Water Quality

Water quality is determined by the types and concentration of chemical elements found in water that make it suitable or not suitable for irrigation of greenhouse crops.

Understanding the importance of water quality is key to developing a root zone management program. Conserving and managing irrigation water and accounting for its nutrient content are becoming some of the most important responsibilities of greenhouse operators.

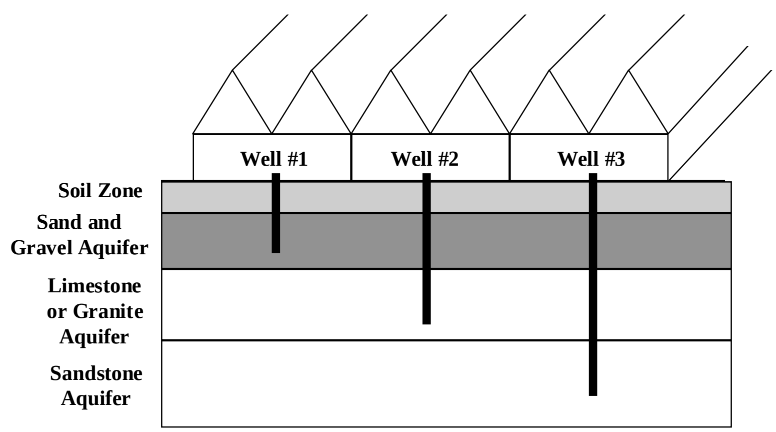
Over the last 15 years, recognition of the importance of groundwater and the need to protect aquifers has added an environmental focus to these responsibilities. Greenhouse operators of the new millennium must be equally concerned about water quality as it relates to the environment as well as its relationship to plant nutrition.

One of the first steps in selecting a site for plant production is to determine the potential sources of irrigation water. There are five main sources:

- Groundwater from wells
- Surface water
- Drainage ponds
- Rain
- Municipal water

Greenhouse operators need to be aware of all the options available. Changing the water source may be a simple solution to water quality or quantity problems instead of implementing expensive water treatment.

Groundwater from Wells



Groundwater from wells was the water source for 50 percent of the greenhouses surveyed in a study done by The Ohio State University.

Groundwater is made up of rain and other water applied to soils. The water drains through the soil profile until it reaches a depth where all soil pore spaces are filled. This saturated zone is called the water table or aquifer.

Groundwater quality varies because of the parent material, usually rock, that makes up the saturated zone. In the Midwest, groundwater is often drawn from limestone aquifers. In the Southeastern and Northeastern United States, the groundwater is from granite aquifers. Groundwater can also come from sand and gravel, sandstone or coral aquifers.

Even on the same site, the depth of the well can have an effect on water quality since well depth will determine the nature of the parent material from which the water is drawn. Elemental concentrations and bicarbonate levels can change with the seasons of the year and the amount of pumping from wells.

Surface Waters

Surface waters include creeks, streams, rivers and large lakes (greater than five acres). The quality of surface water varies.

Like groundwater, flowing water can change in elemental content at different times of the year, primarily because of the amount of rainfall and the elements picked up from soils by runoff.

It is also possible that surface waters can become contaminated with phytotoxic industrial or agricultural chemicals and plant pathogens such as *Pythium*.

Drainage and Runoff Ponds

Drainage and runoff ponds accounted for irrigation water in 10 percent of the greenhouses surveyed.

Drainage ponds are usually a combination of rain water and drain-tile runoff. They are usually less than four acres in area and less than 20 feet deep.

In areas with heavy clay subsoils, water retention ponds can be constructed simply by excavating a large hole. When native clay subsoils are not present, clay is often trucked in to line the pond.

A major decision involved in the construction of ponds as the water source for greenhouses is whether only roof and parking lot rain water will be collected or if field drain and irrigation runoff will also be used. When runoff is mixed with rain water, the potential for discharge of unacceptable levels of nutrients during heavy rainfall episodes is greatly increased. It is not unusual for farm drainage ponds to contain fertilizers and other agricultural chemicals. Biological conditions such as algal growth or low oxygen levels may also be a concern, depending on the size of the pond and the amount of aeration.

Rain

Rain water can be collected from greenhouse or service building roofs without contact with the ground and held in a cement or vinyl-lined cistern.

Rain water will be low in elemental or chemical contaminants unless there is industrial air pollution or fallout on the roofs. Do not expect rain water to be “pure,” that is free of any elements.

The pH of freshly collected rain may be low (4.0 to 5.0). This is not detrimental to crops because it does not resist change in pH and, in fact, changes readily. The pH of rain water may change more than a full pH unit within 24 hours after collection.

Rain is an excellent source of irrigation water that is underutilized in the United States. Information on the monthly amount of rainfall in a particular area can be obtained from the National Oceanic and Atmospheric Administration (NOAA).

Municipal Water

Municipal water includes water supplied by a city, county or other municipality. It may include ground, rain and/or surface water. It is common to blend a number of sources. Thirty-five percent of the greenhouses surveyed used municipal water.

Key concerns about using municipal water for greenhouse irrigation relate to cost, availability and quality.

The cost of municipal water varies. This cost must be compared with the cost of energy for pumping the previous four sources.

Another important consideration is whether the supply of water is guaranteed in time of shortages.

Since much of municipal water is for residential use, you will need to know if water treatment procedures have been used that may influence plant growth. Municipal water often has fluorine added. This is usually not a problem but it can lead to tip or marginal leaf necrosis in some crops. Chlorine, added for purification, has not been considered a problem for plant growth, but this has not been well studied. Occasionally, sodium compounds are added to raise the pH.

Nutritional and Nonnutritional Concerns Related to Water Quality

Once the source of water is identified, collect samples for analyses of inorganic elements, organic compounds and to evaluate the potential presence of biological contaminants. The following table give interpretation values and examples for various water types.

Nutritional Concerns

Some nutrient ions may be present in water at concentrations that are toxic to plants. The most common problems are with boron, sodium and chloride. Other elements of possible concern are chlorine, fluoride and nitrate.

High levels of boron are the most critical water quality problem in certain areas of the United States. While boron is an essential plant nutrient, it is only required in small amounts. It quickly becomes toxic at higher levels. Media soil test levels below 0.5 parts per million are desired.

Sodium in irrigation water can come from road salt, natural underground salt deposits or saline soils found in arid areas. There are a number of problems that can result from too much sodium:

- Osmotic effects on water uptake
- Decreased structure of mineral salts leading to poor drainage and aeration
- Antagonized uptake by roots of other essential cations such as potassium, calcium and magnesium

Recommended levels are less than 50 parts per million of sodium in irrigation water and less than 10 percent of the salts in media. Symptoms of sodium toxicity are marginal leaf chlorosis, followed by marginal necrosis.

City or municipal water is often fluoridated to levels of one to two parts per million. This is not a problem for most crops. Some crops, such as Easter lilies, spider plant and *Dracaena species* can exhibit marginal or tip leaf necrosis as a result. Occasionally, an isolated aquifer may have high levels, one to four parts per million, of natural fluoride. Fluoride toxicity is controlled by elevating the pH to 6.5 and elevating calcium levels which leads to precipitation of the fluoride in the medium so it is not available for plant uptake.

According to environmental guidelines, ground or surface waters with greater than 10 parts per million of nitrate nitrogen are considered to be an environmental contaminant because they may pose a human health hazard, particularly for infants. From a plant production standpoint, the nitrogen could be considered free fertilizer. There is a point at which high levels, above 50 to 75 parts per million, provide too much fertility. This may be the case in plug production or at the end of the production cycle when nitrogen levels should be reduced to provide longevity for the consumer. Water sources in the greenhouse and support buildings should be labeled as suitable or not suitable for human consumption, depending on the nitrate nitrogen levels.

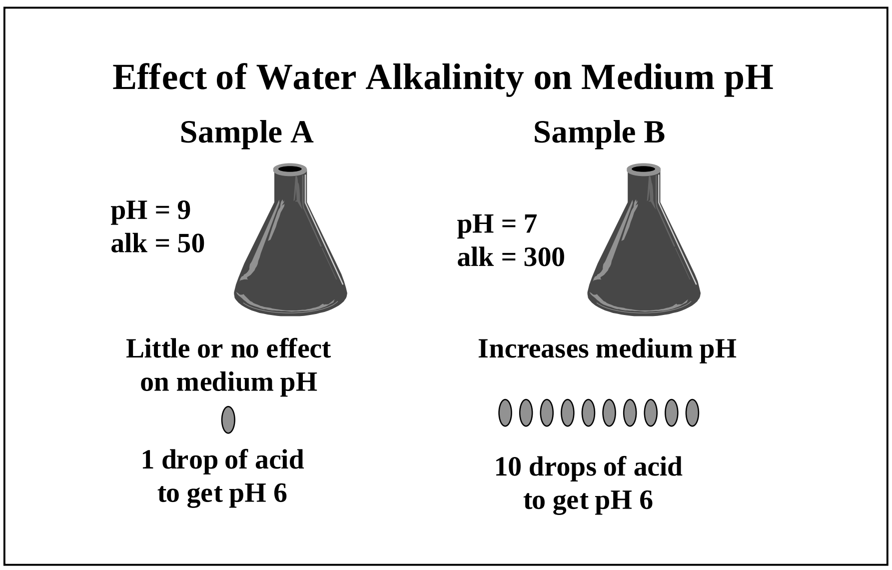
A second nutritional concern about water quality is the effects of soluble salts on media electroconductivity and water uptake.

In some cases, soluble salts from irrigation water or fertilizers may be present at levels that do not create a direct toxicity problem. The soluble salts accumulate over time in the root medium. As water is absorbed by plant roots, the salts are left behind. When the level of soluble salts becomes too high, water may be present in the root zone but not available to the plant because of the effect of osmosis. The faster soluble salts accumulate, the less plant roots can adapt to the stress.

The electroconductivity (EC) is usually an indication of the presence of excess soluble salts that will cause osmotic effects.

Water alkalinity as measured in parts per million of calcium carbonate, and not water pH, is the most important factor influencing the pH of the growing medium. While pH is a measure of the actual hydrogen ion concentration, alkalinity is a measure of the ability to neutralize acids. The pH of irrigation water can be very high, 8 to 10, and have little effect on the pH of the growing medium, depending on the alkalinity.

Using the alkalinity measurement, a grower can predict water's potential to cause an increase or decrease in growing medium pH. In the example below, we compare two water sources, one with an alkalinity of 50 parts per million, the other 300 parts per million. Note the effect on medium pH and the amount of acid needed to get to pH 6.



Sometimes water alkalinity can be too low. The water has no buffering capacity and is too pure. Low levels of calcium (Ca), magnesium (Mg), and sodium (Na) may signal low alkalinity. If the alkalinity is too low, then the medium pH will fluctuate more widely, depending on whether acid or basic fertilizers are used. When media pH goes below 6.0 for some crops and 5.5 for most crops, micronutrient toxicities can occur, along with calcium deficiency.

Water alkalinity can be determined by *titration*, which is very easy to do with a commercially available kit. A measured sample of water is treated with a dye that changes color around a pH of 4.5. Acid is added until the dye changes color and the amount of acid is related to the alkalinity. Since titration kits are inexpensive and easy to use, every greenhouse should consider having one.

Calcium and magnesium are perhaps the two nutrient elements that vary the most in greenhouse water supplies. Groundwater from limestone aquifers may contain calcium levels in excess of 100 parts per million, while water from sandstone or granite aquifers may have fewer than 10 parts per million.

The term hardness is often used to describe the level of calcium and magnesium in water. With very “soft” water, levels of calcium and magnesium may be low enough to limit plant growth. To prevent this deficiency, either more dolomitic lime or gypsum can be added to the root medium prior to planting or water soluble forms of calcium and/or magnesium, such as calcium or magnesium nitrate, can be included in the fertility program.

The ratio of calcium to magnesium in plant tissues and the fertilization program is important. In plant tissue, there should be close to two parts calcium for each part magnesium. Magnesium nitrate fertilizer can be used with calcium nitrate to balance calcium and magnesium levels properly in irrigation water.

Nonnutritional Concerns

The first is **sulfur odors**. In some areas high levels of sulfur or hydrogen sulfide are present in groundwater. The area around Toledo, Ohio, and southeastern Michigan is one example where irrigation water used in greenhouses may have this water quality problem. The “rotten egg” smell during or following irrigation is the most common sign of the presence of sulfur or sulfides. Decreasing growing medium pH may also be an indication of sulfur in irrigation water.

Residues on plant foliage can be a problem with hard water sources, even when the water is acidified, because of the formation of calcium or magnesium carbonates, sulfates or phosphates. Iron can also lead to residue problems on plants that are irrigated over the foliage or in propagation.

Bicarbonate deposits from alkaline water can clog drip irrigation systems and mist and fog nozzles. With alkaline water, acidification helps reduce scaling, but with phosphoric or sulfuric acid, the remedy is not complete since sulfate and phosphate deposits continue to form.

Another concern is the **effect of pH on pesticide activity**. Under high pH, or basic conditions, certain chemicals may undergo hydrolysis or split into smaller compounds that are no longer active.

Irrigation water from streams, lakes or ponds may contain algae, weed seeds, plant pathogens such as *Pythium, Phytophthora*, and *Rhizoctonia* and bacterial pathogens such as *Erwinia* and others. The presence of pathogenic organisms in irrigation water does not indicate that there will be problems. There are many greenhouses that use pond water with no treatment. Indications are the warmer the climate and the water, the greater probability that there will be problems. Any operation using or planning to use pond water should have a plan to deal with algae or diseases if problems occur.

Fuel oil or unwanted pesticides or herbicides can contaminate surface or groundwater, resulting in a negative impact on plant growth. More importantly, contamination may indicate a greater environmental problem. The presence of fuel oil may indicate a need to remove storage tanks. The presence of pesticides may indicate illegal dumping, buried waste or runoff from adjacent properties.

Water Treatment Options

Once a thorough review of the water analysis has been completed, some treatment may be needed to improve water quality. Currently there are only a few water treatment practices that are commonly used in greenhouses.

Whether or not treatment is needed and the type of treatment used will depend on the type of water.

Water can be:
- Pure and soft with low alkalinity of less than 80 parts per million bicarbonate with an electroconductivity of less that 0.3
- Moderately alkaline with 100 to 200 parts per million bicarbonate
- Hard with high alkalinity greater that 200 parts per million. Hard water usually has a calcium concentration greater than 60 parts per million and a magnesium concentration greater than 25 parts per million.

Water can have sodium bicarbonate as a contaminant, resulting in high alkalinity.

Sodium chloride as a contaminant results in high salts problems, with electroconductivity levels from 1.5 up to 3.0.

High boron resulting in boron toxicity can quickly lead to reductions in growth and leaf necrosis.

High sulfur level leads to foul odor and possibly falling medium pH.

Acidification

Injection of inorganic (mineral) acids is one option for treating high-alkalinity irrigation water. The primary inorganic acids used are sulfuric, phosphoric and nitric acids.

Recently organic acids, such as Seplex-L from GreenCare, have been used to neutralize alkalinity. These organic acids provide safety; however, organic acids are weaker and may not be as effective when alkalinity is very high.

Acids are available in various strengths and degrees of purity. Look for technical-grade purity to avoid any contaminants that may damage young seedlings. Strong acids are highly corrosive in concentrated form. Wear protective clothing, including eyeguards, when handling acids. Sulfuric acid is commonly available in fairly pure form, 93 percent by weight. It produces substantial heat when added to water. Phosphoric acid, usually available at 75 or 85 percent grade, is the least corrosive of the three acids. Nitric acid, available in some areas at 61 percent grade, is quite corrosive and must be handled with great care.

If it is necessary to use acids, the amount to add should be carefully determined. Safely, effectively and consistently adding acid to irrigation water is perhaps the biggest challenge. High quality injection equipment must be purchased and maintained since concentrated acids will quickly destroy equipment not designed for long term acid injection.

The following table provides the amount of acid in fluid ounces to be added per gallon of water for each ppm of bicarbonate when adjusting alkalinity level.

Acid	**fl oz acid per gal of water & ppm bicarb**	**ppm bicarb neutralized by 1 oz acid per 100 gal**	**ppm P, S or N for 1 oz acid per 100 gal**
75% phosphoric	0.00012	87	32
85% phosphoric	0.0001	98	36
93% sulfuric	0.000055	191	30
50/50 85% P / S	0.000077	145	18 P / 15 S
61% nitric	0.00017	57	17

Filtration

Filtration removes solids and biological organisms from pond or surface water or recycled water. Filtration includes a variety of physical and chemical methods and options.

The most common filtration method is sand filtration. A sand filter will remove many weed seeds and other possible contaminants. It can be back-washed and therefore has a relatively low maintenance cost.

Other sand-like materials can be used to filter the water, including diatomaceous earth or fine anthracite coal. It is possible to design a mixed bed with coarse materials for removing large particles and fine materials for removing smaller particles.

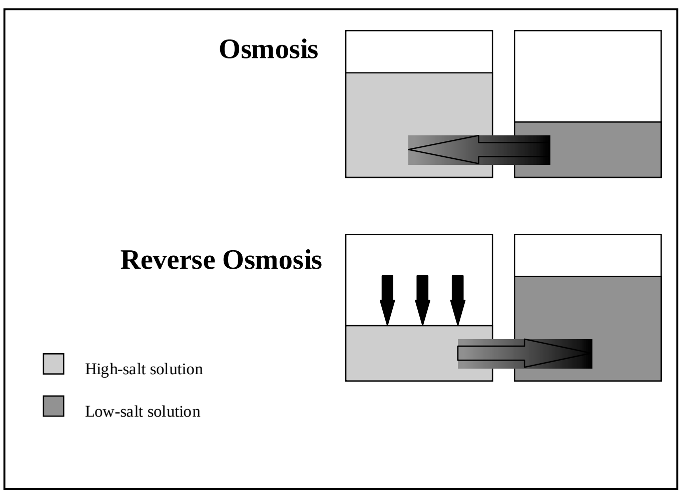
Filter screens can also be used to remove algae and pathogens. However, even the finest filter screens practical for a commercial greenhouse may not remove fungal spores.

The goal of filtration is to remove as much of the organic matter as possible and then to determine if chemical treatment is needed. If chemical treatment is required, the filtration process will minimize and standardize the amount of chemical needed since the majority of daily or seasonal fluctuations in organic matter will have been removed.

Reverse Osmosis

When the quality of water is unacceptable, the crop value high and alternative sources of water not available, the cost of water purification may be justified. Reverse osmosis (RO) treatment is currently the most economically feasible method for the greenhouse industry. One of the key points to remember when looking into reverse osmosis is that the value of the crop <u>must</u> justify the cost of the treatment.

This diagram contrasts osmosis and reverse osmosis.



Osmosis: water moves across the membrane toward the high-salt solution until equilibrium is reached; salts do not move through.

Reverse osmosis: when pressure is applied to the high-salt solution, the water moves through the membrane, leaving the salts behind. Twenty to 50 percent of the initial solution, enriched in solutes, remains to be carried away.

Keep in mind that the membranes are delicate and expensive. They must be protected from bacterial contamination and contact with certain elements commonly found in water, such as iron, calcium and magnesium. It is often necessary to install equipment to remove or reduce iron levels and a water softener to remove calcium and magnesium. Chlorine used in water purification is detrimental to some membranes and must be removed by activated carbon filters before the water enters the reverse osmosis unit.

Purification is only possible if some of the water is discarded. As was indicated, 20 to 50 percent of the initial solution may need to be carried away. Where to put this water is an important issue to consider.

Chlorination, Ozonation, Heat or Ultraviolet Treatment

If treatment is needed to remove algae and pathogens, such as fungi, bacteria and viruses, options include chlorination, ozonation, heat or ultraviolet treatment.

Large volumes of water, such as those in municipal water treatment plants, are treated with chlorine gas to remove algae and disease organisms. There are limited examples of chlorine gas being used in treatment of water for large ornamental plant production facilities in Florida and California. Careful maintenance and regulation is necessary because concentrated chlorine gas is toxic to people and animals.

Ozone can be used to remove inorganic and biological contaminants. The advantage is that no residual chemicals are added to the treated water. The disadvantages are the difficulty in attaining acceptable flow rates with equipment that is currently available; the high cost of systems that are capable of treating water at high flow rates; and the lack of documentation of ozone’s effectiveness on plant pathogens.

Biological contaminants and plant pathogens can be killed in water passed through clear tubes and treated with high levels of ultraviolet light. The UV rays penetrate the bacteria, viruses, fungi or algae and destroy the DNA which allows the organisms to reproduce. At this time, ultraviolet treatment is not economically feasible for commercial bedding and pot plant greenhouses.

Heating water to near the boiling point for brief periods of time has been tested in the Netherlands for treatment of biological contaminants in irrigation water. Energy costs and exposure time limit the flow rates possible.

Key Points to Remember:

- Know as much about your water source as possible, including the quality and quantity of water available.
- Have water analyzed regularly. Keep results of analysis on file so changes over time can be monitored.
- Water alkalinity directly affects the growing media pH, so use acid injection to control moderate to high alkalinity. Consider carefully which acid to use and how much.
- Consider switching to a different water source if your well water is of poor quality.

For additional information, see the articles on **Water Quality** and **Evaluation of Greenhouse Water Sources** provided in this booklet.