Irrigation Water Quality For BC Greenhouses

Floriculture FACTSHEET

File No. 400-06

An abundant supply of good irrigation water is the first step to producing high quality greenhouse crops. Small amounts of impurities are found in almost all water sources, and while some of these may be beneficial, others can be harmful to plant growth. It is even possible for irrigation water to be too “pure”, leading to undesirable instabilities in pH. Therefore, every greenhouse fertilizer program should start with a complete irrigation water quality analysis.

Factors Affecting Water Quality

Ionic balance

When elemental compounds dissolve in water, they separate, or dissociate into their respective ions. However, sodium bicarbonate is present in its dissolved state as sodium ions (Na+) and bicarbonate ions (HCO_3^-). Ions having a positive charge are called cations, and ions having a negative charge are called anions. In any solution, the total number of anions tends to balance with the total number of cations. This provides a handy way of double checking the accuracy of your water analysis test. (For more information see inset - '***Checking Your Water Analysis***'.) However, it is not the actual anionic/cationic balance that is important in determining the quality of an irrigation source, but the relative amounts of ions in the water and which of those ions tend to predominate.

Hard Water and Soft Water

Pure distilled water is said to be very soft since it contains no dissolved minerals. Likewise, rainwater and most surface water supplies are soft because they contain relatively few minerals. However, soft water does not always mean the absence of minerals. Highly mineralized water supplies where sodium predominates as the main cation are also said to be soft. (See Figure 1, Page 3). Soft water will produce a soap lather easily. Hard water contains high amounts of dissolved calcium and/or magnesium and does not produce a soap lather easily. Although not as desirable for washing and cleaning purposes, hard water is usually preferable to high sodium soft water when it comes to greenhouse production. Some types of water softening equipment replace the calcium and magnesium in water with sodium. This makes them unsuitable as water treatment devices for greenhouse production.

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Salinity

The total amount of dissolved salts in a water supply constitutes its salinity. The cells of plant roots absorb water as a result of the differences in osmotic pressure between the cell contents and the surrounding soil water. Whenever the salinity of the soil solution is near to or greater than that of the cell contents, plants are unable to take up sufficient water for growth, cell pressure maintenance, and transpiration. Some species are more sensitive to high salts than others and mature plants can tolerate higher salts than young seedlings. Since liquid feeding programs add additional fertilizer salts to the irrigation water it is usually desirable to start with water sources that have as low a salinity level as possible.

Non fertilizer salts tend to accumulate in soils since they are not removed or used by the crop. Therefore, water sources with a high salinity content of nonnutritive elements may require heavy leaching to reduce salt buildup in the growing media. This can lead to wasting fertilizers and unacceptable levels of greenhouse run-off. High salinity water sources are less suited for use in sub-irrigated or recycled systems. When used in misting systems, highly saline water can leave a residue on plants and mineral precipitates may cause clogging of emitters.

Salinity is usually measured as a determination of the electrical conductivity (EC) of a solution. Conductivity increases with salinity. The standard unit for measuring conductivity is the millisiemen (mS). Another commonly used unit is the millimho (mmho) which is equal to the millisiemen (mS). Sometimes salinity values are reported in microsiemens (µS) or micromhos (µmmho) when the water is very pure. One µS is 1/1000th of a mS. Yet another commonly used unit of measurement for salinity is total dissolved salts (TDS), measured in parts per million (ppm). An EC reading of 1 mS is equal to about 666 ppm TDS.

Managing High Salinity in Water Supplies

- *dilute with collected rainwater or other low salinity water sources*
- *use reverse osmosis water treatment, particularly for misting cuttings, irrigating seedlings, and salt sensitive crops*

Fertilizers

The presence of plant-available nutrients in the greenhouse water supply does not usually present a problem, unless they exceed the amounts normally fed to plants. However, they must be taken into account when formulating nutrient solutions. Certain fertilizer materials, such as phosphoric acid, will react at high concentrations with dissolved calcium and magnesium to form insoluble precipitates that may clog drippers. Water supplies high in calcium and magnesium may not be suited for use in mist systems due to the accumulation of unsightly mineral residues on plant surfaces.

Toxicity Problems

- **Sodium** - high sodium levels can contribute to salinity problems, interfere with Mg^{+2} and Ca^{+2} availability, and cause foliar burns associated with poor water uptake and sodium accumulation in the tissues. The Sodium Absorbtion Ratio (SAR) is an indication of the sodium hazard. Most labs now report SAR adj. (adjusted) which includes a variety of other chemical factors that are taken into account to more accurately assess the sodium hazard.

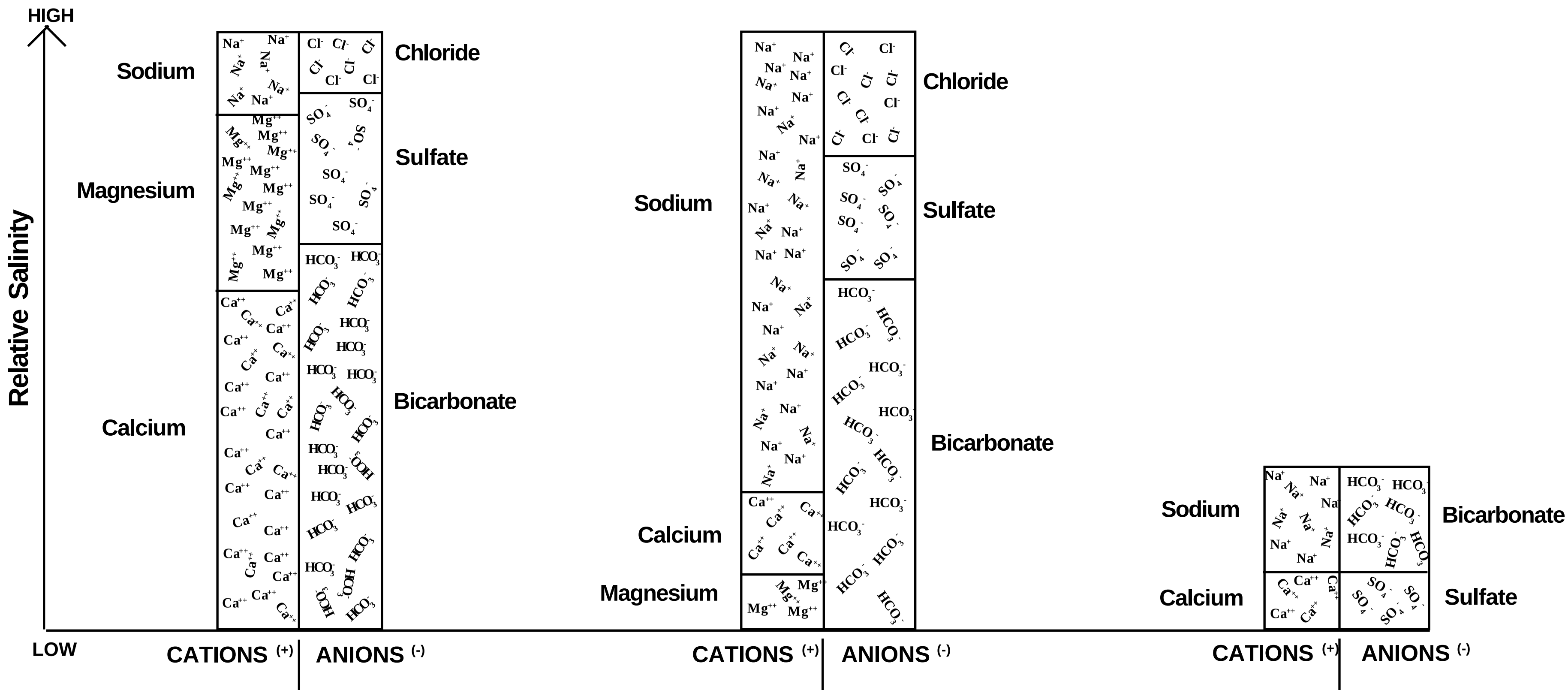
- **Chloride** - often associated with sodium since sodium chloride (table salt) is a common constituent of some water supplies, particularly well water. Levels above 140 ppm are considered toxic to plants.

- **Fluoride** - levels above 1 ppm may cause foliar problems on sensitive crops such as lilies and freesias. Since flouride can accumulate in greenhouse media it is best to find water supplies as close to zero as possible. The small amount of fluoride that is applied to drinking water in some cities for dental health purposes does not usually pose a problem for horticulture.

- **Boron** - although a necessary plant nutrient, boron may sometimes be present in toxic quantities for plant growth. High boron levels are commonly associated with alkaline soil formations in areas of low rainfall.

Figure 1.

DISSOLVED MINERALS IN WATER



An example of hard water
(Calcium & Magnesium are the dominant cations.)

This water might be marginally acceptable for greenhouse use depending on the salinity and the bicarbonate level.

An example of high sodium soft water
(Sodium is the dominant cation.)

This water would not be acceptable for greenhouse use without treatment to remove sodium.

An example of low sodium soft water
(Some minerals are present but at much lower concentrations.)

This water would be fine for greenhouse use.

Water Treatment Methods

Reverse Osmosis
The phenomenon of osmosis occurs wherever two salt solutions are separated by an appropriate semi-permeable membrane. The membrane allows only water to pass through, leaving behind the dissolved salts and solids. Under normal circumstances water moves from the area of low salt concentration to the side with higher concentration until the concentration of salts on both sides is equal. This is the mechanism by which root cells absorb water.

In reverse osmosis (RO), a pressure is applied on one side of the membrane to force water through in the opposite direction of osmosis, resulting in purified water on one side of the membrane and increasingly concentrated salts on the pressurized side. The process continually or intermittently flushes the concentrates from the pressurized side resulting in a small percentage of concentrated waste water, and a high percentage of purified water.

Reverse osmosis units are the most commonly used water treatment systems in commercial greenhouses because of their high capacity, continuous duty, and relatively low cost.

De-ionisation
Specialized exchange resins are used to bind dissolved salts, replacing them with hydrogen and hydroxyl ions which are the main constituents of pure water. When the resins become saturated, they must be replaced, or flushed out with strong acids or alkalis. These systems require periodic shutdown to change or clean the resin columns.

Distillation
Due to the high energy cost of boiling and condensing water, these units are seldom used commercially.

Heat Treatment
Heat pasteurization to about 60ºC will kill most pathogens in water sources, but won't appreciably affect the mineral content, although some precipitation of iron and calcium may occur.

Ultraviolet Light
UV rays are used to kill pathogens and other living organisms in the water. The light radiation does not substantially affect the mineral content with the exception of certain precipitates of iron, manganese or calcium, and it is only useful in water that has low turbidity. Therefore, if the source water is cloudy, or contains lots of particulate matter, UV treatments will be less effective. Filtration prior to UV treatment may increase it's effectiveness.

Filtration
Many degrees of mechanical filtering can be used to purify and clean water. Reverse osmosis is a type of ultrafiltration, and the only one that will remove dissolved minerals. Sand, ceramic, cellulose, and composite filtration systems are all effective in sieving various particulates and organisms from the water supply. Almost any degree of filtration is possible, down to the submicron level. However, depending on the turbidity of the supply water, ultra fine filters may become clogged too often to be useful. In such cases, backwashable sand filters are often used for primary filtration to remove the larger particles.

Acidification
High alkalinity water supplies may require the injection of acids to neutralize bicarbonates and adjust pH. Table 1 can be used as a rough guide for reducing bicarbonate levels to about 50 ppm. An alkalinity or bicarbonate test should be performed occasionally as a final check. The actual amount of acid used should be the amount that produces the desired feeding solution pH.

Figure 4.

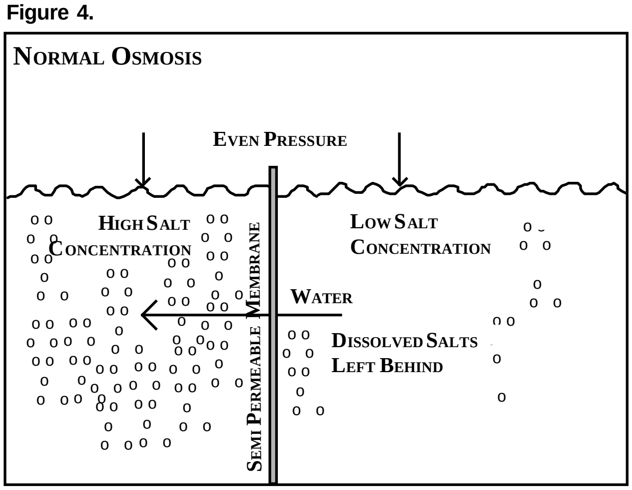
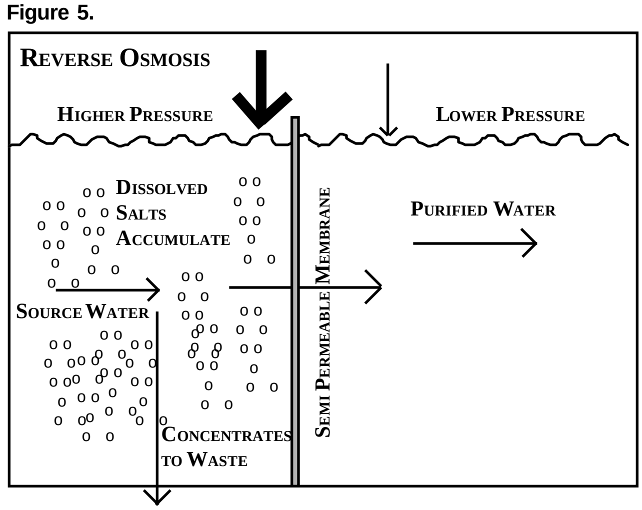


Figure 5.



pH and Alkalinity

pH

pH is a measure of the relative acidity (hydrogen ion concentration) in the water supply. It is influenced by alkalinity. The pH of the soil solution affects the relative availability of nutrients (Figures 2 & 3). Most greenhouse crops require a pH of about 5.5-6.5 in the growing medium. The pH of the irrigation source may influence medium pH depending on the buffering capacity of the medium (it's ability to neutralize acids). In general, water with high alkalinity will tend to raise medium pH. The amount of acid or base needed to change the pH of a water supply is determined by the alkalinity of the water. The purer the water the easier it is to change the pH. Water that is “too pure” may require the addition of a small amount of buffering agent, such as potassium bicarbonate, to stabilize the pH and prevent nutrient precipitation in the feeding solutions.

Alkalinity

The alkalinity of a water source is more significant than it’s pH because it takes into account the principal constituents that affect a water’s ability to influence media pH. An alkalinity test measures the combined amount of carbonate ($CO_3^{=}$), bicarbonate (HCO_3^-), and hydroxl (OH^-) ions. A pH measurement, on the other hand, only indicates the relative concentration of hydrogen ions, and provides essentially no information on how the water will affect medium pH. Alkalinity rises as the amount of dissolved carbonate and bicarbonate rises. Since bicarbonate and carbonates will neutralize acidity, and acids, in turn, will neutralize them, it is possible to correct water and media pH once the alkalinity is known. Highly alkaline waters can be adjusted by adding phosphoric, sulfuric, or nitric acids. This will tend to reduce media pH over time. And similarly, overly acidic conditions can be corrected by increasing the alkalinity of the irrigation water. Alkalinity test values are usually reported in ppm (parts per million) or meq (millequivalents per litre) of calcium carbonate ($CaC0_3$).

Figure 2.

How Medium pH Affects the Availability of Plant Nutrients.

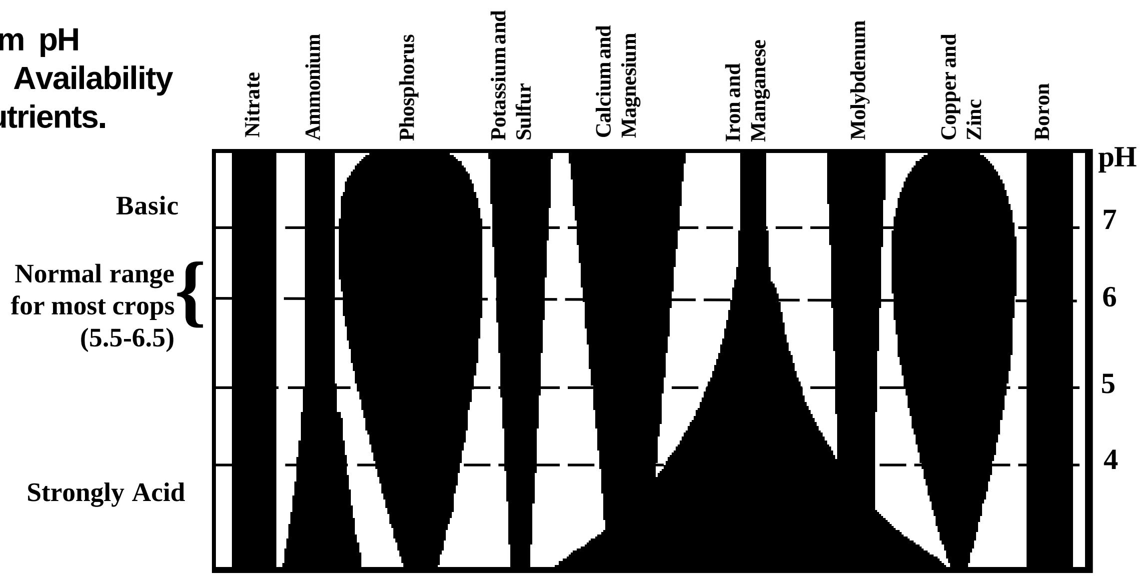


Figure 3.

Factors Influencing Planting Medium pH.

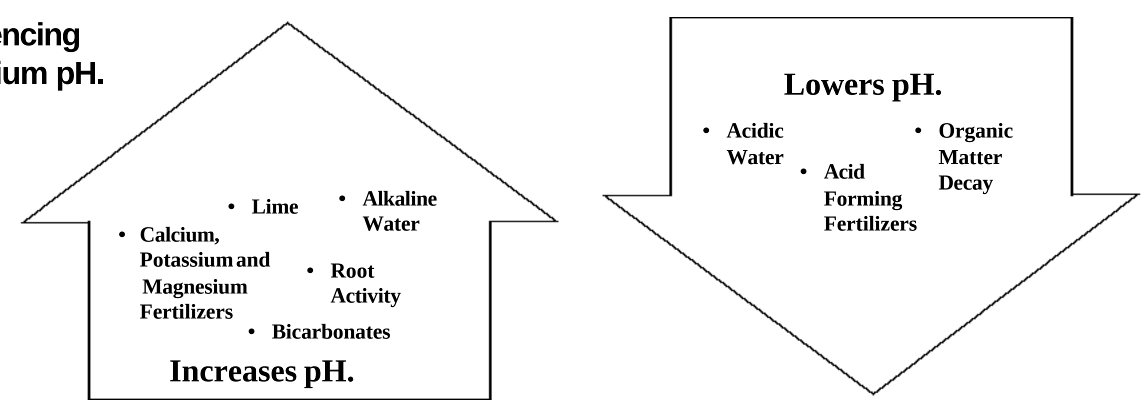


Table 1. Acid Injection Rates* to Achieve a Residual Bicarbonate of 50 ppm or Lower

Bicarbonate	Amount to Remove	Acid Injection Nitric Acid (62%)	 Phosphoric Acid (75%)
Present (ppm)	(ppm)	ml/1000 l water	ml/1000 l water
0	0	0	0
50	0	0	0
75	25	3.4 ml	4.3 ml
100	50	6.8 ml	8.4 ml
125	75	10.2 ml	12.6 ml
150	100	13.6 ml	16.8 ml
175	125	17.0 ml	21.0 ml
200	150	20.4 ml	25.2 ml
225	175	23.8 ml	29.4 ml
250	200	27.2 ml	33.6 ml
275	225	30.6 ml	26.8 ml
300	250	34.0 ml	42.0 ml

***These rates are approximate. Use a pH meter for final calibration to the desired pH, and have the solution checked by a laboratory before using. Use extreme caution when handling acids. Always refer to the MSDS (Material Safety Data Sheet) before handling any chemicals.**

Managing high alkalinity water supplies:

- *dilute with rainwater*
- *use acidifying fertilizers*
- *acid injection*
- *use a lower pH growing medium (ie pH 5.5 instead of 6.0)*

Managing low alkalinity water supplies:

- *use a higher pH medium (ie: pH 6.0 instead of 5.5)*
- *use less acidifying fertilizers*
- *add potassium bicarbonate to about 60 ppm*
- *reduce or discontinue using fertilizer acids (ie: phosphoric acid)*

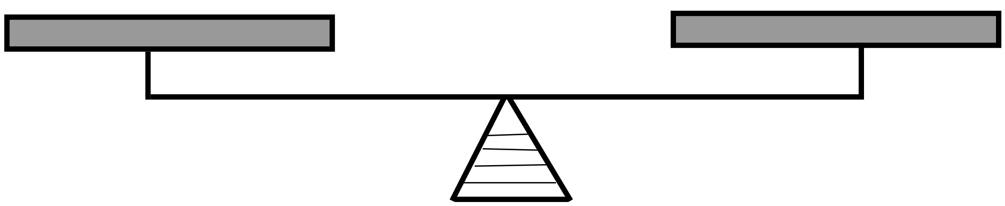
Checking Your Water Analysis

Most labs do an excellent job of analysing irrigation water samples. However, mistakes can happen. Minor inaccuracies are not easy to catch, but there are two methods for spotting glaring errors in the test values.

Method I: The Ion Balancing Act

The sum of the anions (negatively charged ions) and cations (positively charged ions) of the major constituents should balance (or very nearly balance). Some labs will use this method to automatically double check their accuracy. If you add up the sum of the major cations and the sum of the major anions the two numbers should be nearly identical, or within 10% of one another. For example:

Cation	**Test Value (ppm)**	**÷**	**Equivalent Weight**	**=**	**meq/ℓ**	**Anion**	**Test Value (ppm)**	**÷**	**Equivalent Weight**	**=**	**meq/ℓ**
K^+	1.7		39		.044	$HC0_3^-$	39.7		62		.64
Mg^{++}	4.1		12		.342	$S0_4^=$	19.3		48		.402
Na^+	5.3		23		.230	$C1^-$	17.7		35.5		.499
Ca^{++}	20.6		20		1.03	$N0_3^-N$	.9		14		.064
			Sum of Cations		1.646	=			Sum of Anions		1.605



Method 2: Actual EC vs. Calculated EC

You can calculate an approximate EC (electrical conductivity) value for a water source or feeding solution by adding up all the major anions or cations.

The formula is as follows:

$$\frac{\textbf{(Total anions in meq/litre)} \quad \underline{\textbf{or}} \quad \textbf{(Total cations in meq/litre)}}{\textbf{10}}$$

$$\textbf{= EC in mS/cm at } 25^{o}\textbf{C}$$

You can then compare this calculated EC to the EC actually measured. You should perform this calculation twice, once for the cations and once for the anions. If one side is a lot different than the measured EC, suspect an error.

Most labs will retain a portion of your sample, so that they can retest it if any questions arise about the analysis.

BCMAFF Greenhouse Irrigation Water Quality Guidelines

	Upper Limit	Optimum Range
pH		5-7 pH
EC plugs & seedlings General Production	0.75 mmhos (500 mg/l)* 1.25 mmhos (800 mg/l)	near zero near zero
SAR (Sodium Absorption ratio)	4 mg/l	0 - 4 mg/l
Alkalinity	200 mg/l	0 - 100 mg/l
Bicarbonate Equivalent	150 mg/l * *	30 - 50 mg/l
Calcium	120 mg/l	40 - 120 mg/l
Magnesium	24 mg/l	6 - 24 mg/l
Iron	5 mg/l	1 - 2 mg/l
Manganese	2.0 mg/l	0.2 - 0.7 mg/l
Boron	0.8 mg/l	0.2 - 0.5 mg/l
Zinc	2.0 mg/l	0.1 - 0.2 mg/l
Copper	0.2 mg/l	.08 - 0.15 mg/l
Molybdenum	0.07 mg/l	.02 - 0.05 mg/l
Fluoride	1.0 mg/l	0 (particularly for sensitive crops, like lilies & freesias)
Sulfate	240 mg/l	24 - 240 mg/l
Chloride	140 mg/l	0 - 50 mg/l
Sodium	50 mg/l	0 - 30 mg/l

* mg/l = ppm

Water sources with analyses within these guidelines can be considered suitable for greenhouse irrigation purposes. Water analyses with parameters that exceed these limits may not be suitable for commercial production without treatment or modification.

* * Acidification is usually required to correct pH if the bicarbonate equivalent is above 50 mg/l.