PACE INSIGHTS
March, 1998 Volume 4 Number 3 Page 1

Water Amendments - Gypsum, Acid, and Sulfur Burners!

by, Larry J. Stowell, Ph.D. and Wendy Gelernter, Ph.D.

Irrigation water quality and soil chemistry go hand-in-hand. Whatever elements and chemicals are in the irrigation water end up in the soil. These elements and chemicals, commonly referred to as salts, can have a profound effect upon soil chemical and physical conditions and plant health. Therefore, when we look at the soil chemical composition in irrigated areas of the world, the chemical composition of the irrigation water becomes a critical factor. Waters can be too pure, too salty, out of balance, or just right. This *PACE Insights* will discuss several critical water evaluation parameters and will delve into the questions of:

- When is the use of water amendments appropriate?
- Which amendment will do the best job in improving irrigation water-soil interactions?

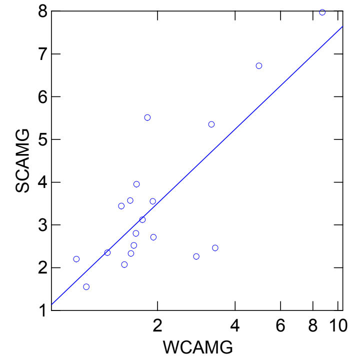
The focus will be on fairway soils because they are more sensitive to water quality problems than sandy greens. Although there are many amendment strategies available, we will limit discussion to the most appropriate and popular options for California golf course irrigation waters.

Soil quality: Where is the first place you should look if you think you have a water quality problem? The soil! If soils accept water during irrigation and rainfall and they do not puddle or are not excessively dry, the soil has passed the first step in the evaluation process. Following visual inspection of water movement through the soils, review soil test results. The key soil parameters that are affected by water quality are listed in Table 1. If your fairway soil samples fall within all of the parameters listed in Table 1, your water probably does not require amendment. If any of these parameters are off, for example calcium represents only 60% or sodium exceeds 10% of the total cation exchange, you may have a developing water quality problem. Depending upon the seriousness of the problem, corrections can be made directly to the soil (for example applications of gypsum to displace sodium and magnesium) or the irrigation water might be amended.

Calcium, magnesium and sodium: Calcium (Ca) plays a critical role in forming soil clay aggregates and is also important in plant growth and health. If calcium is present in low levels relative to magnesium and sodium, soil structure can be damaged and plant stress may be the result. In recent years, the negative role of high magnesium (Mg) in soil has been identified. Like sodium (Na), high magnesium disperses the soil clay particles to result in plugging the water conducting soil pores and reduction of hydraulic conductivity. The desired percentage of soil magnesium is less than 20% of the exchangeable cations (Keren, 1992, Oster, 1998). With a target soil calcium percentage of at least 68%, and desired magnesium below 20% of the total exchange, the desired soil Ca:Mg ratio is greater than 3:1 (based upon meq of each element). Figure 1 illustrates the interaction between water Ca:Mg ratios and soil Ca:Mg ratios. The results reported in Figure 1 indicate that a water Ca:Mg ratio of about 2:1 should result in a soil Ca:Mg ratio of about 3:1.

As with Ca:Mg ratios, soil Ca:Na ratios need to be in proper balance to insure that excessive sodium does not result in soil dispersion problems similar to that seen with high magnesium. In this case, sodium at less than 10% of the total exchange capacity or a Ca:Na ratio of greater than 7:1 is desired to prevent soil clay particles from dispersing and plugging soil pores that results in a reduction in soil hydraulic conductivity. In addition to reducing soil hydraulic conductivity of the soil, both Ca:Mg and Ca:Na ratios play a role in water infiltration of the soil surface. Waters that contain high magnesium and sodium may slow down surface infiltration, especially in overhead irrigation systems, by dispersing the clay particles at the soil surface. For these reasons, the desired cation ratios for Ca:Mg and Ca:Na in water have been set at 2:1. There was not a significant correlation between water Ca:Na ratios and soil Ca:Na ratios when the PACE database was examined. We suspect this is the result of the fact that sodium leaches fairly easily from the soil, while Ca and Mg are more strongly held by the soil exchange sites.

Figure 1. Correlation between water Ca:Mg (WCAMG) ratio and resulting soil Ca:Mg (SCAMG) ratio. Based upon this model, a Ca:Mg ratio of 2:1 is needed to obtain a soil ratio of about 3:1 (soil Ca:Mg = 1.77+5.76 * ($\log_{10}$(water Ca:Mg)), $R = 0.65$, $p<0.005$). Data represents the water and average fairway analyses from 19 California golf courses.



If there are no soil problems, then irrigation water is performing adequately and there is no need for amendment to your water source. In most cases, however, soils do not meet all of the guidelines in Table 1. Therefore, it is likely that the irrigation water contains one or more undesirable components or insufficient quantities of calcium. **One word of caution. The models and formulas presented below are important tools in helping you decide whether to amend irrigation water. But your decision should also take into account the performance of the fairways as well. If the turf is healthy and the fairways are neither too wet nor too dry, but the formulas tell you to amend, it's time to ask more questions before going any further**

Table 1. Soil analytical parameters that provide a guideline for identifying irrigation water problems. These values should be reviewed in the fall of the year after a season of irrigation. Values for percent calcium, magnesium and sodium were obtained using Melich III extraction. Soil salinity refers to the electrical conductivity of a saturated paste extract. Percent of soil samples that fail to meet the desired soil guidelines are based upon the average fairway soil results for 19 California golf courses.

Soil Parameter	Desired Guideline	Percent of samples that fail to meet desired guideline
Percent Calcium	68% or higher	84
Percent Magnesium	10 - 20% but not higher than 20%	58
Percent Sodium	10% or less	5
Ca:Mg ratio	More than 3 meq Ca to 1 meq Mg	53
Ca:Na ratio	More than 11 meq Ca to 1 meq Na	100
Soil Salinity	Less than 3 dS/m for cool season turf Less than 5 dS/m for warm season turf	47 16

Water Quality: Evaluating water quality and selecting a water amendment if one is needed can be a daunting task. We have tried to identify the key characteristics of some California waters (Table 2) to better understand when amendment is needed and which amendments should be used. After reviewing the PACE Turfgrass Research Institute data base of water analyses, three factors stand out as being critical - 1) calcium in relation to magnesium and sodium, 2) bicarbonate and its interaction with the cations, and 3) salinity of the water. The bottom line is that most waters have too little calcium and too much magnesium and sodium, which can result poorly performing, high sodium, high magnesium soils.

Table 2. Water quality parameters frequently used to assess the acceptability of irrigation water and the need for amendment. Percent of water samples that fail to meet the desired water guidelines are based upon the average water results for 19 California golf courses. The soil evaluations in Table 1 are from the same courses.

Water Parameter	Desired Guideline	Percent of samples that fail to meet desired guideline
Sodium absorption ratio (SAR)	6.0 or less	5
EC - SAR	EC > 0.5 + 0.05 * SAR	16
Bicarbonate	90 ppm or less and represent less than 50% of anions	53
Residual Sodium Carbonate (RSC)	1.25 or lower	0
Ca:Mg ratio	More than 2 meq Ca to 1 meq Mg	73
Ca:Na ratio	More than 2 meq Ca to 1 meq Na	95
Water Salinity	1.2 dS/m or less for cool season turf	47% > 1.2 dS/m 5% > 3.0 dS/m

There are three basic amendment strategies for improving calcium, sodium and magnesium interactions in soil -- gypsum injection, gypsum application to soil and acid injection. To determine which strategy is best for your golf course, take a look at how your irrigation water measures up to the water quality guidelines presented in Table 2. To help decipher this complex information, definitions of some of the key parameters are provided at the end of this article.

Gypsum Injection: Commercial gypsum is a product of the earth that is mined from a variety of locations throughout the country. Gypsum is the principal component of drywall and plaster of paris. During the day, you are probably not very far from gypsum in one form or another. The chemical formula for gypsum is $CaSO_4{\bullet}2H_2O$. At normal room temperature, 0.24 grams of gypsum will dissolve in 100 ml of water. On a more useful scale, 6521 lbs of gypsum theoretically could be dissolved in an acre foot of water under ideal conditions. More reasonable rates of injection range between 2 and 5 meq/l of calcium (Ca). One meq Ca will be delivered per liter of solution when 234 lbs of gypsum are dissolved in one acre foot of water. The highest rate of gypsum injection per acre foot of water using current gypsum injection systems is about 5 meq Ca/l (1165 lbs gypsum/acre ft) - well within the theoretical solubility of gypsum in water. This 5 meq rate would result in application of approximately 2 tons of gypsum/acre/year, if 3 acre feet of water is used each year for fairway irrigation. If higher rates of gypsum are required to balance soils, it will have to be applied directly to the soil, as a powder or a granule.

At the same time gypsum injection provides calcium, it also adds to the salinity of the irrigation water. In some cases this is desirable but in others it is a detriment. Gypsum injection will increase the electrical conductivity of the water 1 dS/m for every 3133 lbs of gypsum dissolved per acre foot of water. In the example above, 234 lbs of gypsum injected per acre foot of water will increase the water electrical conductivity (EC) by 0.07 dS/m. At the high rate of 5 meq Ca/l gypsum will increase the EC of the water by 0.4 dS/m.

If your irrigation water does not meet the desired EC-SAR guideline listed in Table 2, and if your soil chemistry tests indicate a need for higher soil calcium levels, then gypsum injection is the desired route of amendment. This is because in addition to adding calcium to the system, gypsum also increases the water EC, which in turn will help water reach the desired EC-SAR guideline to improve water infiltration. Even if your water does not require amendment, gypsum injection can still be used to deliver calcium to soils. In this case, your decision to inject or not would be based on the ease of use and cost of gypsum injection systems vs. soil applications of gypsum (see below) at your course.

Gypsum application to soil: If your water passes the EC-SAR test, gypsum can be added directly to the soil surface in the form of a powder or granule. The average fairway soil in the PACE database requires approximately 2 tons of gypsum/acre/year to achieve the desired level of 68% calcium. Check your own soil reports to determine the exact rate of gypsum required on your fairways. Typically, gypsum is applied at the time of spring fairway aeration.

Acidifying agents: Acidifying agents can act either in the water or in the soil. In the irrigation water, they work to reduce bicarbonate levels, and in the soil, they act to release calcium and magnesium from their corresponding carbonate forms. The end result of these reactions is the same -- bicarbonates are removed from the soil so that soil calcium and magnesium are not complexed into water insoluble calcium and magnesium carbonates (lime). Instead, calcium and magnesium are released from their lime form and become soluble, and therefore available, in the soil.

The most popular acidifying materials are sulfuric acid (H_2SO_4), Urea/sulfuric acid (N-pHuric, US-10), and sulfur burners that produce sulfur dioxide (SO_2) which in turn produces sulfurous acid (H_2S0_3), which acts similarly to sulfuric acid.

If magnesium had the same beneficial soil interactions that calcium has, the use of acid injection would improve soil conditions dramatically. Unfortunately, we now know that magnesium is detrimental to the soil structure, in a similar manner to sodium. Therefore, in California's high lime soils, the use of acid injection has mixed results. Through the solubilization of calcium, a benefit is created, but the solubilization of magnesium creates a whole different set of problems to deal with.

Bottom line: Bicarbonates are high in California irrigation water but so are Ca and Mg which results in the formation of lime. The low residual sodium carbonate values that we see here (see definitions below) suggest that free sodium bicarbonate will not reach the soil - it will be calcium and magnesium carbonate (lime) instead. For these reasons, for the majority of waters and soils that have been observed in California, only addition of calcium - most commonly in the form of gypsum - will improve water and soil chemistry.

Greens: The discussion above has been restricted to fairways alone. Greens are another issue altogether. Because infiltration rates are higher and it is easier to leach greens compared to fairways, soil applications of gypsum are encouraged. A good program entails application of 10 lbs gypsum/1000 sq ft at the time of the monthly 1/4 inch aeration. Following application with a leaching irrigation helps insure that soil surface chemistry remains in good condition.

Finally, remember that the use of water and soil amendments to improve soil performance can be a complex issue. Consult a certified professional agronomist (CPAg) or certified professional soil scientist (CPSS) if you require assistance in evaluation of your specific situation

Definitions

SAR: Sodium absorption ratio is a measure of the relative abundance of sodium to calcium and magnesium. Unfortunately, the SAR does not account for the negative impact of magnesium. In fact, the SAR decreases as magnesium increases. The cutoff for sustainable use of a water without problems is an SAR of 6.0. The equation is:

$$SAR = \frac{Na(meq/l)}{\sqrt{\frac{Ca(meq/l) + Mg(meq/l)}{2}}}$$

EC-SAR: This relationship determines whether the water contains insufficient salts to penetrate the surface of the soil dependent upon the EC and the SAR of the water. The EC must be greater than 0.05*SAR+0.5 to have good soil infiltration.

Bicarbonate: Bicarbonates complex with calcium and magnesium to from insoluble calcium and magnesium carbonates, or lime. When sodium and bicarbonates are present together, the result is a problematic reduction of calcium and magnesium and more available sodium in the soil. Desired bicarbonate levels in water are less than 90 ppm; bicarbonates should represent less than 50% of the total anions on a meq/l basis.

Residual sodium carbonate: This factor evaluates whether there is sufficient calcium and magnesium in the water to tie up all of the carbonate and bicarbonate. If there are excess bicarbonates, then sodium is likely to accumulate in the soil. The formula is RSC = total carbonates (CO3+HCO3) - (Mg+Ca). All values are in meq/l. Values greater than 1.25 suggest a problem and acid injection may be needed to remove the excess carbonates and bicarbonates.

References:

Carrow, R.N., and Duncan, R.R. 1998. Salt-Affected turfgrass sites: assessment and management. Ann Arbor Press, Chelsea, Michigan.

Keren, R. 1991. Specific effect of magnesium on soil erosion and water infiltration. Soil Sci. Soc. Am. J. 55:783-787.

Oster, J.D., Singer, M.J., Fulton, A., Richardson, W., and Prichard, T. 1992. Water penetration problems in California soils: Diagnoses and solutions. Kearney Foundation of Soil Science, Division of Agriculture and natural Resources, University of California.

Oster, J.D., 1998. Slphychm Note: Magnesium effects on soil physical properties - hydraulic conductivity and infiltration rate. http://esce.ucr.edu/OSTER/SLPHYCb.htm.

Stowell, L.J. 1995. How does your irrigation water measure up? Golf Course Management, 63:58-62.

PACE Consulting
1267 Diamond Street
San Diego, CA 92109