COMMON WATER PROBLEMS AND THEIR CORRECTIONS

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More problems. . .

INTRODUCTION

Home water supplies often contain dissolved minerals, gasses, bad smells, and unsightly appearances that are objectionable to the homeowner. Usually these problems can be easily corrected by the use of water treatment equipment. Common water problems, their causes and corrective treatments are presented here.

Frequently there can be several methods of correcting a given problem. The selection of the type of equipment and treatment depends on the severity of the problem, the amount of attention the homeowner desires to give the equipment, the cost of the equipment, and the amount of water available to assure proper equipment performance.

It is a very good idea to never under any circumstances select or install equipment on a private water supply without first obtaining a water analysis.

GLOSSARY OF COMMON TERMS USED IN WATER TREATMENT

Grains per Gallon (GPG) - A means of expressing the amount of dissolved minerals in water. One grain per gallon equals 17.1 parts per million (ppm).

Parts Per Million - a common term used in water analysis. One part per million (ppm) equals one pound per million pounds of water. Parts per million may be converted to grains per gallon by dividing by 17.1. One part per million is equal to one milligram per liter.

Compensated Hardness - Always used for determining water softener capacity. It takes into account the amount of iron present in the water as well as hardness content. To determine compensated hardness, add three times the iron content in ppm to the actual hardness.

Example: Actual hardness = 45 grains per gallon, Iron content = 3 ppm (parts per million, same as mg/L, or milligrams per Liter). Twice the iron content (2x3)=6 plus the actual hardness - 45 equals a compensated hardness of 51 grains per gallon.

Ion - Electrically charged ions form when any mineral is dissolved in water. (e.g. when common salt (NaCl) is dissolved in water it forms positively charged ions (NA+) and negatively charged ions (CL-). The positively charged ions are called cations and the negatively charged ions are anions.)

pH - This term is used to express the acidic or basic strength of water. The pH scale ranges from 0 to 14. A pH of 7 is neutral indicating a balance between acidic and basic elements. Values below 7 indicate increasing acid strength as the pH approaches 0. Values above 7 indicate increasing basic strength as the pH approaches 14.

COMMON WATER PROBLEMS AND THEIR CORRECTIONS

HARDNESS - EPA Maximum Contaminant level: N/A

Hardness is due to calcium and magnesium dissolved in water and is measured in grains or ppm. Iron can also contribute to hardness. These elements form scale in piping, water heaters, and dishwashers causing expensive repairs. Hard water increases soap consumption, starches your laundry, leave a scratchy feeling after bathing, leaves hair hard to manage, scales glasses and dishes, and affects taste and tenderness of many cooked foods.

Hardness is removed with a water conditioner (or water softener). The proper size and type of softener depends upon:

1. The compensated hardness (iron content determined)

2. The amount of water used per day (outside faucets excluded)

3. Flow rate required

While this is a matter of opinion to many consumers, usually a water softener should be installed over 5 grains of hardness. By most accounts, anything 5 grains and over is considered hard water and will scale. It is important to understand that the word "hardness" is not a technical term, merely a term of descriptive convenience, hence the difficulty sometimes in determining what exactly is hard water.

IRON- EPA Maximum Contaminant level: *0.3 ppm*

Iron in water imparts a disagreeable metallic taste. It combines with the tannin in tea, coffee, and alcoholic beverages to produce an unpleasant gray to black appearance. It causes red stains in toilets, plumbing fixtures, tableware and laundry. As little as 0.3 ppm of iron can cause these problems.

Iron can exist in water in one of two forms or both. Treatment depends on the form of iron present. Waters containing "ferrous iron" are clear and colorless when drawn. Exposure to air converts ferrous iron into the the insoluble, reddish brown "ferric iron".

Iron may be removed from water by the following methods, depending upon the amount and type of iron present.

FERROUS IRON - A water softener can remove up to 5 ppm of ferrous iron depending upon size and the type of softener. Very large water softeners can remove up to 10 ppm of iron.

FERRIC IRON - If the water contains considerable ferric iron as evidenced by a reddish brown color, use a sediment filter ahead of the water softener. The sediment filter will remove a portion of the insoluble ferric iron and the water softener the soluble ferrous iron.

If a water softener is not your cup of tea, there are other Iron filters which can remove the iron content in your water: Oxidizing filters (greensand), Collodial type filters, Catalytic Filters, and Chlorination and filtration.

Oxidizing iron filters (greensand filters)- Oxidizing filters can remove up to 10 ppm of both ferric (oxidized) and ferrous (clear) iron. They work well with all types of private water system pressure tanks. Sulphur removal is also possible with these filters when levels are 2.0 ppm or less. In cases where both iron and sulphur are present it is suggested that a sediment filter/water softener combination be installed for removal of all iron. The sulphur can then be removed by an oxidizing filter installed after the softener. Oxidizing filters require backwashing and regeneration with a chemical, potassium permanganate. Automatic and manual types are available. Do not use oxidizing filters on water supplies that have a pH of 6.8 or less, sulphur in excess of 2.0 ppm or iron amounts exceeding 10 ppm.

Collodial type filters can remove up to 15 ppm of both ferric (oxidized) and ferrous (clear) iron. It is preferred that they are installed in conjunction with permanent air head type pressure tanks. Colloidal filters are generally backwashed once every 12 days and requires salt to regenerate. They require a water source capable of delivering flows in excess of 5.0 gallons per minute. Successful iron removal is possible within the pH range of 5.5 thru 9.5. Colloidal filters will not work properly on waters that contain tannins or sulphur.

Catalytic type filters can remove up to 10 ppm of both ferric (oxidized) and ferrous (clear iron) as well. The most popular catalytic iron filter is the pyrolox media. Pyrolox works on the principle of a catalyst reaction, but itself remains relatively unchanged. This reaction is accompanied with the formation of intermediate compound or compounds, such as higher oxides of manganese. By alternate composition and decomposition of these oxides, the pyrolox is left unchanged. Pyrolox works on a principle whereby the hydrogen sulfide, iron, and manganese are actually oxidized in the media and simple backwashing cleans the bed. No chemical regeneration is required and nothing is imparted into the drinking water.

Pumice filters can remove up to 25 ppm of both ferric and ferrous iron. The key to Pumice is using it in conjunction with a micronizer and air vent tank. The oxidixed iron works with the pumice to colloid into larger object big enough to be stopped by the pumice media.

A micronizer and air vent tank is a good supplement to assist in any oxidation process. A micronizer is installed ahead of some sort of water storage tank (usually a pressure tank) and its purpose is to inject air into the stream of water passing by. Once air is in the water it works to solidify (oxidize) the iron in the water. The water then either drops to the bottom of the tank to be backwashed through a special bottom drain that might be on the tank, or it passes to the particular iron filtering media in use and stops in the media awaiting backwash.

Chlorination and filtration - this means of iron removal is recommended only when a sulfur, extreme iron bacteria, or taste and odor problem also exists. Use a chemical solution pump to feed chlorine (household bleach) into the line ahead of the pressure tank. Chlorine causes iron in the water to form particles which can be filtered. On low pH waters an acid neutralizing compound should be added to the chlorine solution to facilitate iron removal. Use an activated carbon filter following the pressure tank to remove the iron particles as well as any excess chlorine. **NOTE - THE SUCCESS OF THIS METHOD OF IRON REMOVAL DEPENDS UPON AT LEAST 20 MINUTES OF CONTACT TIME FOR THE CHLORINE TO FULLY REACT WITH THE IRON. THIS CONTACT TIME CAN BE PROVIDED BY A LARGE PRESSURE TANK OR AN ADDITIONAL STORAGE TANK.**

Acidic and Iron corrosion - Waters with a pH below 7 (acid waters) usually will cause iron-pick up in piping systems and contribute to iron staining problems. Blue to green staining will result if the piping is copper. The lower the pH, the greater the corrosive tendency of the water. ***The recommended pH limits of water for use in the home are 7.0 to 10.6. Waters with pH less than 6.8 contain sufficient acidity to cause significant corrosion and should always be treated.*** **Waters containing appreciable amounts of oxygen also tend to be corrosive. Two common methods of treatment to prevent corrosion are:**

1. Neutralization of acidity with an alkaline material.

2. Surface protection with a polyphosphate.

Neutralization of Acid Waters - Acid neutralizing filters contain a mineral that reacts with acidity to raise the pH of water. This process slowly dissolves the mineral and adds a few grains of hardness to the water. Because of the increased hardness and the iron content, a softener is recommended after the mineral is added. The combination of an acid neutralizer filter and softener can be applied to acidic waters containing up to 15 ppm of iron. Acid neutralizing filters require frequent backwashing and the addition of several pounds of mineral once a year.

NOTE: WATERS WITH PH BELOW 5.5 REQUIRE SPECIAL ATTENTION.

Chemical Solution Pump - A chemical solution pump may be used to feed a solution of acid neutralizer into the water system. The feed solution is prepared by dissolving a rapidly soluble powder form of acid neutralizer in water. Both the strength of the feed solution and the chemical solution pump rate can be adjusted to produce any desired pH. On private well systems, the chemical solution pump is wired into the pressure switch so that it operates with the well pump. In the absence of an electrically operated well or water pump (i.e. city or gravity pressure supply) it would be best to use an acid neutralizing filter.

Acid neutralizer solution used with a chemical solution pump provides positive pH elevation without the addition of hardness. After initially setting the pump, no attention is required other than periodic solution preparation and occasional check of pH. Elevating the pH to 8.2 will eliminate the corrosive effects of carbon dioxide which may be present on the water as a dissolved gas.

Surface protection with PolyPhosphate - Polyphosphate is widely used to protect water systems from corrosion. It is not a treatment of water, but instead a treatment of the metal surfaces of the water system. The water is used as a carrier to take polyphosphate to these surfaces where a thin protective film is formed on the metal. This film insulates the metal from attack by oxygen and other corrosive elements**.**

CHLORINE- EPA Maximum Contaminant level: N/A

Cholrine taste and odor in the water is usually caused by Chlorine's deliberate introduction into municipal water supplies for the destruction of bacteria and volatile organics. Chlorine can exist in water in its free state (Called free chlorine) or can make chlorine compounds. Both are equally objectionable.

The most cost effective method to remove chlorine from the water is through a backwashable granular activated carbon filter. This non-maintenance solution eliminates the need to continually change cartridge filters and the media lasts much longer than the cartridge counterparts.

Carbon Filter Cartridges can also be used, but a block carbon filter lasts longer and provides a better sediment filtration than a granular activated cartridge filter. If a reverse osmosis system is used, use only a CTA membrane.

MUSTY, MOLDY, OR WOODY SMELL - EPA Maximum Contaminant level: N/A

Caused by decay of organic matter or non-harmful bacteria. Use a backwashable carbon filter to remove the taste, odor, as well as sediment. In severe cases chlorination of the well and piping system will be necessary.

A reverse osmosis system would serve well to clear up drinking water.

OIL OR GAS - EPA Maximum Contaminant level: Varied based on compound

Caused by natural elements in underground water or by leakage of oil or gasoline storage tanks. Activated carbon filters have been successful in many cases. However, because of the many constituents which might cause this type of taste and odor, results cannot be guaranteed.

ROTTON EGG ODOR IN COLD WATER- EPA Maximum Contaminant level: *N/A*

Caused by hydrogen sulfide gas . This gas is very corrosive and will react with iron to form a black sludge of iron sulfide. Most sulfur waters contain from 1 to 5 ppm of hydrogen sulfide.

Use a chemical feed pump to feed chlorine (bleach) in to the line ahead of the pressure tank (3 ppm of chlorine is required for each ppm of hydrogen sulfide). Chlorine causes the formation of sulfur particles that can be filtered. Install an activated carbon filter following the pressure tank to remove the sulfur particles as well as any excess chlorine.

If it is your desire to have a non-maintenance, non-chemical solution, an aerator (up to 5 ppm of hydrogen sulfide) will solve your problem.

ROTTON EGG ODOR IN HOT WATER ONLY- EPA Maximum Contaminant level: *N/A*

Caused by sulfate reducing bacteria.

Since a magnesium anode in the water heater creates a condition favoring their growth, remove the magnesium anode. Drain and flush the water heater and chlorinate the water heater. Install a polyphosphate feeder on the cold water inlet to the water heater for corrosion protection.

SALTY OR BRACKISH TASTE - EPA Maximum Contaminant level: *250 mg/L*

Caused by high chloride or sulfate content. When the total of chlorides and sulfates exceeds 65 grains per gallon, the disagreeable taste will be noticed by almost all people.

Filtering by Reverse Osmosis is the best way to solve this problem.

SEWAGE - EPA Maximum Contaminant level: Varies on compound

The first thing to do if you suspect that your water is contaminated by sewage is to send a water sample to your local, provincial, or national governing body to determine if sewage pollution is present in your water supply.

Eliminate the source of contamination if possible (Surface runoff, cracked well casing, proximity to septic tank, faulty well seal, etc..). Next, install a chemical feed pump to feed chlorine (household bleach) into the system to a slight excess (i.e. more than is required to react with the amount of contamination present). This assures sufficient chlorine in the system to protect against small fluctuations in the amount of contamination present. Install a drip valve after the chlorinator and get a test kit to test chlorine content. Install a backwashable carbon filter to remove excess chlorine and test for chlorine both before the block carbon filter and after. The reduction of chlorine should be considerable.

Finally, a reverse osmosis unit at the end of the process is recommended (CTA membrane).

NITRATES - EPA Maximum Contaminant level: *10 mg/L*

Nitrates occur in water as a result of seepage through nitrate bearing rocks or soils. The nitrate may also come from fertilizers or pollution with organic wastes. Cyanosis ("blue baby") may occur in infants whose drinking or fomula water contains a high concentration of nitrates. Water containing more than 10-20 ppm of nitrate expressed as nitrogen should not be used for infant feeding. Nitrate is reduced to Nitrite in the body.

Nitrates can be removed from drinking water through Reverse Osmosis. Reductions of up to 96% are achieved.

Nitrates may also be removed throughout the whole house with a Nitrate selective Anion Resin Water Conditioner.

FLOURIDES - EPA Maximum Contaminant level: *2 mg/L*

Flouride in water can be both good or bad, depending on the levels of concentration. Research has shown that a concentration of about one milligram per liter (mg/L or ppm) of fluoride in drinking water reduces tooth decay.

When drinking water contains excessive flouride above two ppm, it causes "endemic dental fluorsis". Sometimes called "Colorado Brown Stain", it appears as a dark brown spotting of the teeth or causes them to become chalky white. Above four milligrams of fluoride per liter can cause crippling skeletal fluorosis, a serious bone disorder.

Reverse Osmosis systems are effective at removing up to 96% of all Flourides present in water. A less expensive way to remove flourides is through a tricalcium phosphate filter.

CARBON DIOXIDE OR CARBONIC ACID - EPA Maximum Contaminant level: N/A

Rain water as it is falling through the sky absorbs Carbon Dioxide to make Carbonic Acid. This acid when it comes into contact with limestone absorbs the calcium from the limestone and this chemical reaction is where hard water comes from. At times, the carbonic acid can't dissolve any substance in the ground, remains acidic, and waits until it gets into a homeowner's house before it begins to dissolve metal pipes and appliances. In certain parts of the country where this problem is prevalent, it is serious.

The solutions are several, but probably the most effective is feeding a solution of soda ash sodium carbonate (NA2CO3). The carbonic acid and the sodium corbonate react directly to form sodium bicarbonate. This method of treatment offers the advantage of not adding hardness to the water.

If Carbon Dioxide is acute, installing an aerator may be all that is necessary to raise the pH.

For less maintenance solutions, passing the water through a calcite feeder effectively neutralizes the carbonic acid and leaves the water slightly hard.

SODIUM - EPA Maximum Contaminant level: N/A

High concentrations of sodium tend to increase the corrosive action of water, give it unpleasant taste, and tend to hamper the operation of ion exchange softeners in the removal of hardness.

Reverse Osmosis, distillation, and deionization remove sodium from water.

METHANE - EPA Maximum Contaminant level: N/A

Wells that contain methane are generally located in areas where gas and oil wells are common sights.

When water contains methane gas it is important to aerate it prior to use for either industrial or household purposes.

PHENOL - EPA Maximum Contaminant level: N/A

An industrial waste. In concentrations as low as 1 part per billion, this can cause an objectionable taste in chlorinated water due to the formation of chlorophenols.

This may be removed by a backwashable carbon filter.

LEAD - EPA Maximum Contaminant level: 0.015 mg/L

At one time it was not generally known that Lead could be poisonous. Unfortunately, this was a time when many of our cities were beginning to provide underground plumbing to many neighborhoods. Lead was used as a soldering agent to fix pipes together. Lead can be extremely dangerous to small children and should be a priority to eliminate.

Certain carbon filters are good lead deterrents as well as a mixed bed de-ionizer.

TOTAL DISSOLVED SOLIDS - EPA Maximum Contaminant level: *500 mg/L*

Pure water is a good conductor of electricity, true or false? The answer might suprise you. Pure water is a very poor conductor of electricity, in fact, it is highly resistant to electrical impulses. Its the other stuff in the water that make it a good conductor of electricity, and the more stuff, the better conductor of electricity water is. The primary inorganic ions that make up TDS is Calcium Ca++, Magnesium Mg++, Sodium Na+, Iron Fe++, Manganese Mn++, Bicarbonate HCO3-, Chloride Cl-, Sulfate SO4--, Nitrate NO3-, Carbonate CO3--.

Reverse Osmosis is the best way to eliminate these wide varieties of total dissolved solids.

VOLATILE ORGANICS

Algae, Diatoms, Fungus, Molds, Bacteria, Viruses, 30 micron worms, Protozoa, Nematodes, need we say more, nasty stuff.

Disinfection methods include distillation, Reverse Osmosis, UV Light, Chemical disinfectants.

CHLORIDE - EPA Maximum Contaminant level: 250 mg/L

A natural forming mineral in seawater and sedimentary rock. The main problems with chlorides have to do with taste, corrosion to pipes, and chlorides is well known for being toxic to plants.

The best way to get rid of chlorides is through Reverse Osmosis or distillation.

FOAMING AGENTS - EPA Maximum Contaminant level: 0.5 mg/L

Detergents, fertilizer, pesticides, herbicides. At small levels, mainly has a negative aesthetic effect.

Carbon filtration or distillation.

MANGANESE - EPA Maximum Contaminant level: 0.05 mg/L

Naturally occurring metamorphic and sedimentary rocks, industrial contaminant. Taste is affected. Staining, scaling, and discoloration of water.

Water Softening.

pH - EPA Maximum Contaminant level: <6.5, >8.5

Carbonates, bicarbonates, carbon dioxide, industrial contaminants. If highly acidic (less than 6.5) it causes corrosion to pipes. If highly basic (greater than 8.5) it causes staining.

Calcite Feeder for low pH, Dealkalyzer for high pH.

SILVER - EPA Maximum Contaminant level: 0.1 mg/L

Natural mineral deposits, battery manufacturing, plating, medical and pharmaceutical manufacturing. Causes Argyria - discoloration of skin.

Ion exchange, Reverse Osmosis, Distillation.

SULFATE - EPA Maximum Contaminant level: 250 mg/L

Naturally occurring, gypsum, mine and industrial wastes. Gives off bad taste and has laxative effects.

Ion exchange, Reverse Osmosis, Distillation.

ZINC - EPA Maximum Contaminant level: 5 mg/L

Corrosion of plumbing materials, industrial contamination. Gives off a foul taste.

Ion exchange, Reverse Osmosis, Distillation.

TURBIDITY - EPA Maximum Contaminant level: 0.5 - 1.0 NTU

Turbidity is caused by erosion runoff and discharges. It mainly has to do with measuring the light shining through a container holding water in question. The less the light, the more the turbidity, the more the light, the less the turbidity. Primarily, turbidity inteferes with UV light or Chlorine disinfection. For this reason it needs to be removed.

Turbidity can be removed by filtration, Reverse Osmosis, Distillation.

COPPER EPA Maximum Contaminant Level: *1.3 mg/L*

Caused by corrosion of interior household and building pipes. Causes stomach and intestinal distress. Wilson's disease.

Ion exchange, Reverse Osmosis, Distillation.

ACIDIC WATER EPA **Maximum Contaminant Level:** ***6.5 pH***

Source - Acidic waters usually attain their acidity from the seepage of acid mine waters, or acidic industrial wastes. Acid mine waters are frequently too low in pH to provide suitable drinking water even after neutralization and treatment.

Treatment - Acidic water can be corrected by injecting soda ash or caustic soda (sodium hydroxide) into the water supply to raise the pH. Utilization of these two chemicals slightly increases the alkalinity in direct proportion to the amount used. Acidic water can also be neutralized up to a point by running it through calcite, corosex or a combination of the two. The calcite and the corosex both neutralize by dissolving and they add hardness to the water as the neutralization takes place; therefore, they both need to be replenished on a periodic basis.

ALUMINUM

Source - Aluminum (Al+3) is an abundant metal in the Earth's surface, but its solubility in water is so low that it is seldom a concern in municipal or industrial water systems. The majority of natural water contains from 0.1 ppm up to 9.0 ppm of Aluminum, however the primary Source of Aluminum in drinking water comes from the use of aluminum sulfate (alum) as a coagulant in water treatment plants. The total dietary exposure to aluminum salts averages around 20 mg/day. Aluminum is on the US EPA's Secondary Drinking Water Standards list with suggested levels of 0.05 - 0.2 mg/l; dependent on case-by-case circumstances.

Treatment - Aluminum can be removed from water by a cation exchanger but hydrochloric acid or sulfuric acid must be used for regeneration to remove the aluminum from the resin. While this is suitable for an industrial application it is not recommended for domestic use unless it is in the form of a cation exchange tank. Reverse Osmosis will reduce the aluminum content of drinking water by 98 + %. Distillation will reduce the aluminum content of water by 99 + %. Electrodialysis is also very effective in the reduction of aluminum.

AMMONIA

Source - Ammonia (NH3) gas, usually expressed as Nitrogen, is extremely soluble in water. It is the natural product of decay of organic nitrogen compounds. Ammonia finds its way into surface supplies from the runoff in agricultural areas where it is applied as fertilizer. It can also find its way to underground aquifers from animal feed lots. Ammonia is oxidized to nitrate by bacterial action. A concentration of 0.1 to 1.0 ppm is typically found in most surface water supplies, and is expressed as N. Ammonia is not usually found in well water supplies because the bacteria in the soil converts it nitrates. The concentration of Ammonia is not restricted by drinking water standards. Since Ammonia is corrosive to copper alloys it is a concern in cooling systems and in boiler feed.

Treatment - Ammonia can be destroyed chemically by chlorination. The initial reaction forms chloramine, and must be completely broken down before there is a chlorine residual. Organic contaminants in the waste stream will be destroyed by the chlorine before it will react with the ammonia. Ammonia can also be removed by cation exchange resin in the hydrogen form, which is the utilization of acid as a regenerant. Degasification will also remove Ammonia.

ARSENIC

Source - Arsenic (As) is not easily dissolved in water, therefore, if it is found in a water supply, it usually comes from mining or metallurgical operations or from runoff from agricultural areas where materials containing arsenic were used as industrial poisons. Arsenic and phosphate easily substitute for one another chemically, therefore commercial grade phosphate can have some arsenic in it. Arsenic is highly toxic and has been classified by the US EPA as a carcinogen. The current MCL for arsenic is 0.05 mg/l which was derived from toxicity considerations rather than carcinogenicity.

Treatment - If in an inorganic form, arsenic can be removed or reduced by conventional water treatment processes. There are five ways to remove inorganic contaminants; reverse osmosis, activated alumina, ion exchange, activated carbon, and distillation. Filtration through activated carbon will reduce the amount of arsenic in drinking water from 40 - 70%. Anion exchange can reduce it by 90 - 100%. Reverse Osmosis has a 90% removal rate, and Distillation will remove 98%. If the arsenic is present in organic form, it can be removed by oxidation of the organic material and subsequent coagulation.

BACTERIA

Source - Bacteria are tiny organisms occurring naturally in water. Not all types of bacteria are harmful. Many organisms found in water are of no health concern since they do not cause disease. Biological contamination may be separated into two groups: (1) pathogenic (disease causing) and
(2) non-pathogenic (not disease causing). Pathogenic bacteria cause illnesses such as typhoid fever, dysentery, gastroenteritis, infectious hepatitis, and cholera. All water supplies should be tested for biological content prior to use and consumption. E.Coli (Escherichia Coli) is the coliform bacterial organism which is looked for when testing the water. This organism is found in the intestines and fecal matter of humans and animals. If E.Coli is found in a water supply along with high nitrate and chloride levels, it usually indicates that waste has contaminated the supply from a septic system or sewage dumping, and has entered by way of runoff, a fractured well casing, or broken lines. If coliform bacteria is present, it is an indication that disease causing bacteria may also be present. Four or fewer colonies / 100 ml of coliforms, in the absence of high nitrates and chlorides, implies that surface water is entering the water system. If pathogenic bacteria is suspected, a sample of water should be submitted to the Board of Health or US EPA for bacteriological testing and recommendations. The most common non-pathogenic bacteria found in water, is iron bacteria. Iron bacteria can be readily identified by the red, feathery floc which forms overnight at the bottom of a sample bottle containing iron and iron bacteria.

Treatment - Bacteria can be treated by microfiltration, reverse osmosis, ultrafiltration, or chemical oxidation and disinfection. Ultraviolet sterilization will also kill bacteria; but turbidity, color, and organic impurities interfere with the transmission of ultraviolet energy and may decrease the disinfection efficiency below levels to insure destruction. Ultraviolet treatment also does not provide residual bactericidal action, therefore periodic flushing and disinfection must be done. Ultraviolet sterilization is usually followed by 0.2 micron filtration when dealing with high purity water systems. The most common and undisputed method of bacteria destruction is chemical oxidation and disinfection. Ozone injection into a water supply is one form of chemical oxidation and disinfection. A residual of 0.4 mg/l must be established and a retention time of four minutes is required. Chlorine injection is the most widely recognized method of chemical oxidation and disinfection. Chlorine must be fed at 3 to 5 ppm to treat for bacteria and a residual of 0.4 ppm of free chlorine must be maintained for 30 minutes in order to meet US EPA standards. Reverse Osmosis will remove 99+ % of the bacteria in a drinking water system.

BARIUM

Source - Barium (Ba^{+2})is a naturally occurring alkaline earth metal found primarily in the midwest. Traces of the element are found in surface and ground waters. It can also be found in oil and gas drilling muds, waste from coal fired power plants, jet fuels, and automotive paints. Barium is highly toxic when its soluble salts are ingested. The current MCL for Barium is 2.0 mg/l.

Treatment - Sodium form cation exchange units (softeners) are very effective at removing Barium. Reverse Osmosis is also extremely effective in its removal, as well as Electrodialysis.

BENZENE

Source - Benzene, a byproduct of petroleum refining, is used as an intermediate in the production of synthesized plastics, and is also an additive in gasoline. Gasoline contains approximately 0.8 percent benzene by volume. Benzene is classified as a volatile organic chemical (VOC) and is considered a carcinogen by the US EPA. Benzene makes its way into water supplies from leaking fuel tanks, industrial chemical waste, pharmaceutical industry waste, or from run off of pesticides. The current US EPA MCL for Benzene is 0.005 mg/l.

Treatment - Benzene can be removed with activated carbon. Approximately 1000 gallons of water containing 570 ppb of benzene can be treated with 0.35 lbs of activated carbon, in other words; 94,300 gallons of water can be treated for every cubic foot of carbon. The benzene must be in contact with the carbon for a minimum of 10 minutes. If the required flow rate is 5 gpm, then 50 gallon of carbon is required; which converts to approx. 7 cu. ft. The activated carbon must be replaced when exhausted.

BICARBONATE ALKALINITY

Source - The Bicarbonate (HCO3) ion is the principal alkaline constituent in almost all water supplies. Alkalinity in drinking water supplies seldom exceeds 300 mg/l. Bicarbonate alkalinity is introduced into the water by CO2 dissolving carbonate-containing minerals. Alkalinity control is important in boiler feed water, cooling tower water, and in the beverage industry. Alkalinity neutralizes the acidity in fruit flavors; and in the textile industry, it interferes with acid dying. Alkalinity is known as a "buffer".

Treatment - In the pH range of 5.0 to 8.0 there is a balance between excess CO2 and bicarbonate ions. The bicarbonate alkalinity can be reduced by removing the free CO2 through aeration. The alkalinity can also be reduced by feeding acid to lower the pH. At pH 5.0 there is only CO2
and 0 alkalinity. A strong base Anion Exchanger will also remove alkalinity.

BORATE (BORON)

Source - Borate B(OH)4- is a compound of Boron. Most of the world's boron is contained in sea water. Sodium borate occurs in arid regions where inland seas once existed but have long since evaporated. Boron is frequently present in fresh water supplies in these same areas in the form of non-ionized boric acid. The amount of boric acid is not limited by drinking water standards, but it can be damaging to citrus crops if it is present in irrigation water and becomes concentrated in the soil.

Treatment - Boron behaves like silica when it is in an aqueous solution. It can be removed with an Anion Exchanger or adsorbed utilizing an Activated Carbon Filter.

BROMINE (BROMIDE)

Source - Bromine is found in sea water and exists as the bromide ion at a level of about 65 mg/l. Bromine has been used in swimming pools and cooling towers for disinfection, however use in drinking water is not recommended. Ethylene bromide is used as an anti-knock additive in gasoline, and methyl bromide is a soil fumigant. Bromine is extremely reactive and corrosive, and will produce irritation and burning to exposed tissues. Over 0.05 mg/l in fresh water may indicate the presence of industrial wastes, possibly from the use of pesticides of biocides containing bromine. Bromide is extensively used in the pharmaceutical industry, and occurs normally in blood in the range of 1.5 to 50 mg/l.

Treatment - Reverse Osmosis will remove 93 -96 % of the bromide from drinking water. Since bromine is a disinfectant, it along with the disinfection by-products can also be removed with Activated Carbon, Ultrafiltration, or Electrodialysis.

CADMIUM

Source - Cadmium enters the environment through a variety of industrial operations, it is an impurity found in zinc. By-products from mining, smelting, electroplating, pigment, and plasticizer production can contain cadmium. Cadmium emissions come from fossil fuel use. Cadmium makes its way into the water supplies as a result of deterioration of galvanized plumbing, industrial waste or fertilizer contamination.. The US EPA Primary Drinking Water Standards lists Cadmium with a 0.005 mg/l MCL.

Treatment - Cadmium can be removed from drinking water with a sodium form cation exchanger (softener). Reverse Osmosis will remove 95 - 98 % of the cadmium in the water. Electrodialysis will also remove the majority of the cadmium.

CALCIUM

Source - Calcium is the major component of hardness in water and is usually in the range of 5 - 500 mg/l, as $CaCO_3$. Calcium is derived from nearly all rock, but the greatest concentrations come from limestone and gypsum. Calcium ions are the principal cations in most natural waters. Calcium reduction is required in treating cooling tower makeup. Complete removal is required in metal finishing, textile operations, and boiler feed applications.

Treatment - Calcium, as with all hardness, can be removed with a simple sodium form cation exchanger (softener). Reverse Osmosis will remove 95 - 98 % of the calcium in the water. Electrodialysis and Ultrafiltration also will remove calcium. Calcium can also be removed with the hydrogen form cation exchanger portion of a deionizer system.

CARBON DIOXIDE

Source - Free carbon dioxide (CO_2) exists in varying amounts in most natural water supplies. Most well waters will contain less than 50 ppm. Carbon Dioxide in water yields an acidic condition. Water (H_2O) plus carbon dioxide (CO_2) yields carbonic acid (H_2CO_3). The dissociation of carbonic acid yields hydrogen (H^+) and bicarbonate alkalinity (HCO_3). The pH value will drop as the concentration of carbon dioxide increases, and conversely will increase as the bicarbonate alkalinity content increases.

$H_2O + CO_2 <====> H_2CO_3 <====> H^+ + HCO_3^-$

Water with a pH of 3.5 or below generally, contains mineral acids such as sulfuric or hydrochloric acid. Carbon Dioxide can exist in waters with pH values from 3.6 to 8.4, but will never be present in waters having a pH of 8.5 or above. The pH value is not a measurement of the amount of carbon dioxide in the water, but rather the relationship of carbon dioxide and bicarbonate alkalinity.

Treatment - Free CO_2 can be easily dissipated by aeration. A two column deionizer (consisting of a hydrogen form strong acid cation and a hydroxide form strong base anion) will also remove the carbon dioxide. The cation exchanger adds the hydrogen ion (H^+) which shifts the above equation to the left in favor of water and carbon dioxide release. The anion resin removes the carbon dioxide by actually removing the bicarbonate ion. A forced draft degasifier placed between the cation and anion will serve to blow off the CO_2 before it reaches the anion bed, thus reducing the capacity requirements for the anion resin. The CO_2 can be eliminated by raising the pH to 8.5 or above with a soda ash or caustic soda chemical feed system.

CARBON TETRACHLORIDE

Source - Carbon tetrachloride ($CCl4$) is a volatile organic chemical (VOC), and is primarily used in the manufacture of chlorofluoromethane but also in grain fumigants, fire extinguishers, solvents, and cleaning agents. Many water supplies across the country have been found to contain measurable amounts of VOC's. VOC's pose a possible health risk because a number of them are probable or known carcinogens. The detection of VOC's in a water supply indicates that a pollution incident has occurred, because these chemicals are man-made. See Volatile Organic Chemicals for a complete listing. The US EPA has classified carbon tetrachloride as a probable human carcinogen and established an MCL of 0.005 mg/l.

Treatment - Reverse Osmosis will remove 70 to 80% of the VOC's in drinking water as will ultrafiltration and electrodialysis. Carbon tetrachloride as well as the other volatile organic chemicals (VOC's) can also be removed from drinking water with activated carbon filtration. The adsorption capacity of the carbon will vary with each type of VOC. The carbon manufacturers can run computer projections on many of these chemicals and give an estimate as to the amount of VOC which can be removed before the carbon will need replacement.

CHLORIDE

Source- Chloride (Cl^{-1}) is one of the major anions found in water and are generally combined with calcium, magnesium, or sodium. Since almost all chloride salts are highly soluble in water, the chloride content ranges from 10 to 100 mg/l. Sea water contains over 30,000 mg/l as NaCl. Chloride is associated with the corrosion of piping because of the compounds formed with it; for example, magnesium chloride can generate hydrochloric acid when heated. Corrosion rates and the iron dissolved into the water from piping increases as the sodium chloride content of the water is increased. The chloride ion is instrumental in breaking down passivating films which protect ferrous metals and alloys from corrosion, and is one of the main causes for the pitting corrosion of stainless steel. The SMCL (suggested maximum contaminant level) for chloride is 250 mg/l which is due strictly to the objectionable salty taste produced in drinking water.

Treatment - Reverse Osmosis will remove 90 - 95% of the chlorides because of it's salt rejection capabilities. Electrodialysis and distillation are two more processes which can be used to reduce the chloride content of water. Strong base Anion Exchanger which is the later portion of a two column deionizer does an excellent job at removing chlorides for industrial applications.

CHLORINE

Source- Chlorine is the most commonly used agent for the disinfection of water supplies. Chlorine is a strong oxidizing agent capable of reacting with many impurities in water including ammonia, proteins, amino acids, iron, and manganese. The amount of chlorine required to react with these substances is called the chlorine demand. Liquid chlorine is sodium hypochlorite. Household liquid bleach is 5-1/4% sodium hypochlorite. Chlorine in the form of a solid is calcium hypochlorite. When chlorine is added to water, a variety of chloro-compounds are formed. An example of this would be when ammonia is present, inorganic compounds known as chloramines are produced. Chlorine also reacts with residual organic material to produce potentially carcinogenic compounds, the Trihalomethanes (THM's): chloroform, bromodichloromethane, bromoform, and chlorodibromomethane. THM regulations has required that other oxidants and disinfectants be considered in order to minimize THM formation. The other chemical oxidants being examined are: potassium permanganate, hydrogen peroxide, chloramines, chlorine dioxide, and ozone. No matter what form of chlorine is added to water, hypochlorite, hypochlorous acid, and molecular chlorine will be formed. The reaction lowers the pH, thus making the water more corrosive and aggressive to steel and copper pipe.

Treatment - Chlorinated water can be dosed with sulfite-bisulfite-sulfur dioxide or passed through a activated carbon filter. Activated carbon will remove 880,000 ppm of free chlorine per cubic foot of media.

CHROMIUM

Source - Chromium is found in drinking water as a result of industrial waste contamination. The occurrence of excess chromium is relatively infrequent. Proper tests must be run on the water supply to determine the form of the chromium present. Trivalent chromium (Cr=3) is slightly soluble in water, and is considered essential in man and animals for efficient lipid, glucose, and protein metabolism. Hexavalent chromium
(Cr=6) on the other hand is considered toxic. The US EPA classifies chromium as a human carcinogen. The current Drinking Water Standards MCL is .005 mg/l.

Treatment - Trivalent chromium (Cr+3)can be removed with strong acid cation resin regenerated with hydrochloric acid. Hexavalent chromium (Cr+6)on the other hand requires the utilization of a strong base anion exchanger which must be regenerated with caustic soda (sodium hydroxide) NaOH. Reverse Osmosis can effectively reduce both forms of chromium by 90 to 97%. Distillation will also reduce chromium.

COLOR

Source - Color in water is almost always due to organic material which is usually extracted from decaying vegetation. Color is common in surface water supplies, while it is virtually non-existent in spring water and deep wells. Color in water may also be the result of natural metallic ions (iron and manganese). A yellow tint to the water indicates that humic acids are present, referred to as "tannins". A reddish color would indicate the presence of precipitated iron. Stains on bathroom fixtures and on laundry are often associated with color also. Reddish-brown is ferric hydroxide (iron) will precipitate when the water is exposed to air. Dark brown to black stains are created by manganese. Excess copper can create blue stains.

Treatment - Color is removed by chemical feed, retention and filtration. Activated carbon filtration will work most effectively to remove color in general. Anion scavenger resin will remove tannins, but must be preceded by a softener or mixed with fine mesh softener resin. See the headings Iron, Manganese, and Copper for information their removal or reduction.

COPPER

Source - Copper (Cu+3) in drinking water can be derived from rock weathering, however the principal Sources are the corrosion of brass and copper piping and the addition of copper salts when treating water supplies for algae control. Copper is required by the body for proper nutrition. Insufficient amounts of copper leads to iron deficiency. However, high doses of copper can cause liver damage or anemia. The taste threshold for copper in drinking water is 2 - 5 mg/l. The US EPA has proposed a maximum contaminant level (MCL) of 1.3 mg/l for copper.

Treatment - Copper can be reduced or removed with sodium form strong acid cation resin (softener) dependent on the concentration. If the cation resin is regenerated with acid performance will be enhanced. Reverse osmosis or electrodialysis will remove 97 - 98 % of the copper in the water supply. Activated carbon filtration will also remove copper by adsorption.

CRYPTOSPORIDIUM

Source - Cryptosporidium is a protozoan parasite which exists as a round oocyst about 4 to 6 microns in diameter. Oocysts pass through the stomach into the small intestine where it's sporozoites invade the cell lining of the gastrointestinal tract. Symptoms of infection include diarrhea, cramps, nausea, and low grade fever.

Treatment - Filtration is the most effective treatment for protozoan cysts. Cartridge POU filters rated at 0.5 micron are designed for this purpose. **Back to Contaminant list.**

CYANIDE

Source - Cyanide (CN-) is extremely toxic and is not commonly found at significant levels in drinking water. Cyanide is normally found in waste water from metal finishing operations. The US EPA has not classified cyanide as a carcinogen because of inadequate data. No MCL level established or even proposed.

Treatment - Chlorine feed, retention, and filtration will break down the cyanide. Reverse Osmosis or Electrodialysis will remove 90 - 95 % of it.

FLUORIDE

Source - Fluoride (F+) is a common constituent of many minerals. Municipal water treatment plants commonly add fluoride to the water for prevention of tooth decay, and maintain a level of 1.5 - 2.5 mg/l. Concentrations above 5 mg/l are detrimental to tooth structure. High concentrations are contained in waste water from the manufacture of glass and steel, as well as from foundry operations. Organic fluorine is present in vegetables, fruits, and nuts. Inorganic fluorine, under the name of sodium fluoride, is a waste product of aluminum and is used in some rat poisons. The MCL established for drinking water by the US EPA is 4 mg/l.

Treatment - Fluoride can be reduced by anion exchange. Adsorption by calcium phosphate, magnesium hydroxide or activated carbon will also reduce the fluoride content of drinking water. Reverse osmosis will remove 93 - 95 % of the fluoride.

GIARDIA LAMBLIA

Source- Giardia is a protozoan which can exist as a trophozoite, usually 9 to 21 mm long, or as an ovoid cyst, approximately 10 mm long and 6 mm wide. Protozoans are unicellular and colorless organisms that lack a cell wall. When Giardia are ingested by humans, symptoms include diarrhea, fatigue, and cramps. The US EPA has a treatment technique in effect for Giardia.

Treatment - Slow sand filtration or a diatomaceous earth filter can remove up to 99 % of the cysts when proper pretreatment is utilized. Chemical oxidation - disinfection, Ultrafiltration, and reverse osmosis all effectively remove Giardia cysts. Ozone appears to be very effective against the cysts when utilized in the chemical oxidation - disinfection process instead of chlorine. The most economical and widely used method of removing Giardia is mechanical filtration. Because of the size of the parasite, it can easily be removed with precoat, solid block carbon, ceramic, pleated membrane, and spun wrapped filter cartridges.

HARDNESS

Source - Hard water is found over 80% of the United States. The hardness of a water supply is determined by the content of calcium and magnesium salts. Calcium and magnesium combine with bicarbonates, sulfates, chlorides, and nitrates to form these salts. The standard domestic measurement for hardness is grains per gallon (gpg) as $CaCO_3$. Water having a hardness content less than 0.6 gpg is considered commercially soft. The calcium and magnesium salts which form hardness are divided into two categories: 1) Temporary Hardness (containing carbonates), and 2) Permanent Hardness (containing non-carbonates). Below find listings of the various combinations of permanent and temporary hardness along with their chemical formula and some information on each.

*** Temporary Hardness Salts ***

1. Calcium Carbonate ($CaCO_3$) - Known as limestone, rare in water supplies. Causes alkalinity in water.
2. Calcium Bicarbonate [$Ca(HCO_3)_2$] - Forms when water containing CO2 comes in contact with limestone. Also causes alkalinity in water. When heated CO_2 is released and the calcium bicarbonate reverts back to calcium carbonate thus forming scale.

3. Magnesium Carbonate ($MgCO_3$) - Known as magnesite with properties similar to calcium carbonate.
4. Magnesium Bicarbonate [$Mg(HCO_3)_2$] - Similar to calcium bicarbonate in its properties.

*** Permanent Hardness Salts ***

1. Calcium Sulfate ($CaSO_4$) - Know as gypsum, used to make plaster of paris. Will precipitate and form scale in boilers when concentrated.
2. Calcium Chloride ($CaCl_2$) - Reacts in boiler water to produce a low pH as follows: CaCl2 + 2HOH ==> Ca(OH)2 + 2HCl
3. Magnesium Sulfate ($MgSO_4$) - Commonly known as epsom salts, may have laxative effect if great enough quantity is in the water.
4. Magnesium Chloride ($MgCl_2$) - Similar in properties to calcium chloride.

Sodium salts are also found in household water supplies, but they are considered harmless as long as they do not exist in large quantities. The US EPA currently has no national policy with respect to the hardness or softness of public water supplies.

Treatment - Softeners can remove compensated hardness up to a practical limit of 100 gpg. If the hardness is above 30 gpg or the sodium to hardness ratio is greater than 33%, then economy salt settings can not be used. If the hardness is high, then the sodium will be high after softening, and may require that reverse osmosis be used for producing drinking water.

HYDROGEN SULFIDE

Source - Hydrogen Sulfide (H_2S) is a gas which imparts its "rotten egg" SULFIDE odor to water supplies. Such waters are distasteful for drinking purposes and processes in practically all industries. Most sulfur waters contain from 1 to 5 ppm of hydrogen sulfide. Hydrogen sulfide can interfere with readings obtained from water samples. It turns hardness and pH tests gray, and makes iron tests inaccurate. Chlorine bleach should be added to eliminate the H_2S odor; then the hardness, pH and iron tests can be done. Hydrogen sulfide can not be tested in a lab, it must be done in the field. Hydrogen sulfide is corrosive to plumbing fixtures even at low concentrations. H_2S fumes will blacken or darken painted surfaces, giving them a "smoked" appearance.

Treatment - H_2S requires chlorine to be fed in sufficient quantities to eliminate it, while leaving a residual in the water (3 ppm of chlorine is required for each ppm of hydrogen sulfide). Activated carbon filtration may then be installed to remove the excess chlorine.

IRON

Source - Iron occurs naturally in ground waters in three forms, Ferrous Iron (clear water iron), Ferric Iron (red water iron), and Heme Iron (organic iron). Each can exist alone or in combination with the others. Ferrous iron, or clear water iron as it is sometimes called, is ferrous bicarbonate. The water is clear when drawn but when turns cloudy when it comes in contact with air. The air oxidizes the ferrous iron and converts it to ferric iron. Ferric iron, or ferric hydroxide, is visible in the water when drawn; hence the name "red water iron". Heme iron is organically bound iron complexed with decomposed vegetation. The organic materials complexed with the iron are called tannins or lignins. These organics cause the water to have a weak tea or coffee color. Certain types of bacteria use iron as an energy Source. They oxidize the iron from its ferrous state to its ferric state and deposit it in the slimy gelatinous material which surround them. These bacteria grow in stringy clumps and are found in most iron bearing waters.

Treatment - Ferrous iron (clear water iron) can be removed with a softener provided it is less than 0.5 ppm for each grain of hardness and the pH of the water is greater than 6.8. If the ferrous iron is more than 5.0 ppm, it must be converted to ferric iron by contact with a oxidizing agent such as chlorine, before it can be removed by mechanical filtration. Ferric iron (red water iron) can simply be removed by mechanical filtration. Heme iron can be removed by an organic scavenger anion resin, or by oxidation with chlorine followed by mechanical filtration. Oxidizing agents such as chlorine will also kill iron bacteria if it is present.

LEAD

Source - Lead (Pb+2) found in fresh water usually indicates contamination from metallurgical wastes or from lead-containing industrial poisons. Lead in drinking water is primarily from the corrosion of the lead solder used to put together the copper piping. Lead in the body can cause serious damage to the brain, kidneys, nervous system, and red blood cells. The US EPA considers lead to be a highly toxic metal and a major health threat. The current level of lead allowable in drinking water is 0.05 mg/l.

Treatment - Lead can be reduced considerably with a water softener. Activated carbon filtration can also reduce lead to a certain extent. Reverse Osmosis can remove 94 to 98 % of the lead in drinking water at the point-of-use. Distillation will also remove the lead from drinking water.

LEGIONELLA

Source - In July 1976, there was an outbreak of pneumonia effecting 221 people attending the annual Pennsylvania American Legion convention at the Bellvue-Stratford Hotel in Philadelphia. Out of the 221 people infected, 34 died. It wasn't until December 1977 that microbiologists were able to isolate a bacterium from the autopsy of the lung tissue of one of the legionnaires. The bacterium was named "Legionella pneumophila" (Legionella in honor of the American Legion, and pneumophila which is Greek for "lung-loving") and was found to be completely different from other bacteria. Unlike patients with other pneumonias, patients with legionnaire's disease often have severe gastrointestinal symptoms, including diarrhea, nausea, and vomiting. The US EPA has not set a MCL (maximum contamination level) for Legionella, instead it has outlined the treatment method which must be followed and the MCLG is 0 mg/l.
Treatment - Chemical oxidation-disinfection followed by retention, then filtration could be used. Since Legionella is a bacteria, Reverse osmosis or Ultrafiltration are the preferred removal techniques.

MAGNESIUM

Source - Magnesium (Mg+2) hardness is usually approximately 33% of the total hardness of a particular water supply. Magnesium is found in many minerals, including dolomite, magnesite, and many types of clay. It is in abundance in sea water where its' concentration is five (5) times the amount of calcium. Magnesium carbonate is seldom a major component of in scale. However, it must be removed along with calcium where soft water is required for boiler make-up, or for process applications.
Treatment - Magnesium may be reduced to less than 1 mg/l with the use of a softener or cation exchanger in hydrogen form. Also see "Hardness".

MANGANESE

Source - Manganese (Mn+4, Mn+2) is present in many soils and sediments as well as in rocks whose structures have been changed by heat and pressure. It is used in the manufacture of steel to improve corrosion resistance and hardness. Manganese is considered essential to plant and animal life and can be derived from such foods as corn, spinach, and whole wheat products. It is known to be important in building strong bones and may be beneficial to the cardiovascular system. Manganese may be found in deep well waters at concentrations as high as 2 - 3 mg/l. It is hard to treat because of the complexes it can form which are dependent on the oxidation state, pH, bicarbonate-carbonate-OH ratios, and the presence of other minerals, particularly iron. Concentrations higher than 0.05 mg/l cause manganese deposits and staining of clothing and plumbing fixtures. The stains are dark brown to black in nature. The use of chlorine bleach in the laundry will cause the stains to set. The chemistry of manganese in water is similar to that of iron. High levels of manganese in the water produces an unpleasant odor and taste. Organic materials can tie up manganese in the same manner as they do iron, therefore destruction of the organic matter is a necessary part of manganese removal.

Treatment - Removal of manganese can be done by ion exchange (sodium form cation - softener) or chemical oxidation - retention - filtration. Removal with a water softener dictates that the pH be 6.8 or higher and is beneficial to use countercurrent regeneration with brine make-up and backwash utilizing soft water. It takes 1 ppm of oxygen to treat 1.5 ppm of manganese. Greensand filter with potassium will remove up to 10 ppm if pH is above 8.0. Birm filter with air injection will reduce manganese if pH is 8.0 to 8.5. Chemical feed (chlorine, potassium permanganate, or hydrogen peroxide) followed by 20 minutes retention and then filtered with birm, greensand, carbon, or Filter Ag will also remove the manganese.

MERCURY

Source - Mercury (Hg) is one of the least abundant elements in the earth's crust. It exists in two forms, an inorganic salt or an organic compound (methyl mercury). Mercury detected in drinking water is of the inorganic type. Organic mercury inters the food chain through fish and comes primarily from industrial chemical manufacturing waste or from the leaching of coal ash. If inorganic mercury inters the body, it usually settles in the kidneys. Whereas organic mercury attacks the central nervous system. The MCL (maximum contamination level) for mercury set by the US EPA is 0.002 mg/l.
Treatment - Activated carbon filtration is very effective for the removal of mercury. Reverse osmosis will remove 95 - 97 % of it.

METHANE

Source - Methane (CH4), often called marsh gas, is the primary component of natural gas. It is commonly found where land fills once existed and is generated from decaying of plants or other carbon based matter. It can also be found in and around oil fields. Methane is colorless, odorless, nearly invisible, highly flammable, and often found in conjunction with other gases such as hydrogen sulfide. Even though methane gas gives water a milky appearance which makes it aesthetically unpleasant, there are no known health effects.
Treatment - Aeration or degasification is the only way to eliminate the problem of methane gas. Venting the casing and/or the cap of the well will reduce the problem of methane in the water, but may not completely eliminate it. Another method is to provide an atmospheric holding tank where the methane laden water can be vented to allow the gas to dissipate. This method may not be 100% effective either. An aerator or degasifier is the proper piece of equipment to utilize for the removal of methane. Water is introduced through the top, sometimes through spray nozzles, and allowed to percolate through a packing material. Air is forced in the opposite direction to the water flow. The water is then collected in the bottom of the unit and repressurized.

NICKEL

Source - Nickel (Ni+2) is common, and exists in approximately 85% of the water supplies, and is usually around 1 ppb (part per billion). The US EPA has classified nickel as a possible human carcinogen based on inhalation exposure. Nickel has not been shown to be carcinogenic via oral exposure. No MCLG (maximum contamination level goal) has been proposed.
Treatment - Nickel behaves the same as iron, and can be removed by a strong acid cation exchanger. Activated carbon filtration can be used to reduce the amount of nickel in drinking water, but may not remove it all. Reverse osmosis will remove 97 - 98 % of the nickel from drinking water.

NITRATE

Source - Nitrate (NO3) comes into water supplies through the nitrogen cycle rather than via dissolved minerals. It is one of the major ions in natural waters. Most nitrate that occurs in drinking water is the result of contamination of ground

water supplies by septic systems, feed lots, and agricultural fertilizers. Nitrate is reduced to nitrite in the body. The US EPA's MCL for nitrate is 10 mg/l.
Treatment - Reverse Osmosis will remove 92 - 95% of the nitrates and/or nitrites. Anion exchange resin will also remove both as will distillation.

NITRITE

Source - Nitrites are not usually found in drinking water supplies at concentrations above 1 or 2 mg/l (ppm). Nitrates are reduced to nitrites in the saliva of the mouth and upper GI tract. This occurs to a much greater degree in infants than in adults, because of the higher alkaline conditions in their GI tract. The nitrite then oxidizes hemoglobin in the blood stream to methemoglobin, thus limiting the ability of the blood to carry oxygen throughout the body. Anoxia (an insufficiency of oxygen) and death can occur. The US EPA has established the MCL (maximum contaminant level) for nitrite at 1 mg/l.
Treatment - Nitrites are removed in the same manner as nitrates; reverse osmosis, anion exchange, or distillation. See Nitrate - Treatment.

ODOR

Source - Taste and odor problems of many different types can be encountered in drinking water. Troublesome compounds may result from biological growth or industrial activities. The tastes and odors may be produced in the water supply, in the water treatment plant from reactions with treatment chemicals, in the distribution system, and/or in the plumbing of consumers. Tastes and odors can be caused by mineral contaminants in the water, such as the "salty" taste of water when chlorides are 500 mg/l or above, or the "rotten egg" odor caused by hydrogen sulfide. Odor in the drinking water is usually caused by blue-green algae. Moderate concentrations of algae in the water can cause it to have a "grassy", "musty" or "spicy" odor. Large quantities can cause the water to have a"rotten", "septic", "fishy" or "medicinal" odor. Decaying vegetation is probably the most common cause for taste and odor in surface water supplies. In treated water supplies chlorine can react with organics and cause odor problems. Odor is listed in the Secondary Drinking Water Standards by the US EPA. The contaminant effects are strictly aesthetic and a suggested Threshold Odor Number (TON) of 3 is recommended.

Treatment - Odor can be removed by oxidation-reduction or by activated carbon adsorption. Aeration can be utilized if the contaminant is in the form of a gas, such as H2S (hydrogen sulfide). Chlorine is the most common oxidant used in water treatment, but is only partially effective on taste and odor. Potassium permanganate and oxygen are also only partially effective. Chloramines are not at all effective for the treatment of taste and odor. The most effective oxidizers for treating taste and odor, are chlorine dioxide and ozone. Activated carbon has an excellent history of success in treating taste and odor problems. The life of the carbon depends on the presence of organics competing for sites and the concentration of the odor causing compound.

ORGANICS

Source - Organic matter makes up a significant part of the soil, therefore water soluble organic compounds are present in all water supplies. Organic matter is reported on a water analysis as carbon, as it is in the TOC (total organic carbon) determination. The following is a list of organics which is regulated under the Safe Drinking Water Act of 1986.

Endrin
Lindane
Methoxychlor
Toxaphene
2,4-D
2,4,5-TP
Aldicarb
Chlordane
Dalapon
Diquat
Endothall
Glyphosate
Carbofuran
Alachlor
Epichlorohydrin
Toluene
Adipates
Hexachlorocyclopentadiene
1,1,2-Trichloroethane
2,3,7,8-Tetrachlorodibenzodioxin (dioxin)
Vydate
Simazine
Polynuclear aromatic hydrocarbons (PAH)
Polychlorinated biphenyls (PCB)
Phthalates
Atrazine
Acrylamide
Dibromochloropropane (DBCP)
1,2-Dichloropropane
Pentachlorophenol
Pichloram
Dinoseb
Ethylene dibromide (EDB)
Dibromomethane
Xylene

Organics come from **three major Sources**:

1. The breakdown of naturally occurring organic materials.
2. Domestic and commercial chemical wastes.
3. Chemical reactions that occur during water treatment processes.

The **first Source** is comprised of humic materials, microorganisms, and petroleum-based aliphatic and aromatic hydrocarbons. The **second source**, derived from domestic and commercial chemical wastes include wastewater discharges, agricultural runoff, urban runoff, and leaching from contaminated soils. Organic contaminants comprising the **third source** which are formed during water treatment include disinfection by-products such as THM's (Trihalomethanes), or undesirable components of piping assembly such as joint adhesives.

Treatment - Activated carbon is generally used to remove organics, color, and taste-and-odor causing compounds. The contact time and service flow rate dictate the size of the carbon filter. When removing organics, restrict flow rates to 2 gpm per square foot of the filter bed. Reverse Osmosis will remove 98 to 99% of the organics in the water. Ultrafiltration (UF) and nanofiltration (NF) have both been proven to remove organics. Anion exchange resin also retains organics, but periodically needs cleaning.

PESTICIDES

Source - Pesticides are common synthetic organic chemicals (SOCs). Pesticides reach surface and well water supplies from the runoff in agricultural areas where they are used. Certain pesticides are banned by the government because of their toxicity to humans or their adverse effect on the environment. Pesticides usually decompose and break down as they perform their intended function. Low levels of pesticides are found where complete break down does not occur. There is no US EPA maximum contamination level (MCL) for pesticides as a total, each substance is considered separately.

Treatment - Activated carbon filtration is the most effective way to remove organics whether synthetic (like pesticides) or natural. Ultrafiltration will also remove organic compounds. Reverse Osmosis will remove 97 - 99% of the pesticides.

pH

Source - The term "pH" is used to indicate acidity or alkalinity of a given solution. It is not a measure of the quantity of acid or alkali, but rather a measure of the relationship of the acid to the alkali. The pH value of a solution describes its hydrogen-ion activity. The pH scale ranges between
0 and 14.
Acidic [0]=========[7]==========[14] Alkaline
Typically all natural waters fall within the range of 6.0 to 8.0 pH. A value of 7.0 is considered to be a neutral pH. Values below 7.0 are acidic and values above 7.0 are alkaline. The pH value of water will decrease as the content of CO2 increases, and will increase as the content of bicarbonate alkalinity increases. The ratio of carbon dioxide and bicarbonate alkalinity (within the range of 3.6 to 8.4) is an indication of the pH value of the water. Water with a pH value of 3.5 or below, generally contains mineral acids such as sulfuric or hydrochloric acid.
Treatment - The pH can be raised by feeding sodium hydroxide (caustic soda), sodium carbonate (soda ash), sodium bicarbonate, potassium hydroxide, etc. into the water stream. A neutralizing filter containing Calcite (calcium carbonate - CaCO3) and/or Corosex (magnesium oxide - MgO) will combat low pH problems, if within the range of 5 to 6. the peak flow rate of a neutralizing filter is 6 gpm / sq. ft. Downflow filters require frequent backwashing is required to prevent "cementing of the bed". A 50 - 50 mix of the two seems to provide the best all around results. Upflow neutralizers don't experience the problem of "cementing" of the bed.

POTASSIUM

Source - Potassium (K+) is an alkaline metal closely related to sodium. It is seldom that one sees it analyzed separately on a water analysis. Potassium is not a major component in public or industrial water supplies. Potassium is, however, essential in a well balanced diet and can be found in fruits such as bananas.
Treatment - Potassium can be removed by a cation exchange resin, usually in the form of a softener. It can also be reduced by 94 - 97% utilizing Electrodialysis or reverse osmosis.

RADIUM

Source - Radium (Ra) is a radioactive chemical element which can be found in very small amounts in pitchblende and other uranium minerals. It is used in the treatment of cancer and some skin diseases. Radium 226 and radium 228 are of most concern when found in drinking water because of the effects on the health of individuals. Radium 228 causes bone sarcomas. Radium 226 induces carcinomas in the head. Radioactivity in water can be naturally occurring or can be from man-made contamination. Radiation is generally measured in curies (Ci). One curie equals 3.7 x 1010 nuclear transformations per second. A picocurie (pCi) equals 10-12 curies. The US EPA has set the MCL (maximum contamination level) for radium 226 and 228 at 5 pCi/L under the NIPDWR (national interim primary drinking water regulations).
Treatment - Radium can be removed by sodium for cation exchange resin in the form of a water softener. Reverse Osmosis will remove 95 - 98% of any radioactivity in the drinking water.

RADON

Source - Radon (Rn) is a radioactive gaseous chemical element formed in the atomic disintegration of radium. Radon 222 is one of the radionuclides of most concern when found in drinking water. It is a naturally occurring isotope, but can also come from man-made Sources. All radionuclides are considered carcinogens, but the organs they target vary. Since radon 222 is a gas, it can be inhaled during showers or while washing dishes. There is a direct relationship between radon 222 and lung cancer.Under the NIPDWR (national interim primary drinking water regulations), the MCL (maximum contamination level) for radon 222 is set at 15 pCi/L (see radium for explanation of how radiation is measured).
Treatment - Radon is easily removed by aeration, since it is a gas. Carbon filtration is also very effective in removing radon.

SELENIUM

Source - Selenium (Se) is essential for human nutrition, with the majority coming from food. The concentration found in drinking water is usually low, and comes from natural minerals. Selenium is also a by-product of copper mining / smelting. It is used in photoelectric devises because it's electrical conductivity varies with light. Naturally occurring selenium compounds have not been shown to be carcinogenic in animals. However, acute toxicity caused by high selenium intake has been observed in laboratory animals and in animals grazing in areas where high selenium levels exist in the soil. The US EPA has established the MCL for selenium at 0.05 mg/l.

Treatment - Anion exchange can reduce the amount of selenium in drinking water by 60 - 95%. Reverse Osmosis is excellent at reduction of selenium.

SILICA

Source - Silica (SiO_2) is an oxide of silicon, and is present in almost all minerals. It is found in surface and well water in the range of 1 - 100 mg/l. Silica is considered to be colloidal in nature because of the way it reacts with adsorbents. A colloid is a gelatinous substance made up of non-diffusible particles that remain suspended in a fluid medium. Silica is objectionable in cooling tower makeup and boiler feedwater. Silica evaporates in a boiler at high temperatures and then redeposits on the turbine blades. These deposits must be periodically removed or damage to the turbine will occur. Silica is not listed in the Primary or the Secondary Drinking Water Standards issued by the US EPA.
Treatment - Silica can be removed by the anion exchange portion of the demineralization process. Reverse Osmosis will reject 85 - 90% of the silica content in the water.

SILVER

Source - Silver (Ag) is a white, precious, metallic chemical element found in natural and finished water supplies. Silver oxide can be used as a disinfectant, but usually is not. Chronic exposure to silver results in a blue-gray color of the skin and organs. This is a permanent aesthetic effect. Silver shows no evidence of carcinogenicity. Silver has a suggested level of 0.1 mg/l under the US EPA Secondary Drinking Water Standards.
Treatment - Silver can be reduced by 98% with distillation, up to 60% with activated carbon filtration, up to 90% with cation exchange or anion exchange (dependent on the pH), or up to 90% by Reverse Osmosis.

SOCs (Synthetic Organic Chemicals)

Source - Over 1000 SOCs (Synthetic Organic Chemicals) have been detected in drinking water at one time or another. Most are of no concern,but some are potentially a health risk to consumers. Below is a list of synthetic organic chemicals along with the proposed MCL (maximum contamination level) in mg/l as determined by the US EPA Primary Drinking Water Regulations.

Synthetic Organic Chemicals	Proposed MCL in mg/l
Acrylamide	0.0005
Alachlor	0.002
Aldicarb	0.01
Aldicarb sulfoxide	0.01
Aldicarb sulfone	0.04
Atrazine	0.002
Carbofuran	0.04
Chlordane	0.02
cis-1,2-Dichloroethylene	0.07
DBCP	0.0002
1,2-Dichloropropane	0.005
o-Dichlorobenzene	0.6
2,4-D	0.1
EDB	0.00005
Epichlorohydrin	0.002
Ethylbenzene	0.7
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Lindane	0.0002
Methoxychlor	0.4
Monochlorobenzene	0.1
Polychlorinated biphenyls	0.0005
Pentachlorophenol	0.2
Styrene	0.005
Tetrachloroethylene	0.005
Toluene	2.0
2,4,5-TP	0.05
Toxaphene	0.005
Trans-1,2-Dichloroethylene	0.1
Xylene	10.0

Treatment - Activated carbon is generally used to remove organics. Flow rates should be restricted to 2 gpm per square foot of the filter bed. Reverse Osmosis will remove 98 to 99% of the organics in the water. Ultrafiltration (UF) and nanofiltration (NF) both will remove organics. Anion exchange resin also retains organics, but periodically needs cleaning.

SODIUM

Source - Sodium (Na) is a major component in drinking water. All water supplies contain some sodium. The amount is dependent on local soil conditions. The higher the sodium content of water, the more corrosive the water becomes. A major Source of sodium in natural waters is from the weathering of feldspars, evaporates and clay. The American Heart Association has recommended a maximum sodium level of 20 mg/l in drinking water for patients with hypertension or cardiovascular disease. Intake from food is generally the major Source of sodium, ranging from 1100 to 3300 mg/day. Persons requiring restrictions on salt intake, usually have a sodium limitation down to 500 mg/day. The amount of sodium obtained from drinking softened water is insignificant compared to the sodium ingested in the normal human diet. The amount of sodium contained in a quart of softened, 18 grain per gallon water is equivalent to a normal slice of white bread. Sodium in the body regulates the osmotic pressure of the blood plasma to assure the proper blood volume. Sodium chloride is essential in the formation of the stomach acids necessary for the digestive processes. The US EPA sponsored a symposium which concluded that there is no relationship between soft water and cardiovascular disease. There is also no MCL published for sodium, however the US EPA suggests a level of 20 mg/l in drinking water for that portion of the population on severe sodium restricted diets of 500 mg/day or less.
Treatment - Sodium can be removed with the hydrogen form cation exchanger portion of a deionizer. Reverse Osmosis will reduce sodium by 94 - 98%. Distillation will also remove sodium.

STRONTIUM

Source - Strontium (Sr) is in the same family as calcium and magnesium, and is one of the polyvalent earth metals that shows up as hardness in the water. The presence of strontium is usually restricted to areas where there are lead ores, and its concentration in water is usually very low. Strontium sulfate is a critical reverse osmosis membrane foulant, dependent on its concentration. There is no MCL for strontium listed in the US EPA Drinking Water Standards.

Treatment - Strontium can be removed with strong acid cation exchange resin. It can be in sodium form as in a water softener or the hydrogen form as in the cation portion of a two-column deionizer. Reverse Osmosis will also reduce strontium but as stated above strontium sulfate is a membrane foulant.

SULFATE

Source - Sulfate (SO4) occurs in almost all natural water. Most sulfate compounds originate from the oxidation of sulfite ores, the presence of shales, and the existence of industrial wastes. Sulfate is one of the major dissolved constituents in rain. High concentrations of sulfate in drinking water causes a laxative effect when combined with calcium and magnesium, the two most common components of hardness. Bacteria which attack and reduce sulfates, causes hydrogen sulfide gas (H2S) to form. Sulfate has a suggested level of 250 mg/l in the Secondary Drinking Water Standards published by the US EPA.
Treatment - Reverse Osmosis will reduce the sulfate content by 97 - 98%. Sulfates can also be reduced with a strong base anion exchanger, which is normally the last half of a two-column deionizer.

TASTE

Source - Generally, individuals have a more acute sense of smell than taste. Taste problems in water come from total dissolved solids (TDS) and the presence of such metals as iron, copper, manganese, or zinc. Magnesium chloride and magnesium bicarbonate are significant in terms of taste. Fluoride may also cause a distinct taste. Taste and odor problems of many different types can be encountered in drinking water. Troublesome compounds may result from biological growth or industrial activities. The tastes and odors may be produced in the water supply, in the water treatment plant from reactions with treatment chemicals, in the distribution system, and /or in the plumbing of consumers. Tastes and odors can be caused by mineral contaminants in the water, such as the "salty" taste of water when chlorides are 500 mg/l or above. Decaying vegetation is probably the most common cause for taste and odor in surface water supplies. In treated water supplies chlorine can react with organics and cause taste and odor problems. See "ODOR" for more information.
Treatment - Taste and odor can be removed by oxidation-reduction or by activated carbon adsorption. Aeration can be utilized if the contaminant is in the form of a gas, such as H2S (hydrogen sulfide). Chlorine is the most common oxidant used in water treatment, but is only partially effective on taste and odor. Potassium permanganate and oxygen are also only partially effective. Chloramines are not at all effective for the treatment of taste and odor. The most effective oxidizers for treating taste and odor, are chlorine dioxide and ozone. Activated carbon has an excellent history of success in treating taste and odor

problems. The life of the carbon depends on the presence of organics competing for sites and the concentration of the taste and odor causing compound.

TOTAL DISOLVED SOLIDS (TDS)

Source - Total Dissolved Solids (TDS) consist mainly of carbonates, DISSOLVEDbicarbonates, chlorides, sulfates, phosphates, nitrates, calcium, magnesium, SOLIDSsodium, potassium, iron, manganese, and a few others. They do not include gases, colloids, or sediment. The TDS can be estimated by measuring the specific conductance of the water. Dissolved solids in natural waters range from less than 10 mg/l for rain to more than 100,000 mg/l for brines. Since TDS is the sum of all materials dissolved in the water, it has many different mineral Sources. The chart below indicates the TDS from various Sources.

Source	TDS - mg/l
Distilled Water	0
Two-column Deionizer Water	8
Rain and Snow	10
Lake Michigan	170
Rivers in U.S. (average)	210
Missouri River	360
Pecos River	2600
Oceans	35,000
Brine Well	125,000
Dead Sea	250,000

High levels of total dissolved solids can adversely industrial applications requiring the use of water such as cooling tower operations, boiler feed water, food and beverage industries, and electronics manufacturers. High levels of

chloride and sulfate will accelerate corrosion of metals. The US EPA has a suggested level of 500 mg/l listed in the Secondary Drinking Water Standards.
Treatment - TDS reduction is accomplished by reducing the total amount in the water. This is done during the process of deionization or with Reverse Osmosis. Electrodialysis will also reduce the TDS.

THM's (Trihalomethanes)

Source - THM's (Trihalomethanes) are produced when chlorine reacts with residual organic compounds. The four common THM's are trichloro-methane (chloroform), dibromochloromethane, dichlorobromomethane, and bromoform. There have been studies that suggest a connection between chlorination by-products and particularly bladder and possibly colon and rectal cancer. An MCL of 0.10 mg/l for total THM's exists.
Treatment - Trihalomethanes and other halogenated organics can be reduced by adsorption with an activated carbon filter.

TOC (Total Organic Carbon)

Source - TOC is a measurement to track the overall organic content of water. The organic content of the water will appear on the water analysis as C (carbon). The TOC test is the most common test performed to obtain an indication of the organic content of the water. Nonspecific tests utilized to determine the organic content of water are given below.
BOD- Biochemical oxygen demand - expressed as O2
CCE- Carbon-chloroform extract - expressed in weight
CAE- Carbon-alcohol extract (performed after CCE)
COD- Chemical oxygen demand - expressed as O2
Color- Color - reported as APHA units
IDOD- Immediate dissolved oxygen demand - expressed as O2
LOI- Loss of ignition - expressed in weight
TOC- Total organic carbon - expressed as C
The above tests are used to determine organic content of the water, for more information about different types see "ORGANICS".
Treatment - Procedures and suggestions for reduction of TOC is given under the heading "ORGANICS".

TURBIDITY

Source - Turbidity is the term given to anything that is suspended in a water supply. It is found in most surface waters, but usually doesn't exist in ground waters except in shallow wells and springs after heavy rains. Turbidity gives the water a cloudy appearance or shows up as dirty sediment. Undissolved materials such as sand, clay, silt or suspended iron contribute to turbidity. Turbidity can cause the staining of sinks and fixtures as well as the discoloring of fabrics. Usually turbidity is measured in NTUs (nephelometric turbidity units). Typical drinking water will have a turbidity level of 0 to 1 NTU. Turbidity can also be measured in ppm (parts per million) and it's size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids, larger than molecules, but not visible by the naked eye; ranging in size from .001 to .150 mm (1 to 150 microns). The US EPA has established an MCL for turbidity to be 0.5 to 1.0 NTU, because it interferes with disinfection of the water.
Treatment - Typically turbidity can be reduced to 75 microns with a cyclone separator, then reduced down to 20 micron with standard backwashable filter, however flow rates of 5 gpm/ sq. ft. are recommended maximum. Turbidity can be reduced to 10 micron with a multimedia filter while providing flow rates of 15 gpm/sq. ft. Cartridge filters of various sizes are also available down into the submicron range. Ultrafiltration also reduces the turbidity levels of process water.

URANIUM

Source - Uranium is a naturally occurring radionuclide. Natural uranium combines uranium 234, uranium 235, and uranium 238; however, uranium 238 makes up 99.27 percent of the composition. All radionuclides are considered carcinogens; however, the organs each attacks is different. Uranium is not a proven carcinogen but accumulates in the bones similar to the way radium does. Therefore, the US EPA tends to classify it as a carcinogen. Uranium has been found to have a toxic effect on the human kidneys. Under the NIPDWR (national interim primary drinking water regulations), the MCL (maximum contamination level) for uranium is set at 15 pCi/L (see radium for explanation of how radiation is measured).
Treatment - Uranium can be reduced by both cation or anion dependent upon its state. Reverse Osmosis will reduce uranium by 95 to 98%. Ultrafiltration will also reduce the amount of uranium. Activated alumina can also be utilized.

VIRUSES

Source - Viruses are infectious organisms which range in size from 10 to 25 nanometers [1 nanometer = one billionth (10-9) of a meter]. They are particles composed of an acidic nucleus surrounded by a protein shell. Viruses depend totally on living cells and lack an independent metabolism. There are over 100 types of enteric viruses. Enteric viruses are the viruses which infect humans. Enteric viruses which are of particular interest in drinking water are hepatitis A, Norwalk-type viruses, rotaviruses,adenoviruses, enteroviruses, and reoviruses. The test for coliform bacterial is widely accepted as an indication whether or not the water is safe to drink, therefore tests for viruses are not usually conducted. The US EPA has established an MCL which states that 99.99% reduction or inactivation for viruses. Major enteric viruses and their diseases are shown below.

Virus	Disease
Enteroviruses	Polio, Aseptic meningitis, and Encephalitis
Reoviruses	Upper respiratory and gastrointestinal illness
Rotaviruses	Gastroenteritis
Adenoviruses	Upper respiratory and gastrointestinal illness
Hepatitis A	Infectious hepatitis
Norwalk-type	Gastroenteritis

Treatment - Chemical oxidation / disinfection is the preferred treatment. Chlorine feed with 30 minute contact time for retention, followed by activated carbon filtration is the most widely used treatment. Ozone or iodine may also be utilized as oxidizing agents. Ultraviolet sterilization or distillation may also be used for the treatment of viruses. **Back to Contaminant list.**

VOCs (Volatile Organic Chemicals)

Source - VOCs pose a possible health risk because many of them are known carcinogens. Volatile organic chemicals are man-made, therefore the detection of any of them indicates that there has been a chemical spill or other incident. Volatile organic chemicals regulated under the Safe Drinking Water Act of 1986 are listed below.

Volatile Organic Chemicals	US EPA MCL in mg/l
Trichloroethylene	0.005
Tetrachloroethylene	0.005
Carbon tetrachloride	0.005
1,1,1-Trichloroethane	0.2
1,2-Dichloroethane (ethylene dichloride)	0.005
Vinyl chloride	0.002
Methylene chloride (dichloromethane)	0.002
Benzene	0.005
Chlorobenzene	0.1
Dichlorobenzene	0.6
Trichlorobenzene	0.07
1,1-Dichloroethylene	0.007
trans-1,2-Dichloroethylene	0.1
cis-1,2-Dichloroethylene	0.07

Treatment - The best choice for removal of volatile organic chemicals is Activated carbon filtration. The adsorption capacity of the carbon will vary with each type of VOC. The carbon manufacturers can run computer projections on many of these chemicals and give an estimate as to the amount of VOC which can be removed before the carbon will need replacement. Aeration may also be used alone or in conjunction with the activated carbon. Reverse Osmosis will remove 70 to 80% of the VOCs in the water. Electrodialysis and Ultrafiltration are also capable of reducing volatile organic chemicals.