Greenhouse
FACTSHEET

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Irrigation Water Quality for B.C. Greenhouses

INTRODUCTION

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. For instance, sodium bicarbonate would be present in its dissolved state as sodium (Na+) and bicarbonate ions (HCO-). 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 the section on 'Checking Your Water Analysis' on page 5.) However, it is not the actual anionic/cationic balance that is important in determining the quality of an irrigation source. Water quality is based on the relative amounts of ions present 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. 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, which makes them unsuitable as water treatment devices for greenhouse production.

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. Some plants 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, crops irrigated from a water source that has 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 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 (µmho) when the water is very pure. One µS is 1/1000th of a mS. Salinity is also measured by the level of total dissolved salts (TDS), which is measured in parts per million (ppm). An EC reading of 1 mS is equal to about 666 ppm TDS.

The salinity of water can be reduced by diluting with collected rainwater or other low salinity water sources. It can also be reduced by water treatment systems such as reverse osmosis.

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. Sodium can interfere with the availability of Mg^{+2} and Ca^{+2}, and can cause foliar burns due to 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 – is 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 fluoride 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.

WATER TREATMENT METHODS

Reverse Osmosis

The phenomenon of osmosis occurs wherever two salt solutions are separated by a semi-permeable membrane. The membrane allows only water to pass through, leaving behind the dissolved salts and solids. Under normal circumstances, water will move from the area of low to high salt 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 60^{o}C 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 its effectiveness.

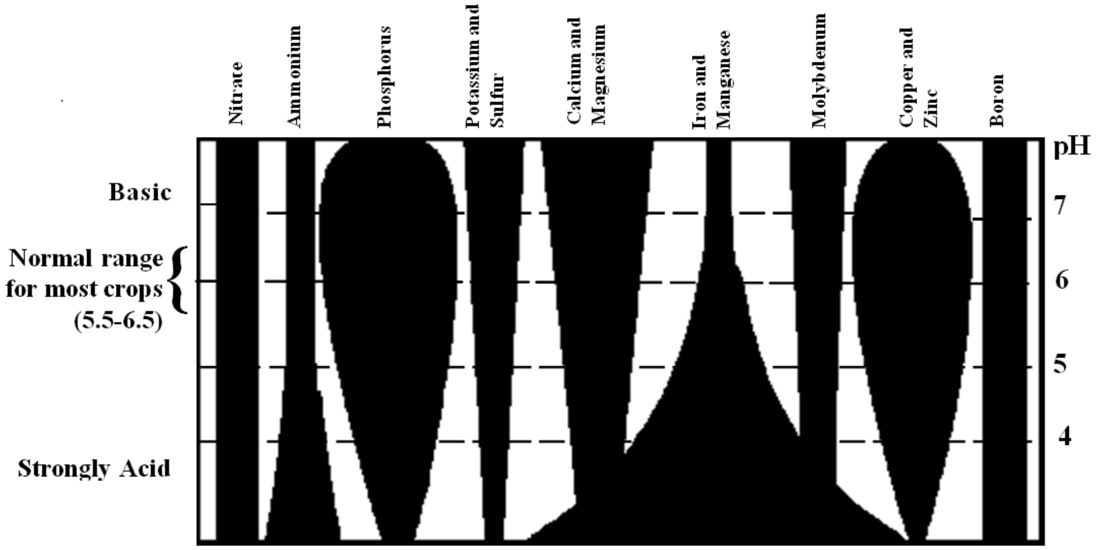
Filtration

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, back-washable 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. 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 1. The impact of media pH on the availability of plant nutrients.



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 (Figure 1). Most greenhouse crops require a pH of about 5.5 to 6.5 in the growing medium. The pH of the irrigation source may influence the pH of the medium depending on its buffering capacity or ability to neutralize acids. In general, water with high alkalinity will tend to raise the pH of the medium.

Table 1. Factors that increase and decrease the pH of the soil solution.

Increases pH	Lowers pH
• Alkaline water	• Acidifying fertilizers
• Bicarbonates	• Acidic water
• Calcium, potassium and magnesium fertilizers	• Decaying organic matter
• Lime	
• Root activity	

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 its pH because it takes into account the principal constituents that affect water's ability to influence media pH. An alkalinity test measures the combined amount of carbonate ($CO_3^{=}$), bicarbonate (HCO_3^-), and hydroxyl (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.

The alkalinity of a solution rises as the amount of dissolved carbonate and bicarbonate rises. Since bicarbonates 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.

Table 2. Rates[1] of acid injection to achieve a residual bicarbonate level of 50 ppm or lower.

Bicarbonate (ppm)	Amount to Remove (ppm)	Nitric Acid (62%)	Phosphoric Acid (75%)
		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 mL	21 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	36.8 mL
300	250	34 mL	42 mL

[1] 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 MSDS (Material Safety Data Sheet) before handling any chemicals.

Highly alkaline water can be corrected by adding phosphoric, sulfuric or nitric acid. Acid injection will tend to reduce media pH over time. Other methods to reduce alkalinity include: using a lower pH growing medium (i.e., pH 5.5 instead of 6.0), using an acidifying fertilizer or diluting with rainwater.

Methods to correct for overly acidic conditions include: increasing the alkalinity of the irrigation water (e.g. add potassium to about 60 ppm), using a higher pH growing medium (i.e., pH 6.0 instead of 5.5), use fertilizers with high basicity, or reduce or discontinue using fertilizer acids.

Alkalinity test values are usually reported in ppm (parts per million) or meq (milli-equivalents per litre) of calcium carbonate ($CaC0_3$).

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. The sum of the major cations and the sum of the major anions 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		0.044	HCO_3^-	39.7		62		0.64
Mg^{++}	4.1		12		0.342	$SO_4^=$	19.3		48		0.402
Na^+	5.3		23		0.230	Cl^-	17.7		35.5		0.499
Ca^{++}	20.6		20		1.030	NO_3^-N	.9		14		0.064
			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 solution by adding up all the major anions or cations. The formula is as follows:

$$\boxed{\text{Total anions } \textbf{or} \text{ cations in meq/litre} \div 10 = \text{EC in mS/cm at } 25^{o}\text{C}}$$

Compare the calculated EC to the EC actually measured. If the calculated EC is quite different than the measured EC, suspect an error. You should perform this calculation twice, once for the cations and once for the anions. Most labs will retain a portion of your sample, so they can retest it if a question arises about the analysis.

Table 3. Greenhouse irrigation water quality guidelines; water analyses with parameters that exceed these limits may not be suitable for commercial production without treatment or modification.

	Upper Limit	**Optimum Range**
pH	-	5 – 7
EC		
Plugs & Seedlings	0.75 mmhos (500 mg/l) [1]	Near zero
General Production	1.25 mmhos (800 mg/l)	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 [2]	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 mg/L	0.2 – 0.7 mg/L
Boron	0.8 mg/L	0.2 – 0.5 mg/L
Zinc	2 mg/L	0.1 – 0.2 mg/L
Copper	0.2 mg/L	0.08 – 0.15 mg/L
Molybdenum	0.07 mg/L	0.02 – 0.05 mg/L
Fluoride	1 mg/L	0 mg/L [3]
Sulfate	240 mg/L	24 – 240 mg/L
Chloride	140 mg/L	0 – 50 mg/L
Sodium	50 mg/L	0 – 30 mg/L

[1] mg/L = ppm

[2] Acidification is usually required to correct pH if the bicarbonate equivalent is above 50 mg/L.

[3] Particularly for sensitive crops, such as lilies and freesias.