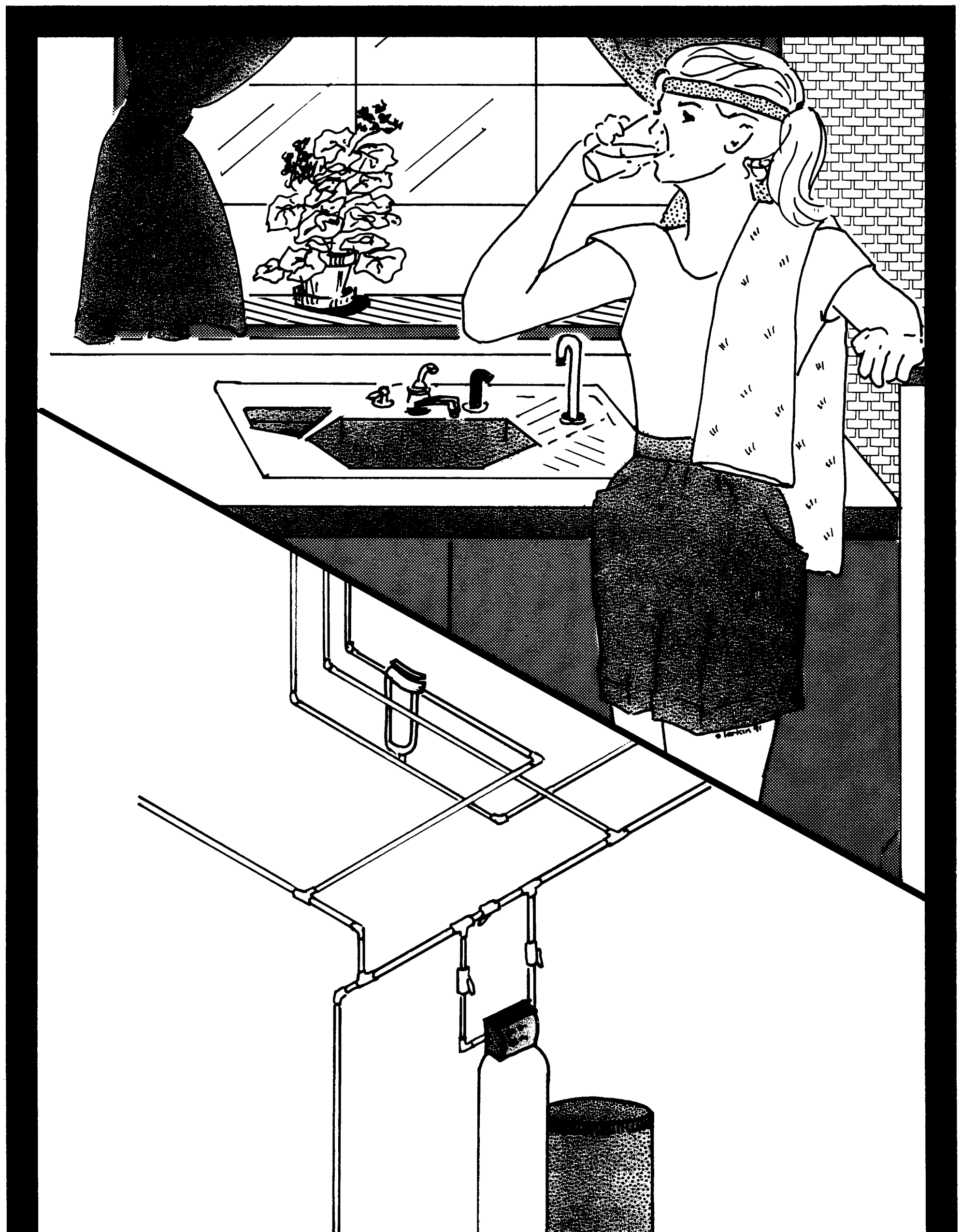
Wisconsin Water Treatment Handbook



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Wisconsin Water Treatment Handbook

This is a teaching aid prepared by Safety and Buildings Division Bureau of Integrated Service's staff for the plumbing industry as an introduction to water treatment theory and installation.

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Safety and Buildings Division
201 West Washington Avenue
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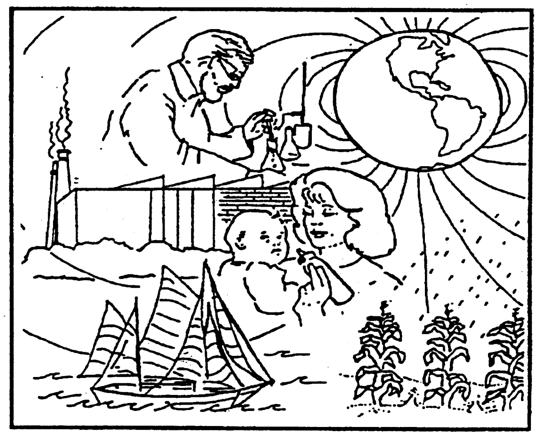
Introduction

Water is the basis for life on this planet.

"There is nothing that can live without water. Water is the basic material of protoplasm, the life stuff of the living cell. Stained red with necessary impurities it becomes blood, to transport the body's nutrients and wash away its wastes. *Sticky with sugar in the stems of plants, it becomes sap. We drink it; we grow our crops with it; we use it for a multitude of industrial purposes, for transport and for cooling, as a solvent and as a raw material, for food, for furniture, for books, for automobiles, for jewelry, for gasoline, and for everything else under the sun" (Ashworth 1982).*

Many people have engaged in hunger strikes to prove their point or advance a cause. An Irish prisoner in 1981 made demands of the British government. He refused to eat and would accept only drinking water. After sixty-six days he died. If the same prisoner had refused water he probably would have been dead within 10 days. He needed a longer time to live so that his protest would be widely publicized and the changes he needed might be accomplished. Protesters realize that without water the time for publicity, and possibly change, does not exist.



The continuation of life depends on the almost immediate availability of water.

It is understandable that water should be palatable (agreeable to the taste), however it is a necessity that water is potable for human life. Potable water as defined in the Wisconsin Uniform Plumbing Code is ...

"Water which is:
(a) Safe for drinking, personal or culinary use; and
(b) Free from impurities present in amounts sufficient to cause disease or harmful physiological effects and conforming in its bacteriological and chemical quality to the requirements specified in ch NR 809."

Nonpotable water has been a problem for centuries. Roman troops boiled their water to prevent dysentery. Catastrophic plagues in the Middle Ages were caused by water born virus or bacteria. By the late nineteenth century, the world's population began to recognize the need for water treatment to prevent disease. Cholera epidemics in England in the mid-eighteen hundreds took 250,000 lives. The late 1800s and early 1900s proved a dangerous time in the eastern United States as typhoid epidemics took their toll. Due to the increased population density, municipal treatment plants were constructed. Many of these plants used chlorine to kill bacteria. Between 1920 and 1930, this process drastically reduced mortality rates due to typhoid (Ashworth 1982).

Water treatment has recently become an important aspect of the plumbing industry. Customers no longer need to accept unpleasant tastes or odors in their domestic water and some wish to reduce their exposure to regulated contaminants that may be present, although within standards. Devices available to the general public are numerous and diverse. The public has become accustomed to clean, clear drinking water and demands that the industry provides it.

The plumbing industry must respond to this public demand for high quality drinking water. The trade must gain knowledge of what filters and appliances are available and how they operate, so they may advise clients in a professional manner. It is to this need that the Safety and Buildings Division of the Wisconsin Department of Commerce directs this manual.

1 Water

To understand the operation of water treatment devices one must first understand water and how it reacts with other substances.

Water molecules are very small. There are roughly a million million million million molecules of water in one drop. The water molecule is unique in the environment because of its characteristics.

The water molecule (H_20) is made up of one oxygen atom and two hydrogen atoms. The hydrogen atoms, which are smaller than the oxygen atom, are approximately 105° apart.

The water molecule is dipolar, like a magnet. See Figure 1.1.

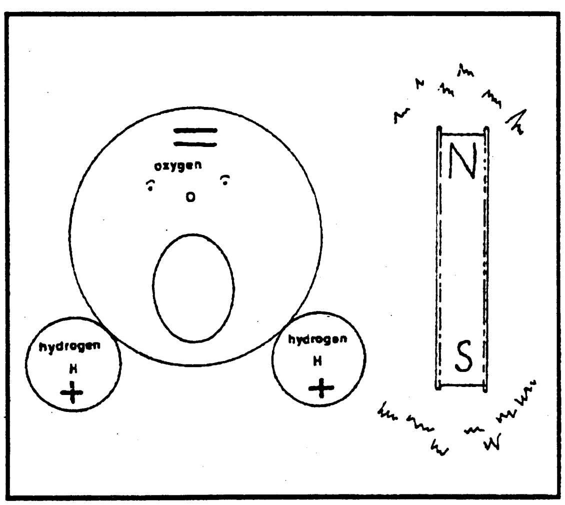


Figure 1-1: Water, the dipolar molecule

Each molecule of water has a positive and a negative side. The oxygen carries a negative charge and the hydrogen carries a positive charge. Water molecules are attracted to one another because of this charge.

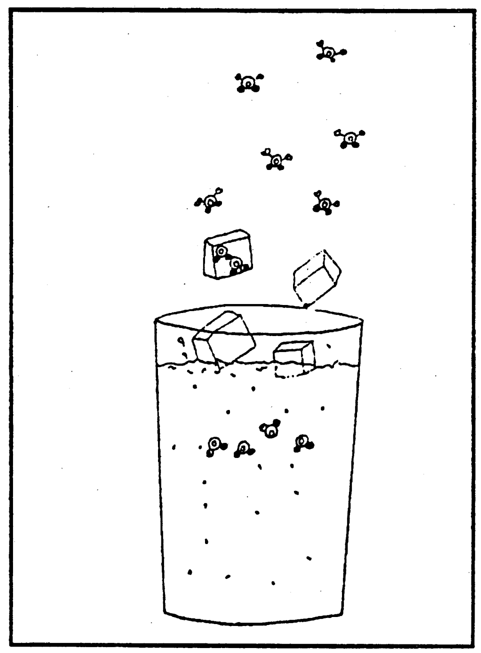


Figure 1-2: Ice floats because it is less dense than water

Because of this attraction, called hydrogen bonding, water requires much energy to become steam. Steam, with this high energy content, is an effective energy transfer medium. Water is an efficient heat transfer fluid because water releases more heat when cooling or absorbs more heat when heating than many other substances.

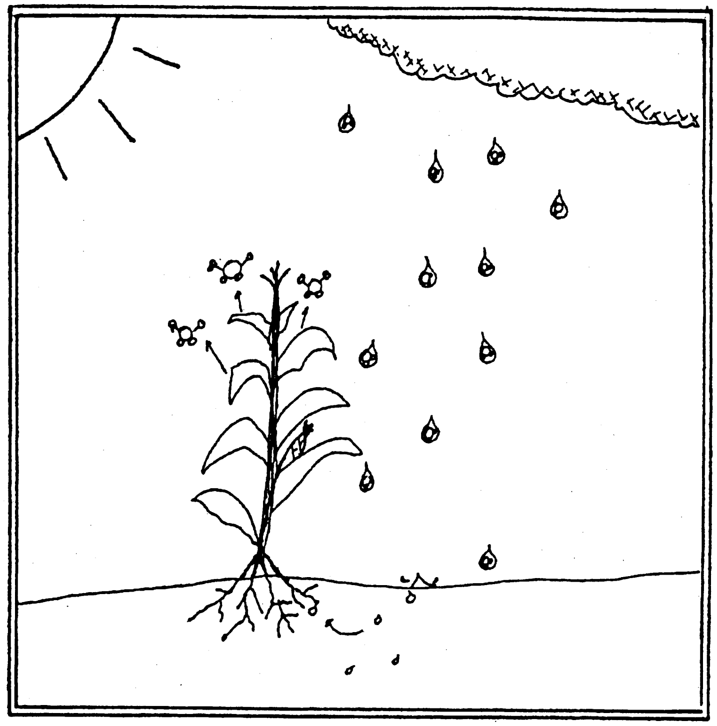


Figure 1-3: Water exists as a solid, liquid, or gas in nature.

Upon freezing, water forms a crystalline structure which expands. Ice is less dense than liquid water because of this crystal structure. Therefore, ice floats! See Figure 1-2. If this wasn't the case, as ice formed and sank, lakes would freeze from the bottom up, and Summer wouldn't be long enough to thaw lakes to the bottom. Gradually, ice could build up and life, as we know it, would not continue.

Water exists as a solid, liquid, or gas in nature, see Figures 1-2 and 1-3.

Water has a high surface tension. This high surface tension of water is also caused by hydrogen bonding. Because of this property, a needle will "float" on water and water "crawls" up the side of a container. This surface tension also is partly responsible for the capillary action in plants and makes it possible for water to defy gravity by moving upward through the soil in small pores and crevices.

Water is often called "the universal solvent". Water molecules tend to isolate ions from compounds that water contacts. Ions are elements in water that are positively or negatively charged. The substances that contact water become ionized, with the water molecules separating the ions preventing them from forming their original compounds again.

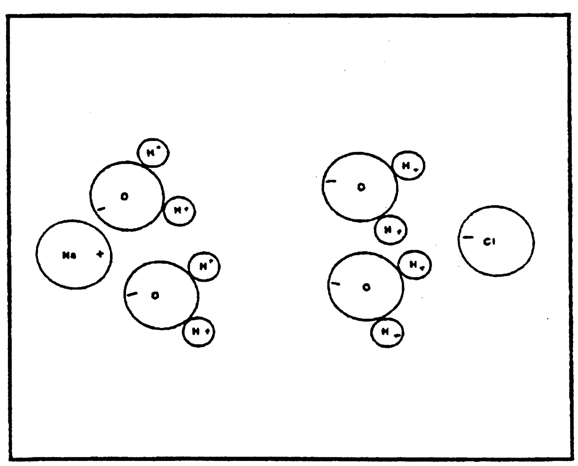


Figure 1-4: Water, the Universal Solvent.

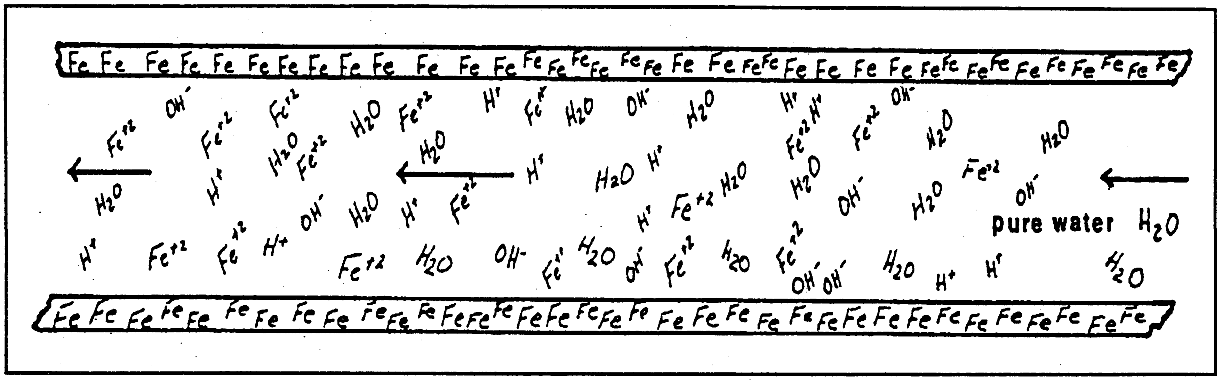


Figure 1-5: Water's effect on iron pipe in a water dsitribution system.

Pure water (H_20) doesn't exist in nature. Water's ability to dissolve minerals causes water in the natural state to contain many other constituents. If pure water were introduced into a distribution system made of metal, the water would dissolve the pipe slowly from the inside out. See Figure 1-5.

In the natural cycle of water, called the hydrologic cycle, the same solvent traits of water appear. See Figure 1-6.

As rain passes through the air, it picks up (or dissolves) impurities. As water flows in creek beds, the minerals it passes are dissolved in the water and become part of the solution. Water percolating through the ground or passing through cracks in bedrock to underground aquifers carries with it molecules of other substances it contacts. This is a continuous cycle that has existed since life began on earth. The water we use today is the same water used years ago.

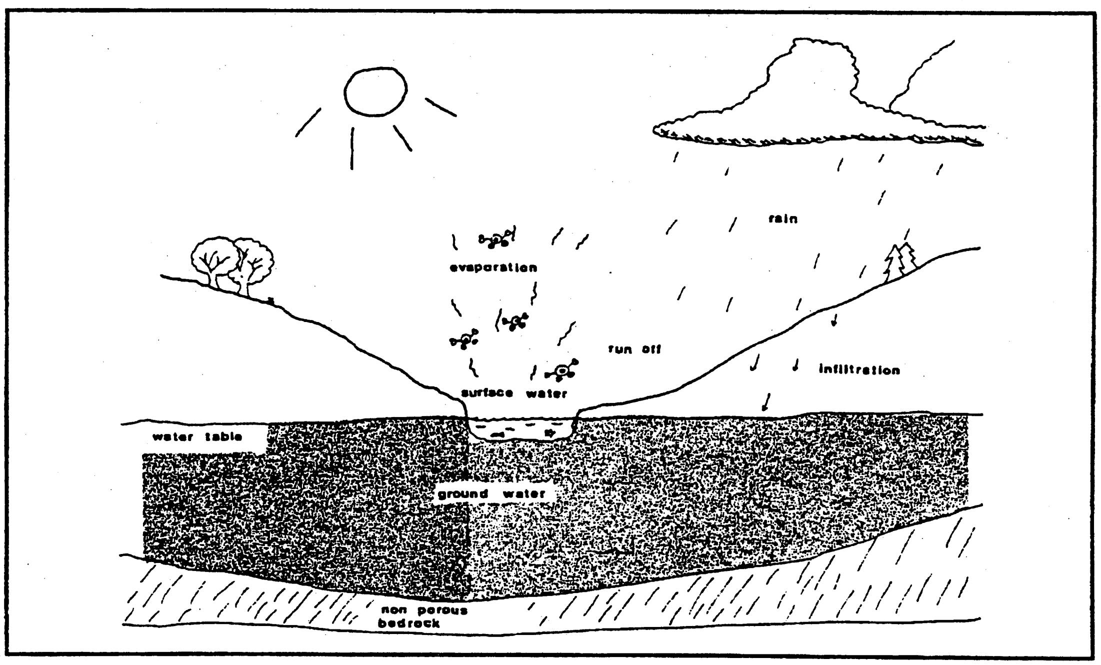


Figure 1-6: The Hydrologic Cycle

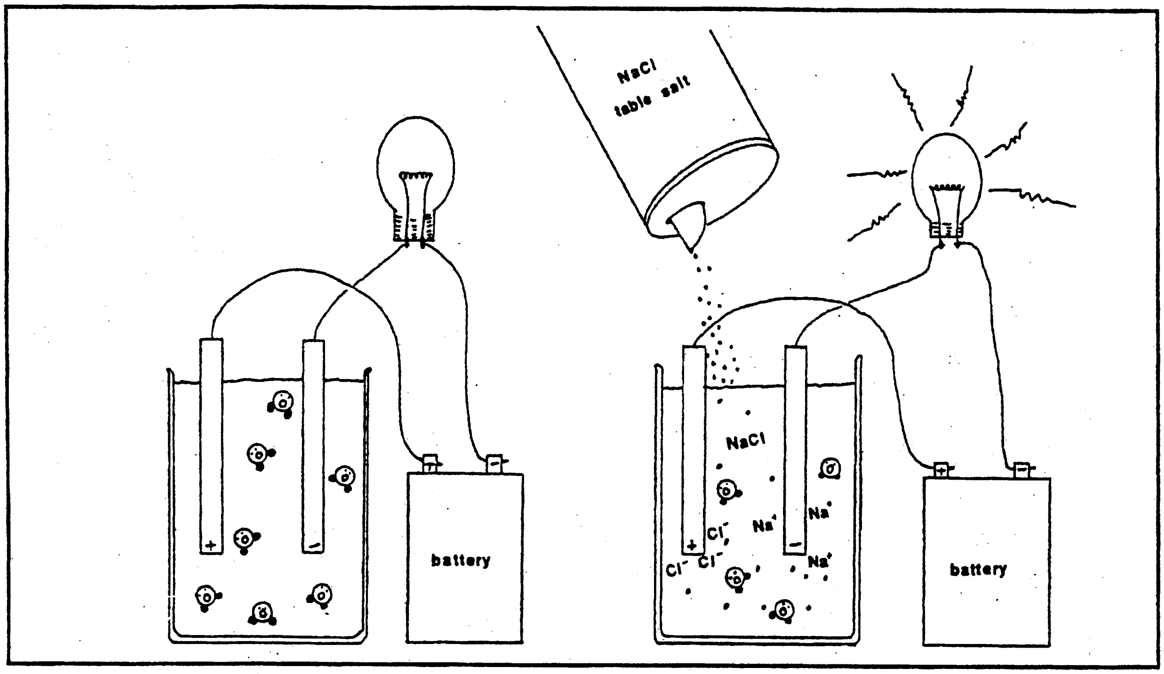


Figure 1-7: Water as an electrical conductor

Water, in its pure form, is an insulator. It cannot conduct electricity. With dissolved materials added to pure water it can conduct electricity. See Figure 1-7. In the field, there is no pure water. The puddle you step in as you repair a pump will conduct electricity. It is a safety hazard and caution must be used when dealing with electricity and water.

Osmosis is an important process that all living cells employ. Osmosis is defined as the process by which water molecules move through a permeable membrane separating a less concentrated solution from a more concentrated solution in a direction to dilute the more concentrated solution. This means that the water on both sides of a membrane "likes" to exist in the same relationship with other molecules. Where there is a concentration difference, the water travels across the membrane to obtain an equal concentration on each side. See Figure 1-8.

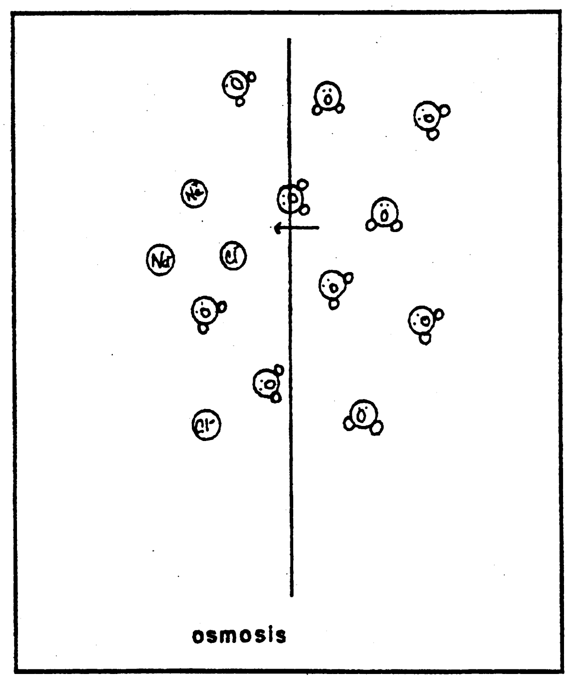


Figure 1-8: Osmosis

pH

pH stands for "[p(otential of) H(ydrogen)]" and is a measurement of whether a liquid is acidic or basic. The pH scale is a range between 0 and 14, with 7 as neutral.

- below 7 is acidic
- above 7 is basic

This acid-base relationship in water is caused by the number of positively charged hydronium ions (H_3O^+), as compared to the negatively charged hydroxyl ions (OH^-).

The pH of a solution can change with time and its contact with air. Because of this, a water sample should be tested for pH immediately when it is drawn.

pH, when considered alone, has no damaging effects to health. However, the effects from an excessively high or low pH may cause various problems.

In some cases, corrosion is more likely with a pH of less than 6.5. Metals such as copper and lead, which can dissolve in certain waters, can induce serious illness. A sour tasting water may be caused by a pH of less than 4.

A high pH may cause a bitter taste and scale can form in pipes if other conditions are right.

Wisconsin drinking water is commonly found to range from 4.5 to 12.

The pH ranges acceptable for specific uses are shown in Figure 1-9.

CONTAMINANTS

When referring to domestic water treatment, contaminants are the "additives" in water. Contaminants are not necessarily harmful in drinking water. For example, chlorine is added to disinfect water and fluoride is added to prevent tooth decay.

Some contaminants pose health-related risks to people and others simply affect the aesthetics of the water.

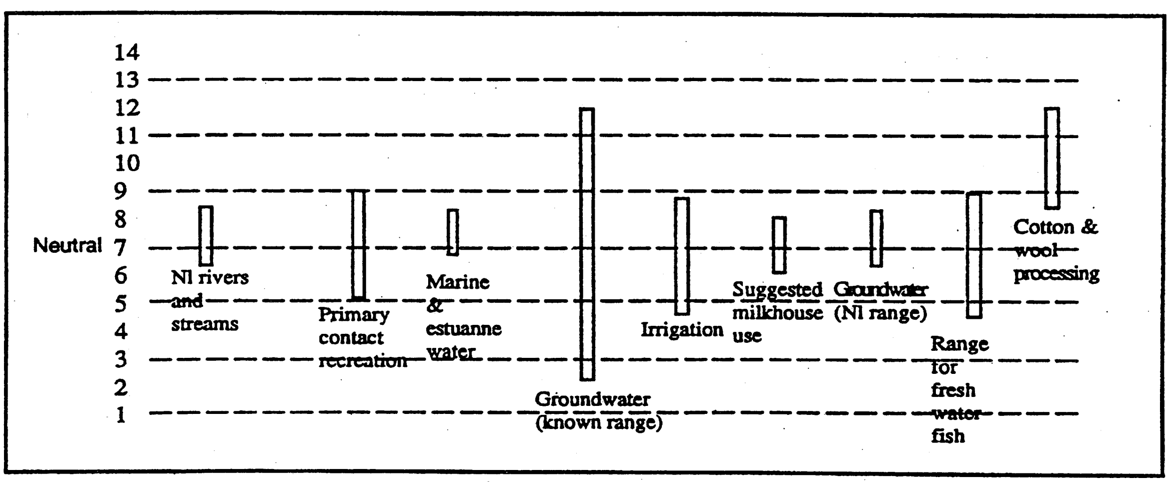


Figure 1-9: pH ranges

HEALTH-RELATED CONTAMINANTSs

Health-related contaminants can result in either an acute or chronic illness.

An *acute* health related contaminant is one which poses an immediate danger to the person drinking the water. The acute problem is one which requires an emergency response. Some biological contaminants are examples of acute health-related contaminants. Drinking water that contains virulent viruses, cysts, or infectious bacteria could cause immediate serious illness.

In contrast, a *chronic* health-related contaminant is a constituent that may slowly cause or contribute to health problems. Minute amounts of pesticides that exceed lifetime health advisory levels would be chronic health-related contaminants.

AESTHETIC CONTAMINANTS

An *aesthetic* contaminant or non-health-related contaminant is a constituent of water that poses no health threat to the person using or drinking the water. Iron within acceptable levels, total dissolved solids, and hardness are examples of such contaminants.

DRINKING WATER REGULATIONS

The federal Safe Drinking Water Act requires the Environmental Protection Agency (EPA) to set drinking water regulations which community water systems must meet. These regulations are divided into two categories: "primary drinking water regulations" and "secondary drinking water regulations."

Primary drinking water regulations include contaminants which may affect the health of people. Secondary drinking water regulations are for contaminants which cause aesthetic effects. The concentrations for these contaminants are called "maximum contaminants levels" or MCLs.

The state Department of Natural Resource lists the primary and secondary maximum contaminant levels for Wisconsin in NR809, Wisconsin Administrative Code. MCLs are subject to change. To obtain the most recent MCLS, contact the DNR at 608-266-0821. A copy of the EPA's list is in the appendix of this manual.

Units of concentration used on laboratory reports can vary from what is used in advertising literature for a specific water treatment device. Units which are often used include:

ppm: parts per million,
1 ppm = 1 part contaminant in 1,000,000 parts water.

mg/L: milligrams per liter,
1 mg/L = 1 milligram contaminant per 1 liter of water.
One mg/L is approximately equivalent to 1 ppm.

ppb: parts per billion,
1 part contaminant in 1,000,000,000 parts water.

ug/L: micrograms per liter,
1 ug/L = 1 microgram contaminant per 1 liter of water.
One ug/L is approximately equivalent to 1 ppb.

gpg: grains per gallon,
1 gpg = 17.1 ppm.

1 000 ug/L = 1 mg/L and 1 000 ppb = 1 ppm.

To put the units in more common context, 1 part per million is equal to one inch per sixteen miles, or 1 part per million is equal to one minute in two years. 1 part per billion is equal to 1 inch per 16,000 miles, or 1 part per billion is equal to one second in 32 years.

DISSOLVED SOLIDS

"Dissolved solids" and "total dissolved solids" are terms used to describe the concentrations of minerals dissolved in water. If you **filtered** a gallon of water, and then completely boiled the water away, the solids left in a pan would be the total **dissolved** solids in that gallon of water.

Total solids include both suspended and dissolved solids. If you boiled away a gallon of water **without filtering** it, what would be left in the bottom of the pan would be the total solids in that gallon of water.

The National Secondary Drinking Water Regulations recommend the concentration limit of dissolved solids not exceed 500 mg/L in public water supplies. Many city water supplies exceed this recommendation; 500 mg/L is a guideline rather than a limit. A high concentration of dissolved solids can result in poor tasting water.

"Water with several thousand parts per million of dissolved solids is generally not palatable, although those accustomed to highly mineralized water may complain that less concentrated water tastes flat. More often, a change in the source of drinking water may cause gastric disturbances rather than the concentration of dissolved solids in the water itself." Rainwater and Thatcher (1960, p. 269)

With typical water softeners, total dissolved solids levels greater than 500 mg/L may interfere with exchange sites on resin beads. Higher levels of regeneration may be needed where TDS levels are high.

HARDNESS

"Hard water" is a term that has no precise meaning because "hard" water in one place might be considered soft in another. Calcium and magnesium ions in water are the major cause of hardness.

Note that measuring the concentration of the two is sometimes referred to as "total hardness" or "hardness." If one is just measuring the concentration of calcium, it is referred to as "calcium hardness."

Both calcium and magnesium can combine with other chemicals to form scale on the inside of heaters, boilers, or heat exchangers. The hardness of water effects how soaps react and how thoroughly soaps clean because hardness can form precipitate with soaps. Hard water is not hazardous to your health.

Hardness is usually measured in grains per gallon (gpg) or mg/L as Calcium Carbonate ($CaC0_3$). A grain is a measurement of weight. 7,000 grains = 1 pound. The grains per gallon measurement came from ancient times where a grain of chalk produced a certain hardness in a gallon of water. The hardness of water was compared to this control.

One grain per gallon = 17.1 mg/l(milligrams per liter)

The Water Quality Association has developed a general scale of hardness, shown in Table 1-1.

mg/l	gpg	Description
0-17	0-1	soft
17-60	1-3.5	slightly hard
60-120	3.5-7	moderately hard
120-180	7-10.5	hard
over 180	over 10.5	very hard

Table 1-1: General Scale of Hardness

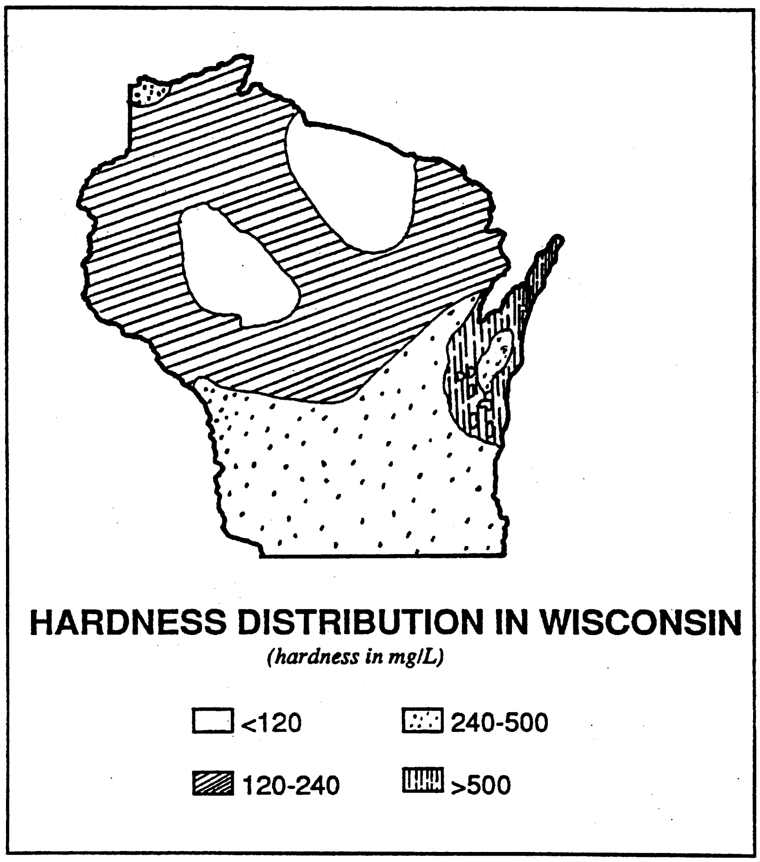


Figure 1-10: Hardness of Wisconsin's Groundwater

IRON

Iron in drinking water may be clear water iron, or precipitated iron.

Precipitated iron, also called insoluble iron, or iron in the ferric state, is the visible iron in domestic water. Water containing ferric (Fe^{+3}) iron is sometimes referred to as "red water."

Clear water iron, also called "soluble iron" or "iron in the ferrous state" (Fe^{+2}), is the most common type found in groundwater. Soluble iron will not show up immediately in a glass of water drawn from the tap. When soluble iron mixes with oxygen from the air, the iron combines with oxygen and the red color of iron in the insoluble ferric state may be formed. This is accomplished by chemical "oxidation," is a process which removes electrons from an atom, ion, or a compound, and changes the chemical make-up and sometimes the physical behavior of chemicals. Ferrous iron can be oxidized to ferric iron by the introduction of other chemical oxidants. These include chlorine, ozone, and potassium permanganate.

The federal Food, Drug and Cosmetic Act has assigned a secondary contaminant concentration limit for iron in drinking water as 0.3 mg/L. The limit is based on the non-health related (aesthetic) considerations of fixture staining and an unpleasant "iron" taste.

LEAD

Lead is a toxic metal that can damage the brain, kidneys, nervous systems, blood cells, and reproductive systems. Children's bodies tend to absorb more lead than adults subject to the same concentration.

The present Safe Drinking Water Act limit, the maximum contaminant level is 15 micrograms per liter.

Lead water services, lead-based solder joints, and brass fittings and valves all can contribute to elevated lead levels in drinking water.

Wisconsin laws have been modified to reduce the amount of lead in drinking water contributed by plumbing systems, specifically:

a. In 1979, lead pipe was banned from use in water supply systems;
b. In 1984, lead based solder and lead based flux was banned from use in water supply systems;
c. In 1988, lead-tipped gaskets were banned from use in water supply systems; and
d. In 1988, a law was passed requiring that all pipes and fittings be made of materials that contain not more than 8 percent lead throughout the piping system.

Water supplies that form a protective scale coating usually do not have a problem with lead leaching into the water.

Water supplies that do not form a protective scale coating on pipes usually have a significant lead concentration. The longer the water is in contact with parts of plumbing systems containing lead, the higher the lead concentration.

NITRATE

Nitrate is a mixture of nitrogen and oxygen (NO_3). Sources of nitrate in drinking water include: agricultural fertilizers, private sewage disposal systems, the atmosphere, legume type plants, animal excrement, decaying plant materials, or other sources. The air we breath is about 78% nitrogen, so some of the nitrate in drinking water is attributed to air, while the majority is traced to decay, agricultural chemicals, and industrial wastes.

The federal limit for nitrate concentration in drinking water (for humans) is 10 mg/L as N. The nitrate concentration can be reported in two different forms:

Nitrate (as N) = 10 mg/L

Nitrate (as NO_3) = 45 mg/L

Because of the difference in these limits, the laboratory report or test instructions must be very clear as to which type of nitrate concentration is being presented. If not specified, do not assume that the concentration is reported as nitrate as N. Contact the testing laboratory for further details.

Adults are able to consume large quantities of nitrate without ill effects. The major adult human intake of nitrate is from food. Foods which contain nitrate include spinach, lettuce, beets, and carrots.

Since 1945 health officials have known that high nitrate levels in drinking water supplies (above 10 mg/L as N) may pose a risk to some infants. In small children (under six months), nitrate may be converted to nitrite. Nitrite acts on red blood cells to reduce their oxygen-carrying capacity. Without enough oxygen in the bloodstream, the baby becomes blue and starts to suffocate. Without proper medical attention this "blue baby" could die. Nitrate may be transmitted to a child through formulas mixed with water containing a high nitrate concentration. Removing the nitrates from the baby's diet will usually reverse the symptoms.

Some studies show that high levels of nitrates in water for livestock (usually higher than those levels affecting infants) may cause abortions in brood animals and a high percentage of deaths in calves and piglets.

CHLORINE

Chlorine can be a gas, liquid, or solid. Chlorine is usually added to water to control unwanted bacteria growth or to precipitate certain contaminants (like iron).

The amount of chlorine added to the water supply is sometimes called "chlorine dosage." Some of the chlorine is consumed by bacteria, organic matter, and other oxidizable substances.

The amount of chlorine consumed is called the "chlorine demand."

The amount of chlorine remaining in the water supply is called the "chlorine residual." The chlorine residual causes the chlorine taste in some municipal water supplies. The chlorine residual can be as small as 0.1 ppm and as high as 2 ppm.

Chlorine Residual equals Chlorine Dosage minus Chlorine Demand

Chlorine can be added to water in two different forms: free chlorine and combined chlorine. Table 1-2 shows examples of free and combined chlorine. The advantage of free chlorine is that it kills bacteria quicker than combined chlorine. The disadvantage of free chlorine is that it is more likely to form disinfection by-products called trihalomethanes (THMs). Chlorine by itself is not a health hazard, however THMs are chronic health-related contaminants. THMs may not exceed 80 ppb in the water supply.

The potential for the formation of THMs is related to the amount of certain organic matter in the water supply. Usually organic matter is more likely to be found in surface water supplies like Lake Michigan, Lake Winnebago, the Mississippi River, etc. Because of this, municipalities with surface water supplies usually treat their water with combined chlorine which is less likely to form THMs.

The chlorine residual in the water supply can be a combination of free and combined chlorine in the water supply.

Total Chlorine Residual equals Free Chlorine Residual plus Combined Chlorine Residual

Table 1-2: Free and Combined Chlorine

Free Chlorine	Combined Chlorine
chlorine gas	monochloramine
hypochlorous acid	dichloraniine
hypochlorite ion	nitrogen trichloride

RADIUM AND RADON

Uranium is a natural element found within the earth's crust. It makes up a minute portion of the earth at about four parts per million. As this uranium breaks down it transforms into different radioactive elements. About halfway through this decay process, the origina l uranium-238 becomes radium-226. Radium, as it decays, turns into radon-222, which is radon gas. Radon gas is inert.

As the radon gas decays further, however, it breaks down in to some very dangerous molecules. These molecules of polonium-218, lead-214, bismuth 214, and polonium-214 are transformed further into non-radioactive lead-210 within 50 minutes after the transformation of radon has begun. See Figure 1-11. As these small particles decay, they give off radiation. If the radon gas was inside someone's home, and then transformed to particles of these radioactive solids, they could be inhaled and attached to lung tissue, where they continue their decay, shooting off dangerous radiation.

Wisconsin has relatively high radium levels in two areas of the state due to two specific rock formations: the deep sandstone of the state's Eastern quarter, and the crystalline granite rock of North Central Wisconsin.

The current standards for drinking water, set in the Safe Drinking Water Act and the Food, Drug and Cosmetic Act include the suggested safe levels for radium as: Combined Radium 226 and 228 = 5 pCi/l. A pCi, or picoCurie, is a measurement used when addressing radioactive elements. One Curie equals 37 billion radioactive decays per second. A picoCurie is 1 trillionth of a Curie.

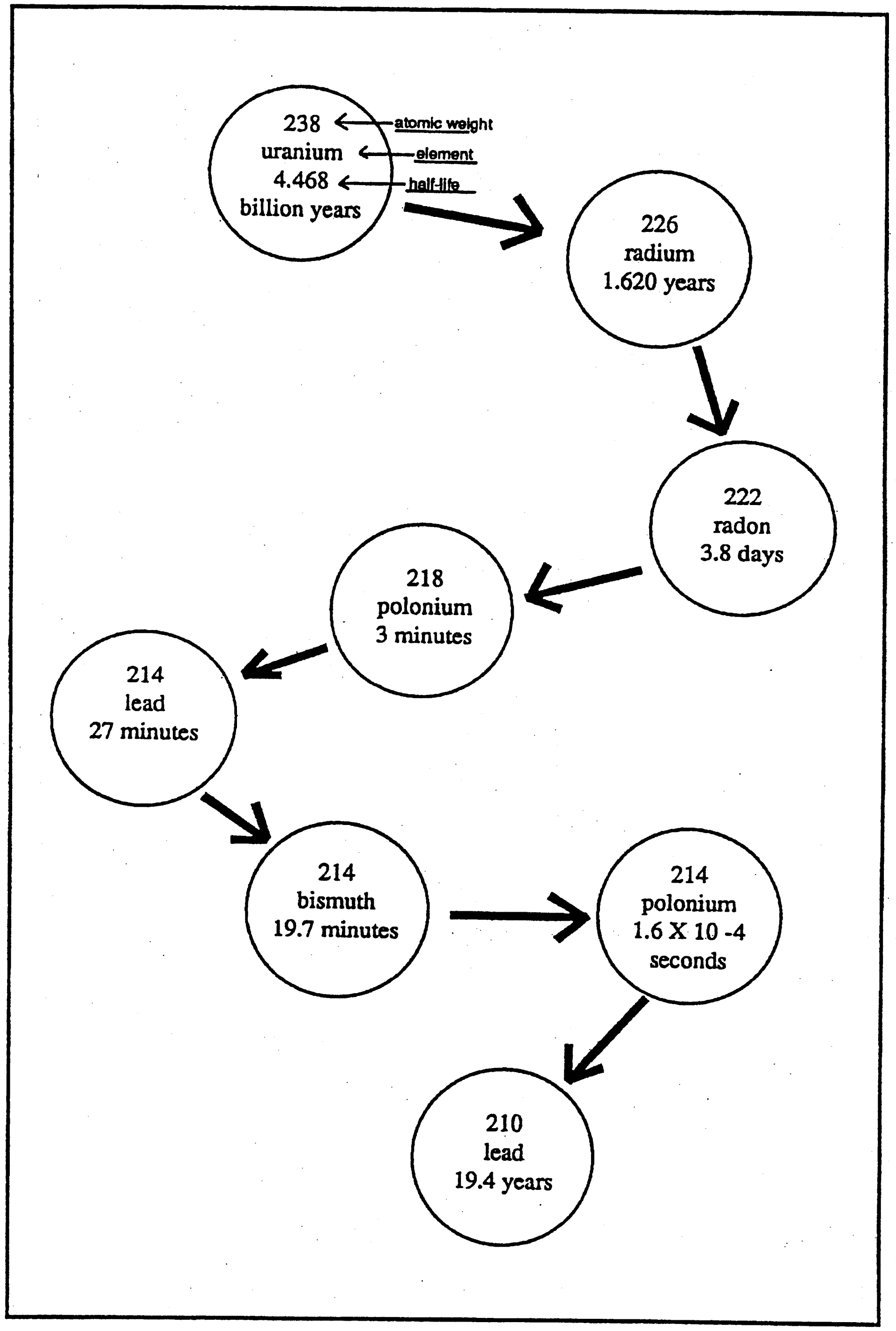


Figure 1-11: The decay chain of radon (LaFavore 1987)

ORGANICS

Organic chemicals include both natural and synthetic molecules containing carbon and (usually) hydrogen. Some organics are very soluble in water (like sugar), and some are very insoluble (like plastic). Some naturally occurring organics are responsible for taste, odor, and color in the water supply.

Even in small amounts some organic chemicals are very dangerous to health. Laboratories will sometimes measure organics such as pesticides in parts per billion. High concentrations of VOCs can cause nausea, dizziness, tremors, and other health related concerns. Some VOCs are known carcinogens (cancer causing agents).

Volatile organic chemicals (VOCs) are organic chemicals that evaporate, or volatilize, when exposed to air. VOCs dissolve many other substances, so they are frequently used as solvents and cleaning agents.

Some common VOCs are gasoline, industrial solvents, paint thinners, drain cleaners, air fresheners, and household products (like spot & stain removers). The names of some of these chemicals include: trichloroethylene(TCE), tetrachloroethylene, trichloroethane, benzene, toluene, and xylene.

VOCs usually combine with water due to leaks in tanks or hazardous substance spills. Wisconsin has approximately 1,000 hazardous spills per year and 65 percent of these are petroleum spills. The level of danger due to these spills is influenced by soil materials, rock formations, and the distance from the spill to any potable well.

Synthetic organic compounds (SOCs) include insecticides and herbicides used in agriculture. Insecticides and herbicides are classes of pesticides. Table 1-3 lists several pesticides and their present Maximum Contaminant Levels (MCLs). MCLs are enforceable standards for public drinking water supplies.

Table 1-4 lists various pesticides and their Lifetime Health Advisory levels as established by the Environmental Protection Agency (next page). These Health Advisories are not enforceable, and include a 100- to 1000-fold margin of safety. Water that contains pesticides at or below this level should be considered safe for drinking for a lifetime.

SOCs are sprayed on or incorporated into fields. Seepage through the ground, sometimes aided by rain, can result in SOCs mixing with groundwater before the compound decays. Certain conditions make this contamination more likely, such as sandy soils, heavy rainfall or irrigation, and cool temperatures. Aldicarb is an insecticide used in potato farming which has been found in the wells of the central sands area of Wisconsin. A report conducted by the EPA indicted that less than 1 percent of wells in the United States contain hazardous levels of pesticide residues. The two most frequently detected pesticides nationally are DCPA (DacthalR) and atrazine.

Once in the groundwater, pesticides continue to break down, but usually much slower than in surface layers of soil. Groundwater carrying pesticides away from the original point of application can lead to contaminated well samples years later in a different location.

PRIMARY DRINKING WATER REGULATIONS PESTICIDES (in mg/L)	
Alachlor (Lasso)	.002
Aldicarb (Temik)	.003
Aldicarb suflone	.003
Aldicarb sulfoxide	.004
Atrazine	.003
Carbofuran (Furadan)	.04
Chlordane	.002
Dibromochloropropane (DBCP)	.0002
2,4-D	.07
Ethylene Dibromide (EDB)	.00005
Pentachlorophenol	.001
Heptachlor	.0004
Heptachlor epoxide	.0002
Lindane	.0002
Methoxychlor	.04
Toxaphene	.003
2,4,5-TP (Silvex)	.05

Table 1-3: Maximum Contaminant Levels

Pesticide Lifetime Health Advisories (ppb) Jan. 1989

60	ametryn- Ametrex, Gesapax®	0.2	1,3 dichloropropene- DCP, Telone
20	bentazon- Basagran®	1	acifluorfen- Blazer®, Carbofluorfen, Tackle®
700	butylate- R-1910, Sutan®	3	baygon- Propoxur, Unden®, Blattanex®
700	carbaryl- Sevin®	90	bromacil- Borea®, Hyvar®, Uragan®
10	cyanazine- Bladex	700	carboxin- D-735, DCMO, Vitavax®
200	dalapon- Dowpon, Ded-Weed®	100	chloramben- Amiben, Vegiben®
200	dicamba- Banvel®	2	chlorothalonil- Bravo, Daconil®
7	dinoseb- DNBP, Dinitro	0.6	diazinon- Spectracide®, Basudin®, AG-500
200	diphenamid- Dymid®, Enide®	0.3	disulfoton- Disyston®, Dithiodemeton®
10	diuron- DCMU, Karmex®	0.2	ETU- Breakdown of EBDC pesticides
2	fenamiphos- Nemacur®	90	fluometuron- Cotoron ®, C-2059
200	hexazinone- Velpar®	0.02	hexachlorobenzene- HCB, Perchlorobenzene
100	metolachlor- Dual®, Primextra®	200	methomyl- Dupont 1179, Lannate®, Nudrin®
200	metribuzin- Lexone®, Sencor®	400	methoxychlor- Malate®, DMDT, Methoxy-DDT
200	oxamyl- Vydate ®, DPX-1410	100	prometon- Gesafram®, Pramitol®
200	Pentachlorophenol- PCP	50	pronamide- Kerb®, Propyzamide
500	pichloram- Tordon®	90	propachlor- Bexton®, Ramrod®
100	propham- IPC, Beet-Kleen®	10	propazine- Gesomil®, Milogard®, Primatol P®
90	terbacil- Sinbar®	4	simazine- Princep®, Aquazine®
1	terbufos- Counter®	500	tebuthiuron- Graslan®, Spike®
5*	trifluralin- Treflan® (*EPA letter)	3500	DCPA

Table 1-4: Pesticide Health Advisory Levels

MICROBIOLOGICAL CONTAMINANTS

All natural water is likely to contain living organisms. Surface water supplies contain higher levels of microbial organisms because surface water is exposed to the environment. Ground water usually contains fewer micro-organisms because the water has percolated through the soil and is filtered, to a degree, and also because the lack of sufficient oxygen in groundwater suffocates or inactivates some micro-organisms. The micro-organisms that inhabit water supplies include: bacteria, viruses, and protozoan cysts

Bacteria

The earth's surface is a very good filter to remove bacteria from ground water supplies. However, problems can occur where fractured rock formations, crevassed bedrock, or poorly installed or cracked well casings allow the surface waters to channel to the aquifer

Most water-carried bacteria are harmless to humans. There are groups which cause nuisances, groups which extend illnesses and cause infections, and some which are can cause death.

Some of the more dangerous bacteria cause anthrax in animals and tetanus, botulism, cholera, typhoid fever, acute diarrhea, swamp fever, tularemia, and tuberculosis.

Harmless bacteria include the coliform bacteria grown in test tubes to indicate the presence of human sewage. (See chapter 2 for additional information on coliform bacteria.)

Nuisance causing bacteria include: Actinomycetes, iron bacteria, and sulfur bacteria.

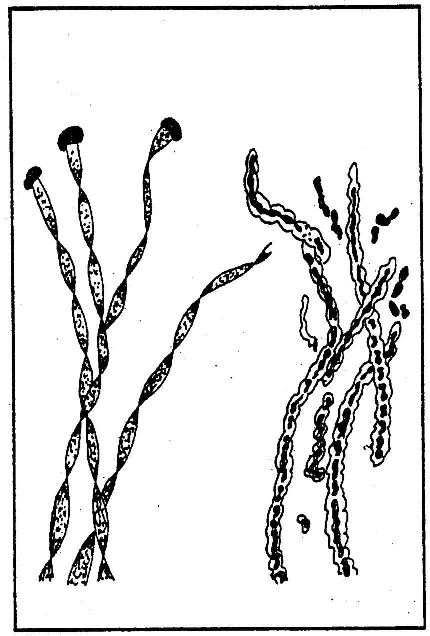


Figure 1-12: Magnified view of two types of iron bacteria

Actinomycetes are bacteria which produce a musty taste or odor in water.

Crenothrix, Gallionella, Sphaerotilus, and Leptothrix are types of iron bacteria, which are common worldwide. They combine iron or manganese with oxygen and use this as a source of energy. Signs of iron bacteria in water include a brown slime that builds up on well screens, pipes, and water closets. A water system infected with iron bacteria may smell like fuel oil, cucumbers, or sewage.

Sulfur bacteria are not as common in wells as are iron bacteria, but they are quite similar in action. There are two types of sulfur bacteria. The sulfur oxidizers live only where there is oxygen. As they feed on sulfide they produce sulfur which is a slime that coats pumping equipment and wells. Sulfate reducers or (SRBs) live only where there is little or no oxygen. One of the by-products this bacteria produces is sulfide gas, which has a rotten egg smell. (That smell can also be produced by a magnesium anode rod in a water heater.)

Hydrogen sulfide gas can be harmful to humans, however the level found in most wells is not dangerous. The corrosion caused by hydrogen sulfide can affect metallic plumbing systems.

The bacteria found in soils, including iron and sulfur bacteria, are sometimes transmitted to new wells by unsanitary drilling procedures or pump installation practices. Proper chlorination of wells and equipment can help prevent bacterial contamination.

Viruses

Viruses, the smallest organisms that can cause disease, are very hard to detect and resist treatment by medication. Two infamous strains include polio and hepatitis. Many cold and flu type diseases are caused by viruses. Viruses can move great distances in ground water, especially in limestone regions.

Protozoa

Many protozoa (one-celled animals) are harmless in water. There are some, however, that cause disease. When a parasitic protozoan finds itself in uncomfortable surroundings (like expelled from the warmth of a host's body) it forms a hard covering, called a "cyst." See Figure 1-13. This provides the protozoan to survive outside the body. Body wastes (feces) that contain pathenogenic cysts may contaminate drinking water and a person drinking this water could contract a disease.

The protozoa Entamoeba histolytica is a troublesome parasite in the human body. This parasitic ameba can exist in a person's large intestine, living in harmony with the host, eating bacteria and other foods the intestine contains. Because of reasons yet unknown, this protozoa changes its way of life and attaches to the intestine wall. There it secretes an enzyme that dissolves the intestinal lining, causing an ulcer. The disease is called "amebic dysentery." In severe cases of amebic dysentery the entire intestinal wall can be destroyed and peritonitis (an infection in the abdominal covering) can occur or ulcers can appear in the brain or other vital organs. Amebic dysentery caused 58 deaths and almost 1,000 cases of Amoebiases in 1933 at the Chicago World's Fair.

The Giardia Lamblia cyst and the Cryptosporidium oocyst cause acute diarrhea which can last two or three months in humans. The diarrhea can recur if not treated. Both the Giardia cyst and the Cryptosporidium oocyst are resistant to the chlorine dosages usually used for disinfection. Proper filtration of water containing these protozoa can be effective in removing the cysts.

Entamoeba Histolytica *Giardia Lamblia* *Giardia Lamblia cyst*

Chapter One Notes

Chapter One - Self Check

1. The chemical symbol for a molecule of water is ________.
2. The three states of water are solid, liquid, and __________.
3. Water is sometimes called the "Universal ______________.
4. The natural cycle of water is called the ________________ cycle.
5. In general, the water on the floor of a basement (can or cannot) ____________ conduct electricity.
6. pH stands for the ______________ of a ________________.
7. If water is filtered and completely boiled away, the solids left in the pan are called the ______________________.
8. Contaminants (are or are not necessarily) ______________ harmful in drinking water.
9. 14 gpg of hardness can be converted to _______ mg/L of hardness.
10. One-celled animals are also called __________________.

* Answers for self-checks are in the appendix of this manual.

2 Installation

There are general installation practices and testing procedures that are applicable for most treatment devices, some of which are very complicated. When the treatment solution is difficult or putting the test results together seems confusing, ask for help from one of the following sources:

Department of Natural Resources, Bureau of Drinking Water and Groundwater, P.O. Box 7921, Madison, WI 53707, 608-266-0821. (See the state map in the appendix for district office locations);

Safety and Buildings Division, 201 West Washington, P.O. Box 7162, Madison, WI 53701, 608-267-1401; or

The specific device manufacturer or the manufacturer's literature.

CHOOSING TREATMENT SYSTEMS

To make a decision as to the most suitable system for each specific installation, the designer/installer of a water treatment device or system must rely on:

1. Testing of water supplies;
2. Consumer needs and expectations; and
3. The designer's own on site observations.

TESTS ON WATER SUPPLIES

Municipal water supplies are tested periodically by the purveyor. There are federal Safe Drinking Water Act regulations that govern purveyor responsibilities, some of which are now changing.

Information relating to microbiological contamination, chlorine and fluoride concentrations, iron and hardness levels, and pressure available at the main can be obtained from the purveyor.

A consumer served by a municipal water supply might request that an aesthetic contaminant municipal water be reduced. This might include reducing a chlorine taste or reducing the hardness of the water. The purveyor can at times affect the aesthetics. (When referring to water treatment devices, the term "reduce" should be used, not the word "remove." Devices usually do not completely "remove" a contaminant. Consumers need to be aware that reduction, rather than removal, is the realistic expectation of water treatment.)

There is an expectation that municipal purveyors will monitor and alleviate health-related contamination.

There is, however, health-related contamination that can occur after the city water has left the main in the street. A leak in a water service can aspirate (draw or suck) contaminants into the drinking water. Lead contamination in excess of the advisory levels can occur due to lead-lined tanks, brass and lead fittings and pipe, or lead-based flux and solder. Even a dangerous backflow situation can contaminate a household water supply. A municipal water supply does not always ensure the fact that "safe" water exists at the tap

.

The lack of scheduled sampling in most private wells permits water quality problems to exist without detection for long periods of time. Rural home owners should take it upon themselves to test their well water frequently to prevent serious illness. A water test is required by the Department of Natural Resources when a new well is put into service. Lending institutions frequently require coliform bacteria and nitrate water tests before a home loan is approved.

The coliform test is used to measure the possibility of biological contamination in a water supply. There are so many different types of viruses, bacteria, and protozoan cysts that may contaminate a drinking water supply, that an "indicator" is needed to make testing easier and affordable.

Most harmful (pathogenic) organisms in drinking water are likely to come from the feces of animals or humans. A harmless bacteria called the coliform bacteria is present in animal and human sewage and serves as the indicator for drinking water testing. Coliform bacteria are indicators that disease-producing organisms have access to your water supply.

One style of coliform test is done by injecting drinking water samples into five test tubes with a selective growth medium. The presence of coliform bacteria in this growth medium will produce a gas within the test tube. If any of the five tubes, over time, indicate the growth of coliform bacteria, the well sample is said to be unsafe and further testing is necessary to find out if the test was valid or if the well is contaminated by some organic matter. There are other tests on the market, but the five tube method is the most commonly used.

Laboratories will require that water collected for a bacteria test be kept uncontaminated by outside influence. The procedure recommended by one health laboratory is as follows (also see figure 2-1):

1. Obtain a suitable container from the laboratory;

2. If possible, sterilize faucet by using a propane torch;

3. Let the water run for at least ten minutes before taking sample. (Cold hard water should be taken - NOT SOFT WATER.);

4. Open sterilized container, being sure not to touch the inside of the cap or bottle rim; Fill to about 2/3 full and carefully replace top;

5. Water sample should be submitted as soon as possible, preferably within six hours of collection. Samples not submitted immediately after collection should be refrigerated until they are taken to the laboratory. Samples older than 48 hours will not be accepted for analysis.

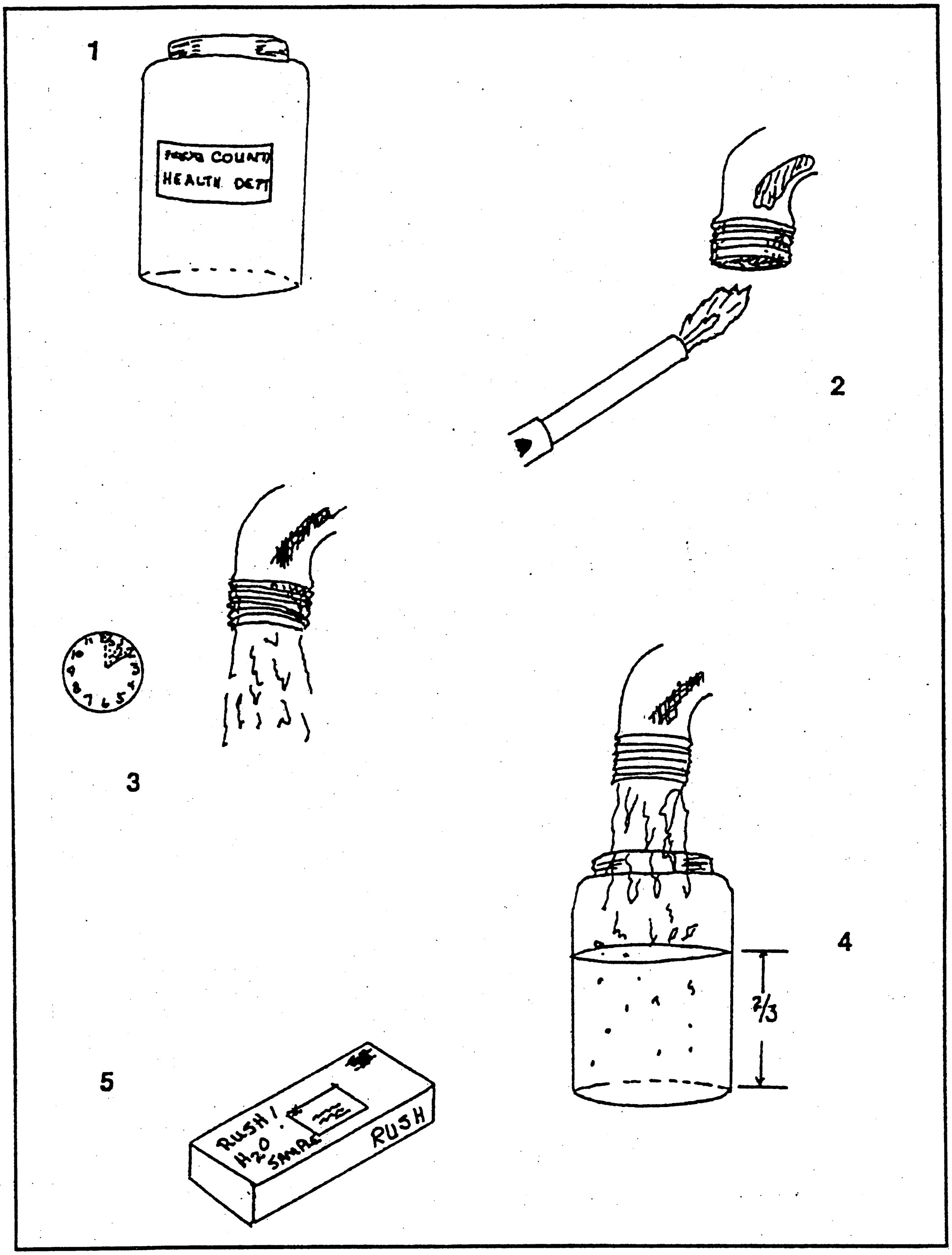


Figure 2-1: Taking a water sample correctly

A nitrate test is carried out to discover if the level of nitrates in the water is high enough to pose a health risk to infants. (See nitrates, Chapter 1.)

There are in home tests which are adequate to determine levels of pH, iron, and hardness. To substantiate the results of home tests, a laboratory can also conduct these tests.

(pH requires a test immediately upon drawing the sample. pH changes rapidly when the water sample is exposed to air, and a test should be taken as soon as the water is drawn. Tests on pH hours after drawing the water show different results. Frequently the test results for industrial monitoring wells report pH at the site and pH hours after the sample is taken, at the laboratory.)

Water testing for health-related contaminants requires an accurate assessment. At home testing is NOT advisable for health-related contaminants. That testing should only be done by a certified laboratory. A list of laboratories that are currently certified in the state is included in the appendix of this manual.

Some home tests use heavy metals and dangerous chemicals to obtain results, and the certified testing labs are better able to deal with these residuals.

Existing water conditions in the surrounding area may warrant further tests that are health-related but not routinely administered. A suspected petroleum spill may indicate the need for a screening test for VOCs. In agricultural areas, especially in sandy soils, it may be beneficial to test for pesticides that have been discovered in neighboring wells. There may be a known groundwater contamination in an area. If so, the Department of Natural Resources may have already collected samples and have test results available.

Request the tests that seem most sensible for each situation. Coliform and nitrate tests are usually inexpensive. Some of the other tests, however, can be very expensive for the home owner. Cost can become the limiting factor in what tests are accomplished.

CONSUMER NEEDS AND EXPECTATIONS

Pertinent information can sometimes be gathered by simply asking the consumer the right questions:

"Why do you believe you need/want a water treatment device? Is it because the results of a water test indicated a health risk? Do you believe the water is too hard? What reasons did they have for calling to evaluate their water supply? "

"Have you had your water tested recently?" If the answer is yes, a copy of the report will help suggest a logical treatment system. Perhaps more testing is necessary to confirm the results of the test. At times additional testing is required to localize a contamination source. High levels of lead in drinking water can be traced by sampling various points in a distribution system.

"What results do you expect of a treatment device and what are you willing to pay for these results?" A water supply may contain hardness water and chlorine. Maybe someone's willing to accept the hardness of their water supply, but they wants the chlorine level reduced to improve the taste. Their expectations may require installation of a activated carbon filter that treats only the water at the tap in the kitchen.

DESIGNER'S EXPECTATIONS

A designer/installer's own observations can determine the type of system required. The setting at the pressure switch, the discharge rate of the pump, or the available flow rate can affect the type of system acceptable. The "slime" created in a toilet tank may indicate the presence of iron bacteria. The red color in the water or staining the fixtures associated with iron or the black manganese color may be evident. The characteristic scale formation on faucets that indicates hard water may be seen. All these direct observations can help the designer provide the consumer with the most logical choice of treatment systems.

POINT OF USE OR POINT OF ENTRY?

Once the problems to be treated are known, the installer and consumer must decide whether to use a point-of-use (POU) or point-of-entry (POE) device. See Figure 2-2.

POU devices are installed on the supply to an individual faucet or appliance. Usually the cost to treat the entire residence prohibits POE treatment and POU treatment is more logical. POU devices frequently include small activated carbon filters for drinking water taps. Other POU devices are reverse osmosis (R/O) units, distillers, and sedim ent filters upstream of appliance solenoid valves.

A POE treats the entire water distribution, perhaps with the exception of outside hydrants, a hard water drinking tap, or some other terminal that does not require treatment. POE is frequently used with softeners, iron filters, and activated carbon systems. Where it is cost effective, POE systems are usually the optimum choice.

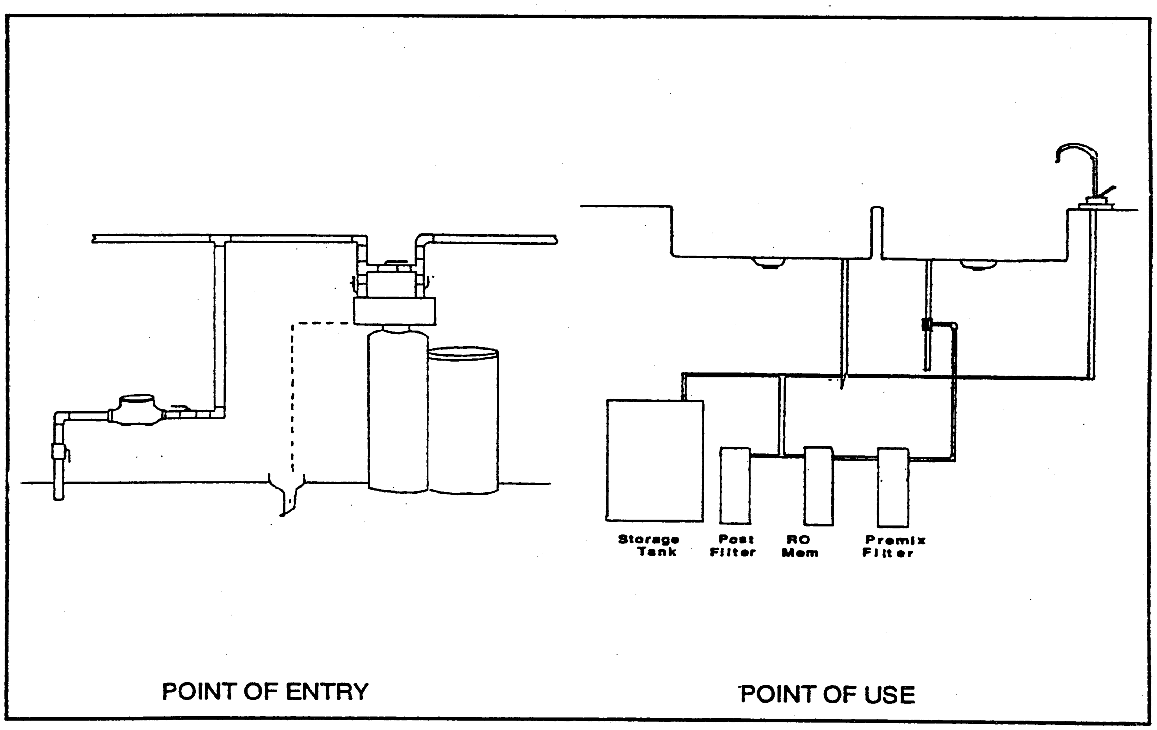


Figure 2-2: Point-of-Entry and Point-of-Use

PRESSURE AND PRESSURE LOSS

The pressure available to a device can enable the device to work effectively or it can prohibit the installation of that device unless a booster pump is used upstream of the device.

Pressure loss may also be a consideration when choosing between POU or POE systems. The pressure loss through a device such as an R/O unit may be so great that only a POU unit is practical, unless a repressurizing pump is installed.

Manufacturers include the pressure required at the device inlet with their installation instructions. Pressure loss through a device or system should always be taken into account **before** the installation.

In designing treatment device installation for POE devices such as softeners, specify a pressure loss at a service flow rate. If the pressure loss is not specified on a plan review submittal, a POE device pressure loss of 15 psi is usually assumed. If a pressure loss at a flow other than the service flow rate is needed, manufacturers of devices have pressure loss graphs which depict the pressure loss versus service flow rate. See Figure 2-3.

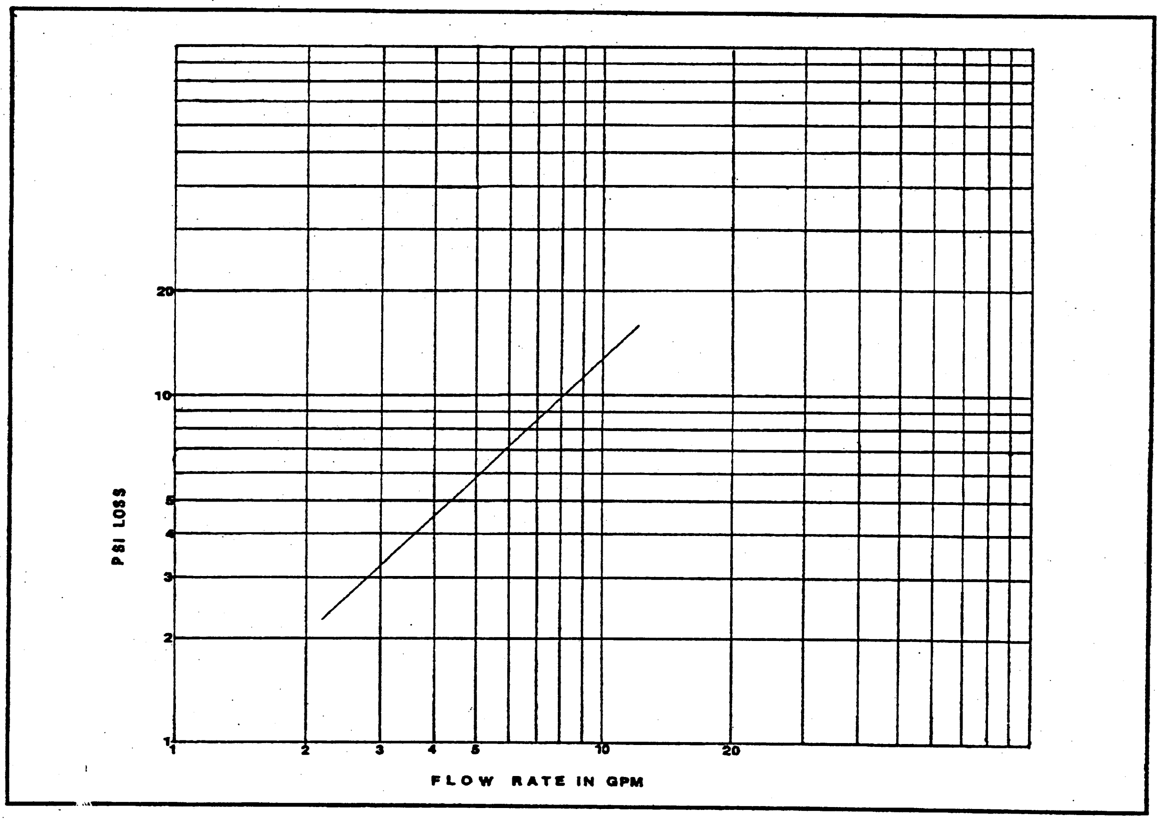


Figure 2-3: Pressure loss through devices

For POU devices it is important that the required operating pressure is available at the device inlet. As long as the POU device serves only one outlet, this minimum pressure is usually sufficient for the delivery of water. Consult the manufacturer's specifications regarding pressure loss.

Refer to the "Sizing The Water Supply System" manual distributed by the Safety and Buildings Division Bureau of Integrated Services for further information on how pressure loss affects the water distribution system.

TEMPERATURE

The manufacturer usually specifies maximum and minimum operating temperatures. The minimum is usually just above freezing. The maximum temperature is usually around 100F. Most devices (one exception is distillation units) are designed for cold water use.

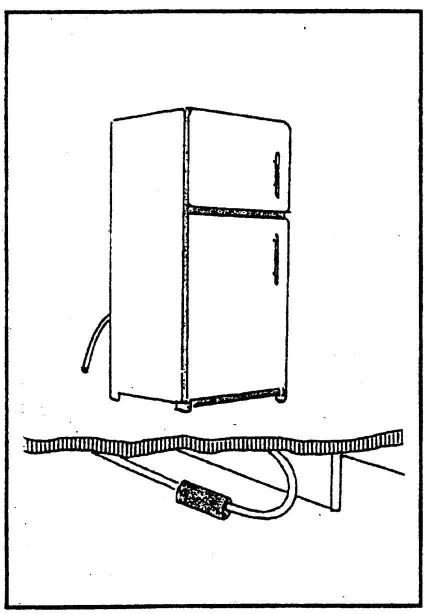


Figure 2-4: Fixture supply connectors

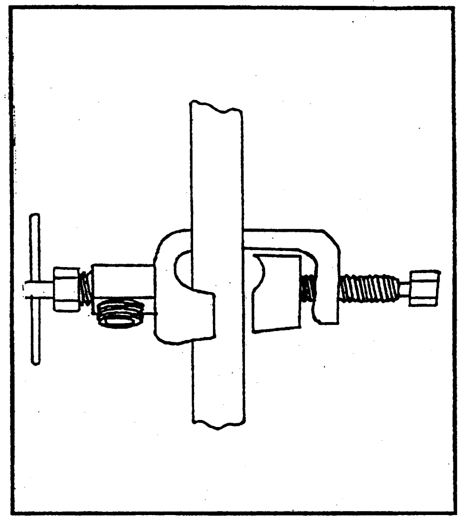


Figure 2-5: Self-tapping saddle for water supply

WATER SUPPLY

Comm 82.40(7)(g) states: "The fixture supplies serving all plumbing fixtures, appliances and pieces of equipment shall be at least 1/2 inch in diameter." Fixture supply **connectors**, which may be smaller in diameter than the 1/2 inch, may be up to ten feet in length from a single faucet or outlet to a water cooler device, water heater, or water treatment device which is to individually serve the faucet or outlet. See figure 2-4. The minimum diameter must meet the minimum required by the manufacturer in addition to the minimum code requirements.

Point of use devices that serve **one** fixture or appliance may be valved by using a self-tapping saddle as specified in Comm 82.40(8)(h). See Figure 2-5.

A valve serving a device that supplies more than one fixture would be required to meet the sizing requirements as listed in Comm 82.40.

Table 84.30-9
WATER DISTRIBUTION PIPE AND TUBING

Material	Standard
Brass	ASTM B43
Cast iron	ASTM A377; AWWA C115/A21.15
Chlorinated polyvinyl chloride (CPVC)[a]	ASTM D2846
Copper[b]	ASTM B42; ASTM B88
Ductile iron	ASTM A377; AWWA C115/A21.15; AWWA C151/A21.51
Galvanized steel	ASTM A53; ASTM A120
Polybutylene (PB)[a] for agricultural use and pure-water use	ASTM D3309
Stainless steel	ANSI B36.19M; ASTM A270; ASTM A450

Note a: Plastic pipe and tubing installed underground shall be in accordance with ASTM D2774. See Appendix for further explanatory material.

Note b: Copper tubing, type M, may not be installed underground.

Figure 2-6: Table 84.30-9 Approved water distribution materials

TO BYPASS OR NOT TO BYPASS

Comm 82.40(8)(d)4 states: "Water distribution piping shall be provided to bypass a water softener and an iron removing device. The bypass piping may be an internal part of the water softener or iron removal device." For an integral part of the control valve (head) to be acceptable as a bypass, the control valve must be removable while the bypass remains operational. See Figure 2-6

.

Some water treatment devices should never be bypassed. A system that reduces health-related contaminants should not have a bypass installed. If a certain style of gate valve were installed in such a bypass, no one would know if the bypass were open or shut without physically turning the handle. If there is a question about whether a bypass should be installed on a system, contact the DNR as noted on page XXX.

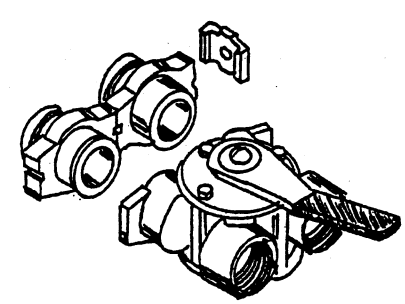


Figure 2-7: Approved internal bypass

DRAIN LINES

Many treatment devices require a receptor to receive the backwash discharge. Comm 82.33(9)(k) requires that a drain from a water treatment device "discharge to a drain system through indirect waste piping by means of an air gap." The indirect waste piping begins at the termination of the discharge tubing from the treatment device. See Figure 2-7. Upstream of that discharge point is considered to be water distribution piping and must meet requirements pertaining to materials for water distribution as listed in Comm Table 84.30-9. See Figure 2-8.

The small diameter drain piping for devices like reverse osmosis systems are approved during the product approval process. The size of the drain piping is usually specified by the manufacturer. The drain pipe size from softeners is usually 1/2-inch or 3/4-inch. The drain size from a small reverse osmosis system is usually 1/4-inch.

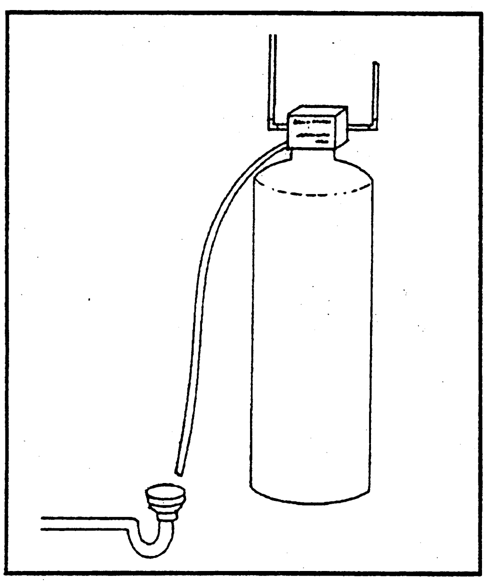


Figure 2-8: Point of discharge from device is the beginning of the indirect waste

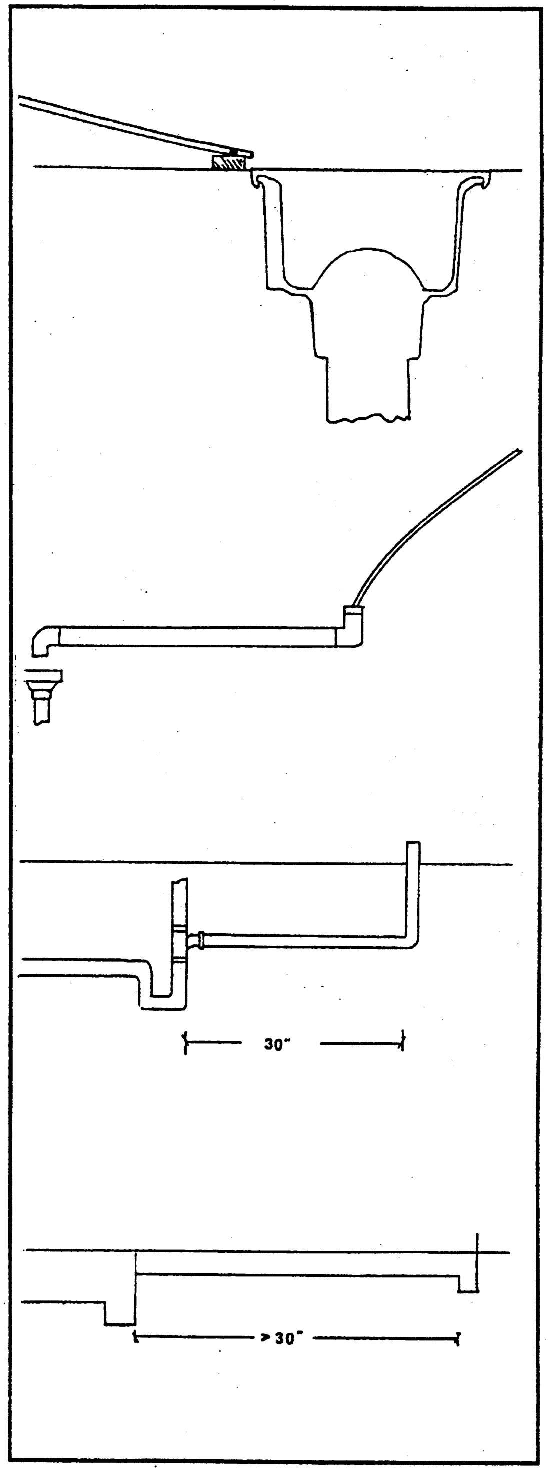


Figure 2-9: Approved air gap installations

Some of the various installations that produce the required air gap are illustrated in Figure 2-9. There are approved manufactured air gaps on the market that may be used as the required air gap for water treatment devices. See Figure 2-10. The flow rate through the devices cannot exceed the manufacturers' ratings. Consult the manufacturers' literature for the air gap **and** the treatment device to make sure they are compatible.

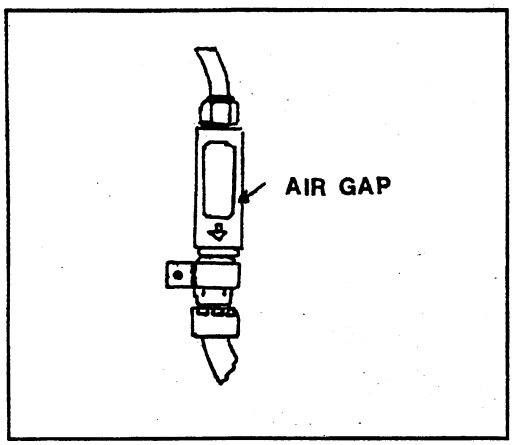


Figure 2-10: Manufactured air gap installation

On POU devices, the air gap required by code may be approved as an integral part of a faucet as in Figure 2-11. When a faucet with an internal air gap is provided, the connection may be upstream of a P trap and installed using a saddle fitting as per Comm 84.30(5)(d)1 & 2. See Figure 2-12. The saddle in Figure 2-12 must be installed on the fixture side of a P-trap and may not be installed on a P-trap receiving the discharge from a garbage disposal.

Air gap devices that do not comply with minimum air gap dimensions specified in Comm 82.41 must receive approval from the Safety and Buildings Division before installation. See the product descriptions for "Air Gap Device" and "Faucet, Internal Air Gap" in the *Wisconsin Plumbing Product Register* for current approvals.

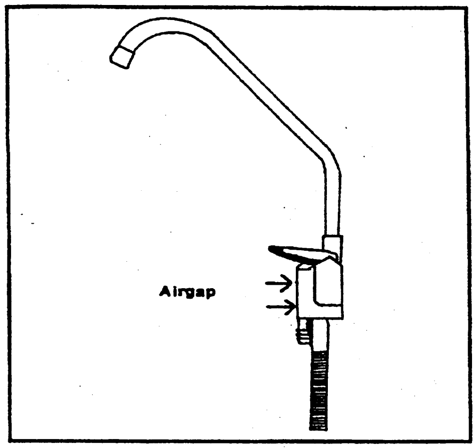


Figure 2-11: Internal air gap

RECEPTORS

Receptors for indirect wastes are listed in Comm 82.33(8). They include waste sinks, and stand pipes, floor sinks, and local waste piping. An interpretation that allows a floor drain to be used as a receptor for water treatment devices is reprinted in the appendix of this manual. Figure 2-13 illustrates several acceptable receptors and installations. Remember, the air gap or equivalent protection is required, regardless of the choice of receptor.

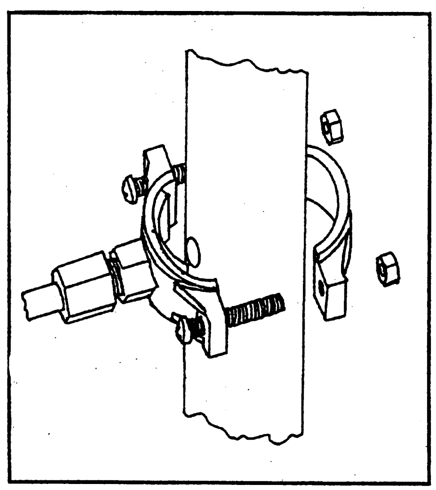


Figure 2-12: Approved drain saddle fitting

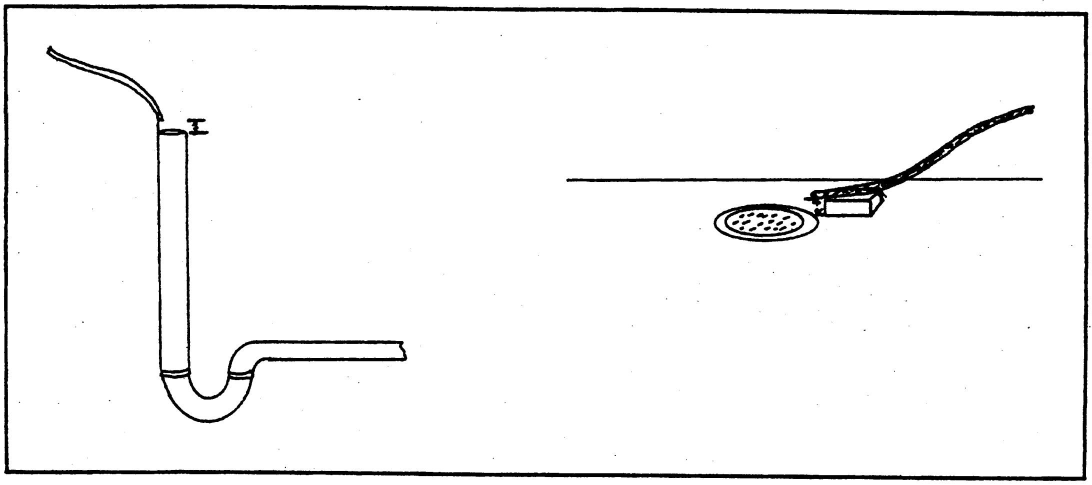


Figure 2-13: Approved receptors

DISCHARGE POINTS

The discharge ofbackwash or regeneration water from water treatment devices has different system destinations.

Softener discharge can be directed to the storm or sanitary system. Sanitary systems include Private Onsite Wastewater Treatment Systems (POWTS). Comm 82.36(3)(b) states: "Where no storm sewer system or combined sanitary-storm system is available or adequate to received the anticipated load, the storm water, surface water, and clearwater wastes shall be discharged in accordance with local government requirements."

The backwash discharge from a softener that reduces the concentration of radium in the water supply should not discharge to grade, but may be directed to either the sanitary or municipal storm system.

Backwash from iron filters that contain potassium permanganate (KMnO as an oxidizing agent must discharge to sanitary as concentrated KMnO is a highly toxic chemical.

When chlorine is used as an oxidizing agent, or when other chemicals are used as additives or backwash agents, the discharge should not be discharged to grade. If you have any questions contact the DNR for further information, as noted on page 90.

The discharge of softener backwash into POWTS has been studied by the Small Scale Waste Management Program at the University of Wisconsin in Madison. It is believed that in certain soils the introduction of brine solution may actually enhance the permeability of soils. The discharge from softeners, iron filters, reverse osmosis units, or activated carbon filters may be directed to the private sewage system. The backwash discharge from a softener that reduces the concentration of radium in the water supply should not discharge to grade but may be directed to either the sanitary or piped storm system.

ELECTRICAL CONNECTIONS

An electrical outlet should be available if one is required for operation of the device. If additional wiring is needed, call a qualified electrician.

GROUNDING AND BONDING

In interior wiring systems there are two types of grounds, system grounds and equipment/conductor enclosure grounds.

System grounds are the grounding rods or wires that ground the entire electrical system. They protect the residence from electrical fires and the inhabitants from accidental injury. Wisconsin's electrical code requires dwelling units be provided with two code-compliant grounding rods.

Equipment grounds serve individual devices and their metal casings. Water treatment devices with electrical connections require grounding by means of a grounded outlet. DO NOT install a device using the "cheater" adapter (See Figure 2-14) or by pulling the grounding prong from the plug.

The National Electrical Code defines bonding as "The permanent joining of metallic parts to form an electrically conductive path which will assure electrical continuity and the capacity to conduct safely any current likely to be imposed."

If a plastic softener head is installed on a metallic piping system there must be bypass or "jumper" permanently placed around the head to maintain the electrical continuity through the residence. This jumper must meet the sizing requirements in the National Electrical Code. Consult a qualified electrician to perform this installation.

DNR INSTALLATION APPROVAL

Installation of water treatment devices on some water supplies may require Department of Natural Resources (DNR) installation approval.

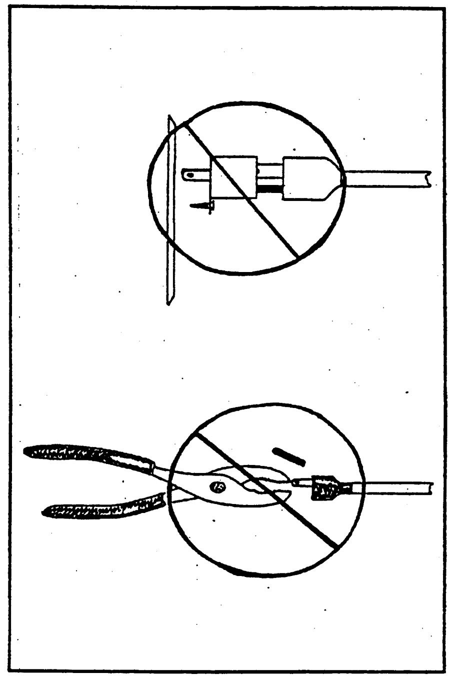


Figure 2-14: Electrical "don'ts" during installation

If the water is from a community water supply you normally do not need any DNR installation approval. However, you may need to obtain a local plumbing permit. Check with the local plumbing inspector to see if you need to obtain a permit to install the device.

If the water is from a private or non-community water supply you may need to obtain a DNR installation approval. That approval is required if any of the following conditions apply:

1. The water treatment device is intended to control bacteriologically unsafe water;

2. The water treatment device is to be installed on or within a well or when water treatment occurs within the well;

3. The water treatment device is intended to control contaminant levels in excess of primary drinking water standards in a private water system and the contaminant levels exceed the influent concentrations specified in the Safety and Buildings plumbing product approval letter;

4. The water treatment device is intended to control contaminant levels in excess of primary drinking water standards or health advisories in a non-community water system

5. The DNR informs the water system owner/operator that the water system contamination is complex and DNR installation approval is required;

6. The DNR has ordered the use of a water system to be discontinued; or

7. The water system is treated with fluoride.

Any questions about the need for a DNR installation approval should be directed to Department of Natural Resources Bureau of Drinking Water and Groundwater, P.O. Box 7921, Madison, WI 53707, 608-266-0821.

SAFETY AND BUILDINGS DIVISION PRODUCT APPROVAL

The Department of Commerce Safety and Buildings Division reviews water treatment devices for sale or use in Wisconsin. The review applies to devices that are connected to the water piping, including those attached to faucets. Examples of water treatment devices include, but are not limited to, water softeners, iron filters, reverse osmosis systems, distillation units and activated carbon filters. Water treatment devices must receive written approval from the Safety and Buildings Division prior to sale or installation.

The review is for the following:

1. Rendering inactive or reducing aesthetic contaminants (e.g. chlorine, hardness, iron, iron bacteria, taste, odor, etc.) and health-related contaminants (e.g. lead, nitrate, organic compounds, etc.)

2. Suitability of construction materials for use with potable water;

3. Ability of the device to withstand the pressure and temperatures to which it will be subjected; and

4. Proper installation and operation instructions.

Approval letters issued by the Safety and Buildings Division list the contaminants that the device has been tested to reduce, the influent concentrations, the effluent concentrations, the detection limit, the flow rate, and the maintenance cycle. The maintenance cycle is usually specified as a certain number of gallons.

Before buying a water treatment device, consumers should ask the seller for a copy of the approval letter to see what contaminants the device is rated to reduce.

For water treatment devices that inject a chemical other than air into the water supply, the Safety and Buildings Division reviews for the following:

A. Maintaining the chemical's concentration in the water;

B. Suitability of construction materials for use with potable water;

C. Ability of the device to withstand the pressures to which it will be subjected; and,

D. Proper installation instructions.

For water treatment devices that only inject air the Safety and Buildings Division reviews the product for b, c, and d listed above.

For information on how to obtain a list of approved water treatment devices, contact the Division of Safety and Buildings P.O. Box 7162, Madison, WI 53707, 608-267-7994.

Chapter Two Notes

Chapter Two Self-Check

1. Water treatment devices do not completely remove a contaminant, they _______________ it.
2. Information relating to pressure at the main can be obtained from the ___________________________________.
3. Coliform tests measure _____________ contamination.
4. Coliform bacteria serve as an _______________ that disease producing organisms are present in water.
5. Point of use devices (may or may not) __________ serve only a single faucet.
6. Point of use devices that serve _________ fixture or appliance may be valved with a self-tapping saddle.
7. Softener backwash discharge can be directed to the ____________ or the storm system.
8. DILHR product approval is required for __________ __________ ____________.

* Answers for self-checks are in the appendix of this manual.

3 Softening

"The most common water quality problem reported by consumers throughout the U.S. is hard water. A U. S. geological survey indicates that hard water is found in more than 85% of the country." *Water Quality Research Council, 1990.*

"Hard" water was named "hard" because of the higher mineral content and because it is considered "harder" to use. It makes rings around bath tubs because of the curds it forms with soap. It also forms scale on appliances, the inside of pipes, and heat exchangers, causing a loss of effectiveness.

The most common process used to change "hard" water to "soft" water is ionic exchange. This is a chemical exchange water treatment process. Because the exchange that takes place in softeners affects the cations in the water, the technical term for softening is "cation exchange."

CATION EXCHANGE

A cation is a positively charged ion. An ion is an atom or group of atoms that contains an electric charge. Cation exchange units, or softeners, are simply tanks filled with cation exchange material (usually called resin) through which water flows. In addition to the chamber holding the exchanger, some units include a control valve and a tank containing the regeneration solution (usually brine).

One explanation of the cation exchange process is the "park bench" principle (Smith, etal. 1990). Each bead or particle of exchange medium contains thousands of exchange sites on its surface. Imagine that each site is like a two-seat park bench. When the exchanger (the softener) is prepared, each of the park benches is filled by two sodium ions sitting side by side. See Figure 3-1. Each sodium ion has an atomic weight of 23 and a singular positive charge (+1).

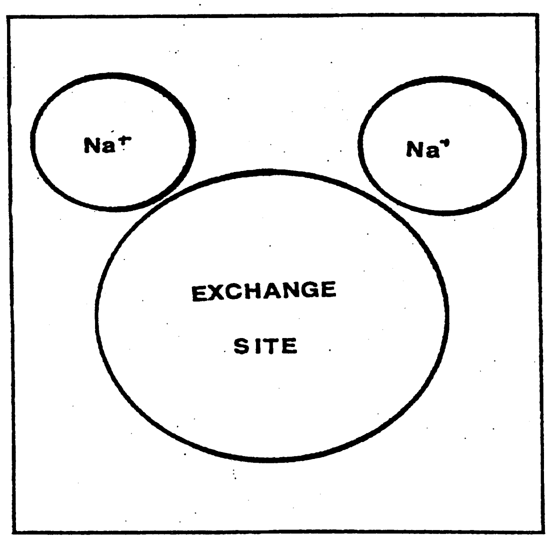


Figure 3-1: Prepared exchanger

Hard water containing calcium or magnesium is run through the exchange medium. As the larger (atomic weight of 40), stronger (+2 charged, Ca^{++}) calcium or magnesium ions enter the picture, they quite easily push the two sodium ions off the park bench and take their place. See Figures 3-2 and 3.3. One stronger ion takes their places on the park bench (the exchange site surface), and the sodium ions enter the passing water. Compared to the water with the calcium or magnesium ions, the water with the sodium ions is "softer."

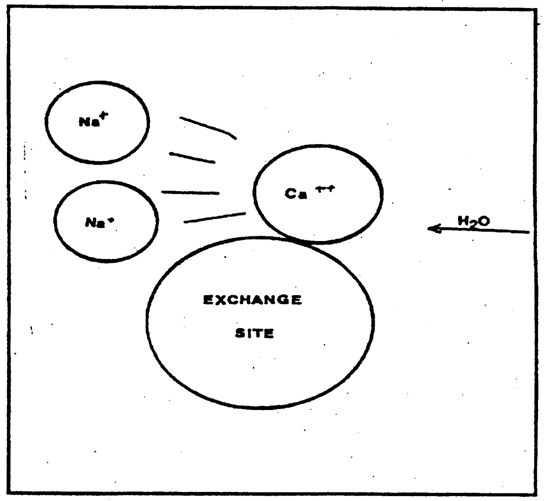


Figure 3-2: Ion exchange taking place within the exchange tank

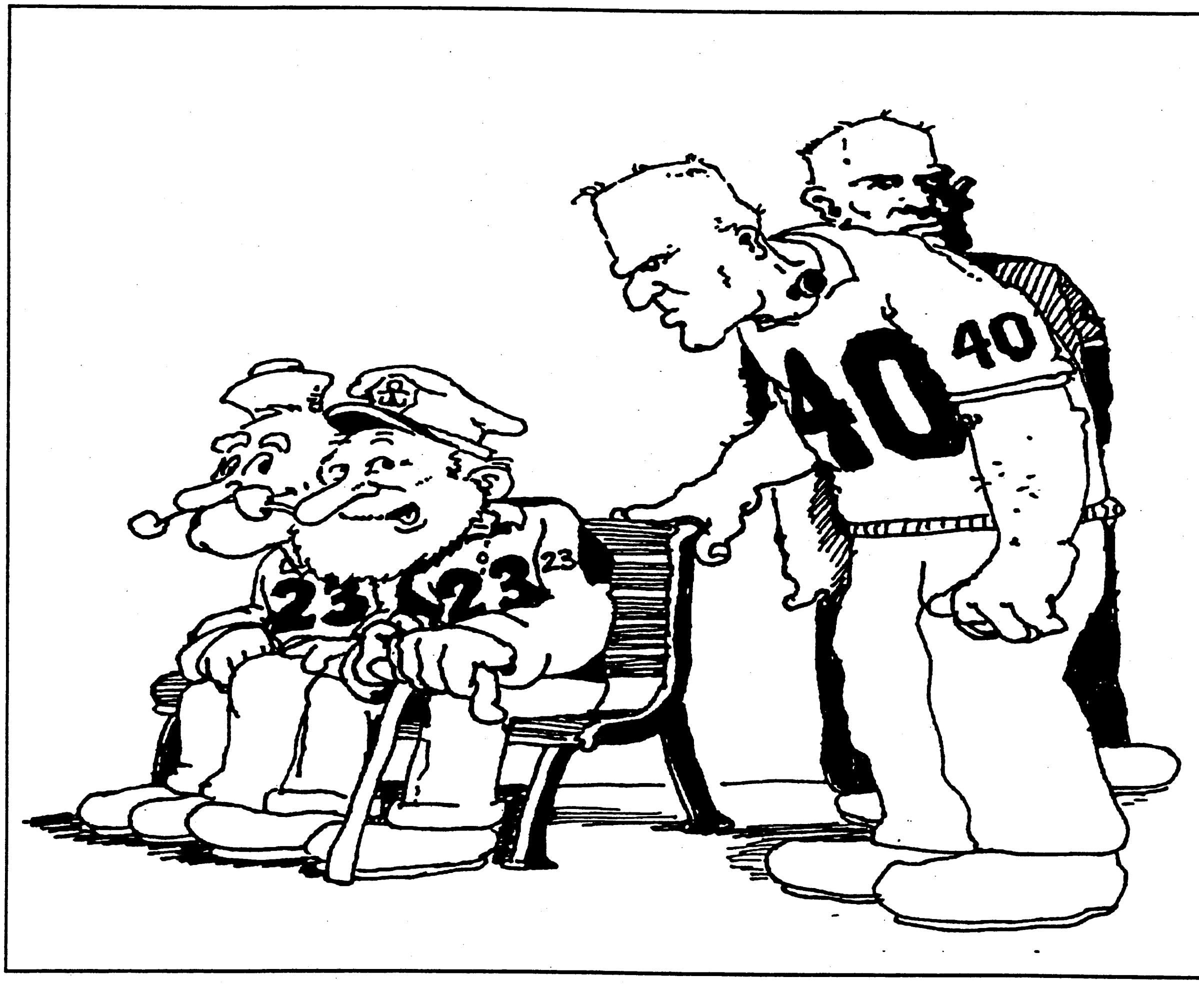


Figure 3-3: The park bench principle, hard ion pushing a couple of salts off a site, can explain ion exchange

For every 15,000 grains of hardness removed, one pound of sodium is added to the water. The concentration of sodium released into the treated water is dependent upon the "hardness" of the water. The more calcium or magnesium ions present in the untreated water, the more sodium displaced and therefore the more sodium present in the treated (softened) water. See Figure 3.4. Some doctors may not allow patients on sodium restrictive diets to drink softened water because of the elevated sodium content.

There must be a way to start the process over again after most of the exchange sites (or park benches) have been used and now are occupied by calcium ions. This is done by "regeneration." The many sodium ions required for reclaiming exchange sites are created by dissolving salt (Sodium Chloride - NaCl) in water in the brine tank. When dissolved, the NaCl forms sodium ions (Na^+) and chloride ions (Cl^-). The brine solution containing the sodium and chloride ions is added to the exchange bed where the sodium ions overwhelm the calcium or magnesium ions and push them back off the benches, with two sodium ions once again take a seat.

This ionic exchange process seems simple, but in actual usage certain cycles must be followed to ensure the most efficient procedure. The system must be regenerated by following a specific schedule. This process includes backwash, brine introduction, rinse, and flush.

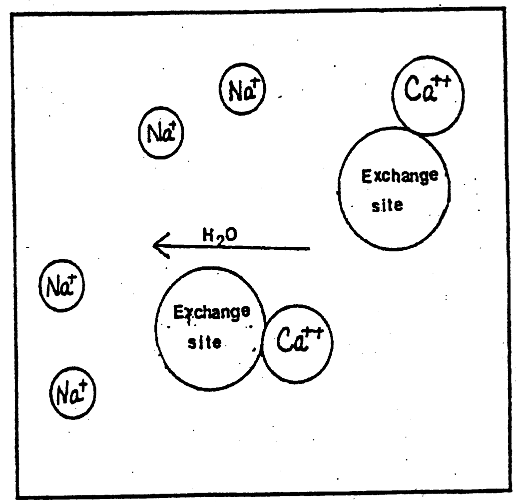


Figure 3-4: The more calcium (or magnesium) in untreated water, the more sodium in treated water

BACKWASH

The exchange medium used in softeners, resin or zeolite, usually takes up only 2/3 of the mineral tank. During backwash this allows room for "stirring up" the ion exchange bed. Backwashing is done to flush any light foreign materials out through the drain line, and to mix up the exchange beads so that the top beads do not remain on top continuously. The beads on top always do the most work, so it's advantageous to mix the beads up during backwash to extend the life of the system. The backwash process also mechanically scrubs the exchanger so it's ready for ionic exchange and "fluffs" the medium so as to allow the best contact surface for exchange. The typical backwash lasts about 12 to 15 minutes at about 4 to 5 gallons per minute per square foot of cross sectional tank area.

This backwash flow is required by the manufacturer and is very important in the function of the device. Too high a flow rate has little benefit to the regeneration process and it wastes water. High flow rates during the backwash can also push the exchange medium out of the mineral tank into the drain line. See Figure 3.5.

Softeners rely on a "pressure compensating" flow control device. About the size of a nickel, this device flexes with an increased pressure differential between the upstream and downstream side. Because of this unique design, this device can maintain approximately the same flow rate at pressures ranging from 20 to 120 psig.

A flow rate that is too low won't flush foreign materials out of the bed, won't stir up the exchange bed, and won't scrub the beads.

BRINE AND SLOW RINSE

After backwashing, the unit draws brine into the mineral tank through an ejector as in Figure 3.6. This part of the regeneration cycle is usually called "brining" or the "brine draw cycle."

Ninety percent of the problems involved in regeneration being caused by lack of vacuum

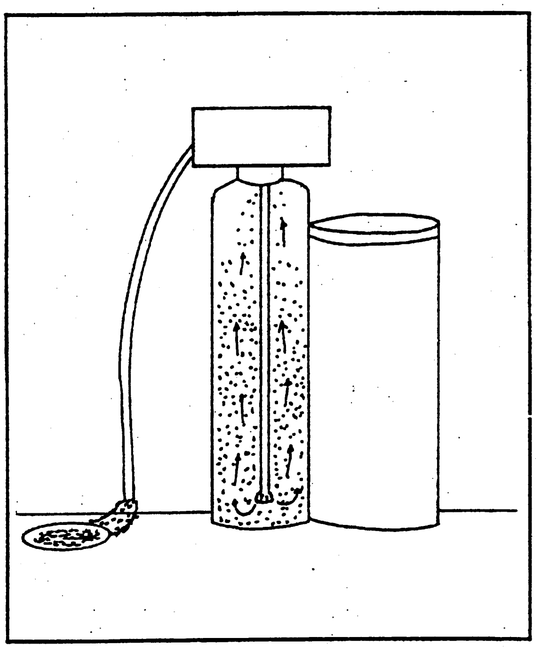


Figure 3-5: High flow rates can push medium out of mineral tanks

created by the ejector. After the brining, the work water continues to flow through the mineral tank and the brine flow stops. The ratio of work water to brine solution pulled through the ejector is approximately one to one. This is called the slow rinse. To obtain the optimum ionic exchange, the dilution and flow rate must be within the manufacturers' recommendations.

One of the most important factors in regeneration is the salt dosage per cubic foot of exchange medium. Figure 3-7 illustrates the efficiency curve as the salt concentration is increased for a particular size softener.

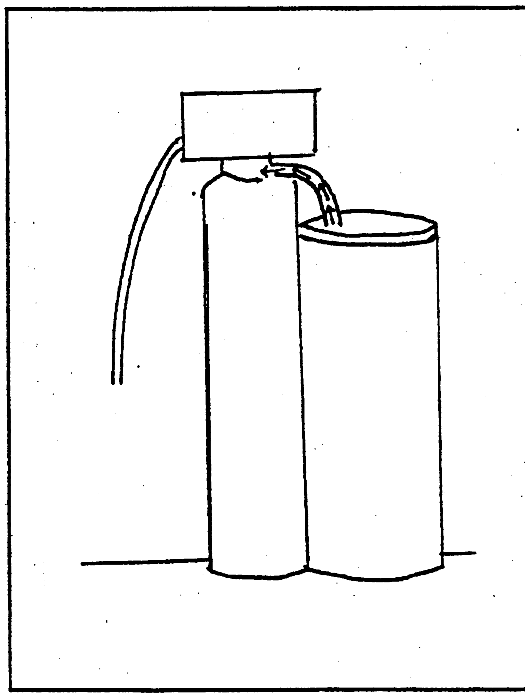


Figure 3-6: ~~The softener~~ head permits brine to enter the exchange tank

RAPID RINSE

The rapid rinse cycle is the last and shortest of the regeneration process. Not all softeners employ this rapid rinse cycle. It usually lasts about six to ten minutes. Water is forced down through the mineral tank The exchange medium is thoroughly flushed and compacted to be ready for the next cycle which is to service the incoming hard water.

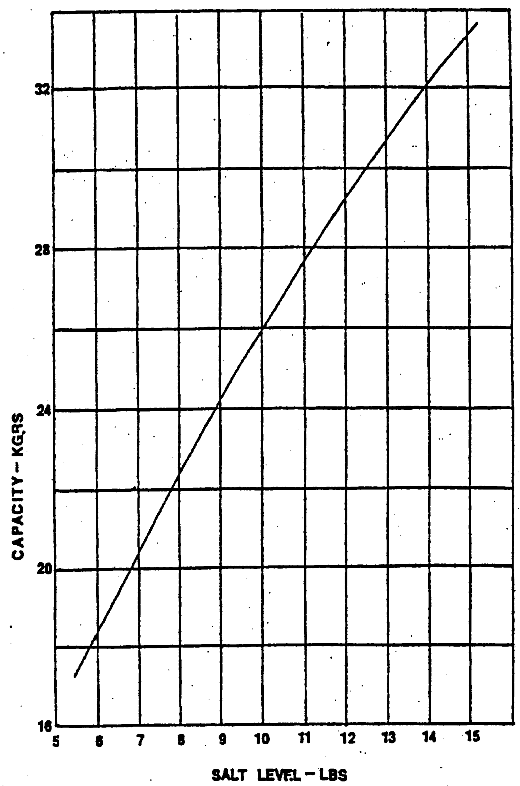


Figure 3-7: Efficiency curve as the salt concentration is increased for a particular size of softener

SOFTENER DESIGN

There are different softener designs on the market today. Figure 3-8 illustrates several common styles:

(1) The standard resin tank accompanied by a separate brine tank;

(2) The cabinet style combining the brine tank and cabinet to allow the unit to resemble a kitchen cabinet;

(3) The dual tank system which may be installed in situations where a continuous supply of softened water is required. One tank is regenerating as the other is in the service mode producing soft water; and

(4) The portable exchange tank which is provided by a water treatment company and is exchanged periodically and rejuvenated at their facility.

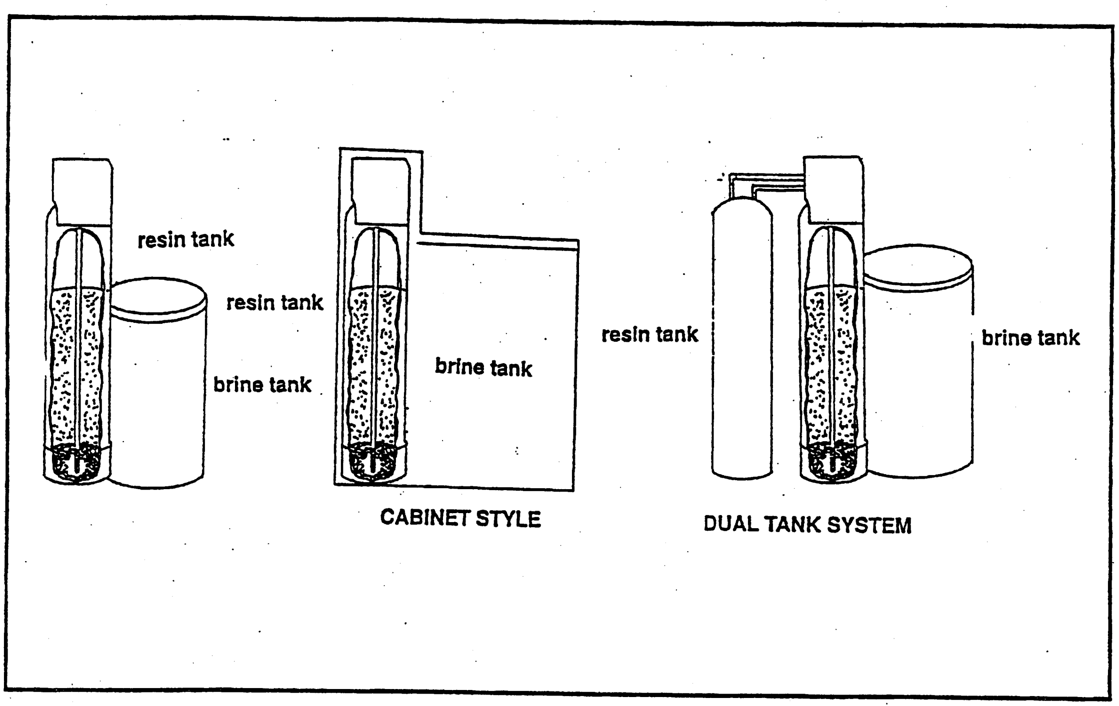


Figure 3-8:Several water softener styles

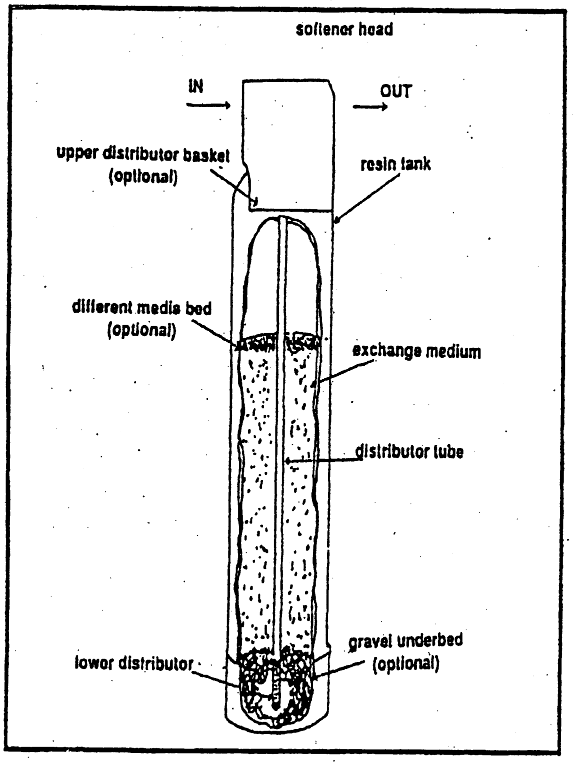


Figure 3-9: Exchange tank design

The basic exchange tank design is illustrated in figure 3-9.

Softener heads perform different functions, depending on their design. Timers installed in some types of heads begin regeneration at specific intervals set at the time of installation. The duration between regeneration cycles is determined by the hardness of the water and the anticipated use. Consult the installation manual for specific instructions. A disadvantage of timer heads is that the softener regenerates even when no water is used between regeneration cycles.

Metered heads control regeneration cycles by metering the amount (gallons) of water passing through the softener. Metered heads are set at the time of installation with the number of gallons the softener will treat before a regeneration cycle is needed. Meter heads will not regenerate until the preset number of gallons are used.

Sensor heads contain sensing devices that initiate regeneration of the exchange bed when the efficiency of the unit deteriorates to a specified point. The advantage of the sensor head is that it begins regeneration only when necessary.

TESTS

The testing should be conducted before sizing a water softening system for total hardness, iron concentration, pH, total dissolved solids, and sediment.

■ Total hardness, as discussed in chapter one, is the major determining factor in sizing a water softening system. The manufacturer's literature for the unit will state the softening capacity of that device in grains per gallon or milligrams per liter.

■ Iron levels affect the efficiency of a water softening system. Soluble iron can be removed to a certain extent by ion exchange, much the same way calcium or magnesium hardness is exchanged for sodium ions. Exchange mediums (resin and zeolite) vary as to their ability to reduce soluble (ferrous) iron in the water supply. Zeolite is usually better at soluble iron reduction than resins. When this type of ionic exchange takes place, the backwash can flush away a limited amount of the iron. Sometimes the ion exchange takes place deep inside the exchange medium bed. If soluble iron oxidizes inside the bed it sometimes becomes impossible to remove from the exchanger. Too much of this type of exchange causes the exchange capacity of the medium to be lost and the softener becomes ineffective. Some manufacturer's specify the use of salt treated with a reducing agent for regeneration to turn the ferric iron back to its clear water state so that it can be removed through regeneration. Iron reduction will be discussed in chapter 5.

If iron has caused damage to a exchange medium bed, there are chemical rejuvenation techniques that can be used. Some manufacturers recommend the use of iron removal additives in the softener at specific intervals. HOWEVER, the manufacturer's literature or the manufacturer's representatives should be contacted prior to attempting any rejuvenation methods.

Treatment of iron problems prior to softening may be accomplished by:

(1) Aeration and filtration;
(2) Chemical coagulation or oxidation and filtration;
(3) Chlorination and filtration; or
(4) Use of manganese greensand filters.

■ pH effects the ability of zeolite exchangers to operate efficiently. Contact the manufacturer as to the limitations of zeolite exchangers in relation to pH. Polystyrene resins, however, will operate equally well in high and low pH water.

■ Total dissolved solids (TDS) may reduce the efficiency of a water softener. A High TDS concentration may require more pounds of salt per regeneration or in some cases a larger softener. There are some manufacturers that require a minimum TDS level for their devices to operate effectively. There are some manufacturers which require a minimum TDS level for their devices to operate efficiently. Consult the manufacturers' recommendations.

■ Sediment can clog exchange beds. Excessive sediment levels may require a prefilter to be installed. Consult the manufacturers' recommendations.

SIZING THE SOFTENER

Sizing the softener is based on three pieces of information:

1. The concentration of hardness in the water supply. Water hardness can be tested by a laboratory. Manufacturers' or sales representatives can test for hardness, but a more accurate test can be obtained from a testing laboratory.

2. The amount of water used daily. Daily usage can be metered to determine an average use. In a residence, the usage can be estimated using formulas. A typical sizing for a five-person household with a 10 gpm water pump and a 20 gpg hardness would be solved as following: 60 gallons per person per day times the number of occupants equals the number of gallons per day used. Therefore, 5

Bed Volume (cubic feet)	*Capacity (15lb/cu. ft.; gr.)*	*Maximum hardness (gpg)*	*Max. Flow Rate (gallons per minute)*
0.3	10,000	20	3-4
0.5	15,000	25-30	5-6
0.7	21,000	40-50	7-8
1.0	30,000	60-70	10-12
1.5	45,000	75-90	15-18

Table 3-1: Choosing a softener based on hardness and flow rate required

people times 60 gallons per day or 300 gallons per day. The daily hardness that must be removed is 300 gallons per day times 20 grains per gallon or 6000 grains per day.

3. The gallons-per-minute flow rate of the water distribution system. Using table 3-1 the softener can be chosen with a 10-gallon per minute pump requiring a one cubic foot exchange medium capacity softener. The softener in this example would have to be regenerated every five days. Manufacturers provide sizing information with their units.

EXCHANGE MEDIUMS

There are two different type of exchange mediums that manufacturers use in softeners. Each has specific ion exchange capabilities. Resin exchange medium is most often made of sulfonated polystyrene copolymer. Some softeners contain zeolite, which is a mineral. The resin exchangers carry the highest capacity for ionic exchange in relation to hardness. Approximately one cubic foot of resin has the theoretical capability of exchanging 30,000 grains of hardness. Zeolites have a lower capacity, approximately 17,000 to 22,000 grains per cubic foot, but has a greater capability to remove clear water iron.

In addition to the exchange medium, some softeners contain a small amount of gravel to improve backwashing, distribution, service flow rate, and slightly improve exchange capacity. Other softeners contain a small bed of activated carbon. However, this activated carbon is not rated to improve taste and odors, nor is it rated to reduce organic chemicals.

Information concerning what is in the softener exchanger is usually contained in the operation/installation manual.

Zeolites of different types may be used on water supplies to adjust pH and reduce iron and manganese. Zeolites require a minimum TDS level to operate correctly.

When cleaning or rejuvenating exchange beds it is necessary to follow the manufacturer's instructions. Certain exchange beds, such as resin, "melt" when they are exposed to a concentrated solution of chlorine for extended periods of time. Zeolites can not stand up to treatment with acids, but may be cleaned with chlorine solutions.

INSTALLATION GUIDELINES

Installation recommendations can very with different devices and installation should always be accomplished after first reading the manufacturer's installation manuals **thoroughly**.

There are some general guidelines that the installer should know and understand.

Water pressure at the device should not be below 20 psig or usually above 100 psig. Too low of a water pressure will give an insufficient flow for the customer, and fixtures downstream of the device may not work properly. Too low of a water pressure will also cause a poor backflush and an ineffective vacuum to pull brine into the exchange tank during regeneration. A water pressure above the recommended maximum may cause resin to be washed out of the tank during backwash. High pressure can also cause noisy operation and may void the warranty on the softener. Pressure-boosting systems or pressure-reducing valves may be installed to remedy pressure problems.

If an electrical outlet is required for the unit, follow the general instructions in chapter two for adequate electrical provision.

An appropriate size drain for the discharge rate of the unit should be provided. See chapter two. Installation instructions should state the drain size required or the discharge capacity of the softener.

Softeners usually only treat cold water. If treating hot water or installing the device close to the water heater, check with the manufacturer for special instructions.

Systems should be protected from freezing temperatures and from direct sunlight. A unit installed outside should be provided with protection from rain and dust. The unit should be removed during freezing temperatures.

There must be space around the unit for adding salt and servicing the device. Careful consideration should be used as to where the domestic water line is proposed and where the new soft lines will be run.

CODE REQUIREMENTS

Comm 82.40(8)(d)4 requires a bypass valve, however, it may be an integral part of the device. Ensure the inlet and outlet of the softener are installed correctly. This is a very important instruction. Softeners installed with the inlet and outlet reversed may allow exchange medium to enter the water distribution system. Some inlets are on the left and some are on the right. The inlet and outlet are usually marked on the device.

The discharge piping from the softener to the drain must be water distribution material as per Table 84.30-9. See Figure 2-6. This distribution piping must terminate with an approved air gap to the sanitary or storm system. See chapter two for more information.

Comm 82.36(3)(c)3 allows clear water wastes from a water softener to discharge to either a sanitary drain system or a storm drain system. See Figure 3-10. Therefore, the softener discharge can be directed to grade if no storm sewer is available. It should be in an area where it will not cause a nuisance. Remember that the salt solution will probably kill grass.

A Plumbing Code Interpretation dated February 1987 clarified the intent of the code allowing a local waste to discharge to the riser from a floor drain to include water softener discharge. If this local waste piping exceeds 30 inches it must be trapped. Comm 84 requires water softeners must conform to NSF Standard 44 in order to be approved in the state of Wisconsin.

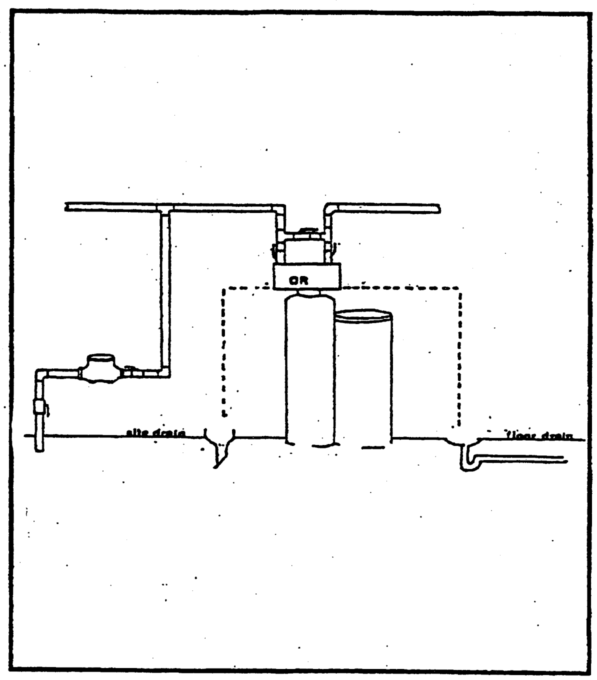


Figure 3-10: Discharge of softener backwash to sanitary or storm

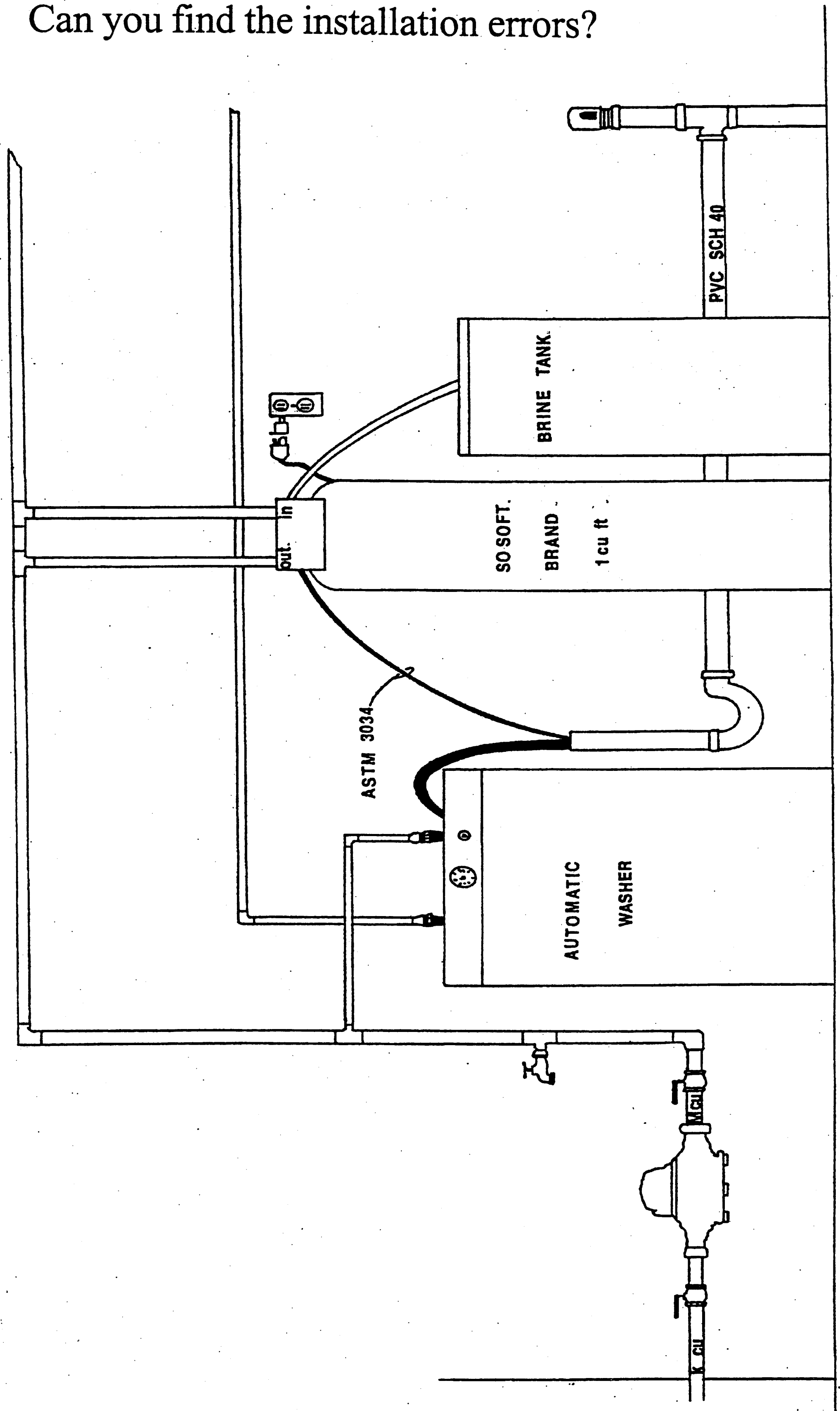
Chapter Three Notes

Chapter Three - Self-Check

1. Softeners can also be called ________ exchange units.
2. The more calcium and magnesium ions present in the untreated water, the more __________ ions in the treated water.
3. The concentrated salt solution is called ____________.
4. The exchange medium usually takes up about ___________ of the mineral tank.
5. pH affects the ability of ___________ exchangers to operate efficiently.
6. If a home uses 500 gallons per day and the water contains 15 gpg hardness, the total hardness to be removed is _________ grains per day.
7. Chlorine should always be used to rejuvenate a softener bed. True or false? ___________
8. Bypass valves for softeners part of the device (may or may not) __________ be an integral
9. A softener will work the same if the inlet and the outlet are reversed. True or false? __________
10. Discharge piping from a water softener must terminate with an acceptable ________ _____________.

*Answers for the self-checks are located in the appendix of this manual.

Can you find the installation errors?



This drawing illustrates 12 installation errors. Circle as many as you can find. The answers are the appendix of this manual.

4 Reverse Osmosis

The process of reverse osmosis was discovered during the early 1950's in California. It was thought to be primarily a desalinization technique, but has come to be the solution for many water treatment problems. With the effectiveness of a RO system generally from 70 to 97%, the process has gained popularity in many areas of water treatment.

Reverse osmosis (RO) is similar to the osmosis process referred to in chapter one. Reverse osmosis uses the semi-permeable membrane like the osmosis process, but reverse osmosis relies on a superior pressure applied to one side of the membrane. Water molecules are attracted to this membrane and the molecules of water work their way though to the other side. Other ions (like salt) are repelled from the membrane. See Figure 4-1.

A RO system not only uses this attraction/repulsion process to reduce impurities, it also acts as an ultrafiltration unit. Ultrafiltration is a filter like process with very small (.0005 micron) pores. RO has been called "hyperfiltration" because the process seems like very fine filtration. Ultrafiltration is accomplished under lower pressure than RO. RO can reduce a greater range of contaminants.

During the product review process the laboratory test results on each device are evaluated. The Safety and Buildings Division approval letter states what contaminants that specific device is rated to reduce. Contaminants listed on approval letters for reverse osmosis units have included the contaminants shown in Table 4-1. Customers should check Safety and Buildings Division approval letters **before** purchasing any treatment device so they understand the verified limitations of the device they are considering.

Table 4-1: Contaminants listed on Safety and Buildings Division product approval letters

2,4-D	copper	selenium
ammonia	fluoride	silver
arsenic	hexavalent chromium	silvex
barium	lead	sodium
boron	lindane	sulfates
bromide	mercury	tannin
cadmium	nickel	total dissolved solids
chlorine	nitrate	trivalent chromium
		zinc

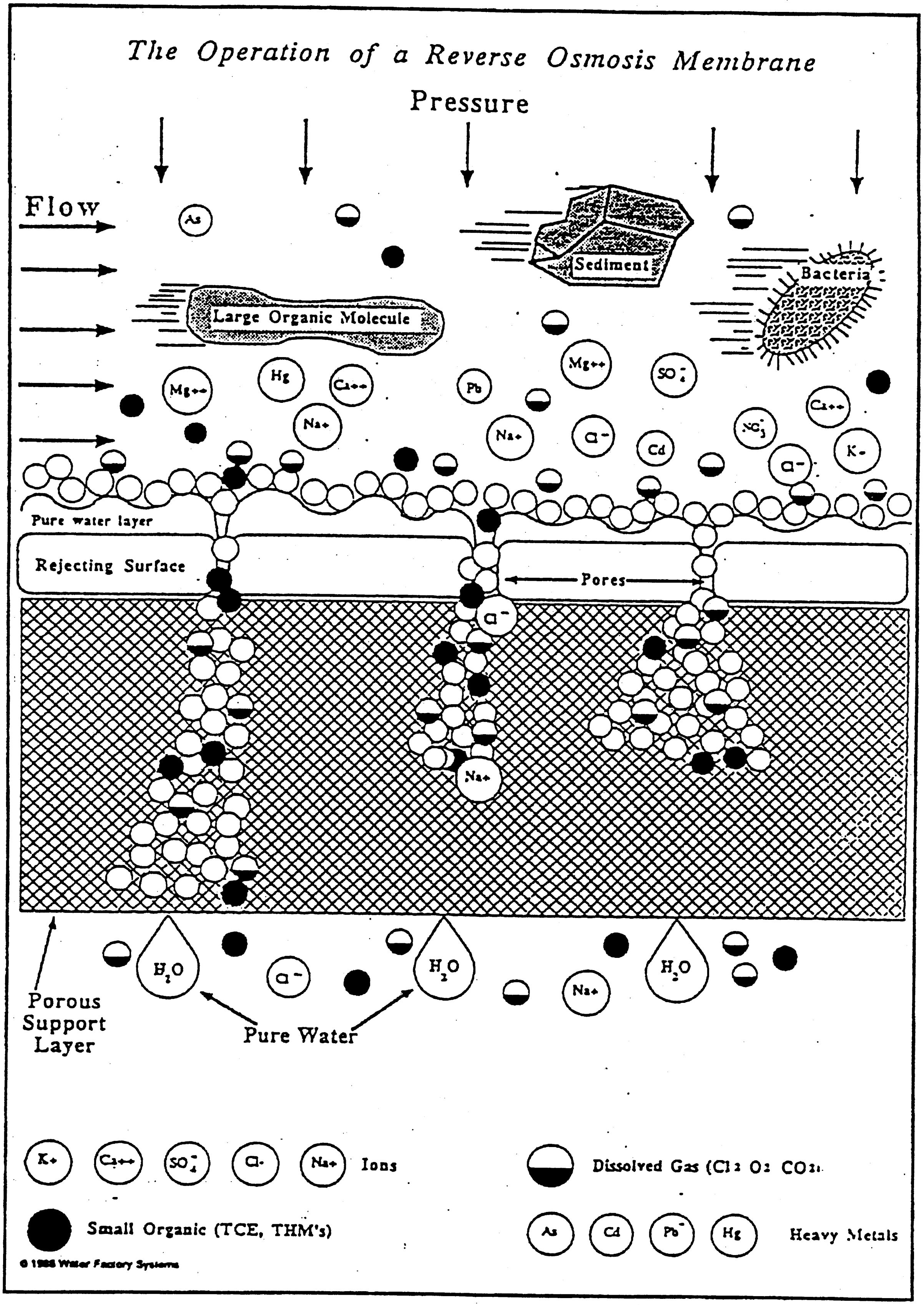


Figure 4-1: The operation of an RO membrane (Water Factory Systems 1991)

"An RO system removes more impurities than any other system designed for home use." *Testing the Waters*

Membranes used in reverse osmosis systems are of two major types, cellulosic membranes and polyamide membranes:

(1) Cellulosic membranes include membranes made of cellulose acetate, pure cellulose triacetate, or a cellulose acetate/ cellulose triacetate blend. Cellulosic membranes can tolerate chlorine better than polyamide membranes, however cellulosic are more susceptible to degradation due to bacteria. Cellulosic membranes should only be used on chlorinated water supplies.

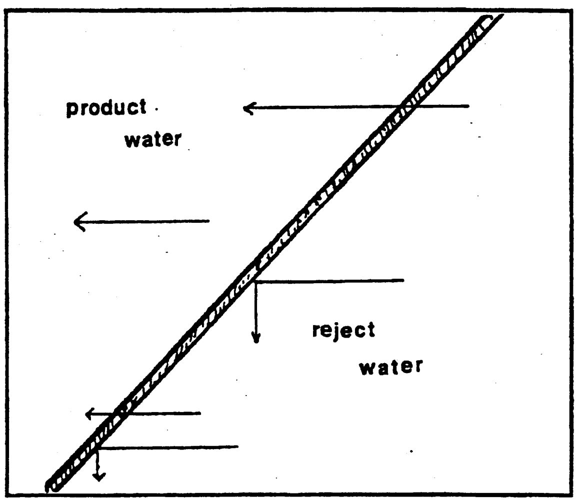


Figure 4-2: Flat plate style configuration.

(2) Polyamide membranes, sometimes called "thin film composite" or "nylon membranes," are susceptible to chlorine degradation. As a result, the incoming water must be free of chlorine or the RO system must contain a carbon prefilter. The resistance of polyamide membranes to bacteria degradation is high.

Membrane configurations currently in use include:

1. The flat plate style refers to water being pushed against a hard plate. See Figure 4-2;

2. Tubular designs have been built with the contaminated (or influent) water passing through tubes. The tube wall is constructed from the membrane material;

3. The spiral or jelly roll design is built so that the contaminated water passes through to the center and the treated water (permeate or product water) flows out of the center of the filter. This configuration is typically used for cellulose membranes See Figure 4-3;

4. A hollow fiber design allows contaminated water to flow into a vessel with encased hollow fibers. Permeate (product water) is discharged through the end of the hollow fibers. This design is typically used for polyamide membranes. See Figure 4-4.

RO systems which produce large amounts of water (more than 100 gallons per day) are constructed with essentially the same components. Usually the components include a high pressure pump (200-400 psi), pressure gauges, and the membrane module.

RO systems which produce small amounts of water are designed to operate only with water distribution line pressure. Because of the

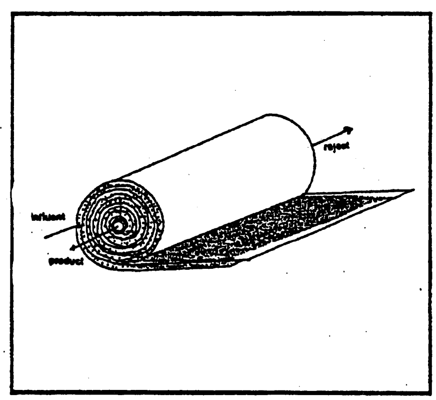


Figure 4-3: The spiral RO design.

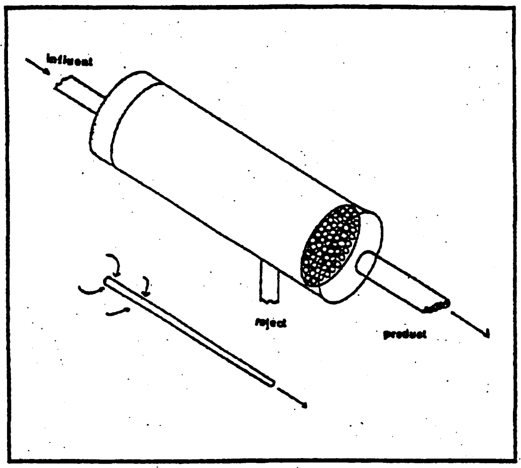


Figure 4-4: The hollow fiber configuration for RO systems.

lower pressure, smaller units produce less than 20 gallons of product water per day. The volume of wastewater is usually three to four times the amount of water produced. RO systems which operate on line pressure usually contain a pressurized storage vessel capable of holding one to ten gallons of water. The dispensing rate is approximately one gallon per minute from the reservoir.

The volume of product water produced by a RO system changes with temperature. A RO system can produce twice as much product water at 80°F as it will at 40°F.

As the water contacts the membrane, the contaminants and/or minerals are left on the membrane and must be washed away by water flowing past the membrane on the incoming side. See Figure 4-1. It seems like the RO system cleans itself, but many times the water entering an RO system must be pretreated in order for the RO system to work properly. Fouling (or the build up of impurities on the membrane) can be caused by sediment deposits, silt deposits, iron, manganese, organics, or biological contaminant growth.

Tests

The testing conducted before installing a RO system should include:

- Hardness
- Iron
- pH
- Chlorine
- Total dissolved solids (TDS)
- Sediment
- Bacteria

■ **Hardness** in the water can foul the RO membrane. Usually, if tests indicate a hardness in excess of 5 gpg in the raw water, then a softener should be installed upstream of the RO system. The RO system will remove the sodium that the softener puts into the water. Before installing a RO system, check the manufacturer's maximum hardness limit for the specific system being installed.

■ An **iron** concentration of 0.5 ppm or above may shorten the life of the RO membrane. If the iron concentration is above the maximum iron concentration specified by the manufacturer, a device should be installed to reduce the iron in the feed water.

■ As illustrated in Table 4-2, specific **pH** ranges are specified for different membranes. If the pH is outside of the manufacturer's specified range the membrane will degrade and may prematurely fail.

■ As noted earlier, some membranes are more sensitive to **chlorine** than others. If the manufacturer requires pre-treatment to reduce chlorine content in the feed water an activated carbon cartridge may be installed to reduce the chlorine level. RO systems with polyamide membranes usually contain activated carbon prefilters for this purpose.

Table 4-2: RO membrane selection chart
Courtesy of Water Factory Systems.

RO Membrane Selection Chart

	CA	CA/CTA BLEND	PURE CTA	TFC (PA)
pH	8.0	8.5	9.0	11.0
Temperature	85 F	85 F	85 F	100 F
Bacteria	little resistance	some resistance	good resistance	bacteria proof
Free Chlorine	excellent resistance	excellent resistance	excellent resistance	poor resistance <1000 ppm hrs
Flux	1.5 gal/sq. ft/ day	1.5 gal/sq. ft/ day	1.5 gal/sq. ft/ day	3.0 gal/sq. ft/ day
% Rejection	90%	92%	94%	97%
Nitrate Rejection	35-40%	40-45%	45-50%	85-90%

■ Extremely high concentrations (2000 ppm and up) of **total dissolved solids** can reduce the effectiveness of RO systems. Most manufacturers set an upper TDS concentration limit for their RO systems. Where TDS concentrations exceed this limit, the RO system should not be installed.

■ **Sediment** can clog the membrane of a RO system. Almost all small RO systems contain a sediment prefilter to protect the membrane from premature clogging. Consult the manufacturer's specifications to see if the unit under consideration is equipped with a sediment prefilter.

■ Cellulosic membranes can be damaged by **bacterial** growth. As a result cellulosic membranes should only be installed on chlorinated water supplies.

No matter what type of membrane is used, if the water tests positive for coliform bacteria, a RO system should not be installed without adequate pretreatment.

Sizing the System

Typical RO systems on the market for residential use produce less than 20 gallons of product water per day. The water produced by RO systems is usually used only for drinking and cooking purposes. A pressurized storage tank is frequently provided with RO systems. "Recovery" is a term which is associated with the performance of a RO system. Recovery is a measure of the system's efficiency in producing product water. Recovery is the percentage of the influent water that passes through the membrane to become treated or product water.

For example:

If 10 gallons of product water are made per day and there is a discharge of 60 gallons per day of reject water, then

$$\frac{10}{(60 + 10)} \times 100 = 14\% \text{ recovery}$$

$$\frac{\text{Volume Product Water}}{(\text{Volume Product Water plus Volume Reject Water})} \text{ times 100 equals Percent Recovery}$$

Installation Guidelines

WATER PRESSURE

The range of water pressure suitable for installation of a residential RO system varies from approximately 30 to 100 psi. Manufacturer's minimum required operating pressures vary. Higher influent water pressures will produce more product water in a specified time than lower influent water pressures. Higher influent pressures will also result in a higher percentage of rejection of contaminants.

Private well water supply pressure variables can sometimes be adjusted at the pressure switch. Physically changing the switch may produce a change in the pressure range of the system. Before increasing the pressure switch settings, be sure the pump and distribution system can accommodate the higher pressure setting.

Sometimes it is necessary to install a booster pump specifically designed to serve the RO system.

MONITOR

A device used to detect increases in the total dissolved solids concentration must be:

a. installed on the product water line for below the counter installations; and

b. accompany the product for above counter installations (connected to the faucet aerator).

ELECTRICAL

An electrical outlet is required for RO systems that use booster pumps. Proper electrical installations is discussed in chapter two. A ground fault circuit is recommended for use with a booster pump. Because RO systems need to have filters changed more often, the chances of electrical shock from

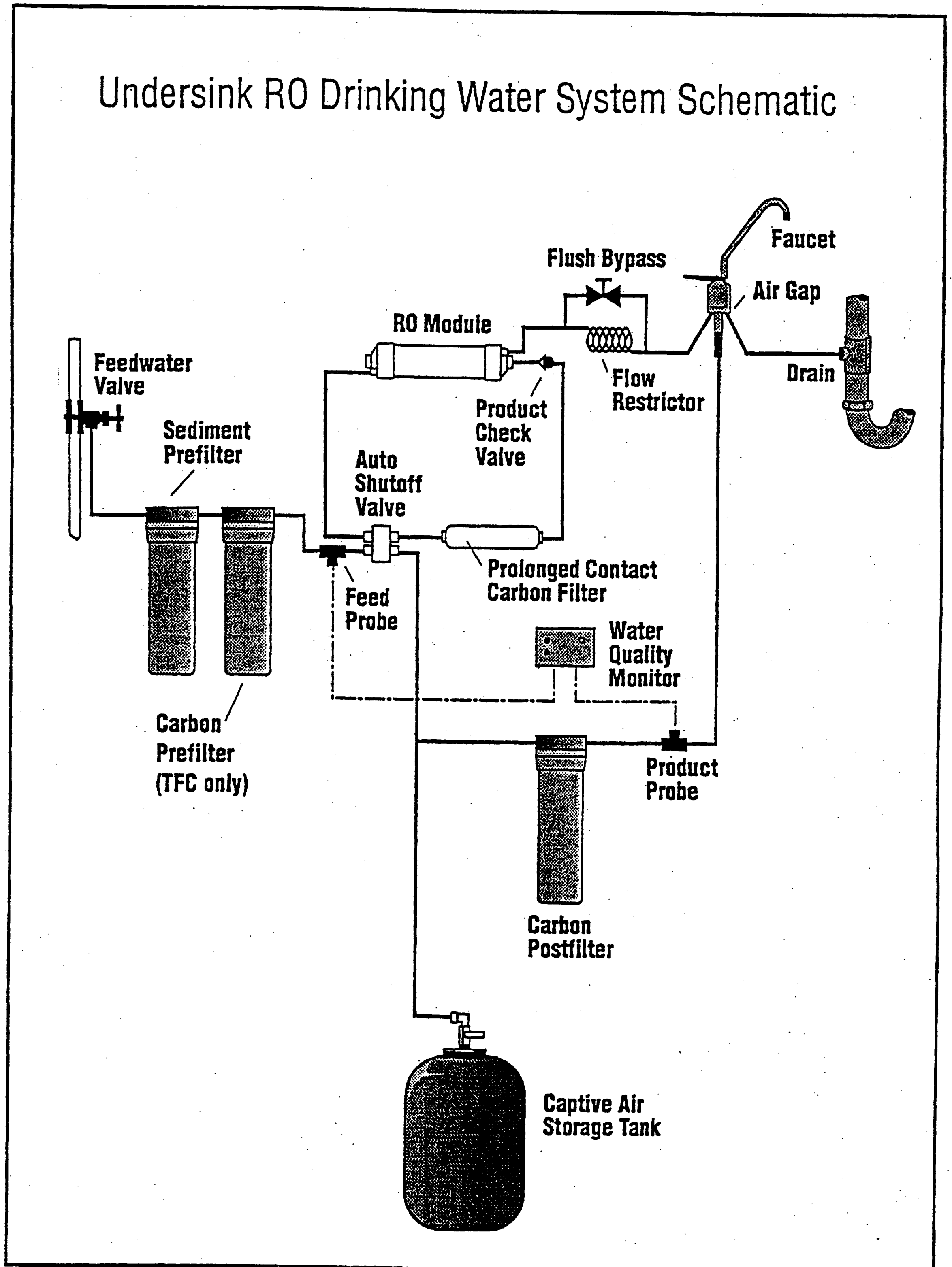


Figure 4-5: Typical under-cabinet installation
Courtesy of Water Factory Systems

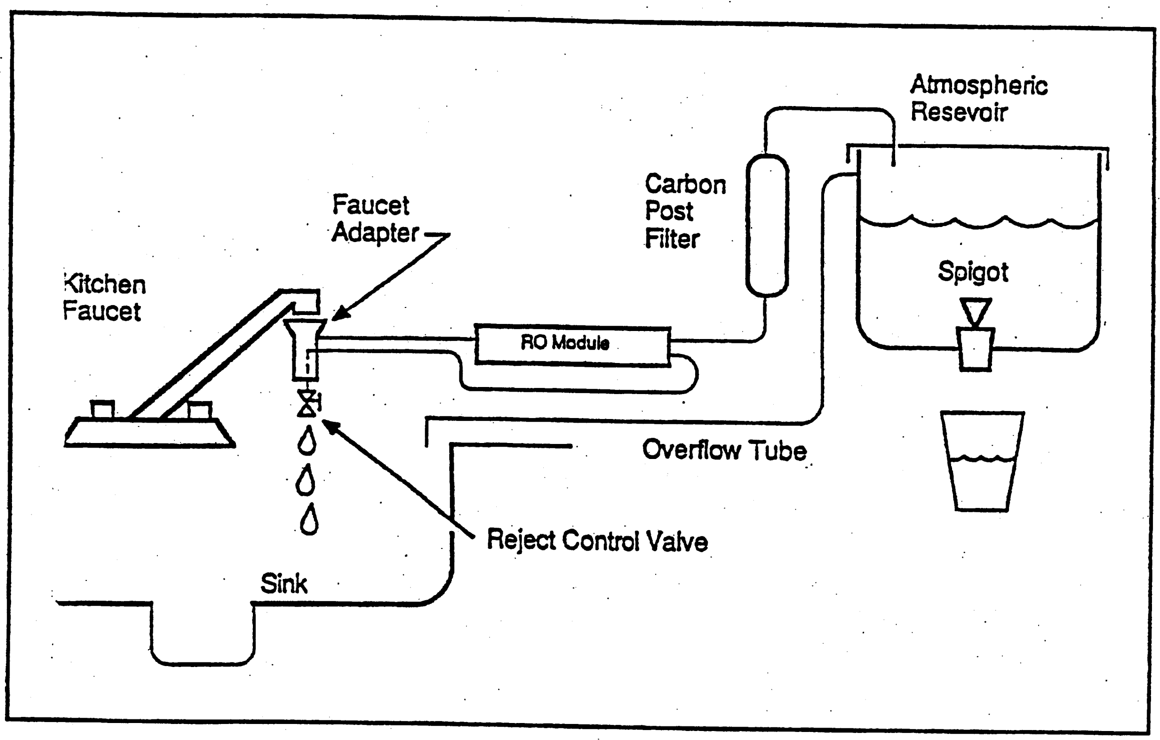


Figure 4-6: Typical countertop installation.
Courtesy of Water Factory Systems

shorts caused by spraying water are increased.

LOCATION

Some RO systems can be installed under cabinets, some are counter top models, and others may require additional room. Make sure that systems installed extended distances from faucets or outlets do not exceed the maximum length specified by the manufacturer.

FLUSHING THE UNITS

Most RO membranes are shipped with disinfectant solution to ensure that the membrane remains wet and bacteria free. The membrane must be flushed prior to using product water. Follow the manufacturer's flushing recommendations.

DRAIN INSTALLATION

The drain from an RO device must discharge through an air gap to the sanitary or the storm system. See chapter 2 for more detailed information. Figures 4-5 and 4-6 illustrate typical RO system installations.

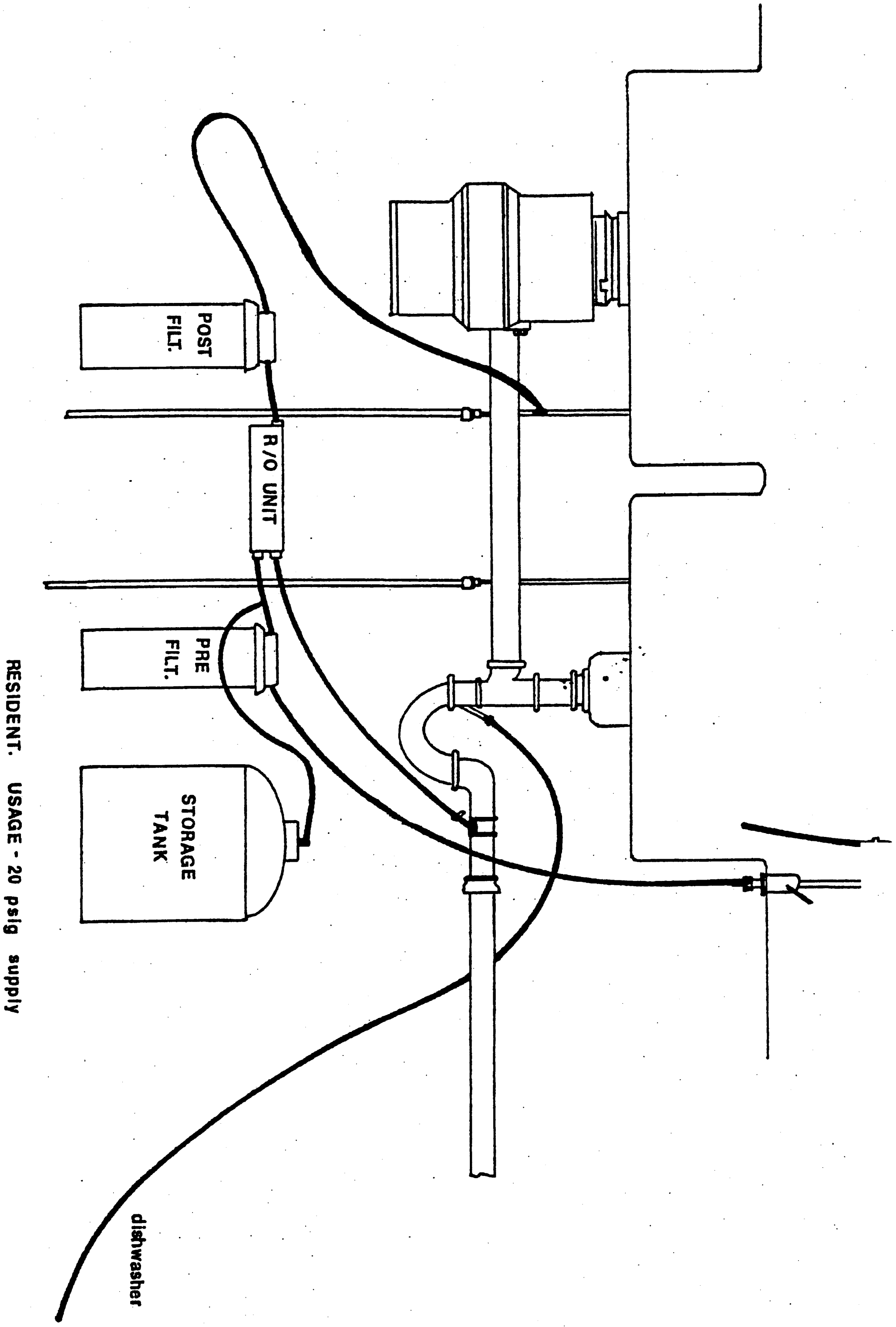
Chapter Four Notes

Chapter Four Self-Check

1. Reverse osmosis uses a _______-________membrane.
2. Membranes are of two major typess ________ and _________.
3. The rejection percentage.(increases or decreases) ___________ with increasing pressure.
4. The production of a small residential use RO system is usually less than ___________ gallons per day.
5. The volume of water produced (increases or decreases) ___________ with increasing pressure.
6. An RO system (will or will not) _________ reduce the TDS content.
7. A ____________ membrane is sensitive to chlorine.
8. A device used to detect _____________ in total dissolved solids must accompany an above-counter installation or be on the product water line of a below-counter installation.
9. Because an RO unit is usually shipped with a disinfectant solution, the membrane should be ____________ prior to usage.
10. The reject water from an RO device must discharge through an acceptable ___________ ____________.

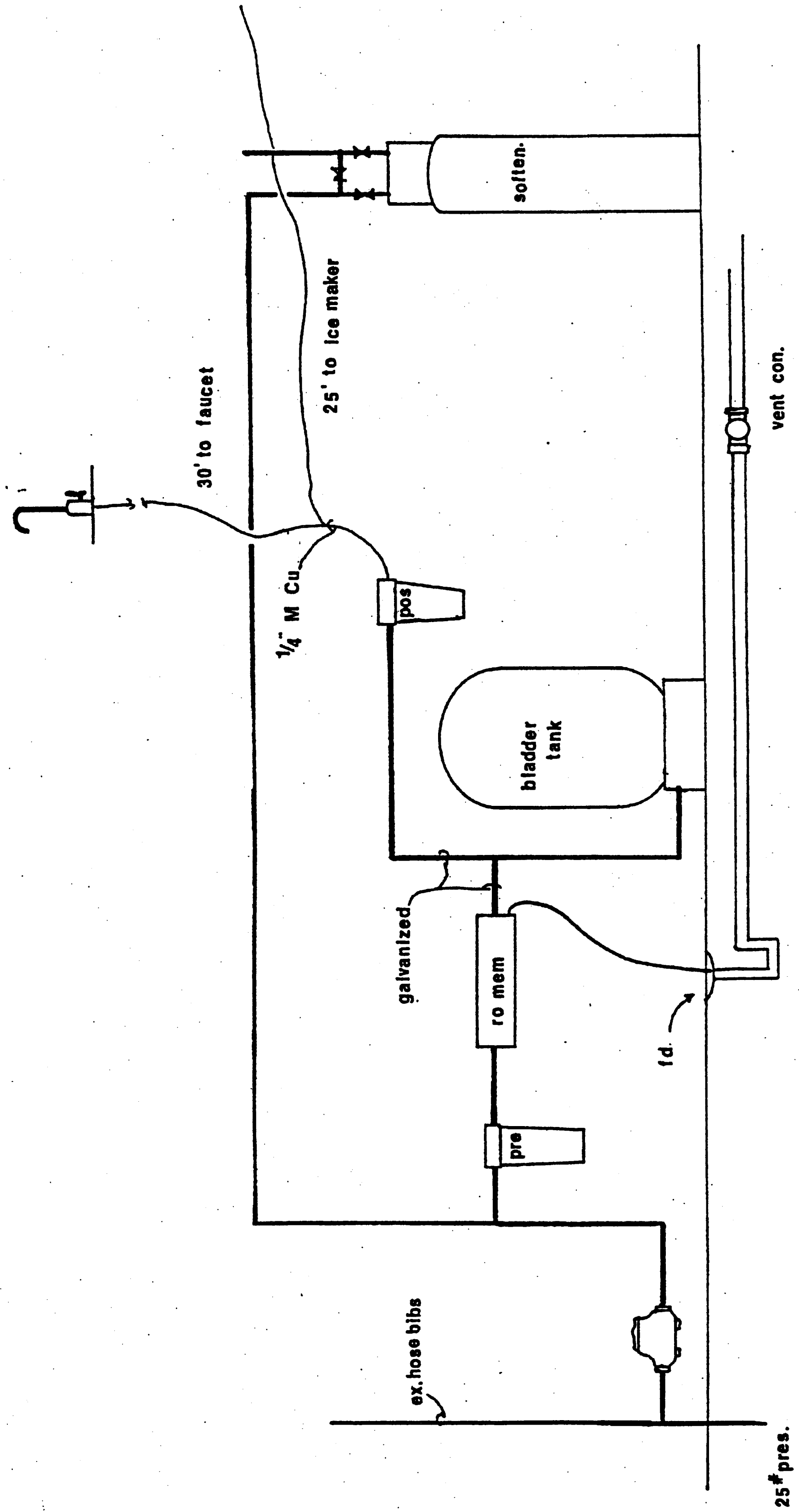
* Answers for self-checks are located in the appendix of this manual.

Can you spot the installation errors?



This drawing illustrates 8 installation errors. Circle as many as you can find. The answers are in the appendix of this manual.

Can you spot the installation errors?



This drawing illustrates 13 installation errors. Circle as many as you can find. The answers are in the appendix of this manual.

5 Iron Reduction

Removing iron from a water supply can be a difficult problem to solve. There are many different types of devices, employing a variety of water treatment principles, for reducing iron. Because variables present in the water affect how the device will operate, not all devices work effectively in all situations.

Primarily an aesthetic contaminant in drinking water, iron may cause a metallic taste, stain fixtures, and clog pipes and valves.

The iron reduction systems discussed in this chapter include softeners and oxidation/filtration devices.

Manganese in the water will react approximately the same as iron in the oxidation process and in softeners. Manganese precipitate is gray-black, instead of the red-orange iron color.

Hydrogen sulfide gas is readily oxidized to form sulfur and will be significantly reduced in water when treated in an oxidation filtration system. Hydrogen sulfide has a very high oxidant demand and water containing hydrogen sulfide will cause the oxidation unit to require more frequent regeneration.

Softeners for Iron Reduction

Some water softener units will reduce the level of iron in water. Iron (Fe^{3+} and Fe^{2+}) is higher on the cation exchange selectivity chart than either sodium (Na^{+}) or calcium (Ca^{2+}). Iron cations will occupy exchange sites in the softener bed. Iron in the ferrous state will inevitably oxidize to the ferric state. Iron that oxidizes in the filter bed can present a problem for softener efficiency. The hard, ferric iron will be heavier than resin beads and backwash may not remove all of the iron particles. When this happens the softener can become clogged with insoluble iron. Some softener manufacturers have produced different backwash techniques to enable their device to discharge particles of iron and to "scrub" resin beads more efficiently. Other manufacturers fill the exchange tank with zeolite instead of resin. The zeolite material is heavier than resin beads and backwash to remove ferric iron from the bed can be accomplished. Chemical iron removal treatments can be applied to softener beds. If a softener is considered for iron reduction, pay particular attention to the manufacturer's specifications for maximum iron levels. Softeners should not be installed where there is measurable iron bacteria, without pretreatment of the iron bacteria.

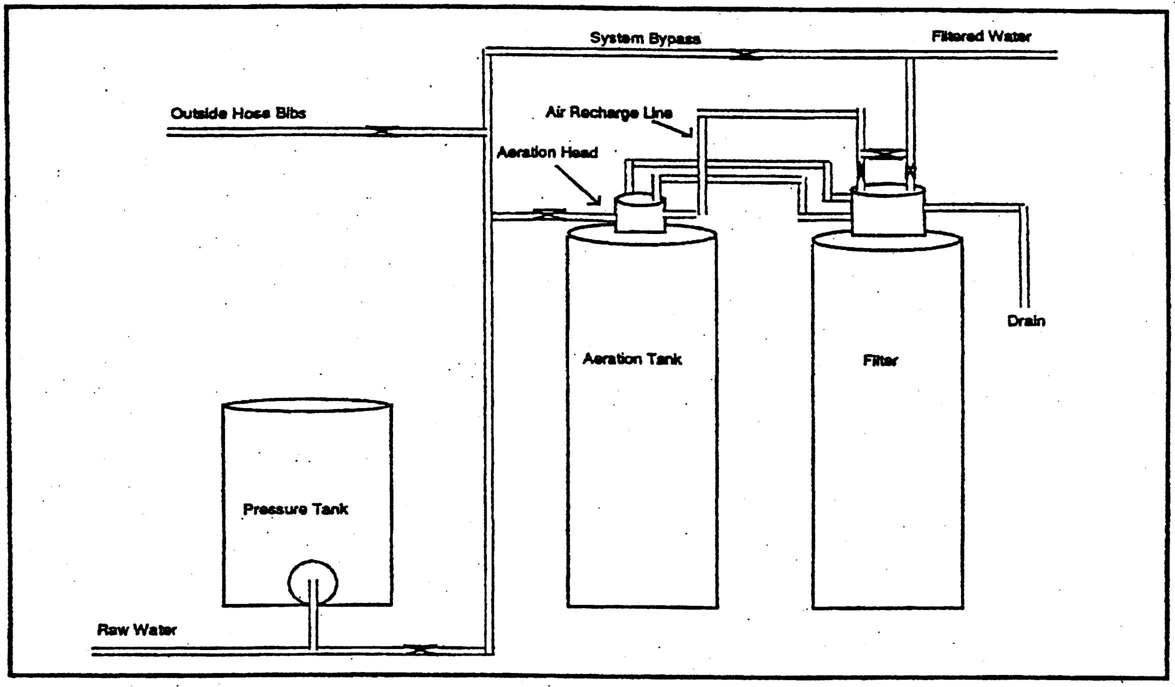


Figure 5-1: Aeration used for oxidation of iron prior to filtration.

Refer to chapter three for more information relating to softeners and their installation requirements.

Chemical Oxidation - Filtration

Ferric iron, also called "clearwater iron," when oxidized becomes insoluble iron. Iron in this ferric state can then be filtered from water. Oxidation can be accomplished by ozonization, aeration, chlorination, or by introducing other chemical oxidants.

Ozonization is infrequently used in domestic treatment devices and will not be discussed in this manual.

Aeration - Filtration

Aeration is a process by which external air is added to domestic water. The oxygen in the air acts as the oxidizing agent. Aeration can occur through an aeration tank which disperses the water through an air chamber to oxidize the ferrous iron. See Figure 5-1. Some units require the installation separate from the control valve of an aspirator for air injection, while other units have the aspirator as an integral part of the head. After oxidation has occurred, a contact time is usually required for the iron precipitate to form. Too short of a contact time will form very small iron particles that may be too small to filter. Temperature also affects the contact time required. Warmer temperatures may reduce the necessary contact time.

In the service position, oxidation takes place after which the insoluble iron is removed by filtration. The normal operation of this device includes a backwash to remove precipitate and a downflow cycle.

Some aeration devices also incorporate calcium carbonate chips to raise the pH of the water. Raising the pH enables the device to operate more effectively.

Additional device limitations are specified in the manufacturer's literature.

BACKWASH AND REGENERATION

If a device includes an automatic head, that head allows fresh water to backwash the precipitated iron out of the system. The air in the system is discharged and fresh air is introduced into the aeration tank.

RAPID RINSE

The last stage of the regeneration cycle is to prepare the filter bed for service. Water passes through the system in the same direction of flow as it would in the service position. This packs the filter bed and prepares the system for service flow again.

TESTS

The tests which should be conducted before installing an aeration unit are:

- pH
- Iron
- Hydrogen Sulfide
- Manganese
- Tannins
- Chlorine

Aeration-filtration devices are affected by **pH** levels; certain devices will not operate correctly at a pH of seven or below. Check the specifications to see that the device proposed will work efficiently under the existing pH conditions.

Check the manufacturer's specifications as to what levels and what types of **iron** in the water can be treated efficiently. . If iron bacteria are present, which can foul the device, treatment of this problem upstream of the filter will probably be required.

Hydrogen sulfide can also be reduced by the treatment device. The size of the unit should be increased when hydrogen sulfide is present. Check manufacturers' specifications as to the extent of reduction and device specific limitations.

Manganese can be reduced by the treatment device. Size of the device must be increased above what would otherwise be required and more frequent backwashing must occur where manganese is in the water.

Organic materials, for example **tannins**, prevent oxidation of iron. If this is a regional water condition. Consult manufacturers' specifications prior to installation.

Chlorine levels may effect the performance of some devices. Read the manufacturer's recommendations concerning chlorine concentrations.

SIZING THE FILTER

To size an aeration filter three criteria must be considered:

1. Maximum iron concentration permitted for this device;
2. Flow rate required for the device to operate effectively; and
3. Additional chemical or physical concerns.

1. The maximum iron concentration approved by the manufacturer may limit or permit the use of one or another system. If the specifications state the maximum **total** iron level is 10 ppm, then both ferric and ferrous levels are included. Some devices (like some softeners) are designed to treat clearwater iron, only.

2. The flow rate required for the distribution system and the flow rate provided by the iron treatment device must be taken into consideration when sizing the system. A building that requires 20 gallons per minute must have a device that will provide at least 20 gallons per minute.

3. Additional concerns must be evaluated prior to the sizing of iron treatment devices. Consult the manufacturers' specifications for these limitations.

INSTALLATION GUIDELINES

Because installation requirements vary from one manufacturer to another consult the specific device's instructions.

Pressure requirements vary on devices, but maximum pressures are routinely from 75 to 100 psig. Pressure reducing valves are required for some devices at the higher pressures. Minimum pressure required is approximately 30 psig.

Backwash flow rates are an important consideration for oxidation filters. Higher rates of backwash flow are required to remove the heavy iron particles. Check manufacturers' minimum requirements.

An appropriate drain for the discharge from the filter should be provided. See chapter two. Iron filters, using aeration for the oxidation agent, may discharge to storm or sanitary.

If electricity is required for the unit, follow the general instructions for adequate electrical provisions. See chapter two.

CHLORINATION/FILTRATION

Chlorine is a strong oxidizing agent. Chemically this process works very similarly to the aeration process previously discussed. The method used to introduce chlorine is varies. In one system, liquid chlorine is injected into the influent water line and divalent (Fe^{+2}) iron is oxidized into its ferric form. A pressure tank, or retention tank, is required to ensure adequate contact time. The manufacturer should specify the capacity for required retention tanks. The precipitate is then filtered by sand, activated carbon, or greensand. Activated carbon filters remove the chlorine taste left after chlorination and, although, not as effective in filtration of precipitate, they are sometimes chosen for this reason.

Another type of system, usually installed on private wells, drops chlorine pellets down the well casing. Filters installed after the pressure tank remove the precipitate. The pellet chlorinators are not approved by DNR to treat *coliform* bacteria contamination. They are approved for the reduction of aesthetic contaminants, only. See Figure 5-2. Chlorinators require monitoring frequently to check for chlorine residuals and to ensure adequate treatment.

The well cap that is installed for use with the pellet chlorinator must be an approved watertight and vermin-proof cap. Sanitary well seals four inches in diameter or larger that discharge below grade are acceptable. Well seals or caps that have above-ground discharges will require approval on a case by case basis. Installations prior to February 2, 1991 were required to have a watertight seal, but specific well caps and seals did not require approval.

The installation of the device on a well and the addition of a chemical into the groundwater supply requires installation

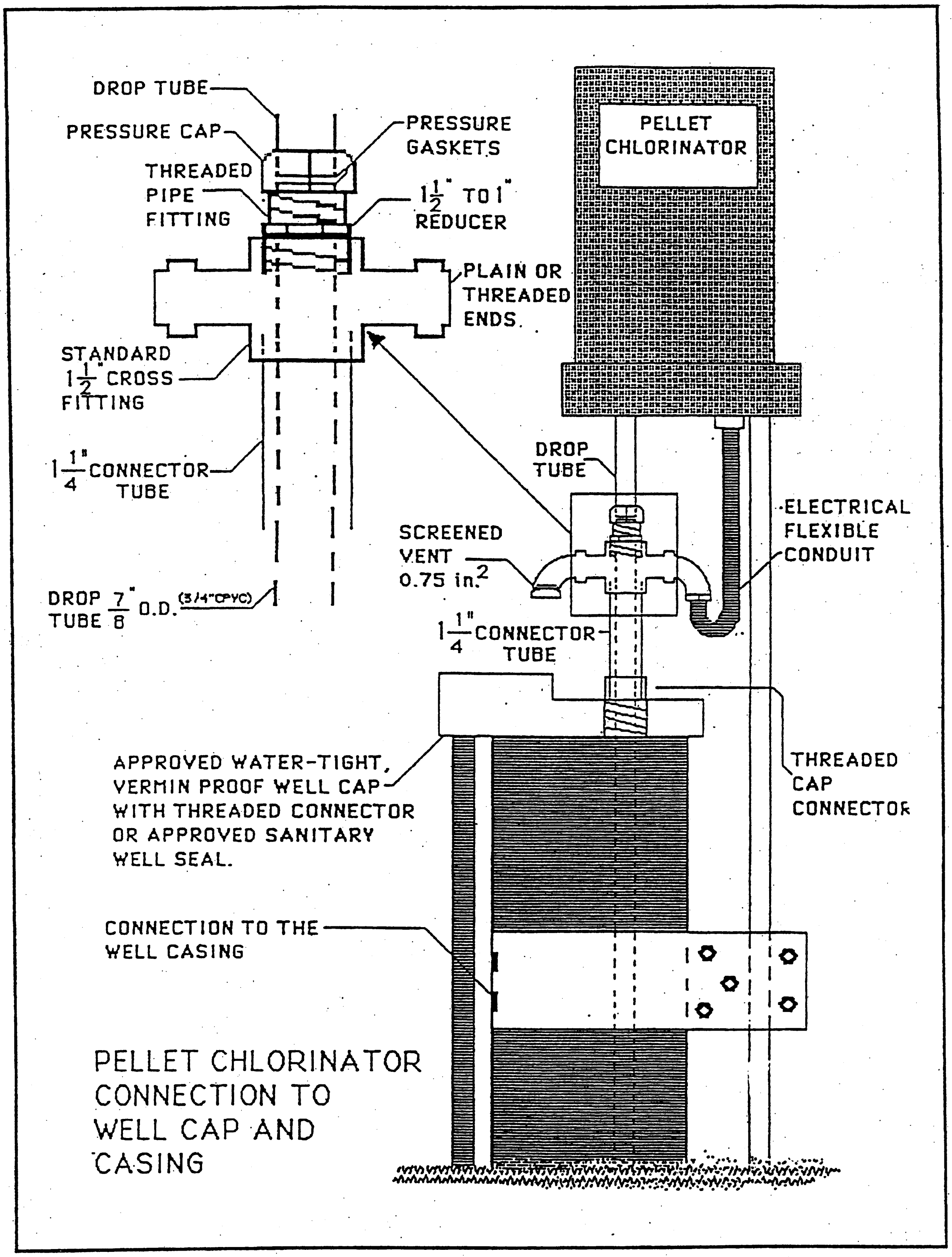


Figure 5-2: Pellet chlorinator installation guidelines.

approval from the DNR, Bureau of Drinking Water and Groundwater, 608-266-3415. See the appendix for further information on pellet chlorinators.

TESTS

Tests should be requested for the following: Total Suspended Solids
pH
Iron

High levels of **total suspended solids** will interfere with the operation of an oxidation/ filtration system. In areas where this is a problem, filters upstream of an oxidation pump may be required.

Chlorination units work best where the **pH** is 7.0 or higher.

The concentration of clear water **iron** should be evaluated and manufacturer's limitations followed.

INSTALLATION GUIDELINES

Installation recommendations can vary with different devices and installation should always be accomplished after first reading the manufacturer's installation instructions thoroughly.

Water pressure is usually limited from 20 to 100 psig. Consult the device's specifications prior to installation. Pressure-boosting systems or pressure-reducing valves may be necessary with extreme pressure variations.

If an electrical connection is required, refer to chapter two regarding bonding and grounding. If a pump or pellet chlorinator runs off the same power source as the well pump, make sure the voltage of the device is the same.

An appropriately sized drain for backwash requirements should be provided (see chapter two for further information). Care should be exercised in areas where children could contact the chlorine. Chlorine is a very strong chemical. Some units come with locking covers on storage tanks.

Care should be taken when installing pellet chlorinators on wells that have torque arrestors installed. The torque arrestors could prevent pellets from reaching the water level and cause severe corrosion problems in the well.

CODE REQUIREMENTS

The Wisconsin DNR requires that the pellet tube extends below the pitless adapter. The tube must have 20 smooth vent holes and a tapered end to promote moisture release.

The drop tube assembly must have a 3/4-square-inch air vent in addition to any venting provided on the well seal or cap.

There are chlorine pellets that contain additives that act as binders to hold the pellets together. The DNR will provide a list of pellets currently manufactured which are approved.

OXIDATION/FILTRATION WITH POTASSIUM PERMANGANATE

There are other oxidizing agents that can be used in treatment devices. The most frequent combination of oxidizing-filtering medium is manganese greensand. See Figure 5-3. Greensand is a natural zeolite that absorbs potassium permanganate, acting as an oxidizing agent. The greensand will also serve as a sediment filter to collect the precipitated iron. Oxidizing filters are also effective in the reduction of hydrogen sulfide and manganese. Greensand filters can be backwashed periodically to remove the iron particles and can also be recharged with permanganate to maintain the filter's oxidizing capabilities. Potassium permanganate is a poisonous chemical. Use care in handling it.

Greensand iron filters can be manual or automatic regeneration. Manual filters will have a combination of valves to allow for backwashing. Automatic filters will have a metered or timed head, similar to that of a softener. A chemical storage container will replace the brine tank and a potassium permanganate solution will occupy this tank. Backwash frequency will depend on the amount of iron in the water.

Because of the small size of greensand grains, a high head loss occurs through these filters. Adequate pressure must be available upstream of the device to compensate for this loss. Consult the manufacturers' literature concerning head loss. Refer to chapter two for more information.

TESTS

Prior to installing a greensand filter the following test results should be acquired:

Suspended solids
pH

Suspended solids may plug the greensand filter. If sediment levels are high, a particulate filter may be required upstream of the oxidizing filter.

The **pH** range for oxidation of this type is approximately from 6.8 to 8.8. pH adjustment may be necessary for the most efficient operation of this device.

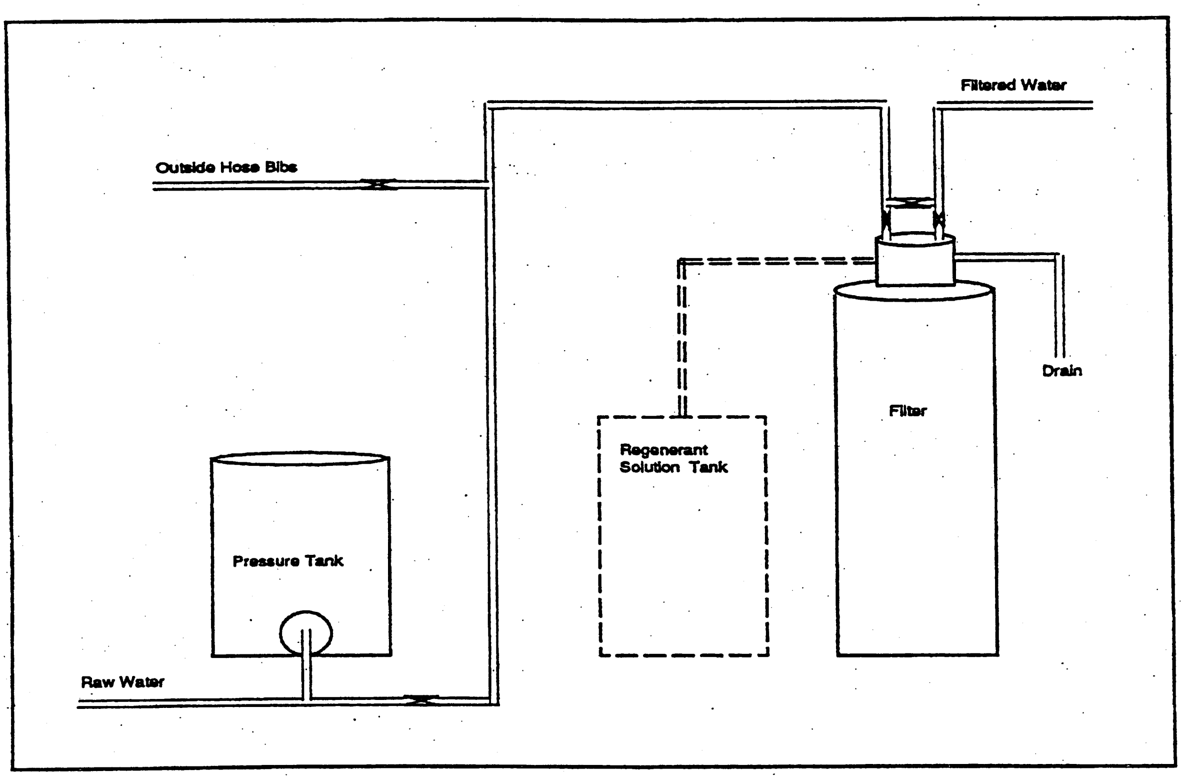


Figure 5-3: Manganese treated mineral filter on a private well.

INSTALLATION REQUIREMENTS

The flow rate required for backwash of oxidizing filters is usually from 5 to 7 gpm. Make sure adequate supply is available to provide for this high backwash rate.

If electricity is required for the unit, follow the general instructions for adequate electrical provisions in chapter two.

Backwash from oxidizing filters which use potassium permanganate must discharge to the sanitary system. Potassium permanganate is a poisonous substance which must not be allowed to discharge to grade or to the storm system. A receptor which receives this backwash must be capable of handling a backwash duration of twenty minutes. See chapter two for more information.

Necessary water pressure is usually between 30 and 100 psig. Consult manufacturers' requirements and, if required, add a pressure-boosting system or pressure-reducing valve.

If a solution tank is required for the potassium permanganate, it should be placed where children will not be able to open the tank. Caution the customer to use extreme caution when handling containers of potassium permanganate.

CODE REQUIREMENTS

A bypass is required to be installed in conjunction with an iron treatment device. See Comm 82.40(8)(d)4.

CATALYTIC FILTRATION

Some iron filters contain a media, called birm, that works as a catalyst to enable the oxygen in the influent water to oxidize ferrous iron. This media is a manganese-coated pumicite that also works as a filter to remove the precipitated iron. Backwashing to remove the iron particles is the only routine maintenance required for this device. One essential condition for this device is that the amount of dissolved oxygen in the influent water must equal at least 15 percent of the iron content. Without this dissolved oxygen, the filter will lose efficiency. Manganese can also be reduced with this filter.

TESTS

Testing that should be accomplished prior to installation includes:

pH
Dissolved oxygen
Sulfides
Total iron
Total manganese

pH affects the efficiency of the birm filter. For iron reduction, a pH of 6.8 or above is optimal. Manganese reduction requires a higher pH of 8 to 9. Pretreatment to raise the pH of the influent water may be necessary.

Dissolved oxygen requirements for birm filters are usually 15 percent above the level of iron in the water. Consult manufacturers' requirements for the most efficient application of each device.

Sulfides, with their higher oxidant demand, adversely affect the birm filter. No hydrogen sulfide should be present in the influent water.

Iron content is important to ascertain, as the device requires the dissolved oxygen levels to be 15 percent higher than the iron content.

Manganese testing is required in areas where manganese is a problem. Manganese will react similarly in the filter and will have an oxidant demand.

INSTALLATION GUIDELINES

The flow rate required for these catalytic filters is approximately from 8 to 12 gpm, depending upon the texture of the filter media. Make sure the flow rate is sufficient for an adequate backwash.

If electricity is required for the unit, follow the general instructions for adequate electrical provisions in chapter two.

Ensure adequate water pressure is available so the system will not be hindered due to pressure loss through the filter. See chapter two for more information regarding pressure loss and sizing.

The receptor to receive the backwash should be capable of accepting the discharge for at least 20 minutes.

CODE REQUIREMENTS

A bypass is required on this, and all other iron treatment devices. Refer to chapter two for more information on code compliant bypass installation.

An appropriate drain for the discharge from the filter should be provided. See chapter two.

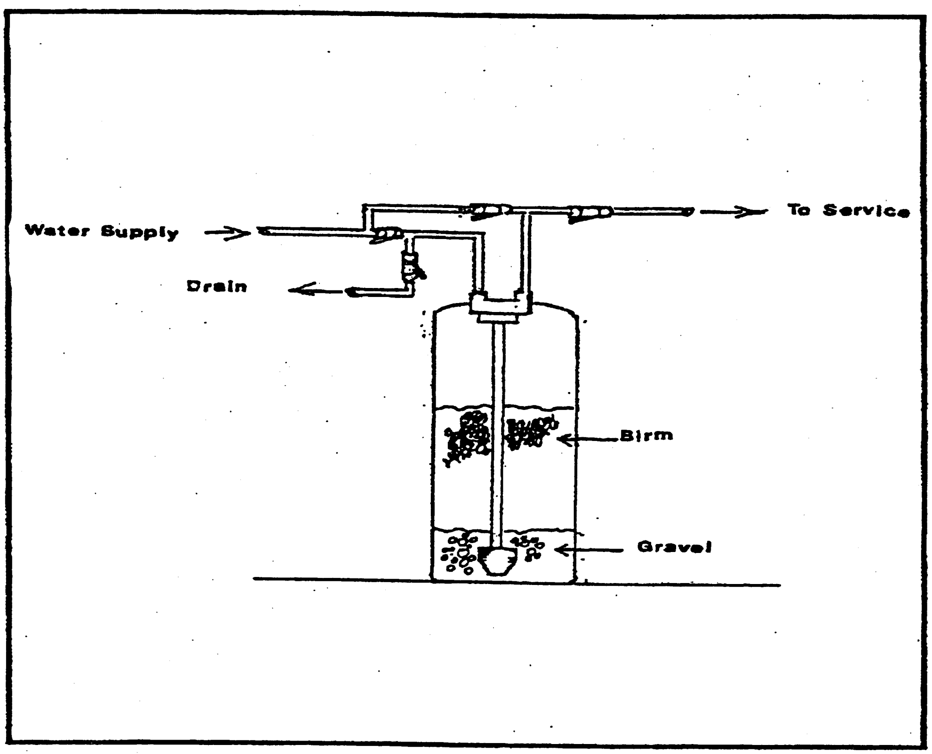


Figure 5-4: Catalytic Filter

Chapter Five Notes

Chapter Five Self-Check

1. Hydrogen sulfide has an extremely high ______________ demand.
2. Zeolites are __________ than resin beads, so precipitated iron is easier to backwash from the zeolite.
3. Clearwater iron is also called iron in the (ferric/ferrous) _________ state.
4. Raising the pH of water enables an aeration device to operate more ___________.
5. One type of chlorination unit drops chlorine _________ into well casings.
6. The DNR requires that a pellet tube must extend below a __________ adapter.
7. A natural zeolite that is used in iron filters is called _____________.
8. A manganese coated pumicite medium is called ____________.
9. Five basic types of filters that can reduce clearwater iron are: ___________, ____________, __________, ___________, and ___________.
10. A bypass (is or is not) __________ required on an iron removal device.

* Answers for self-checks are located in the appendix of this manual.

6 Activated Carbon Filtration

Activated carbon is a broad spectrum adsorbent that is used to remove tastes, odors, and some organic and some inorganic elements and compounds.

Adsorption is "the adhesion of a gas, vapor, or dissolved material on the surface of a solid." Activated carbon is one of the most effective water treatment adsorbents because of its large surface area in relation to its weight. There are many small pores (average diameter is .2 millionth of an inch) that enable activated carbon to have a surface area of approximately 400 to 500 square meters per gram or 150 acres per pound. This is equivalent to a teaspoon of activated carbon having the surface area of a football field. See Figure 6-1.

Water treatment activated carbon is prepared from carbonaceous materials which include bituminous coal, bones, coconut shells, lignite, peat, pecan shells, petroleum base residues, pulp, or wood. The most frequently used raw materials are lignite and bituminous coal. The raw material is carbonized and treated with an oxidizing gas at elevated temperatures.

The ability of different types of activated carbon to adsorb substances is measured by its "phenol" value. This phenol value is the amount of carbon, in parts per billion, required to reduce a standard phenol concentration of 100 ppb to 10 ppb phenol. The phenol value of most commercial carbons is from 15 to 30. The adsorption rate is dependent upon temperature, pH, contact time, competition for room on adsorption sites, and the chemical and physical characteristics of the adsorbent and adsorbate (the thing to be adsorbed). Not all activated carbons react the same to all situations. Care should be taken to select the appropriate medium to best solve the contamination problem. Consult the manufacturers' specifications as to the capabilities of each model.

There are three types of organic contaminants that are reduced by adsorption by activated carbon:

1. Compounds that occur naturally and produce objectionable taste and/or odor.
2. Agricultural or industrial synthetic compounds that may have an objectionable taste and/or odor, or may have an adverse health effect.
3. Disinfection by-products.

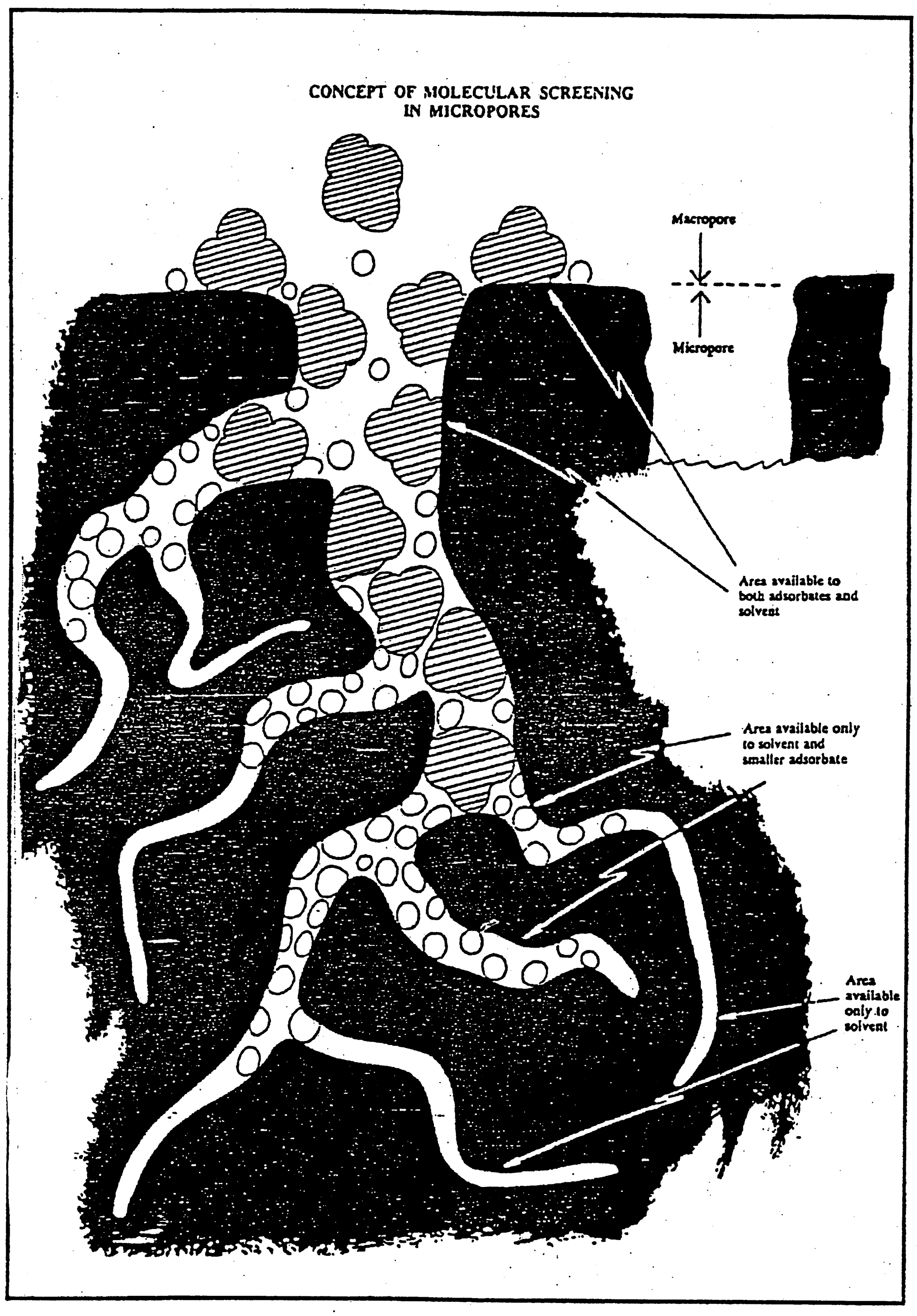


Figure 6-1: The porous surface of activated carbon.

Lindelius's law states that: *"Generally, the less soluble an organic compound is in water, the better it is adsorbed from solution."*

Some readily adsorbed organics include chlordane, benzene, DDT, phenol, toluene, carbon tetrachloride, and components of gasoline. Some poorly adsorbed organics include alcohols, sugars, and starches.

Inorganic compounds that have high adsorption rates include: chlorine and radon gas. Some inorganic compounds that have a low adsorption rate include: nitrate, phosphate, chloride, bromide, and iodide.

GAC, PAC, OR SOLID BLOCK?

Activated carbon can be produced in several forms. Granular activated carbon, or GAC, is frequently used in domestic water treatment filters. See Figure 6-2. Powdered activated carbon, or PAC, is crushed into very small particles and is frequently used to coat filter material or used in a slurry for industrial or municipal treatment. See Figure 6-3. GAC has more surface area and a larger particle size than PAC.

PAC can be pressed into a solid block. The solid block, or pressed block of activated carbon performs differently than the PAC or GAC forms. Inorganics, such as lead, can be reduced more effectively by solid block activated carbon. The manufacturers' literature should be read carefully to evaluate what contaminants may be reduced, and also what conditions are necessary for this reduction to occur. The process used to form the solid block affects the efficiency of the medium. Manufacturers use different "binders" to hold the very finely ground PAC together. This binder can cover some of the surface of the PAC and reduce its surface area and therefore its effectiveness.

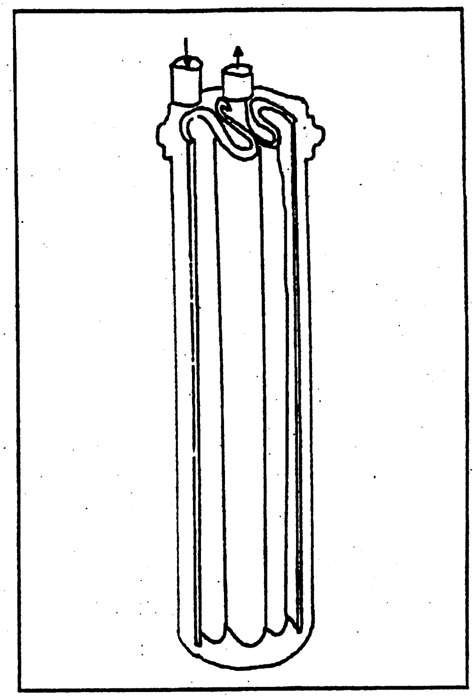


Figure 6-2: Cartridge filter using PAC.

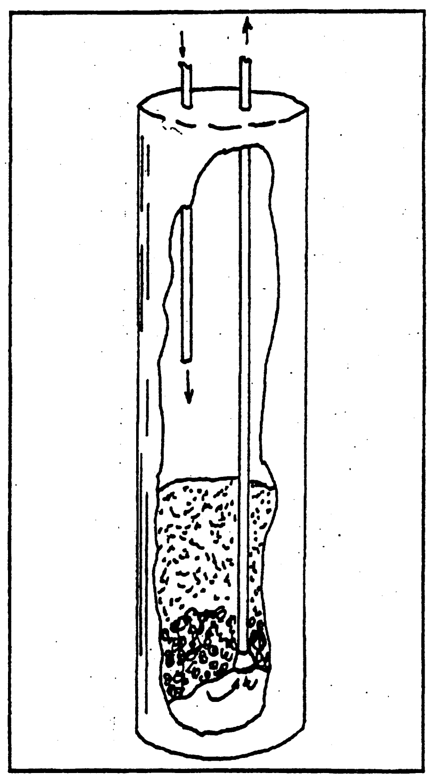


Figure 6-3: Bed type filter with GAC

Some activated carbon is impregnated with silver to inhibit bacterial growth, however, this is not always effective. The federal Environmental Protection Agency requires that silver-impregnated activated carbon filters be registered. This registration is necessary because the device must be tested to show that these filters do not leach silver into the water supply.

All activated carbon filters work best when first put into service. The adsorption capacity of the carbon is used up as contaminants are adsorbed by the medium. To ensure continued contaminant reduction, most carbon filters require replacement of the medium after a certain volume of water has been treated.

Backwash to rejuvenate the filter will only remove sediment and, with some contaminants, this backwash will disrupt the effective operation of the filter. If backwash is recommended by the manufacturer, the flow rate for this backwash is very important. The backwash flow rate must not be high enough to stir the GAC bed, as saturated GAC particles may be redistributed to the bottom of the bed which would allow contaminants to bleed into the distribution system. Some manufacturers claim their filter can be recharged using very hot (145°) water.

If the contaminant is not health-related, the cartridge or medium may be discarded in a landfill. If the filter has been used to reduce VOCs or other health-related contaminants, the medium must be discarded in a hazardous waste site or the medium reactivated in a special furnace by heating to approximately 1800° F in a controlled environment. This reactivation process is impractical for homeowners, but some commercial firms reactivate carbon.

In residential water treatment the activated carbon may be packaged as a small point-of-use filter, or a larger point-of-entry filter. Figure 6-2 shows the flow of water through a typical point-of-use filter. Figure 6-3 illustrates a typical bed-type filter utilizing a GAC medium. Activated carbon filtration systems may include a series of filters if reduction of health related contaminants is desired.

TESTS

The influent water should be tested prior to installing an activated carbon filter. The tests that should be conducted include bacteria, iron, and contaminants to be reduced.

Activated carbon is an excellent medium to support **bacterial** growth. Growth of nonharmful bacteria can still result in taste and odor problems. Some manufacturers instruct consumers to flush the filters to reduce bacteria concentrations.

Because of the potential for bacteria regrowth, all activated carbon filters should be installed on bacteriologically safe water supplies (coliform-free).

Waters containing insoluble (ferric) **iron** should have a five-micron filter upstream of the activated carbon filter. If soluble (ferrous) iron is a problem, pretreatment by a water softener or iron reduction device may be necessary.

Various tests may be needed to determine the **contaminant** and the contaminant concentration in the water supply. The test result should be compared to the performance claims for specific activated carbon filters to see if effective reduction can be expected over the rated life of the filter.

Water purveyors can tell consumers the concentration of a variety of different contaminants in municipal water supplies.

SIZING THE ACTIVATED CARBON FILTER

Flow rate is an important factor in sizing activated carbon filters. Manufacturers state an estimated life of the filter (in gallons) at a specific flow rate. Taste and odor filters need to be replaced when the flow rate is reduced or the taste and odor returns. For health-related contaminants, the volume of product water delivered should be monitored and the product water may need to be tested periodically to ensure that the filter is still reducing the contaminant level.

WATER PRESSURE

Water pressure is an important consideration when installing an activated carbon filter. Pressure loss through point-of-entry filters is usually more critical than pressure loss through point-of-use filters. A solid-block carbon filter can produce a pressure loss of 4 to 20 pounds, depending upon the flow rate through the device.

For further general installation information, refer to chapter two.

Chapter Six Notes

Chapter Six Self-Check

1. Activated carbon is a broad spectrum ____________.
2. A teaspoon of activated carbon contains the equivalent surface area of a _________ ________.
3. All activated carbon devices (do or do not) ____________react the same when attempting to reduce contaminants in water.
4. Some organic materials that are poorly adsorbed by activated carbon include ___________, __________, and ____________.
5. The three forms of activated carbon include ___________, ____________, _________ _________.
6. Some activated carbon is impregnated with ____________.
7. Most carbon filters will require ____________ after a certain volume of water has been treated.
8. Used activated carbon may be discarded or _____________.
9. Activated carbon filters should be installed on bacteriologically .(safe or unsafe) _______________ water supplies.
10. __________________ concentrations in the water supply should be compared to the performance claims for specific activated carbon filters to see if effective reduction can be expected over the rated life of the filter.

* Answers for self-checks are located in the appendix of this manual

APPENDIX

SAFETY AND BUILDINGS DIVISION
BUREAU OF PLUMBING
P. O. BOX 7969
MADISON, WI 53707

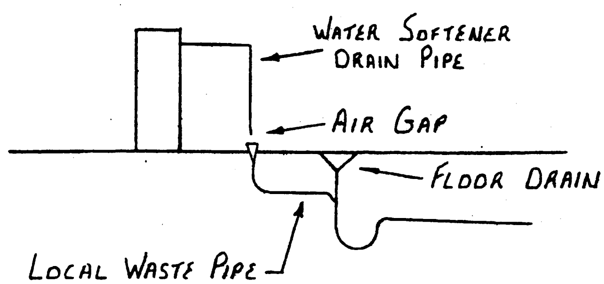
DATE OF ISSUANCE: February 1987

OFFICIAL PLUMBING CODE INTERPRETATION

ILHR 82.33 (8) (c) 2., Wis. Adm. Code

Q. The plumbing code allows local waste piping serving as a receptor for a water heater safety relief valve to discharge to a floor drain. May this type of local waste piping also receive the discharge from a water softener?

A. Local waste piping discharging to a floor drain may receive the discharge from a water softener. The water softener drain piping shall discharge to the receptor by means of an air gap. See sketch below.



James Sargent
Director

SBD-7523 (N.08/85)

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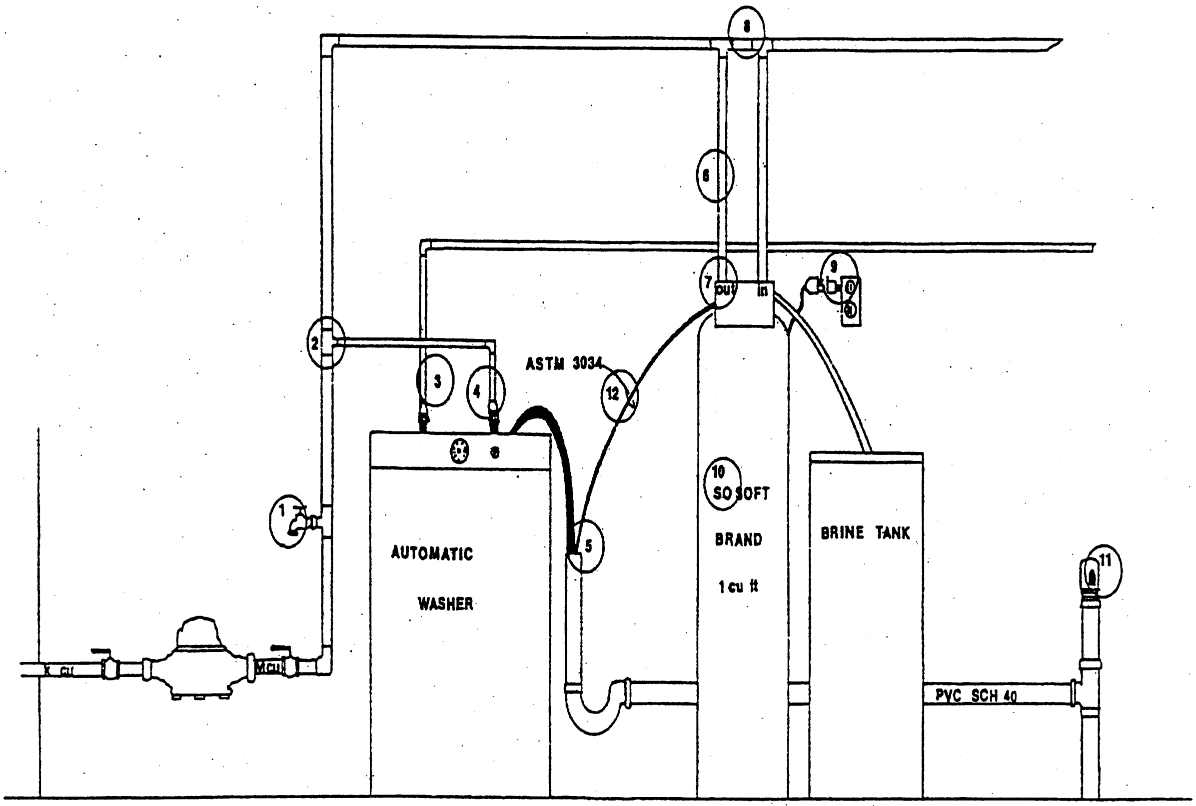
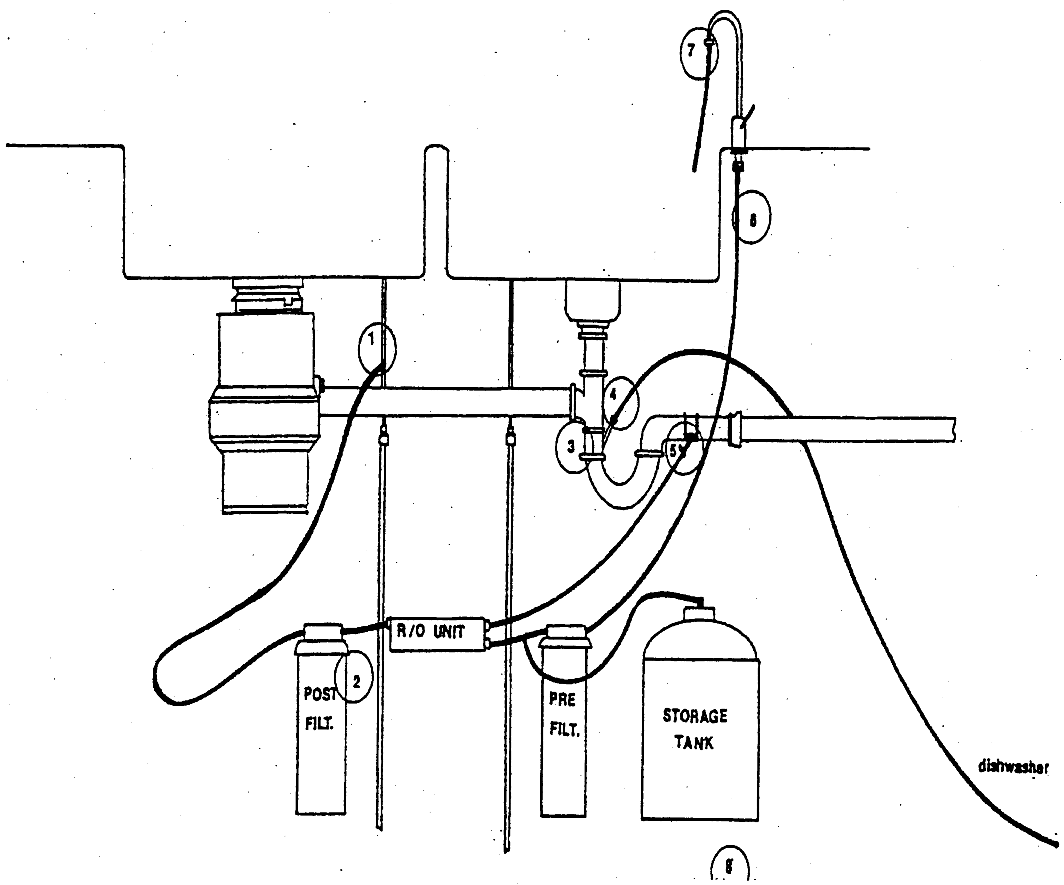


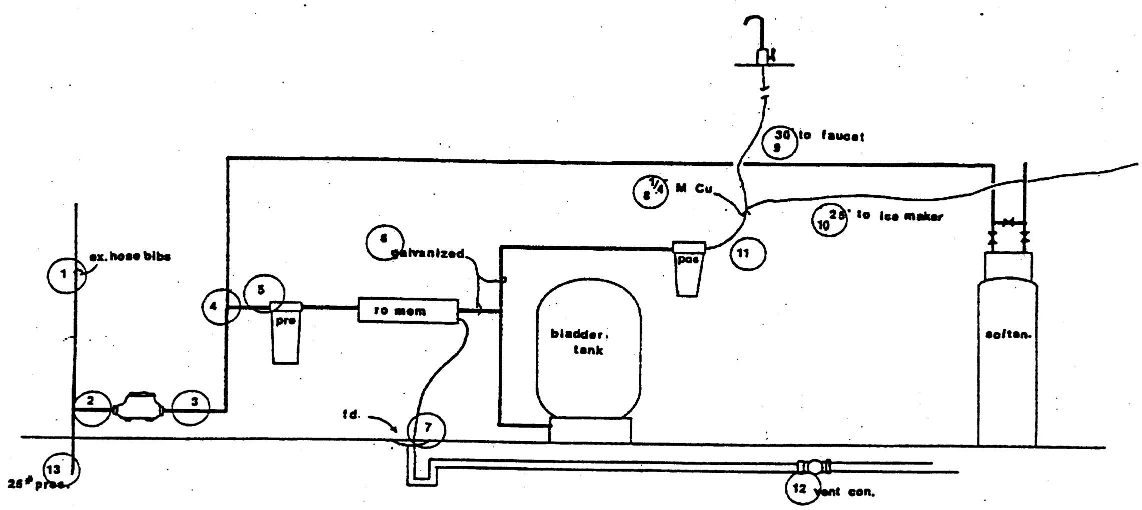
1. Backflow protection on hose bib.
2. Hard water to washer.
3. Valves on washer.
4. Shock arrestors on washer.
5. Air gap on softener discharge.
6. Valve on softener.
7. In and out reversed on softener.
8. No bypass installed.
9. "cheater" on electrical.
10. Not approved softener.
11. Not approved auto-vent.
12. Not approved water distribution material.

Answers to page 74 "Can You Find the Mistakes?"



1. RO connected to hot water on supply tube.
2. Post filter upstream of RO unit and pre filter.
3. Dishwasher and garbage disposer on one trap.
4. Dishwasher connection without air gap.
5. RO unit discharge without air gap and downstream of trap.
6. No TDS monitor installed.
7. No backflow protection on faucet with hose hanging in sink.
8. Not enough pressure for most RO units.

Answers to page 75 "Can You Find the Mistakes?"



1. Exterior hose bibs not metered.
2. No valve.
3. No valve.
4. RO connected upstream of softener.
5. No valve.
6. Galvanized piping downstream of RO.
7. No air gap in discharge from RO.
8. Small diameter, wrong material downstream of RO.
9. Fixture supply too long.
10. Fixture supply too long.
11. No TDS meter downstream of RO.
12. Dry vent connection off horizontal of pipe.
13. Pressure too low for RO installation.

Glossary

Absorption - The process by which one substance is taken into the body of another substance.

Acid - A substance, the aqueous solution of which is capable of turning litmus paper red, of reacting with and dissolving certain metals to form salts, of reacting with bases or alkalis to form salts, or having a sour taste.

Actinomycetes - A class of soil bacteria with a characteristic musty odor.

Adsorption - The process by which a gas, vapor, dissolved material, or very tiny particle adheres to the surface of a solid.

Aeration - To charge or supply a liquid with gas.

Alkalinity - The ability of a solution to neutralize acids.

Anion - An ion with a negative electric charge.

Air gap, drain system - The unobstructed vertical distance through free atmosphere between the outlet of indirect or local waste piping and the flood level rim of the receptor into which it discharges.

Backwash - The process in which beds of filters or ion-exchange tanks are subjected to flow opposite the service-flow direction.

Bacteria - Any of a number of unicellular microorganisms of the class Schizomycetes, occurring in a wide variety of forms, existing either as free-living organisms or as parasites, and having a wide range of biochemical, often pathogenic properties. Bacteria are identified by their shapes: Coccus, spherical; baccillus, rod-shaped; and spirillum, curved.

Biochemical Oxygen Demand (BOD) - A measure of the amount of oxygen required by bacteria for oxidation of the soluble organic matter under controlled test conditions, most often in reference to the strength of waste water or sewage.

Bonding - The means that atoms or groups of atoms are combined into molecules.

Brine - A concentrated salt solution.

Carbonate - A mineral compound characterized by a fundamental structure of CO^{-2} or CO^{-3}.

Cation - An ion with a positive electric charge.

Chlorination - Adding chlorine to water.

Chlorine Demand - A measure of the amount of chlorine needed to consume organic matter or other oxidizable substances in water.

Chlorine Dosage - The amount of chlorine added to water.

Chlorine Residual - The difference between chlorine dosage and chlorine demand, i.e., the amount left in the water.

Clarification - The process of making water clear and free of suspended impurities.

Colloids - A suspension of finely divided particles in a continuous medium, such as an atmospheric fog. The particles do not settle out of the substance rapidly, and are not readily filtered.

Combined Chlorine - Chlorine added in the form of: monochloramine, dichloramine, nitrogen trichloride.

Condensate - The water obtained by evaporation and subsequent condensation.

Conductance - The measure of the ability of a substance to carry an electric charge.

Conductivity - The quality of a substance to transmit electrical charges.

Contaminant - Any physical, chemical or microbiological substance in water

.

Dechlorination - The removal of excess chlorine residual.

Deionization - The process of removing ions from water.

Diatomaceous earth - A white, yellow, or light-gray siliceous earth composed predominantly of the remains of diatoms that typically accumulated in lakes or swamps. It is used as an absorbent and filtering agent.

Diatoms - Organisms related to algae, having a brown pigmentation and a siliceous skeleton.

Dissolved solids - The weight of matter in true solution in a stated volume of water, including both inorganic and organic matter.

Effluent - Something that flows out.

Filtration - The process of separating solids from a liquid by means of a porous substance through which only the liquid passes.

Fixture supply - That portion of a water distribution system serving one plumbing fixture, appliance or piece of equipment.

Fixture supply connector - That portion of a water supply piping which connects a plumbing fixture, appliance or a piece of equipment to the water distribution system.

Flood level rim - The edge of the receptacle from which water overflows.

Flux - Gallons per day of permeate passing through each square foot of membrane surface.

Free Chlorine - The chlorine added to water in the following forms: chlorine gas, hypochlorous chlorine, hypochlorite chlorine.

Hardness - The concentration of calcium and magnesium in water.

Indirect waste piping - Drain piping which does not connect directly with the drain system, but which discharges into the drain system by means of an air break or air gap into a receptor.

Influent - The water (untreated) entering a water treatment device.

Ion - An atom or molecule possessing an electric charge.

Ion Exchange - The replacement of ions by others.

Lignin- The major noncellulose constituent of wood.

Lime - Calcium oxide (CaO)

Local waste piping - means a portion of drain piping which receives the wastes discharged from indirect waste piping and which discharges those wastes by means of an air break or air gap into a receptor.

MCL - Primary Drinking Water Standard: The maximum contaminant level. Maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

MCLG - Maximum Contaminant Level Goal. A non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety.

Methemoglobinemia - An affliction which the oxygen-carrying capacity of red blood cells is reduced result of a reaction with nitrite.

Organic chemical - A carbon compound.

Osmosis - The passing of water through a permeable membrane separating two solutions of different concentrations; the water passes to the more concentrated side.

Oxidation - A reaction in which the atoms in an element lose electrons and the element's valence is responsively increased.

Ozone - An unstable, powerfully bleaching, poisonous, oxidizing agent with a pungent, irritating odor, used to purify and deodorize air, to sterilize water, and as a bleach.

Pathogen - Any organism which may cause disease.

Permeate - The product water from a reverse osmosis membrane.

Pesticide - A chemical used for killing insects, weeds, or anything considered a pest.

pH - A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.

Precipitate - An insoluble reaction product; in an aqueous chemical reaction, usually a crystalline compound that grows inside to become settleable

Product water - The treated water from a water treatment device.

Protozoan - A large group of mostly microscopic, one-celled animals higher on the food chain than bacteria, which consume bacteria.

Recovery - The percentage of product water produced by a reverse osmosis system.

Reduction - A decrease in positive valence or an increase in negative valence by the gaining of electrons.

Reject water - The waste water from a reverse osmosis system.

Reverse Osmosis - A process that reverses the flow of water in the natural process of osmosis.

Rust - A common name for iron oxide.

Secondary Drinking Water Standard - An unenforceable federal guideline regarding the taste, odor, color, and certain other aesthetic effects of drinking water.

Sedimentation - Gravitational settling of solid particles in a liquid system.

Selectivity - The order of preference of an ion exchanger for each of the ions in the surrounding solution.

Soda Ash - A water treatment chemical. Sodium carbonate.

Solute - A substance dissolved in solution.

Solvent- A substance that can dissolve another substance.

Total Solids - The weight of all solids per unit volume of water.

Turbidity - The measure of sediment or foreign particles stirred up or suspended in water. Requires days for sedimentation due to small particle size.

Zeolites - A group of hydrated sodium aluminosilicates, either natural or synthetic.

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DEPARTMENT OF NATURAL RESOURCES

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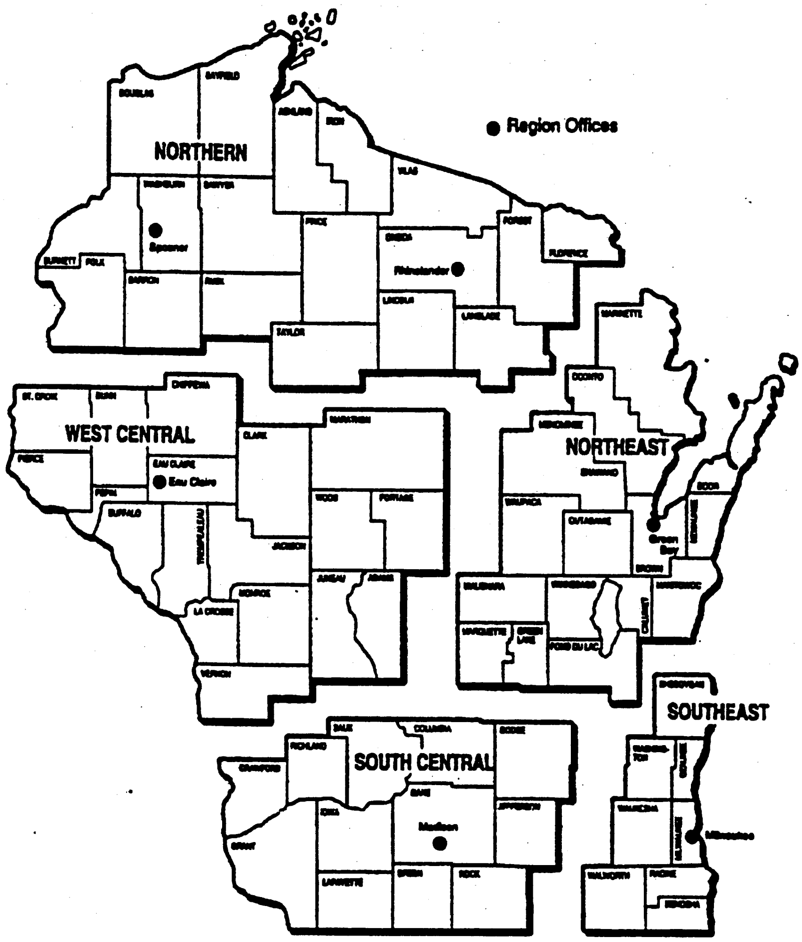

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