HAVE YOU CONSIDERED WATER QUALITY?

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The importance of water in plant growth is becoming more appreciated by horticulturists. Today's concerns are not only quantity of water but also quality. Experience has shown that there are great differences in the chemical composition of waters from various sources. Even though water may be perfectly clear, there may be chemical substances dissolved in it that are injurious to plants.

If a water supply is contaminated with a large supply of dissolved chemicals, there is usually a method to counteract this problem. This paper has been prepared to acquaint plant growers with some to the problems that could and have been experienced by many people and to describe, in some cases, remedial action. Finally an orderly sequence of steps is suggested to help correct a suspected water quality problem.

SOLUBLE SALTS

The term, total soluble salts, refers to the presence of dissolved ions in water. A few of the salts in this category are sodium, potassium, calcium, nitrates, phosphates, sulfates and chlorides. High concentrations of ions in the water can damage plant roots, especially if they accumulate in the soil. Symptoms are expressed as chlorosis or yellowing of the leaves, wilting, leaf burn or necrosis, stunting of the plant, slow growth of seedlings or cuttings, death of the plant, and poor seed germination. If soluble salts are high, a complete water analysis will help determine the ion or ions causing the problem(s).

The total soluble salt content of water can be determined by using a Solu-Bridge, Model RD-B15 (Beckman Instruments, Inc., Cedar Grove, New Jersey) Interpretations of total soluble salt content of irrigation water used for growing plants are found in Table 1

Numerous studies have been conducted to determine the effect of various salts on plants. California studies on azaleas (15), China asters (8), and geraniums (11), using sodium and calcium chlorides at high levels had symptoms appear as slight to severe chlorosis of lower leaves, leaf drop and/or necrotic spots. They also showed some varieties are more tolerant to salts than others (11, 15) Excess salts in gardenias resulted in spotty chlorosis and some marginal leaf burn (15).

In azaleas, Pearson (16) reported saline waters produced a bushy, compact azalea plant whereas the habit of growth on plants irrigated with waters of less salinity was not as compact. In Rex begonias the amount of chloride in the leaf tissue increased as the salt content of the soil increased. Under potted conditions, not only Rex begonias but also azaleas showed marked sensitivity to saline accumulations.

Table 1. Interpretations of total soluble salts content of irrigation water as measured by Model RD-B15 Solu-Bridge (Laurie, Kiplinger and Nelson, 1968).

Solu-Bridge Reading	Interpretation
0.00 — 0.25	Excellent
0.26 — 0 75	Good
0.76 — 1.50	Fair
1.51 — 2.00	Permissible
2.01 plus	Excessive (too salty)

Pearson also showed, in the leaf tissue of the Rex begonia the chloride, sulfur and potassium content increased in a 3 month period when plants were irrigated by sprinkling the leaves or applying water to the soil surface. In this study, four different waters were used.

Seed will not germinate properly when soluble salts are too high. This has been reported for many types of seed. Some of them are salvia and verbena (6), alyssum (5) and snapdragon (18).

The effect of increasing salt content on the rooting of fuschia cuttings has been studied. Sodium chloride was added to waters to increase the dissolved solids to 1200, 1500 and 2000 ppm. More than 90% of the cuttings rooted with the more saline waters. However, the number and vigor of the roots in the sand medium decreased as the concentration of salts increased, and some leaf abcission occurred (16).

Hairy-leaved plants such as Rex begonia and some azaleas may be injured by moderately saline waters as a result of sprinkling plants as a method of watering (16).

Experiments on fuschias have shown that roots of potted plants watered with high-calcium waters usually extend throughout the soil mass. With high-sodium waters, the roots are less vigorous and occur more in the upper two-thirds of the pot. Pearson (16) suggested the difference in roots is due to a subnormal nutritional level of calcium or unfavorable soil structure caused by sodium.

HARDNESS

Hardness is caused by dissolved mineral compounds such as calcium or magnesium carbonates, sulfates or chlorides.Most wells yield water with some degree of hardness. Characteristics of hardness are numerous, including high soap and detergent requirement, spotting of dishes and glassware, bathtub ring, scale deposits in plumbing systems, and skin irritation and dryness

The degree of hardness is measured in "grains per gallon" (gpg) or "parts per million" (ppm). Seventeen ppm equals one gpg. A descriptive classification of hardness is found in Table 2. Treatment should be considered if water contains over 6 grains of hardness per gallon. To select the correct size of treating equipment, the degree of hardness must be determined. When selecting equipment to reduce the water hardness, it is essential to select the proper type so sodium is not involved. For example, the Zeolite process for softening water employs base exchange. Zeolite is a granular material charged with sodium. The calcium and magnesium ions in the water passing over the Zeolite are absorbed, and sodium ions go into solution in their place. The sodium in the water results in "softer" water. However, sodium added to the soil, as a result of irrigation, actually destroys the soil structure and de-flocculates or puddles the soil giving it a poor physical condition. In addition, sodium is then used in the plant in place of calcium and forms sodium pectate between the cells which causes the cells to adhere to each other poorly and the roots disintegrate (17).

Table 2. A classification of water hardness.

Description of Water	ppm[a]	gpg[b]
Soft	0-17	0-1
Slightly hard	17-50	1-3
Moderately hard	50-100	3-6
Hard	100-200	6-12
Very hard	200-500	12-30
Extremely hard	over 500	over 30

a/ ppm denotes parts per million

b/ gpg denotes grains per gallon

Another method used to obtain soft water is the de-ionization process. This provides for removal of the calcium, magnesium, and sodium by substituting H-ions. Here, water passes over an adsorptive medium charged with the H-ions, which adsorbs the calcium and other elements, liberating the hydrogen (17).

Complete de-ionization will occur when this water is passed through a second filter charged with OH-ions, which replace bicarbonates (HCO_3), chlorides (Cl), and sulfates (SO_4). The result is first a surplus of H-ions, then OH-ions to form water. This process should be satisfactory for removing salts from water to be used for plants. It is, however, the most costly (17).

ACID WATER

Acid water occurs in and around areas where there is little or no lime in the rock formations from which water is derived. Acid water is corrosive and dissolves metal components of the water system, including the pump, iron and copper piping, unlined pressure tanks and plumbing fixtures. It can cause water to be rusty when the plumbing system contains steel pipes, and it may leave blue-green stains in systems with copper piping.

The symbol, pH, is used to denote the degree of acidity or alkalinity. Values 7 to 0 are increasingly more acid, with 7 being neutral. Values from 7 to 14 are increasingly more alkaline. The most desirable range is about 7.0.

Acid water generally isn't a problem to the plant grower because it can be counteracted by the use of limestone in growing media. The grower of ericaceous plants desires a low pH anyway; and in areas of acid water, he generally adds some limestone ($CaCO_3$) or gypsum ($CaSO_4$) to supply some calcium for plant growth.

ALKALINE WATER

Many areas of the United States have alkaline water, that is, water with a pH above 7.0. Numerous water supplies range between 7.0 and 9 0. Where the pH is over 7.0, problems may arise with some growing plants.

To resolve a problem caused by too much alkalinity, acid can be injected into the irrigation water. The most commonly available acid is 75% food-grade phosphoric acid. Tayama and Staby (20) reported arsenic toxicity on carnations and azaleas from contaminated phosphoric acid. Therefore, it would be advisable to use the food grade. In some cases, 66° Baume sulfuric acid may be used.

To determine the amount of acid to use, a water analysis is needed and the milliequivalents of bicarbonates and carbonates per liter or hardness must be known. Based on this information, it can be calculated how much acid to use per 1000 gallons of irrigation water Before use, the acid-treated water should be tested. If the pH is too high or too low, adjustments can be made downwards or upwards to attain the desired pH.

Tayama and Staby (20) also reported that phosphoric acid can be mixed in most fertilizer solutions without having some of the elements precipitating from the solution. As a further insurance to avoid precipitation, it would be wise to select a double-headed injector so the fertilizer and acid would be physically separate in concentrated form. This type of injector is carried by suppliers as a standard stock item.

BICARBONATES

Lunt et al. (14) observed a depression in iron accumulation in azaleas when bicarbonates were high. This response may have been due to either the action of bicarbonates or to the hydroxyl ions. On a variety of plants bicarbonates have been found to depress the absorption of iron, and in some plants seem to favor the accumulation of monovalent cations (13, 21).

NITRATES AND NITRITES

In Wisconsin, a study by Crabtree, showed that 55% of the 242 private wells tested contained a nitrate level of 45 ppm or more. He also found nearly 70% of 82 wells contained a nitrate level of 45 ppm or more at one time or another within the period of testing, and about 45% of the wells contained in excess of 45 ppm nitrates throughout the year. In this study, the nitrate concentration in the ground water was highest following wet periods and lowest during dry periods with only a few exceptions. There was no clearly defined relationship between high nitrate concentration and depth of wells examined.

However, Crabtree (3) found that, unlike nitrate, nitrite variation showed some relationship between concentration and well depths, with the highest incidence of nitrite concentration occurring most commonly in shallow and dug wells immediately after heavy precipitation. He concluded that the type of well construction (dug, dug and drilled, or drilled) had no significant effect on nitrate concentrations in the wells sampled during the study period. This was partly due to the great majority of wells sampled being old installations constructed prior to the establishment of state well construction codes, which were inadequately cased or curbed for the most part.

Shaw and Wiley (19) in California showed significant variations in levels of the nitrate ion concentration can occur in analysis of water samples collected from the same well. Variations seem to be associated with at least two factors: (i) the time lag between sampling and actual analysis and (ii) time of continuous pumping prior to sampling. A nearly two-fold increase in the level of nitrate ion concentration in water samples from Well 1 occurred after 4 hours, during which the pump was not running, and a 3½-fold increase occurred after 24 hours which pointed to a multiple aquifer source of water. The change in nitrate ion concentration, with time after sampling, suggested that some undetermined factor is involved that changes nitrates to some other form of nitrogen.

Ewart (6) reported verbena and salvia seed require very low nitrate levels for proper germination.

IRON WATER

Red or rusty water can be caused in several ways. If the water has an acid reaction, corrosion in the plumbing system can give the water a rusty taste and color even though the source contains no dissolved iron. The treatment is to neutralize the water to or near pH 7.0.

Dissolved iron in the form of ferrous bicarbonate is a common occurence in ground water supplies. In the ferrous or dissolved form, it is colorless and tasteless; but when exposed to air, it takes up oxygen and changes to ferric hydroxide, a rusty precipitate which is unsightly.

Another cause of rusty water is bacteria. These are living organisms that feed on the well casing, piping, etc. with which they come in contact. They not only damage the water system but add to the iron content of the water. They result in a slimy accumulation in the pipes, etc.

For farmstead and health purposes, quantities of iron greater than 0.3 ppm are objectionable. Plants can probably tolerate much higher levels.

In many areas the presence of iron in the water can be a problem. This is particularly observed in the propagation bench where cuttings are being bathed in a fine mist of water. The iron salts dissolved in water precipitate out when mixed with oxygen. The iron deposits seldom, if ever, cause injury but are more unsightly than anything else.

To remove or control iron, water softening equipment, an oxidizing filter, chlorination-filtration, or a phosphate feeder can be used. A simple oxidizing system is described below. Each method has advantages and limitations.

A simple device which can be used to eliminate the iron from water is similar to a shower in the bath that sends out a very fine mist of water in an umbrella-like pattern a few feet above a sand filter. A windscreen is generally placed around the spray to insure the water falls through the air to the top of the sand filter. The air / water mixture results in oxidation of the water-borne iron ions, and the dark brown iron oxides settle out and are trapped in the fine sand. The resultant relatively pure water percolates through the sand to a storage tank or cistern which will then be used as the water supply. From time to time the sand filter should be backwashed with the de-ironed water floating the iron up through an outlet above the sand.

BORON

Boron is a nutrient required in very small amounts to insure proper growth and development of plants. Occasionally, a greenhouse water supply is found that contains an excessive amount of this element. Davidson (4) indicated it is unusual for excessive amounts of boron to occur in water supplies east of the Mississippi River. However, such waters have been found in New Jersey, Ohio and Illinois (7). Where boron was a problem in excess amounts, it was primarily found in well waters. Occasionally a municipal water supply will have an excess amount. In roses it has been determined that an excess of 0.4 ppm in the water supply may be toxic and result in a marginal leaf scorch.

According to Davidson (4) there is no practical method for treating water to lower the boron content. Demineralizers will not remove boron. The only solution is to acquire another water source. The boron content available to the plants in soils can be minimized by leaching. It is slightly soluble. Also, by keeping liberal amounts of calcium in the soil, the boron is replaced by the calcium on the soil colloids.

Studies by Kofranek, et al. (10) revealed boron levels of 4.8 ppm in the nutrient solution caused poinsettias to develop an interveinal leaf chlorosis, and marginal leaf scorch followed by leaf abcission. It was also found that high boron levels have less effect on plant size than do high salinity levels. The boron accumulation was in the lower leaves.

Symptoms of boron toxicity in azaleas first show as a slight chlorosis and as time progresses, marginal burning and necrotic spots develop on the lower leaves first, then continue to progress to the younger leaves (15). These workers also demonstrated that 'Sweetheart Supreme' is more sensitive to excess boron while 'Mrs. Fred Saunders' was more tolerant to high levels.

SODIUM FLUORIDE

Many municipal water systems are adding sodium fluoride because of the beneficial effect it has in preventing or reducing cavities in teeth. The amount added is very small, usually about 1 to 2 ppm. Many untreated water supplies contain larger amounts from natural sources and do not injure plants.

CHLORINE

Chlorine is found in most municipal water supplies in amounts of 0.1 to 0.6 ppm with a maximum of 2 ppm. The amounts of chlorine reported as necessary to induce injury to greenhouse plants are 5 ppm for sand; 50 ppm for loam soils; and 10 ppm for cut flowers. It is therefore easy to see why water that is safe for drinking is considered suitable for plants.

If chlorine is a constituent of water, a portion of the dissolved chlorine is vaporized from the water before it reaches the soil. This is particularly true if a water breaker is used or a nozzle that breaks up the water.

MARGINAL MINERAL DEPOSITS

Sometimes a marginal mineral deposit will occur on the foliage of plants not being watered overhead. It is possible that exudation from hydathodes will dry at the leaf edge causing crystals of solids in the plant fluid to accumulate. This is not too common and would occur under conditions of high humidity at night and early morning, followed by a rapid drop in humidity at midday.

ALKYL BENZENE SULFONATE

There has been considerable seepage of domestic waste water from thousands of cesspools on Long Island which has contaminated the shallow ground water in many intensely developed surburban areas. Very high concentrations of constituents such as chloride, nitrate, sulfate, phosphate and bacteria are commonly found in ground water polluted with cesspool effluent.

Foaming of ground water withdrawn from the upper glacial aquifer has occured, and in 1961 several flower growers in the Bellmore-Wantagh area of Long Island indicated that their well water was foamy when it came from the faucet. Tests showed that the water had 1 to 2 ppm alkyl benzene sulfonate (ABS), the active surfactant ingredient in many household detergents. As a result of this concern, Bing and Boodley (1) conducted a study to determine if ABS in the water affected the growth of plants in greenhouse soil.

Preliminary experiments with ABS showed no consistently adverse effects on the growth of chrysanthemum, carnation, snapdragon, fuschia, lantana, nephthytis, philodendron, peperomia, and dracena. The soils were treated with 0, 25 and 50 ppm ABS solutions, which are much higher concentrations than could be expected to occur in water available to plant growers. They concluded that water containing enough ABS to be declared unsafe for drinking or cause foaming is probably not harmful to most plants.

Movement of ground water contaminated with ABS on Long Island is about 1 foot per day. ABS is a moderately stable chemical compound and may remain in the ground water for long periods of time. Without additional input of ABS, natural dilution could reduce the concentration of ABS below detectable levels.

SULFUR WATER AND BLACK WATER

Water which containes sulfides yields an offensive rotten-egg odor, has an objectionable taste, and is corrosive. In combination with iron, ferrous sulfide (FeS) gives the water a black color. Treatments for sulfur water or black water include an oxidation-filtration method or aeration. The aeration process is expensive due to the equipment needed, and the water is exposed to the contaminating influence of the atmosphere.

SEDIMENT AND TURBIDITY

In addition to dissolved gases and minerals, water may carry in suspension other foreign material such as clay, rock flour, silt, and organic matter. In size these impurities may range from colloidal particles that remain in suspension for days to coarse sandy material that settles rapidly. The objectionable aspects of waters of these types are undesirable color and taste, and wear and tear on pump impellers and other water treatment equipment.

If correction cannot be obtained by improving the construction of the water facility, some type of filter is needed to separate the suspended matter from the water. A slow sand filter is preferred where adaptable. A second choice should be a pressurized type filter containing graded sand or the replacable cartridge type containing a porous ceramic or fibrous filter element.

POLLUTION DUE TO INDUSTRIAL WASTES

On Long Island the pollution of shallow ground water with industrial wastes is a serious problem in some areas. In 1962 in the south Farmingdale area, the shallow ground water contained as much as 3.7 ppm of cadmium ions and 14 ppm of hexavalent-chromium ions. The US Public Health Service (1962) established drinking water standards for these two ions. They indicated that concentrations of chromium in excess of 0.05 ppm and cadmium in excess of 0.01 ppm are objectionable.

The hexavalent chromium and cadmium were introduced into the shallow ground water as a result of the discharge of industrial metal-plating wastes into shallow recharge basins. The body of shallow ground water contaminated was about 4000 feet long and had a maximum width of approximately 1000 feet. It had a rate of southward movement of several hundred feet per year, and some of the contaminated ground water was discharging into Massapequa Creek.

The effects of cadmium and chromium ions on plant growth are probably unknown, but this is a good example of what can happen to a water supply through carelessness. In this case it has been estimated that the time required for all detectable traces of the contaminants to disappear may be several tens of years or more (2).

SALT WATER INTRUSION

Overdevelopment of ground water in Kings and Queens Counties on western Long Island has resulted in widespread lowering of water levels, 35 feet below sea level. As a result, a landward hydraulic gradient developed causing salty water to invade the fresh-ground-water reservoir. Since the late 1930's, net ground-water withdrawals have decreased in Kings County, and ground-water levels have recovered substantially.

In Nassau County and southwestern Queens County there are three major tongues or wedges of salty water. The deeper wedge has moved inland in response to local ground-water overdevelopment an average of 1000 feet since the early 1900's. The intermediate wedge has not moved as far inland since that time (2).

CONCLUSIONS

This paper was prepared to make plant growers aware of some of the common water problems. In some cases corrective action was suggested. The corrective methods described are not absolute. Since each situation is different, the remedial measures suggested by experts in the field of water quality may be similar to or different from those mentioned.

If you suspect a water-quality problem, there is an orderly sequence of steps that should be followed for the most satisfactory and economical results. The steps are as follows:

1. Obtain a complete analysis of the water, both bacterial and chemical. The results will indicate what is causing the objectionable characteristic(s).
2. Try to eliminate the cause if possible. If this is not a surface problem such as a broken seal on the casing or a lack of surface drainage away from the wellhead, proceed to step 3.
3. Remove the impurities from the water. This is accomplished by filtration, neutralization of alkalinity or acidity, oxidation or other methods. The conditioning of water to remove harmful chemicals may be necessary in some situations, but the feasibility of water conditioning must be determined from a special study of each individual case.

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LARRY CARVILLE: Thank you very much, Ralph. We have time for a few questions.

JIM CROSS: I would like to ask Dave Morrison what type of probe he uses to determine the quantity of water in the soil.

DAVE MORRISON: We use a probe made by Oldfield Apparatus Company, Oldfield, Wisconsin. This equipment pulls a core of soil which we inspect visually and our water men know from experience what the condition of the core should be for the proper water quality.

LARRY CARVILLE: I wish to thank all of the speakers on this morning's program for a group of papers which were well presented and had a wealth of information in them.

FRIDAY AFTERNOON SESSION

December 9, 1972

The afternoon session convened at 1:30 p.m. in the Terrace Room of the Hartford Hilton Hotel with Mr. Michael Johnson presiding.

MIKE JOHNSON: The purpose of this symposium is to compare how three East Coast nurseries propagate rhododendrons and grow them on in containers.

As the three of us give our individual papers, it might be well to keep a few things in mind in order to put our different methods into perspective. One of the most obvious differences between our three operations is the nursery location. The Conard-Pyle Company, represented by Dick Vanderbilt, is the most southerly, being in the general area of Wilmington, Delaware. The Wells Nursery, represented by Jeremy Wells, is in central New Jersey. Summer Hill Nursery is in southern Connecticut. I was quite surprised, however, when looking up the average number of frost free days for the three different areas, that we only vary about 5 days. The length of the growing season is a factor that is not as great as one would think from looking at a map. However, I am quite sure that there