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Home Water Quality and Safety[1]

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Water, an essential for life on earth, is the most widely distributed nongaseous substance in nature. Because of water's importance, the pattern of human settlement throughout history has often been determined by its availability. Fertile river valleys with abundant water supplies were the centers for beginning civilizations. With growth, demand for water has increased dramatically and its uses have become much more varied. Per capita use in the U.S. is nearly 200 gallons per day. This includes water used in agriculture, industry, recreation, and non-ingested personal consumption. Frequently, each of these uses required a different level of quality in order for the water to be considered adequate.

Good quality drinking water may be consumed in any desired amount without adverse effect on health. Such water is called "potable." It is free from harmful levels of impurities: bacteria, viruses, minerals, and organic substances. It is also aesthetically acceptable, is free of unpleasant impurities, such as objectionable taste, color, turbidity, and odor.

Florida has plentiful sources of fresh water (usually ground water) throughout most of the state. However, some of this water has quality problems. Fortunately, most can be corrected using proper equipment and methods. The most common problems in household water supplies may be attributed to hardness, iron, iron bacteria, sulfides (sulfur), sodium chloride (salt), acidity (low pH), and disease-producing pathogens, such as bacteria and viruses. With intensive agriculture, the leaching of nutrients and pesticides into the water supply may cause additional problems. There is also a growing concern of pollution caused by the leaching of industrial wastes into the aquifers.

Properly located and constructed wells are usually the best sources of water for domestic use. Such water is less likely to be contaminated than water from surface sources. Surface water from streams, lakes, and ponds is almost always contaminated and requires proper treatment for domestic use. The treatment of surface water for human consumption is usually difficult and can be very costly. However, the content of dissolved minerals such as iron, manganese, and calcium is likely to be much lower than in well water.

In view of the possible quality problems, a new water supply should always be tested before use and old sources should be periodically checked for changes. Well water would not be expected to change rapidly, so frequent monitoring would not be necessary. The county health department is equipped to test for bacterial contamination. It determines whether the water is safe for human consumption at the time of the test. Periodic bacteriological tests are desirable thereafter. A second test should be performed for mineral content in order to classify other possible problems and to select the methods and materials necessary for their correction.

The level of testing required by Florida law (Adm. Code 17-22, Florida Department of Environmental Regulations, FDER) varies according to the number of persons supplied by the water system. An individual water supply which serves only one household only requires a bacterial test at time of installation. However, a community water system, which is a public water system serving at least 15 year-round residents must be periodically tested. Because of this additional testing, community supplies tend to be safer than individual systems. The larger the number of people the greater the precautions. In fact, every system in Florida serving more than 1000 persons must be tested for a more extensive list of contaminants, including volatile organics, since June 1, 1985. Starting January 1, 1987 all community water supplies were be required to increase their testing frequency.

EFFECT OF WATER QUALITY ON HUMAN HEALTH

The effect of toxic contaminants on human health can be classified as either acute or chronic. The reaction to a substance causing serious illness or death in an individual within 48 hours after exposure is considered acute toxicity. Chronic toxicity is a longer term effect on health due to frequent exposure to small amounts of a toxic substance. Chronic reactions to chemicals are difficult to study and our knowledge of the chronic toxic effects of nearly all chemicals is very poor. Examples of chronic health effects would be kidney and liver disease, cancer, mental illness, etc.

Based on epidemiological evidence and experimentation on laboratory animals, the U.S. Public Health Service has established maximum contaminant levels (MCLs) allowable in drinking water. Most of these levels allow a sufficient margin of safety; however, one must remember that acceptable contaminant levels vary widely among individuals and population groups. For example, high sodium, which may be harmless for many people, can be dangerous for the elderly, hypertensives, pregnant women, and people having difficulty in excreting sodium. Specific symptoms of different contaminants are presented in more detail in later sections.

BACTERIAL CONTAMINATION

The only required and routine test to be conducted on drinking water from a private well is that for sanitation. The main indicator of the sanitary quality of drinking water is the coliform bacteria count (MCL = average of 1 per 100 ml). A high count of these bacteria is an indication of contamination from a septic system or other fecal pollution source. The presence of coliform bacteria, which can be found in the feces of humans and animals, indicates that there is a high probability of other pathogenic organisms (disease causing germs) present. When water is contaminated with a surface drainage, noncoliform bacteria may also be present in large numbers. This type of contamination may not be harmful since there is only a small probability that drainage water contains pathogenic organisms. However, if the count of noncoliform bacteria is more than 200 per 100 ml, water is also considered to be poor quality.

With recent improvements in the water supply in the U. S ., the transmission of illnesses by drinking water has been infrequent. In Florida, only two cases related to home water wells were recorded in 1984.

Superchlorination followed by dechlorination is the most common solution for potential bacteria in the water supply. Mineral and chemical problems found in an individual home water supply are usually a more common concern than bacteria and often require other treatment.

NUISANCE CONTAMINATION

Nuisance contamination is usually not harmful to humans. The contamination usually results in some decrease in aesthetic value.

Water Hardness

Hardness is defined as the concentrations of calcium and magnesium ions expressed in terms of calcium carbonate, which can be calculated as shown in the equation :

equation.

The most frequently used standard classifies water supplies is shown in Table 1 .

These minerals in water can cause some everyday problems. They react with soap and produce a deposit called "soap curd" that remains on the skin and clothes and, because it is insoluble and sticky, cannot be removed by rinsing. Soap curd changes the pH of the skin and may cause infection and irritation. It also remains on the hair making it dull and difficult to manage. Soap curd picks up the dirt from laundry water and holds it on cloth, contributing to a gray appearance of white clothes. It is especially troublesome when wash water is allowed to drain through the clothes. The use of synthetic detergents may help a little, but the active ingredient in the detergent is partially inactivated by hardness and more detergent must be used for the same cleaning task. Some detergents will produce soap during the reaction with oil or grease on the surface being cleaned and as a result they will also deposit soap curd. A ring around the bathtub and spotting on glassware, chrome, and sinks are constant problems in the presence of hard water. They require additional rinsing and wiping, increasing the time spent on everyday cleaning.

Cooking with hard water can also be difficult, producing scale on pots. Some vegetables cooked in hard water lose color and flavor. Beans and peas become tough and shriveled.

Hard water may also shorten the life of plumbing and water heaters. When water containing calcium carbonate is heated, a hard scale is formed that can plug pipes and coat heating elements. Scale is also a poor heat conductor. With increased deposits on the unit, heat is not transmitted to the water fast enough and overheating of the metal causes failure. Build-up of deposits will also reduce the efficiency of the heating unit, increasing the cost of fuel.

Most natural water supplies contain at least some hardness due to dissolved calcium and magnesium salts. Other minerals, such as iron, may contribute to the hardness of water, but in natural water, they are generally present in insignificant quantities. The total hardness of water may range from trace amounts to hundreds of milligrams per liter.

Iron and Manganese

The presence of iron and manganese in large quantities is very easy to notice because of the reddish brown stain these minerals cause. The stain shows on laundry, sinks, and every other object touched by water. Iron is transported by water in a ferrous state forming a clear, colorless solution until it comes into contact with oxygen. Oxygen changes iron to the ferric state which reacts with alkalinity in the water and forms an insoluble brown ferric hydroxide precipitate called "yellow boy." Iron and manganese occur naturally in ground water, but some iron can be added to the water from corroded pipes.

Iron and manganese in combination with natural or man-made organic compounds will cause even more staining problems. Organic compounds react with iron and manganese to form very stable and difficult to remove darkly colored materials.

In addition to staining problems, large amounts of these metals can influence the taste of water and cause the development of iron and manganese bacteria, which are not a health hazard but are very unpleasant. They form masses of gelatinous and filamentous organic matter that traps the iron and manganese they use for growth. A good indication of their presence in the system is a brown slimy growth in the toilet flush tank.

Turbidity

Solid particles suspended in water absorb or reflect light and cause the water to appear "cloudy." These particles are undissolved inorganic minerals or organic matter picked up over or under the ground. Since the earth acts as an excellent filter, the water from deep wells is usually clear without significant amounts of turbidity. This problem is more common in the water from surface supplies.

The major problem with turbidity is aesthetics, but in some cases suspended matter can carry pathogens with it. Large amounts of organic matter can also produce stains on sinks, fixtures, and laundry. Much like iron, organic matter in water may also produce colors, unpleasant tastes, and odors. These tastes and odors will affect not only drinking water, but the foods and beverages prepared with the water.

Color, Odor, and Taste

It was already mentioned that iron and manganese will produce reddish brown stains. However, the color in water is most often caused by dissolved matter from decaying organic materials. Some color is almost always present in surface water, but it can occur in well water also.

Color makes water unpleasant for drinking and cooking and, like iron and manganese, causes staining. Organic matter very often contributes to tastes and odors. Even very small amounts of it can result in a musty odor and an "off" taste. A major cause of taste and odor problems is metabolites produced by actinomycetes, algae, or other microorganisms.

If water has a distinctive "rotten egg" odor, hydrogen sulfide gas is present in the water supply. Even very low concentrations will result in strong obnoxious odors. In addition to this, the water rapidly tarnishes silver and is corrosive to plumbing metals.

For a pleasant taste, water should have some dissolved minerals. Distilled water without minerals tastes "flat." However, high concentrations of minerals make water taste salty or metallic, and the taste can easily be detected in foods and beverages prepared with highly mineralized water. The presence of dissolved oxygen can improve taste. Faucet aerators will put oxygen in the water and can help remove obnoxious gases.

Corrosion

Corrosion is a natural process involving chemical or electrical degradation of metals in contact with water. The rate of corrosion will vary depending on the acidity of the water, its electrical conductivity, oxygen concentration, and temperature. Acidic water with pH values in the range of 6 to 7 is more corrosive to the metals used in plumbing systems than alkaline water. Both ground and surface water can be acidic.

Common causes for acidic surface water are acid rainfall due to atmospheric carbon dioxide and other airborne pollutants, runoff from mining spoils, and decomposition of plant materials. Acidic ground water can also be caused by the above factors but is mostly controlled naturally by the equilibrium relationship with surrounding minerals. For example, most ground water in Florida is alkaline with pH in the range of 7 to 10 because of the geological formation of the aquifer, which is composed of calcium carbonate (limestone).

Alkaline water does not eliminate corrosion if it has high electrical conductivity. When two different metals such as steel and brass are in contact with a solution which will conduct electricity, a galvanic cell is established. One of the metals will corrode in proportion to the electricity generated. If plumbing is installed using different metals (copper, steel, brass, zinc, and various alloys) corrosion will occur.

Oxygen dissolved in water will also enhance the process of corrosion. Deep well water is usually free of dissolved oxygen, but it is present in surface water. The temperature of water is a significant factor in the rate of corrosion. Above 140°F the rate of corrosion of steel doubles with every 20°F increase in temperature.

METALS AND THEIR IMPORTANCE TO ORGANIC LIFE

Several metal ions such as sodium, potassium, magnesium, and calcium are essential to sustain biological life. At least six additional metals, chiefly transition metals, are also essential for optimal growth, development, and reproduction, i.e. manganese, iron, cobalt, copper, zinc, and molybdenum.

An element which is required in amounts smaller than 0.01% of the mass of the organism is called a trace element. Table 2 shows that the average person weighing 154 lbs (70 kg) requires the following amounts of metals in the body to maintain good health.

Only the last six ions are in small enough quantities to be considered trace elements. Trace metals function mostly as catalysts for enzymatic activity in human bodies. However, all essential trace metals become toxic when their concentration becomes excessive. Usually this happens when the levels exceed by 40- to 200-fold those required for correct nutritional response.

Drinking water containing the above trace metals in very small quantities may actually reduce the possibility of deficiencies of trace elements in the diet. However, in some cases, if the metal is present in the water supply, there is a danger of overdose and toxic effect.

In addition to the metals essential for human life, water may contain toxic metals like mercury, lead, cadmium, chromium, silver, selenium, aluminum, arsenic, and barium. These metals can cause chronic or acute poisoning and should be eliminated from the drinking water if possible.

Metals in a Water Supply and Their Toxic Effects

The reader is cautioned not to be overly concerned about the symptoms and toxic reactions presented here because it is extremely rare for concentrations of these metals in Florida drinking water to exceed the standards presented. Also, many of these metals would cause a change in water taste before dangerous levels are reached. However, if industrial contamination is suspected, then more concern is in order, because levels would increase if not corrected.

Aluminum**:** (no MCL established; 0.2 mg/l considered a safe maximum). High aluminum levels are associated with premature senile dementia (Alzheimer's disease) and two other types of dementia as well.

Arsenic**:** (MCL = 0.05 mg/l). Minor symptoms of chronic arsenic poisoning are similar to those of many common ailments, making actual arsenic poisoning difficult to diagnose. This type of poisoning can make people tired, lethargic, and depressed. Other symptoms are white lines across the toenails and fingernails, weight loss, nausea and diarrhea alternating with constipation, and loss of hair. Arsenic is highly toxic and unfortunately widespread in the environment due to its natural occurrence and former extensive use in pesticides.

Barium**:** (MCL = 1.0 mg/l). Since there are few data on the chronic effects of barium, the MCL includes a large safety factor. High levels of barium can have severe toxic effects on the heart, blood vessels, and nerves. It is capable of causing nerve blocks at high doses. 550 to 600 mg is a fatal dose for humans.

Cadmium**:** (MCL = 0.01 mg/l). Acute cadmium poisoning symptoms are similar to those of food poisoning. Up to 325 mg of cadmium is not fatal but toxic symptoms occur at 10 mg. It is associated with kidney disease and linked to hypertension. There is also some evidence that cadmium can cause mutations.

Calcium**:** (MCL not established). Low calcium intake can be related to hypertension and cardiovascular disorders. There is a link between low calcium intake and osteoporosis. With a low level of calcium in the diet, drinking water may provide a significant portion of the daily calcium requirement.

Chromium**:** (MCL = 0.05 mg/l). It has been shown that freshwater and saltwater aquatic life can be adversely affected by the presence of chromium. The effect of chromium in drinking water has not been thoroughly investigated. However, chromium is known to produce lung tumors when inhaled.

Copper**:** (MCL = 1 mg/l). Studies show that U.S. diets are often deficient in copper. Its deficiency causes anemia, loss of hair pigment, growth inhibition, and loss of arterial elasticity. High levels of vitamin C inhibit good copper absorption. However, water containing amounts higher than 1 mg/l is likely to supply too much of this metal. One milligram per liter is also a taste threshold for the majority of people. Copper is highly toxic and very dangerous to infants and to people with certain metabolic disorders. Uptake of copper is also influenced by zinc, silver, cadmium, and sulfate in the diet.

Iron**:** (MCL = 0.3 mg/l). The presence of iron in drinking water may increase the hazard of pathogenic organisms, since most of these organisms need iron to grow. The bioavailability of iron in drinking water has not been well researched. It is known that iron influences the uptake of copper and lead.

Lead**:** (MCL = 0.05 mg/l). Lead can occur naturally, or result from industrial contamination, or be leached from lead pipes in some water systems. If the plumbing contains lead, higher levels will be detectable in the morning after water has been standing in pipes throughout the night. Lead is a cumulative poison. Lead poisoning is difficult to distinguish in its early stages from minor illness. Early reversible symptoms include abdominal pains, decreased appetite, constipation, fatigue, sleep disturbance, and decreased physical fitness. Long term exposure to lead may cause kidney damage, anemia, and nerve damage including brain damage and finally death.

Magnesium**:** (MCL not established). An average adult ingests as much as 480 mg of magnesium daily. Any excess amounts are quickly expelled by the body. No upper limit has been set for this metal in drinking water. It can, however, create a problem for people with kidney disease. They may develop toxic reactions to high levels of magnesium, including muscle weakness, coma, hypertension, and confusion.

Manganese**:** (MCL = 0.05 mg/l). Excess manganese in a diet prevents the use of iron in the regeneration of blood hemoglobin. Large doses of manganese cause apathy, irritability, headaches, insomnia, and weakness of the legs. Psychological symptoms may also develop including impulsive acts, absent-mindedness, hallucinations, aggressiveness, and unaccountable laughter. Finally, a condition similar to Parkinson's disease may develop.

Mercury**:** (MCL = 0.002 mg/l). Mercury poisoning symptoms include weakness, loss of appetite, insomnia, indigestion, diarrhea, inflammation of the gums, black lines on the gums, loosening of teeth, irritability, loss of memory, and tremors of fingers, eyelids, lips, and tongue. At higher levels, mercury produces hallucinations, manic-depressive psychosis, gingivi-tis, sialorrhea, increased irritability, muscular tremors, and irreversible brain damage.

Selenium**:** (MCL = 0.01 m/l). One recognized effect of selenium poisoning is growth inhibition. There is some evidence that selenium is related to skin discoloration, bad teeth, and some psychological and gastrointestinal problems. On the other hand, a small amount of selenium has been found to be protective against other heavy metals like mercury, cadmium, silver, and thallium.

Silver**:** (MCL = 0.05 mg/l). The first evidence of excess silver intake is a permanent blue-gray discoloration of the skin, mucous membranes, and eyes. Large doses of silver can be fatal.

Sodium**:** (MCL = 160 mg/l). The fact that some patients with heart disease have difficulty in excreting sodium and are put on a low sodium diet has led to the idea that sodium is bad for the heart. However, studies show no correlation between sodium concentration and cardiovascular disease mortality. On the contrary, beneficial correlations for sodium have been reported. Areas where water is hard, highly mineralized, and also high in sodium tend to have lower cardiovascular death rates. This does not contradict the fact that in some individuals the lowering of sodium in a diet is effective in lowering the blood pressure. Depending on age, general health, and sex, sodium may present a problem in drinking water. If the sodium in water exceeds 20 mg/l, it is advisable to contact the family physician for an opinion.

OTHER CONTAMINATION

Chlorides**:** (MCL = 250 mg/l). Chlorides are normally associated with salty water. Sodium chloride is common table salt and also is the salt found in seawater. High chloride levels can cause human illness and also can affect plant growth at levels in excess of 1000 mg/l. Taste threshold is about 250 mg/l for most people.

Fluorides**:** (MCL = 1.4 to 2.4 mg/l, function of climate). The optimum level of fluorides in water for reducing dental cavities is about 1 mg/l. Higher levels could cause mottling of the teeth. For the Florida climate the MCL will be between 1.4 and 1.6 mg/l. Reduced MCL values in a hot climate are justified by increased daily intake of drinking water in warm weather. Controversy over negative and positive effects of adding even small amounts of fluorine to drinking water make it very difficult to accurately summarize its effect on the human body.

Nitrates**:** (MCL = 10 mg/l as N). Nitrates are present in water particularly in regions where agricultural fertilization or organic waste disposal may be polluting water sources. The nitrate level in drinking water is extremely important with infants, because of their high intake of water with respect to body weight. Nitrates in the infant are converted by the body to nitrites that oxidize blood hemoglobin to methemoglobin. The altered blood cells can no longer carry oxygen, which can result in brain damage or suffocation. The upper limit for nitrates in drinking water is 10 mg/l as nitrogen. This is about 45 mg/l of the nitrate ion. Epidemiological studies show a correlation between high nitrate levels and gastric and stomach cancers in humans.

Organic compounds**:** (variable MCL). Organic compounds include a wide range of substances, all of which contain carbon. The common types of industrial organic substances found in water are petroleum products, solvents, pesticides, and halomethanes. These are generally referred to as either hydrocarbons or organic halides (usually chlorinated hydrocarbons). Most organic halides, especially the man-made compounds, have been found to be toxic--acutely at high concentration and chronically at very low concentrations. These types of organic compounds run from methylene chloride (CH_2C_{12}) to DDT (1,1,1-trichloro-2, 2-bis (p-chlorophenyl)ethane). Most volatile (or purgeable) chlorinated organic chemicals can cause cancer. High concentration symptoms include nausea, dizziness, tremors, and blindness. Florida is about to require testing for all 75 halogenated organics in community water systems. The testing methods for these chemicals are very complex, expensive, and time consuming. Usually gas chromatography with mass spectroscopy and a computer search involving expensive equipment and highly trained operators are required. As a result, the average homeowner cannot afford this complete test.

Radionuclides**: radium-226** and **radium-228** (MCL = 5 pCi/l); **tritium** (hydrogen-3, MCL = 20,000 pCi/l); **strontium-90** (MCL = 8 pCi/l). These doses are based on not exceeding 4 millirem/year (rem stands for roentgen-equivalent-man, a radiation dosage unit) of net ,, and photon radioactivity. Excessive levels could cause radiation sickness or bone disease. The presence of radium in drinking water is not of great concern because it is not retained in the body.

Total dissolved solids**:** (TDS, MCL = 500 mg/l). TDS represent mostly the total mineral content of the water (deposits left after evaporation of a water sample), primarily salts, carbonates, and metals. Organic compounds may also be dissolved solids. A high concentration of TDS is an indicator of possibly high volume contamination and further investigation may be recommended.

Sulfates**:** (MCL = 250 mg/l). Sulfates are associated with gypsum formations and are common in several areas of Florida. High sulfate water can cause diarrhea, and in fact was commercially sold as a laxative in the past.

WATER TESTING FOR INDIVIDUALS

The only way to precisely know what is in your water is to have it tested. Generally the only required test for individual supplies is that for bacteria contamination, conducted by the local health department. Upon special request and indicated need the local health department or the Florida Department of Environmental Regulation can run additional tests. If a homeowner is simply curious or has personal concern, private testing sources will have to be used. This testing may become quite expensive.

The first step for any test is getting a reliable, representative sample. The need for careful sampling techniques varies according to the constituent being tested, i.e. bacteria and volatile organics are very sensitive to sample collection procedure while hardness and salts are fairly insensitive to sampling technique. Storage procedures before analysis and time between sampling and analysis are also very important but again vary substantially for each substance.

A general procedure for taking a sample is given below and would be sufficient for many problems including bacteria. In any cases where there is doubt, the laboratory performing the test should be contacted for instructions and a sampling bottle. In fact, in some cases the laboratory may want to take the sample. The following procedures should be followed for general sampling:

- The sampling bottle should be clean and sterile with nothing except the water to be sampled

coming in contact with the inside or cap of the bottle.
- A faucet without leaks around the handle should be selected for sampling. It must be cleaned and dried.
- The water should run for an ample period of time to ensure fresh water from the well before collecting a sample. The water should not make contact with any object before running into the bottle. The sample should be capped immediately to preserve volatile compounds in the water and prevent atmospheric contamination.
- The sample should be analyzed within 24 hours to give accurate results. For best results, on-site testing of water is suggested if possible.

In making a decision whether to test for organic compounds, the following should be considered. First, are there any industrial disposal sites, pesticide users, machine shops, automotive garages, or other industries close enough to contaminate the aquifer? Second, is there any source of chlorine near the aquifer? Chlorinated water can have elevated organic halide levels, commonly trihalomethanes (MCL = 0.1 mg/l). Research is currently being conducted to modify the treatment process to keep these substances from drinking water. However, for now, chlorination will continue to be used to kill infectious organisms in water.

Units of Measure Typically Used to Express Test Results

Most analyses for contaminants provide results in terms of concentration, which are usually expressed in units of either parts per million (ppm) or milligrams per liter (mg/l). These two units are used interchangeably by most persons, but are technically different. For the range of concentrations found in most water supplies, the difference is negligible. However, for uniformity in reporting milligrams per liter is used. Concentrations greater than 10,000 mg/l are commonly expressed in percentage by weight.

In the domestic water treatment industry, water hardness is often reported in grains per gallon. One grain per gallon is equal to 17.1 mg/l.

"Acidity" of water is expressed in pH units. It is the logarithm of the reciprocal of the hydrogen ion concentration [H +] in the solution. For pure water the hydrogen concentration is 1×10^{-7} moles per liter and the solution can be characterized as pH 7. The pH can range from 0 to 14, but most potable water will range from 6.5 to 8.5. Any solution with a pH below 7 is acidic; any solution with a pH above 7 is alkaline.

If you have your water tested for a broad range of substances, do not be surprised if a lot of things are found and reported. Compare results with accepted standards and nuisance levels discussed previously before becoming overly concerned. If a problem is found or confusion as to the meaning of the results develops, then a water quality treatment expert should be consulted. Your local health department or Florida Department of Environmental Regulation office should be notified if a standard MCL is exceeded. These agencies as well as private water treatment companies can be contacted for specific treatment recommendations.

METHODS OF ANALYSIS FOR MINERAL CONTENT

The most common techniques for analyzing water for easily detected factors are colorimetric and titrametric testing methods. Colorimetric testing methods are based on matching color reactions with simulated color standards that represent known values. Titrametric testing methods are the procedures requiring the gradual addition of an accurately standardized solution known as a titrant to the test sample until a color change occurs. Field test kits using these techniques are readily available for the detection of several minerals.

There are other analytical techniques used mostly for analysis of trace elements and organic contaminants.

These include atomic absorption spectroscopy, activation analysis, chromatography, mass spectroscopy, emission spectroscopy, and others. These techniques are usually expensive and require sophisticated laboratory equipment. Specific analytical techniques are listed in FDER Rules and Regulations (Adm. Code 17-21 and 17-22).

METHODS FOR THE CONTROL AND ELIMINATION OF WATER PROBLEMS

With properly installed and maintained treatment systems, most water can be made safe and pleasant to drink. Treatment systems should be checked routinely to detect possible problems. The following paragraphs review specific methods of water treatment and what they are used for. Before getting into the individual treatment processes it will be important to know the general order in which these treatment steps should occur. Multiple treatments are common but if initiated in the wrong sequence, one treatment may negate another. Figure 1 (not available) shows this sequence for a very complete system, all of whose parts will not be required in most cases.

Disinfection

Disinfection is defined as an integrated system of treatment processes that reliably reduces the population of viable pathogenic microorganisms to levels deemed to be safe by public health standards.

The use of chlorine and its compounds is the most common disinfection method in private water supply systems in the U.S. It is inexpensive, readily available in several forms, and effective against bacteria. Its effectiveness is easy to test by measuring the chlorine residue in a system. However, in a small system the time between adding chlorine and using water is so short that relatively high concentrations are required. Larger retention tanks can increase contact time before use and reduce required concentration. Research findings indicate that carcinogenic and mutagenic halogenated organic compounds (halomethanes) can actually be formed during chlorine disinfection when organic substances are present. With this discovery, activated carbon filtration or reverse osmosis units should become a part of all up-to-date home chlorination systems.

Small amounts of water can be disinfected by boiling for 15 minutes. However, the process is energy intensive and may even increase the concentration of other contaminants due to evaporation.

There are other methods of water disinfection. Most of them are still too complex or too expensive for home water supply. They are discussed here for a few reasons. These methods are effective and they are being constantly improved. With the development of new technology they may quickly become a good, feasible solution for water disinfection in individual water supplies. They include ultraviolet radiation, ozonation, iodination, and distillation.

Ultraviolet radiation, in order to be effective, must pass through the water in order to control the bacteria. The water therefore cannot have any turbidity or suspended particles. Ultraviolet radiation adds nothing to the water and does not produce any taste or odor. It is very effective on pathogens but not on protozoan cysts such as those responsible for giardiasis. Because of the possible presence of protozoan cysts, a 5-m filter must be added to the system. Ultraviolet radiation disinfection also requires a safety system, where a photoelectric cell activates an alarm system and/or stops the water pump if the ultraviolet radiation intensity is not sufficient for safe disinfection. The major problems with such a system are cost, fouling of the chamber, collection of sediment, and growth of algae. In the latest ultraviolet radiation systems, Teflon tubes are used instead of quartz tubes and seem to decrease these problems.

Ozone is a very strong oxidizing gas and is very effective in killing bacteria even with short exposure times. In water, ozone (0_3) breaks down to O_2 and O^- and combines with organisms and chemicals. It also does not leave any taste or residue, and is therefore very difficult to detect to determine its effectiveness because a residual amount of O_3 is needed to assure disinfection. With new developments in electronic technology, detection of the short-lived residual ozone in the water may become economical in home water purification systems, but for the present it is not a practical solution.

Addition of iodine into drinking water is a relatively new approach to home water disinfection, though the technique has been around for years. It is very effective on a wide variety of bacteria and does not affect the water taste any more than chlorine. However, iodine is not readily available and the cost is relatively high. It is less reactive than chlorine and has less tendency to form halogenated organics. Physiological effects of prolonged use of iodine, especially on children, are unknown. However, in a newly developed system (the resin-sequestered iodine system) the iodine remains attached to the resin particles. It contacts the organisms in the water and kills them. It does not move beyond the filter or alter the taste of the disinfected water.

Distillation is an effective method for the removal of microorganisms as well as many inorganic chemicals from water. However, distillation alone is usually ineffective in removing purgeable organics from the water since some are carried into the distillate with water vapor. Small units, producing 10 to 15 gallons per day, for drinking and cooking are available for less than $300. One must also remember a considerable amount of energy is needed for the distillation process.

Activated Carbon Filters

Many people have turned to point-of-use activated carbon filtration devices to improve their drinking water. Installation of these filters is usually done for the removal of offensive tastes and odors, color, chlorine, and organics including halogenated organic compounds.

There are some water problems which are not corrected by activated carbon filtration. If the water contains large amounts of magnesium and calcium (hard water), softening is still necessary because an activated carbon unit will not remove hardness. It will not remove dissolved metals such as iron, lead, manganese, and copper or chlorides, nitrates, and fluorides. Small activated carbon units can remove only small portions of hydrogen sulfide.

These filters are not effective against bacteria. In fact, they may promote bacterial growth especially when not used for a few days or when not changed at proper intervals. Some manufacturers claim that filters containing silver discourage the growth of bacteria within the filter. However, research shows that silver-impregnated carbon units do not significantly reduce bacteria problems and may increase the silver content in drinking water up to 0.028 mg/l.

Even with these limitations, activated carbon filters can significantly improve water quality. Carbon filtration can remove more than 90% of cadmium, chromium, manganese, mercury, silver, and tin. It removes many objectionable tastes and odors. It is effective on turbidity, but more economical sand or fiber filters should be used if this is the only problem. It is most effective for removal of chlorine and potentially dangerous and carcinogenic organic compounds, which may be present in a water system as a result of chlorination or industrial pollution.

High reduction efficiencies for halogenated organics are reported by American Water Works Association and will be discussed in the section on volatile organic halide removal.

The efficiency of any activated carbon filter is dependent on the "useful flow rate" of the filter and estimated filter lifetime, which are governed largely by the size of the filter and the amount of carbon it contains. There are two basic types of carbon filters: sink-mounted, which are attached to the faucet outlet, and in-line models connected to the cold water supply line to the house or just beneath the sink depending on the degree of the problem. Quite often the effective lifetime of a carbon filter can be short, which requires the filters to be replaced frequently. To determine the lifetime of a unit requires knowledge of mean and peak flow rate, residence volume of unit, carbon surface area to volume ratio, and the concentration of the various contaminants in the water. To prevent replacing the filter too seldom (contaminants not removed) or too frequently (costly) professional help by trained water quality experts or a continuous testing program for the water is needed, which is usually cost prohibitive. Some filters use powdered activated carbon embedded in a felt-like pad and others use granular activated carbon. It has been found that powdered carbon has a tendency to "unload" certain chemicals after it becomes saturated and, therefore, units containing granular activated carbon are recommended.

Reverse Osmosis

Osmosis occurs when solutions of different concentrations are separated by a semipermeable membrane. The tendency to reach a state of equilibrium between the two solutions (the second law of thermodynamics) causes pressure to exist across the membrane, called osmotic pressure. For example, if salty water and fresh water are separated by a membrane, there is a pressure exerted by the dissolved salt to pass through to the less salty solution, the fresh water, and there is a pressure exerted by the fresh water to flow to the lower water concentration existing in the salty water. If the membrane is permeable to water molecules but not to salt, water will flow through to dilute the salt water. If sufficient external pressure is applied to the salty water solution, the flow of water will be reversed. This process, called "reverse osmosis" (RO), is slowly becoming technologically, commercially, and economically feasible for the production of high quality water from alkaline, brackish, or colored water.

The rate of water flow is proportional to the pressure applied to the higher concentration solution. This pressure is called the feed pressure and its normal range is 100 to 600 lbs per square inch (p.s.i.); however, some new home units run at 40 to 90 p.s.i. Since a semipermeable membrane acts in the system as a filter, its quality and properties are of major importance. The membrane should remove high percentages of dissolved solids, have good chemical and bacteriological resistance, and be able to operate under wide pH and temperature ranges. Most membranes are subject to fouling by hard water, making softening a required pretreatment. The two most commonly used membranes are cellulose acetate and nylon.

Research in North Dakota on the feasibility of reverse osmosis systems in rural homes indicates that it is still a costly process and should be considered for individual houses only under extreme conditions. The quality and useful life of membranes are being constantly improved and this treatment may become cost-effective for individual houses in the near future.

Supplying good quality drinking water to some of the more rapidly growing coastal communities in Florida has become a major problem. In several areas, desalinization is a feasible way of using brackish ground water for potable supplies. The most common water treatment technique used for these conditions is reverse osmosis, which has been installed in more than 150 treatment plants in Florida. Water treated by reverse osmosis may be desalinized to a degree that it can be blended with softened brackish water to lower the cost of treatment, while still meeting the standards for potable water.

One of the major problems with the reverse osmosis process is the disposal of the reject water, a high salt concentration solution. If this water contains high levels of toxic materials, special provisions for its disposal must be made. Most reverse osmosis systems operate at a 50 to 75% conversion rate for brackish water and a 20 to 30% conversion rate for seawater. This means that, at a 75 % conversion rate, 75 gallons of desalinized water will be produced from 100 gallons of feed water and 25 gallons will be reject water. As a result, the total use of water will be higher.

Water Softening

Hard water may be very troublesome in household water supplies. Fortunately, there is a simple solution to hard water problems. A water softener can be installed in the cold water line that serves the house. Water for the lawn, garden and other non-household uses normally bypasses the softener. Softened water is desirable in the bathtub, lavatory, kitchen sink, and laundry room but is undesirable as drinking water. For total household use, the average family will need about 35 gallons per day of softened water per person.

Water softeners usually consist of a tank containing an ion-exchange material such as zeolite or resin beads. When water passes through, calcium and magnesium ions are exchanged for sodium ions. Water-softening capacity must be regenerated at intervals depending on the hardness of water and the capacity of softener. Water softener capacity is given in terms of the number of grains of hardness it will remove between successive regenerations. It is recommended that a softener have enough capacity to last at least three days between regenerations. The choice will depend on water requirements for the household and the peak flow rate. Regeneration of the water softener is accomplished by flushing brine (common salt solution) through the exchange material to replace collected calcium and magnesium ions with sodium ions. The flush brine is a waste and must be disposed of properly.

Many softeners are fully automatic and require only a periodic resupply of salt. They will automatically backwash before regenerating to flush out accumulated sediment and oxidized iron. The sodium content of the softened water supply is directly related to the original hardness. In harder water, more calcium and magnesium ions must be substituted with sodium during the softening process. Some people may be concerned with the increase of sodium in their diet; however, the quantity of sodium obtained from the water will be relatively small. For example, suppose that the hard water contains 10 grains of calcium and magnesium. If we assume that the daily consumption of water is one-half gallon (2 liters) per person and one-third of the hardness is due to magnesium salts and two-thirds to calcium salts, then the increase in sodium in the daily diet is 0.3 g (this assumes 100% efficiency of the exchange process). This can be a significant amount for people limited to 0.5 g or less of sodium per day.

Aeration and Other Methods for Removal of Dissolved Gases

The process of aeration is used to improve the physical and chemical characteristics of water for domestic use. The more important functions of this process are the removal of dissolved gases, such as carbon dioxide, methane, and hydrogen sulfide, and the addition of oxygen necessary for the precipitation of iron and manganese. However, oxygen entering the water may increase its corrosiveness. If organic matter is not present, aeration alone is sufficient to cause precipitation of iron and manganese. Aeration can also partially remove volatile substances causing problems with odor and taste. However, since some substances are not sufficiently volatile, aeration is not always efficient in the removal of odor and taste. The use of aeration should not be considered if water would be subjected to airborne contamination.

Other methods of oxidation can be used for removal of dissolved gases like hydrogen sulfide. Oxidation is necessary for conversion of the gas to forms which can precipitate and therefore be filtered. It can be done using oxidizing filters (green sand filters), chlorination, or treatment with hydrogen peroxide, which has been tested lately for this purpose.

Coagulation, Flocculation, Sedimentation, and Filtration

A large portion of particles suspended in water can be sufficiently small that their removal by sedimentation or filtration is not practicable. Most of these small particles are negatively charged, which is the major cause of the stability of suspended soil particles. Particles which might otherwise settle are mutually repelled by these charges and remain in suspension. Coagulation is a chemical technique directed toward destabilization of particle suspension. The most commonly used coagulant is alum (aluminum sulfate). Coagulation is usually followed by flocculation, which is a slow mixing technique promoting the aggregation of the destabilized (coagulated) particles. Coagulation followed by flocculation as an aid to sedimentation and filtration has been practiced for centuries. It is by far the most widely used process for the removal of substances producing turbidity in water. If water has high turbidity, flocculation followed by sedimentation is often used to reduce the quantity of material prior to entering the filter.

Filters for suspended particle removal can be made of graded sand, granular synthetic material, screens of various materials, and fabrics. The most widely used are rapid-sand filters in tanks. In these units, gravity holds the material in place and the flow is downwards. The filter is periodically cleaned by a reversal of flow and the discharge of backflushed water into a drain. Cartridge filters made of fabric, paper, or plastic material are also common and are often much smaller and cheaper and are disposable. Filters are available in several ratings depending on the size of particles to be removed. Activated carbon filters, described earlier, will also remove turbidity, but would not be recommended for that purpose only.

Iron and Manganese Removal

If the amount of iron and manganese in water is not very significant, it can be removed by most water softeners along with water hardness. When the water softener is regenerated, iron and manganese ions will be flushed out the same way as calcium and magnesium ions. However, with larger amounts of iron in the water (more than 0.1 mg/l), precipitated iron residue may build up on the softening material regardless of backflushing and slowly decrease the efficiency of the softener. This can sometimes be controlled by special cleaning products mixed with the salt used for regeneration of the softeners.

If the iron and manganese concentrations are above 0.1 mg/l (combination of both ions) an iron filter should be used. The medium in this type of filter oxidizes iron and manganese and removes precipitated matter. The most common type is called a green sand filter. These filters also must be flushed periodically and regenerated with potassium permanganate to restore oxidizing power.

The softener and iron filter are effective only if the iron or manganese is not bound to organic matter and there are no iron or manganese bacteria in the water. The oxidizing media of the iron filters are not strong enough to break these materials down. Where iron and manganese are bound to organic matter, or concentrations of these two metals are very high, or iron or manganese bacteria are present, a strong oxidizing substance must be applied before filtration. The most commonly used chemical in these systems is household bleach (hypochloride) injected ahead of the pressure tank. This procedure disinfects the water and at the same time oxidizes iron, manganese, and organic matter, which will then precipitate. Sedimentation and/or filtration is then needed to remove the precipitants. Chlorine solutions tend to lose their strength and require weekly addition to be effective. Activated carbon units or reverse osmosis units should then be used to remove the remaining chlorine and possible halogenated hydrocarbons created from organics. It should be noted that acid prevents the complete oxidation of iron in water and acidity should be neutralized for effective removal of iron. Final choice of the method will depend on iron and manganese concentrations, pH of water, and the presence of the bacteria.

An alternative to iron removal is stabilization with polyphosphates. The application of the polyphosphate must take place before the iron is oxidized with aeration or chlorination. This process is also called sequestration. It does not work well where the concentration of iron is over 1 mg/l. Also, heat will convert polyphosphate to orthophosphate which causes it to lose its dispersing properties. The use of phosphates may stimulate the growth of bacteria so chlorination may still be required. As a result, chlorine might as well be used for iron and manganese removal in the first place.

Nitrate and Nitrite Control

Often the best solution for nitrate and nitrite pollution is relocation of the well or drilling the well deeper into an uncontaminated aquifer. The only effective methods of treatment are distillation, reverse osmosis and high quality ion-exchange columns, but these will often not be economically feasible. Activated carbon filters will not remove nitrates or nitrites.

Volatile Organic Halide Removal

The only effective methods for removing volatile organic halides are activated carbon filtration and reverse osmosis. Reverse osmosis would be feasible only if other problems required its use. Studies done by The American Water Works Association show that the reduction efficiency for halogenated organics by activated carbon filters ranges from 76% for a faucet-mounted unit to 99% for several larger in-line units. However, one must keep in mind that the reduction is dependent on flow rate, contact time, and cleanliness of the unit as discussed in the section on these filters.

Trace Metals Removal

Methods for the removal of trace amounts of toxic metals include distillation, ion exchange, reverse osmosis, and activated carbon filtration. All systems are quite expensive and are usually installed on drinking water lines only. The ion-exchange resins must be selected very carefully with regard to the metals needing removal and other metals present in the water which may interact with the process. The other three methods, distillation, reverse osmosis, and activated carbon filtration, and their limitations were described earlier

Corrosion Control in Household Systems

If the main cause of water corrosiveness is low pH (acidity), the water can be neutralized using special filters containing such materials as calcium carbonate (calcite) or magnesium oxide (magnesia). These filters serve also as mechanical filters and therefore must be backwashed periodically with some additional active material added. Another method of neutralization requires the addition of sodium carbonate (soda ash) into the system. This should be injected ahead of the pressure tank. If chlorination is used, this solution can be mixed with the chlorine solution.

One has to keep in mind that addition of soda ash may slightly increase sodium level in the drinking water, and calcium carbonate filters will increase hardness and alkalinity.

A different approach to the control of corrosion is the injection of certain chemicals, such as polyphosphates and silicates, to create protective films on plumbing components. Selection of noncorrosive plumbing materials, like plastic or polyvinyl chloride, will help. Since corrosion increases with elevated temperatures, water heaters should be set only as high as necessary and temperatures above 140°F are not recommended.

Corrosion associated with other chemicals like hydrogen sulfide and dissolved oxygen must be handled differently. For example, hydrogen sulfide can be treated by activated carbon filtration or chlorination.

SUMMARY

People are becoming increasingly concerned about the safety of their water. Current improvements in analytical methods allow for detection of impurities at very low concentrations in water. Consequently, water supplies once considered to be pure are found to contain various contaminants, very often from natural sources, and usually below harmful concentrations. Water can dissolve thousands of substances, some of which do not dissolve and form a suspension in water. Therefore, we must not expect pure water, but we want to be sure of safe water.

Water systems in Florida that serve more than 1000 residents are periodically tested for many kinds of contamination. In the near future this type of testing will be required for every community water supply (more than 15 residents). The only people who may have a reason for testing their water are the owners of individual water supplies that have some indication of a problem, such as odor or taste. The presence of nearby pollutant sources also may be a good reason for a water test.

This circular should be considered an introduction to some specific water problems one might encounter in Florida, and how one should go about identifying and solving them. For more specific information contact your local county extension office.

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Tables

Table 1. Water supply classification

Hardness	**Concentration**
Soft Water	0 to 1 grain/gallon(0 to 17.1 mg/l)
Slightly Hard Water	1 to 3.5 grains/gallon(17.1 to 51.3 mg/l)
Moderately Hard Water	3.5 to 7 grains/gallon(51.3 to 119.7 mg/l)
Hard Water	7 to 10.5 grains /gallon(119.7 to 179.55 mg/l)
Very Hard Water	Over 10.5 grains/gallon(over 179.55 mg/l)

Table 2. Metals necessary for the human body to remain healthy

Major Metal Ions	**Grams**
Sodium (Na)	70.000
Magnesium (Mg)	40.000
Potassium (K)	250.000
Calcium (Ca)	

	1700.000
Trace Metals	**Grams**
Manganese (Mn)	0.030
Iron (Fe)	7.000
Cobalt (Co)	0.001
Copper (Cu)	0.150
Zinc (Zn)	3.000
Molybdenum (Mo)	0.005

Footnotes

1. This document is Circular 703, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Publication date: May 1986.

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