

WATER TREATMENT

Disinfection:

The most common and widespread health risk associated with drinking water is microbiological contamination. These organisms can be pathogenic (disease causing) and nonpathogenic. Some common pathogens include bacteria, viruses and protozoa. Diseases can vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhea, dysentery, hepatitis or typhoid fever. Thus it makes it important to disinfect the water to ensure its safety. There are many methods that are available for disinfecting the water. The most common methods include chlorination, ozonation and ultraviolet light. Following is a brief overview of these treatment methods and their practicality.

Chlorination

Chlorine is the standard method of disinfection in the United States. Chlorine is typically added by municipalities as chlorine dioxide (ClO_2) in gaseous form. About 5 parts per million of chlorine gas is injected into the water to produce free chlorine, which is the disinfectant. Chlorine dioxide can be dangerous if improperly used or stored. ClO_2 is highly reactive and can explode violently when exposed to heat, sunlight or subjected to a spark. It is considered to have a moderate to high toxicity to humans and it is highly irritating to the eyes, nose and throat. Chlorine dioxide is not recommended for homeowners/consumer use due to its high reactivity.

Chlorine is typically used because it is effective against bacteria, requires a short to moderate contact time, it is readily available in several forms, and we can measure its effectiveness.

There are some drawbacks to using chlorine as the sole means of disinfection. Chlorine in solution is only moderately stable and can be consumed by organic matter such as iron and manganese if they are present in the water. Chlorine in high doses can cause an objectionable taste and odor and it does not destroy all pathogens, such as chlorine resistant cryptosporidium. One of the biggest disadvantages is the formation of chlorine byproducts. Chlorine reacting with humic and fulvic organic compounds, which are present in all natural waters form trihalomethanes (THMs). These byproducts are more problematic in chlorinating surface waters, due to the abundance of humic and fulvic substances in surface waters. The presence of these substances put an extra demand on the chlorine creating a need for a higher chlorine dosage. The higher the chlorine dosage the more byproducts that are formed, making it difficult to control. THM's are regulated under the U.S. EPA Safe Drinking Water Act and are suspected carcinogens. The U.S. EPA recently reduced the Maximum Contaminant Level for THM's in public water supplies due to studies that link THM's with various health affects including miscarriages and cancer.

As stated above, the use of chlorine is typical in public water supplies throughout the United States. It is also a cost effective way to disinfect a private well. See the section of this page on [disinfecting wells](#) for instructions.

Ozonation

Ozone is trivalent oxygen, meaning it has an extra oxygen atom. It is a gas that has a bluish color when concentrated and a pungent yet distinctive odor. One of the most powerful oxidants available, it provides protection against bacteria, viruses and parasites.

Ozone has typically been used in the municipal water, wastewater treatment and bottled water industries and is now becoming more popular in the residential and small business treatment markets. Ozone has been used since the early 1900's especially in European countries such as France, Germany, Switzerland and the Netherlands. It hasn't been until the last 10-15 years that ozonation has gained more popularity in its use in the United States. Ozone is also used for air treatment applications in addition to water treatment.

Due to the benefits it has over chlorine, ozone is being used more frequently as a disinfectant. The greatest advantage of ozone versus chlorine is that ozone is capable of destroying viruses and waterborne parasites that may be resistant to chlorine. Ozone may also remove color and odor from water without leaving a residue. Chlorine on the other hand, adds odor, it may cause bad taste and odor because of the residual amount of chlorine in the water after disinfection. Use of chlorine may also create byproducts known as trihalomethanes, which are suspected carcinogens.

Due to the fact that ozone cannot be packaged stored or shipped, it must be generated on site near the point of injection into the water or wastewater stream. Ozone can be produced in two ways: corona discharge or ultraviolet radiation. Corona discharge generators work by passing air through a high voltage electrical discharge, which converts some of the oxygen into ozone. The feed air must be free of particulates and moisture therefore, sometimes it becomes necessary to use a drier column to ensure low moisture. Ultraviolet radiation works by irradiating an air stream to ultraviolet light, which converts the oxygen into ozone. Once ozone is produced, it is applied to the water typically through an aeration device. There are many pro and cons to each type of ozone system depending on the application. These specifics should be discussed with the manufacturer.

Since ozone is such a strong oxidizer, it is important to consider how it may oxidize naturally occurring elements in the water that may prove harmful. Specifically, it has been discovered that ozone will convert bromide into bromate. Bromide occurs naturally in ground and surface water sources and may also be found in salts that are used in softening systems. When exposed to ozone, bromide can convert into bromate, which is considered carcinogenic.

Before using ozone it should be determined if bromide is present prior to installing any equipment. Testing should also be done after the system is installed to monitor any conversion and to confirm the conversion rates. The conversion rate is dependent on the matrix of the water and how the ozone is being applied. In December of 1998, the EPA established an MCL for bromate at 0.010 mg/L. The earliest compliance date for public water supplies is January 1, 2002. National Testing Laboratories, Ltd. offers special testing packages for Bromide / Bromate testing for anyone using ozone as a treatment option and for bottlers using ozone as a method of disinfection.

In household applications, ozone is used to oxidize inorganics such as iron, manganese, hydrogen sulfide, tannins and nitrates. Ozone is also useful in oxidizing both natural and synthetic organic materials. Some organics react rapidly and are destroyed while others may react more slowly. In certain cases, some organics are only partially oxidized, however, activated carbon filters then become more effective in removing them. Ozone is a wonderful technology for water treatment, but it does

work best in conjunction with other treatment devices such as water softeners, media filters, RO systems, distillation and activated carbon systems.

Ultraviolet Light

Ultraviolet light as a disinfectant has been around for nearly 75 years; however it has only recently become more widely acceptable and available for residential and commercial uses.

It is gaining significant recognition in the scientific arena due to studies indicating its effectiveness, safety and cost efficiency. Ultraviolet radiation is capable of destroying all types of bacteria, viruses and cysts, which may be resistant to chlorine. According to a study conducted by the American Water Works Association the use of ultraviolet light as a disinfectant produces no carcinogenic, mutagenic chloro-organic by-products.

Radiation energy travels in the form of waves. Ultraviolet waves are shorter than the narrow band of waves visible to the human eye. There are three segments of ultraviolet waves: long, medium and short. The short waves have the greatest germicidal effect. These short waves do not occur naturally on the earth's surface, so they need to be produced through a conversion of electrical energy. This conversion is accomplished with a mercury vapor lamp. An ultraviolet system consists of one or more ultraviolet lamps enclosed in a quartz sleeve. The water passes through the disinfection chamber where it is exposed to UV radiation which kill/inactivates bacteria, viruses and cysts adding nothing to the water.

In order to be most effective, the water entering the UV unit should be prefiltered. Trace minerals and particles in the water can reduce the effectiveness because microorganisms can hide behind particulates. The bulbs should be removed and cleaned at least four times per year and replaced annually.

Carbon Filtration

The term carbon in the water treatment industry typically refers to activated carbon. Activated carbon consists of carbon particles that are treated to increase their surface area and adsorptive properties. Adsorption and absorption are two commonly confused terms. In order to clarify the difference the WQA defines absorption as the process of one substance actually penetrating into the structure of another substance while adsorption is defined as the physical process occurring when liquids gases, or suspended matter adhere to the surface of, or in the pores of an adsorbent medium. The treatment of carbon involves heating a carbon material such as bituminous coal, wood or coconut shell to 700° C or less. This heating is done in the absence of air and then activating takes place at 800° C to 1000° C with oxidizing gasses like steam and carbon dioxide, which helps in forming the pores. Activated carbon's large surface area and adsorptive properties make it effective for removal of organic compounds. Carbon is typically used to remove volatile organic compounds, taste, odor, radon and chlorine. There are certain specialty carbons that can remove some of the heavy metals like lead.

There are generally two types of carbon filters, granular activated carbon, more commonly referred to as GAC and carbon block filters. GAC filters contain a bed of granule or powdered carbon, which the water flows through. The bed of carbon material will trap some of the particulates and adsorb some organic contaminants, chlorine, undesirable taste and odors. A drawback to this filter type is that water can essentially channel around the carbon particles avoiding filtration. The large pores also make ideal conditions for bacteria growth. The organic materials adsorbed by the carbon provide

bacteria with a food source. Typically GAC is used on chlorinated water supplies that would not contain pathogenic bacteria, however nonpathogenic bacteria may be present in the water supply and grow on the media. These nonpathogenic bacteria are referred to as heterotrophic bacteria. The presence of these bacteria in water and within water treatment units continues to be a controversial topic among health officials and water treatment professionals.

Carbon block filters are made with activated carbon that is specially treated and bonded to form a uniform matrix with very small pores. The small pore size allows the filter to physically trap particulates including cyst, asbestos and sediment. The block form also slows the flow rate of water through the filter increasing the contact time and thus increasing the reduction capacity. The large surface area provides ample area for adsorption. These characteristics of block filters make them more effective for removing chlorine, taste and organic compounds. If there is significant particulate in the water, a sediment or fiber filter should be considered. These particulates can clog the carbon block, which would reduce the capacity. Bacteria can pose the same problem with carbon block as with the GAC Filters.

The capacity of carbon filters not only varies from filter to filter but can be effected by the type of water being treated. It is almost impossible to predict exactly the capacity of the carbon. The carbon eventually becomes saturated with the absorbed materials and will begin to release them into the treated water. This is called "breakthrough". Manufacturers make general recommendations about the life of the filter. If you are considering using a carbon filter, a water analysis should be done to determine the levels of the contaminants you wish to reduce. Then based on the manufacturer's instruction you can determine how often the filter should be replaced. It may not be a bad idea to change the filter more often than recommended by the manufacture to ensure safe water.

Ion Exchange/Softener

Water softeners are the most common type of ion exchange systems, and the most widely utilized water treatment for homes and businesses. Softeners are used to treat hard water containing calcium and magnesium bicarbonates. There are various other ion exchange units, which are designed to remove other inorganic contaminants such as iron, manganese, barium, radium nitrates and sulfate.

Water Softening

Softeners are used primarily to treat aesthetic problems. Hard water does not cause any adverse health effects if ingested but can cause problems in the home. It leaves build-up or scale in pipes and on fixtures, and can reduce the life of household appliances such as dishwashers, water heaters and washing machines. It also it takes more soap to wash dishes and clothing thoroughly. In addition hardness effects businesses that utilize boilers, water heaters, water chillers and those businesses that require ultrapure water. The Water Quality Association and the American Society of Agricultural Engineers have adopted the hardness level in Table 1 (see below).

Water softeners basically consist of a pressure tank which contains the cation exchange resin, a separate vessel to store the salt needed to make up the brine solution for regeneration and a control valve which directs the flow of water through the service and regeneration cycles. The most commonly used resin is sulfonated polystyrene co-polymer and the standard regenerant common salt (sodium chloride), although potassium chloride is gaining more acceptance. Most softeners are made with monitoring devices which tell the softener when regeneration is needed and automatically begins the regeneration process. The resin is in the form of tiny beads, which are negatively charged cations. These negative cations attract positive cations such as calcium, magnesium or iron. When these positive cations enter the resin bed they are captured by the exchange resin, which in turn releases the sodium or potassium ions. Once all the sodium or potassium is used up from the resin bed, regeneration is necessary. Regeneration is accomplished by passing a brine solution through the resin bed replenishing the exchange ions. The drawback to softening is the addition of sodium or potassium to the treated water. If sodium chloride is being used it may cause health effects for individuals on a low-sodium diet. At this time there are certain states considering regulating the discharge of brine into the sewer systems which may increase operating costs.

Table 1

<u>Term</u>	<u>Grain/Gallon</u>	<u>Mg/Liter</u>
Soft	Less than 1.0	Less than 17.0
Slightly Soft	1.0 to 3.5	17.1 to 60
Moderately Hard	3.5 to 7.0	60 to 120
Hard	7.0 to 10.5	120 to 180
Very Hard	10.5 and over	180 and over

Ion Exchange

Ion exchange for removing minerals such as iron and manganese works much like the softening process explained above with two exceptions. The system must be an airtight closed system so the iron or manganese does not come into contact with air. This is to keep the iron and/or manganese in solution, so it can be exchanged. Manufacturers of softeners limit the amount of iron to five parts per million, although this is a conservative measure. The pH and hardness levels also effect the efficiency of the softener. This makes it important to test and determine the amount of iron, manganese, pH and hardness in the water to determine the best method of reduction. For effective mineral removal it is also important to have the softener regenerate prior to exhaustion of the resin bed. This means it needs to regenerate more frequently than it would for ordinary water softening.

Nitrates and sulfate can also be removed via ion exchange. Rather than cation resin a strong base anion resin should be used, while the regeneration is still done using salt. Due to the tendency of an increased nitrate concentration over time, it is important to test both the treated and raw water periodically. Other heavy metals, including cadmium, copper, zinc and lead can also be removed to some degree via ion exchange. Since these metals are typically present in the cationic form they are removed much like iron. Softeners used to remove these metals should be regenerated with higher salt levels. Higher salt levels provide the extra force necessary to disassociate these stronger affinity ions from the exchange resin. Softening does not necessarily completely remove all of these metals, so water quality analysis is important to assure the effectiveness of the system.

Radium, a naturally occurring form of radiation, can also be removed from drinking water using ion exchange. A strong acid cation exchange softener with a synthetic organic resin is considered to be

most effective. Ion exchange systems have a much greater capacity for removing radium versus any of the other inorganics. This means an ion exchange unit will continue to remove radium even when it is completely exhausted and loaded with calcium and magnesium.

Softening and ion exchange are great ways to treat water depending on the contaminants that need to be reduced. Before choosing any type of water treatment equipment it important to have an analysis of the water to best determine the filtering needs and install the proper equipment.

Reverse Osmosis & Distillation

Reverse Osmosis

Reverse Osmosis technology has been around for nearly 40 years, mostly used in industrial applications such as desalting plants. In recent years reverse osmosis has been reduced in size to meet water treatment needs in various smaller applications.

Reverse Osmosis is designed to reduce the amount of dissolved solids in water including various ions, metals and fine suspended particulates such as asbestos. In order to better understand reverse osmosis as a water treatment technology we must understand the term osmosis. Osmosis is defined by the Water Quality Association as the natural tendency for water to spontaneously pass through a semipermeable membrane separating two solutions of different concentrations. The water will naturally pass from the less concentrated solution containing fewer dissolved solids to the stronger solution containing more dissolved solids. This in effect causes the stronger solutions to become more diluted which equalizes the strength of the solutions on both sides of the membrane. In reverse osmosis, the water pressure is applied to the concentrated side, which forces the process of osmosis into reverse. Pressure is applied to squeeze the water through the membrane from the concentrated side to the diluted side. The diluted side is the treated water, which is collected in a storage tank for future use. The concentrated side consists of the rejected impurities and are washed away in a stream of wastewater. A typical home R.O. System produces 2-3 gallons of treated water for every 10 gallons of water put through the treatment process. This can change based on membrane type, flow control, feed water quality, temperature and pressure. A standard home R.O. System consists of a pretreatment filter(s), RO membrane, flow regulator, post-treatment filters, storage tanks and a dispensing faucet. The pretreatment will usually include a sediment filter to remove large particulates that can clog or tear the membrane. If the raw water is hard, softeners are used as a pretreatment to lengthen the life of the membrane. Carbon filters may also be used as a pretreatment if the source water contains chlorine or other organic compounds that can damage the membrane. The post-treatment is normally an activated carbon filter to remove any organics the R.O. is not capable of removing ensuring safer product water.

As with any water treatment system it is important to properly maintain the systems to ensure reliable performances. Clogs can significantly effect the performance of the treatment systems. If this is detected in the early stages the membrane can be cleaned and regenerated. If this is not caught early the membrane must be replaced. Also keep in mind the pre and post filters must be replaced on a regular basis based on the manufacturer's instructions. Unfortunately it is hard to see when the membrane is being damaged; so many units now include a TDS monitor to warn users when the system is not functioning properly. If your system does not have a TDS monitor you may want to periodically check the TDS levels in the product water to determine if a problem exists.

Distillation

Distillation is one of the oldest methods used for treating water. Distillation was used in ancient times on ships to convert salt water into a drinkable form. Distillation is commonly used to treat residential water because it is one of the most reliable treatment methods. Distillation is used to remove inorganic compounds like nitrates, sodium, hardness, other heavy metals and radionucleides from drinking water.

The distillation process mimics Mother Nature's hydrologic cycle. In distillation the raw water is heated in the boiling chamber to form steam. This steam is then directed over cooling coils where it is

condensed back into water. Inorganics and other impurities are left behind in the boiling chamber to be flushed into the septic or sewage systems. Distillation can also remove certain volatile organic compounds. The removal of volatiles depends on the chemical characteristics such as the solubility and the boiling point of the chemical to be removed. Volatiles that have a boiling point greater than water can be removed effectively by distillation. Volatiles that have lower boiling points are vaporized along with the water and will recontaminate the product water if not removed prior to condensation. Many distillation units are equipped with gas vents, fractional columns or activated carbon filters to remove the volatiles with lower boiling points. Gas vents are small holes in the unit prior to the cooling coils. These holes allow VOC's to escape prior to the condensation. Fractional columns allow VOC's to condense in a different section of the column than where the water would condense. Finally, activated carbon filters are also used to remove VOC's. These units are typically found at the end of the cooling coils and remove the VOC's prior to the water entering the storage tank.

Regular maintenance of a distillation unit includes cleaning the boiling chamber about once a week. If minerals build up in the boiling chamber, you may have to clean with an acid-type cleaner. Vinegar is a good cleaning agent because it contains a weak acetic acid, but you should check the manufacturer's instructions for other recommendations. If the unit has an activated carbon filter this should be replaced regularly as instructed by the manufacturer.