic chemicals. Hydrogen Sulfide gas (H₂S) causes a "rotten egg" odor. Iron and manganese can also impart a rusty taste to the water when present.

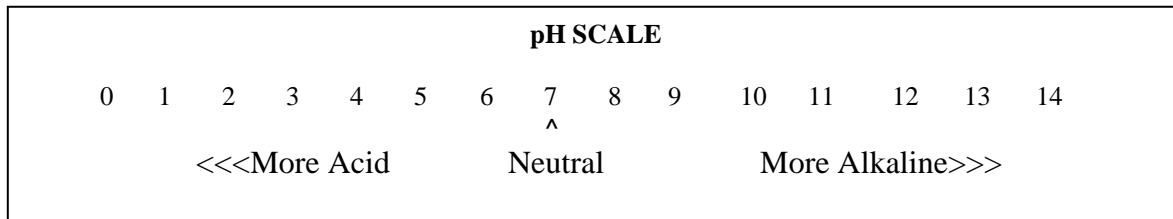
COLOR

Organic compounds released into the water by decaying vegetation cause true color. These organic "dyes" are dissolved in the water and cannot be removed by filtration like turbidity. As leaves fall into the water, tannic acid is leached out giving the water a brownish color. Decaying aquatic plants or humus can create a green color in the water. "Apparent color" is caused by small particles of oxidized iron or manganese that create red or black water problems respectively. Small reddish brown flakes of iron rust cause this type of color and can be removed by filtration .

pH

The pH is the measurement of the acidity of the water. Water is considered to be acidic when it has more hydrogen ions (H^+) in it than hydroxide ions (OH^-). Some of the chemicals that add hydrogen ions (H^+) to the water are hydrochloric acid (HCl), sulfuric acid (H_2SO_4), nitric acid (HNO_3), and carbonic acid (H_2CO_3).

Water is considered to be alkaline when there are more hydroxide ions (OH^-) present than hydrogen (H^+) Sodium hydroxide (NaOH), calcium hydroxide ($Ca(OH)_2$), and magnesium hydroxide ($Mg(OH)_2$), all add hydroxide ions (OH^-) to the water. When the number of hydrogen ions and hydroxide ions are the same the water has a neutral pH. Pure water (H_2O or H-OH) has a neutral pH because the number of hydrogen ions (H^+) and hydroxide ions (OH^-) are equal.



The pH of water is measured on a scale that reads from 0 to 14. The midpoint of the scale is 7. Water with a pH of 7 is neutral. If the water has a pH less than 7, the water is acid and if the pH is greater than 7 it is alkaline. For every whole number that the pH changes the strength of the acid or alkaline properties of the water will change by a factor of ten times. Water that goes from a pH of 9 to a pH of 10 becomes 10 times more alkaline and water at pH of 5 is 10 times more acid than water at a pH of 6.

MEETING WATER QUALITY STANDARDS

Prior to 1976, water quality was regulated by individual state standards. In many cases these standards were only recommendations rather than enforceable regulations. The U.S. Congress passed the Safe Drinking Water Act (P.L. 93-523) in 1976. The law sets permissible levels of substances found in water which could be hazardous to public health. These regulations include Maximum Contaminant Levels or MCL, for inorganic and organic chemicals, radioactivity, turbidity and microbiological levels. Testing and monitoring requirements, reporting and record keeping schedules, and public notification are enforced by individual state agencies.

Water quality standards in New Mexico are enforced through the New Mexico Drinking Water Regulations. This is also the case in most states. The primacy agency, like NMED in New Mexico or ADEQ in Arizona, is given federal funding to monitor and enforce the Safe Drinking Water Act. The state's Drinking Water Regulations include all of the SDWA issues and can also include other code regulations for things like system construction or cross connection prevention.

MEETING WATER CONSUMPTION AND PEAK DEMANDS

Peak water consumption periods will vary daily according to seasons and geographic locations. The major responsibility of the operator is to make sure the water is available when it is needed.

SEASONAL DEMANDS

The amount of water used each day will generally vary according to the time of year. Higher daily demands occur during the hot summer months while the demand will tend to drop off during the winter months. Fluctuations in temperature and rainfall may also dictate a rise or fall in daily water consumption.

DAILY PEAK DEMANDS

Ninety percent of the daily water usage will occur during a 16-hour period. The peak demand periods occur between the early hours of the morning, (5am to 10am) and the early evening hours, (5pm to 10pm.) Demand will usually increase earlier in rural areas. In urban areas, peak demands will be higher during the week while in rural areas the highest peak demands occur on weekends.

COMPONENTS OF A WATER SYSTEM

Water systems are made up of a number of devices that are used to deliver water to the customer. The major components can be divided into the areas of the water production, treatment, and distribution.

WATER SOURCES AND TREATMENT

The source of water can be from groundwater, surface water, or water purchased from another water system. Usually the source of your water will determine the type of treatment necessary. In most circumstances, groundwater requires little treatment. Groundwater quality problems include minerals, hardness, and dissolved gasses. Surface water quality issues are turbidity, tastes and odors, and color. Surface water usually requires chemical treatment and filtration.

A water treatment system consists of a number of different processes that are designed to remove the contaminants that may be present in the source water. These processes may include:

- **Chemical precipitation**
- **Chemical adsorption**
- **Chemical oxidation**
- **Gas stripping**
- **Ion exchange and Demineralization**
- **Filtration**
- **Disinfection**

CHEMICAL PRECIPITATION

The addition of chemicals to adjust pH and create insoluble salts can be used to remove many of the minerals contaminants in the raw water. As these chemicals form solid compounds they can be settled or filtered from the water. This is usually a four-part process that consists of chemical addition, floc formation, sedimentation, and filtration. Softening and turbidity removal are chemical precipitation processes.

CHEMICAL ADSORPTION

Dissolved organic compounds can be adsorbed, or soaked up, by activated carbon. The activated carbon is then removed from the process. This process is used to remove some types of tastes and odors. It is also used to remove organic chemicals in the water that are hazardous to public health.

CHEMICAL OXIDATION

Oxidizing chemicals, like chlorine or ozone, are used to remove certain dissolved metals from water. These chemicals cause metals like iron and manganese to change from a dissolved state to a solid. When these metals become oxidized they are chemically changed into small rust particles that can be settled or filtered out of the water. These chemicals can also be used to chemically oxidize dissolved organic compounds that cause taste and odors in water. In some cases, the by-products that are created pose a health risk.

GAS STRIPPING

The addition of air, and more importantly dissolved oxygen, to water can result in the removal of certain dissolved gasses that are responsible for tastes and odors. This aeration process is known as gas stripping.

ION EXCHANGE AND DEMINERALIZATION

Ion exchange and demineralization processes are used when the source water contains unacceptable amounts of certain minerals. Excessive hardness can result scale formation in the distribution system. Iron and manganese create red and black water problems. These processes are used in situations where chemical precipitation is not an option.

Ion exchange processes will remove minerals, like calcium or iron, and replace them with other minerals, usually sodium or potassium. A water softener is the most common type of ion exchange process. Green sand filters are used primarily for iron removal. Arsenic can also be removed with an ion exchange process that uses activated alumina.

Demineralization processes remove minerals from water directly without the exchange of metallic ions. Distillation, reverse osmosis, and electro-dialysis processes are examples of demineralization processes.

FILTRATION

Filtration is a process that usually follows chemical precipitation or oxidation. It is used to remove small solid particles from the water. Pressure filters and gravity filters are the two basic types of filtering processes. Filtration is the final step in conventional turbidity and mineral removal treatment processes.

DISINFECTION

Disinfection processes are used to kill waterborne pathogens that may be present in the source water. This is usually accomplished by chemical addition. Chlorine, ozone, and chlorine dioxide are some of the chemicals that are used for disinfection. Ultraviolet radiation is a disinfection process that does not require chemical addition.

When ozone or ultraviolet radiation is used for disinfection, it is usually followed by chlorination, since neither process produces a residual that can provide protection from secondary contamination in the distribution system. Disinfection is the final step in making raw source water safe to drink.

DISTRIBUTION SYSTEMS WATER LINES

Main lines transport water from the source or from the treatment facility to the area to be served. These pipes are usually the largest in the system. They also serve as feeder lines for those users who are located along them.

SERVICES

Services are small lines (usually 1" or 3/4") that carry water from the main line to the water user. The service connection includes:

- Some means of tapping the main line or feeder line.
- A corporation stop for turning the water off at the main or feeder line.
- Service pipe or tubing.
- Some type of meter setter which includes a meter stop.
- Water meter.
- A fitting for the water customer's connection.

PUMPS

Pumps are used to move raw water from the source into the treatment facility or from the well into the system. They are also used to move treated water from the treatment facility into the system. Pumps are used to create pressure for the system and to fill the water storage facilities.

STORAGE TANKS

Storage tanks hold a reserve of water for those times when the demand for water is greater than can be supplied by the trunk line or by the pumps. They also provide water for fire protection and for those times when the supply might be interrupted.

CONTROLS

Automatic pump controls sense pressure on the system and turn the pump on when the pressure falls below a desired point or when the water level in the water tower drops below a certain level. When the water level in the tower has been restored or when the systems pressure has been raised to normal, the controls automatically turn the pump off. Pump controls can also turn the pump off, if alarm conditions occur. These types of conditions include; high discharge pressure, motor overload, high motor or bearing temperatures, or low suction pressure.

ISOLATION VALVES

Isolation valves are used throughout the system to stop the flow of water. They are usually gate valves or butterfly valves. The trunk line would have at least one isolation valve per mile of line in small rural systems and in large municipal systems they may need to be located every 300-600 feet. Each branch line should have an isolation valve at the point of connection to the trunk line. The proper location of these valves is important in order to isolate small sections of line for repair in an effort to minimize the number of customers that are out of water.

CONTROL VALVES

Control valves are designed to control flows or pressures in the system. There are a number of different applications for the control valves that may be used in the system. They are usually diaphragm operated globe valves that are controlled by hydraulic pilot systems. Here are some of the applications for control valves in a water system:

- Pressure reducing valves - These valves are used to drop the pressure in a distribution zone in order to avoid damage to the system.
- Pressure relief valves - These valves are used to "bleed" water from the system when the pressures reach a point that could result in damage to the system.
- Altitude valves - These valves are used when two or more storage tanks are on the same main line. An altitude valve will isolate the lower tanks and prevent them from overflowing while the other tanks are filling.
- Pressure sustain/flow limiting valves - These valves are used to limit the amount of flow to a certain portion of the system when it drops the pressure in other sections below a certain point.
- Pump control valves - These valves are designed to replace check valves on booster pumps. They are closed when the pump starts and open slowly to minimize surges in the system. They also close before the pump stops.

SURGE TANKS

Surge tanks act as pressurized shock absorbers in the system. They dissipate the pressure spikes caused by water hammer that is caused by sudden changes in movement in the system. Surge tanks are often installed on the discharge header of a booster station or the discharge on a well. Hydropneumatic storage tanks can also act as surge tanks in small systems.

FIRE HYDRANTS

Fire hydrants allow fire-fighting equipment to draw a large volume of water from the system quickly. They may also be used as sampling sites, flushing stations, and vent points for filling drained lines.

BASIC STUDY QUESTIONS

1. What are the three responsibilities of any public water supplier?
2. What are three examples of public water usage?
3. What is a GWUDI water system?
4. What is the most common type of ion exchange water treatment process?
5. What chemical can cause red water problems?

BASIC SAMPLE TEST QUESTIONS

1. Which of the following is not likely to present a water quality issue in a groundwater system?
 - A. Hardness
 - B. Turbidity
 - C. Iron
 - D. Bacteria
2. Peak daily consumption may be 2.5 times the daily average.
 - A. True
 - B. False
3. Which one of the following pH values is acidic?
 - A. 10.9
 - B. 8.2
 - C. 7.0
 - D. 4.5

4. When do daily peak flows occur?
 - A. In the morning
 - B. In the afternoon
 - C. Late at night
5. Water with a pH of 7.0 is:
 - A. Neutral
 - B. Alkaline
 - C. Acidic
 - D. Aerobic
6. Chemical adsorption is used to remove:
 - A. Minerals
 - B. Organic chemicals
 - C. Bacteria
 - D. Turbidity
7. The chemical used in a gas stripping process is:
 - A. Oxygen
 - B. Chlorine
 - C. Iron
 - D. Ozone