Just a Grain of Salt As salinity increases, turfgrass management will need to increase, too.

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Effluent, recycled, reclaimed, reuse water — all are common terms for the irrigation water being used on courses today.

The escalating demands for potable water use solely for human and industrial use and the shift to decreasing water quality varying in salinity and nutrients for golf course use have increased the management challenges required to maintain acceptable turf performance.

The quality of water applied to recreational turf is as good as it will ever be and over the next decades will get worse. Since salt is the ultimate growth regulator, maintaining turf growth and development, as well as acceptable putting standards on greens and grass survivability will be long-term goals.

The interactions

As irrigation water quality decreases and salinity increases, interactions among the water, soil type and profile, turfgrass species and cultivar and the environment also increase. This four-way interaction is what makes salinity so confusing and complex, and the impact on turfgrass performance becomes increasingly site-specific, where management must be focused on specific "micro-sites."

In the past, such microsites were referred to as "indicator spots." But with salt/nutrient-laden irrigation water, almost every area on a golf course can differ from surrounding areas and and when compared with nearby courses. So, instead of considering only a few indicator spots, the entire turf infrastructure area on the site has a greater chance of exhibiting considerable site-specific differences.

As salinity increases, turfgrass management will subsequently need to increase. If it does not parallel the increase in salinity, the grass performance will eventually decrease, canopy density loss increases, and grass death is usually the result.

Management of salts before, during and after managing the grass should be the top priority; otherwise, salt loading in the soil will result.

Monitoring of a soil's nutritional and salinity status, water quality parameters and their fluctuations, and tissue nutritional status become critical information for management decisions as salinity increases. Standard soil fertility tests will provide basic information on potential nutritional availability in the soil.

Additionally, a superintendent must ask for other salt-related tests, such as the saturated soil paste extract (SPE) analysis (using distilled water or actual irrigation water for analysis) to get proper information on the total salinity impact status of the specific soils on the course. Sampling soils in the 0-3 inch and 3-6 inch zones can provide data on possible downward migration of salt ion localization in the upper soil profile zones. The SPE provides also data on sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP) and other salt ions/compounds such as sodium, chlorides, sulfates, magnesium, and bicarbonates that are not routinely analyzed in some regular salinity soil tests.

Sampling of soils at 0 inches to 3 inches and 3- to 6-inch bulked samples will provide some information on movement of salts through the soil profile and how effectively the soil profile is leaching (moving salts down below the root system and to the drainage lines).

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Ideally, periodically sampling soils from the bottom of the root system or just below this area in the rhizosphere can provide critical indicator information on areas that first exhibit potential salt stress. A superintendent can also ask the analytical laboratories for a salinity analysis of irrigation water; not only the water coming out of the wells, rivers, ponds or lakes, but also the water actually coming out of the sprinkler heads on the golf course. Always collect irrigation water samples from sprinklers out on the front 9 and back 9 holes on the golf course in order to have some idea of the irrigation water quality being applied on site-specific areas.

Finally, superintendents need to collect clippings from good and bad turf areas on the course and submit the tissue for a wet chemistry analysis to provide proper information on nutritional balances and imbalances caused by increasing salinity. Normal soil fertility testing provides data on potential critical nutrient concentrations in the soil, but salt accumulation in the soil profile can also negatively impact potential availability of those nutrients and subsequent turf root absorption of essential elements. Critical nutrient sufficiency requirements for specific turf species and cultivars can often be lower than expected when irrigating with saline water.

Data from the water, soil and tissue analyses can then be used to adjust the fertility program based on the salinity impact of the soil plus the nutrient concentrations that the turf can take up and utilize. Micronutrient imbalances usually occur as salinity increases in the ecosystem.

Table 1

Salt load in irrigation water based on different application rates over a typical 90-acre golf course (1 acre-inch irrigation over 90 acres = 2,443,860 gallons):

Salinity level (parts per million) — Pounds of salt per application

Total dissolved salts	500,000 gallons	750,000 gallons	900,000 gallons
500	2,075	3,113	3,735
1,000	4,150	6,225	7,470
1,500	6,225	9,338	11,205
2,000	8,300	12,450	14,940
3,000	12,450	18,675	22,410
4,000	16,600	24,900	29,880
5,000	20,750	31,125	37,350
10,000	41,500	62,250	70,008
15,000	62,250	93,375	112,050
20,000	83,000	124,500	149,400
34,500	143,175	214,763	257,715

Superintendents cannot manage turfgrass with salinity challenges unless they take a comprehensive, whole systems approach to management. Being one-dimensional in approaching salinity management will cause turfgrass performance and sustainability to suffer. Salts are unforgiving and will slowly and silently accumulate in the soil over years to suddenly cause significant problems in turf canopy density, cosmetic color and playability.

Getting educated

Education starts with becoming familiar with terms such as total dissolved salts (TDS),electrical conductivity of soils and water (ECe and ECw), sodium absorption ratio (SARe and SARw), adjusted sodium absorption ratio (adjSARe and adjSARw), residual sodium carbonates (RSC), impact on general plant growth (ECw, TDS), impact from root contact (sodium [NA], chlorine [Cl], boron [B]), impact from foliage contact (Na, Cl), impact on soil structure (SARw and adjSARw, ECw, TDS).

Critical salinity impacted nutrients that are often at near-toxic or toxic levels include Na, Cl, B, bicarbonates and carbonates and sulfates. Nutrients that are often imbalanced in turfgrasses include calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), nitrogen (N), manganese (Mn), zinc (Zn), copper (Cu) and iron (Fe).

Saline soils have high total dissolved salts. Sodic soils are dominated by excess Na, and saline-sodic soils contain a combination of both high total salts and excess Na.

In addition to irrigation water adding significant levels of nutrients or elements, the leaching program to control soluble salts can also change the availability of soluble nutrients. All components of salinity significantly affect turf rooting and long-term turf performance, lending credence to adoption of the whole ecosystems or holistic approach to management.

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The turfgrasses

Current development of grass cultivars with improved levels of salinity tolerance is providing previously unavailable options for managing grasses, using variable quality recycled and increasingly saline irrigation water.

Development of seashore paspalum (*Paspalum vaginatum* Swartz), the most salt-tolerant warm-season grass species, for golf course use has provided flexibility in managing a turfgrass that is more forgiving as salinity increases in the turf environment. The added advantage of this grass is the tournament-quality attributes and the cosmetic appearance resembling Kentucky bluegrass that occurs with proper management.

Private companies are developing cool-season grasses that have higher salinity tolerance than in the past. The availability of these salt-tolerant cultivars is and will continue to improve turf performance on golf courses. However, there must be a reality check involved.

Just because a course uses a high-salinity-tolerant cultivar does not mean that ocean or highly brackish water should be used long term on the golf course. A primary concern is what impact the increasingly saline irrigation water will have on accumulation of total salts in the soil.

Data in Table 1 provide the realism. If excess total salts accumulate and layer in the soil rhizosphere, a turfgrass salinity threshold level will be reached that will eventually overwhelm the grass. The first impact will be on root system development, redevelopment and maintenance. Secondarily, carbohydrate allocation to shoot maintenance will be decreased, the turf becomes less aggressive and the grass is predisposed to secondary stresses, especially greater disease infestation and occasionally insect problems.

Normally, the first symptom recognized by turfgrass managers is a disease problem. However, salt loading in the soil profile and especially in the upper 2 inches to 4 inches (5 centimeters [cm] to 10 cm) near the crown region will normally be the primary limitation. Water uptake and nutrient availability are usually decreased because of the desiccation of root hairs, branch roots and rhizomes.

Excess salts in the shoot system will suppress stolon growth and tillering because of its growth-regulator effect on gibberellin and cytokinin production. The turf plant reverts to the injury repair mode using carbohydrate reserves and becomes more vulnerable to pathogen and insect attack. Reduced turf canopy density and dead turf are normally the end results. Turf management shifts to a reactive strategy and since high salinity is applied to the turf ecosystem with each irrigation cycle, the battle to manage turfgrasses for survivability and performance becomes an increasing challenge.

The central benefit of a more salt-tolerant grass is that it provides more leeway for the turf manager to manage salts without immediate turf injury. But salts must be managed or the salt-tolerant grass will be overcome because its tolerance threshold level has been surpassed. A common misconception in using a highly salt-tolerant grass is that the grass is "the answer" if poor-quality water is used. But the grass is only one component of the whole system.

A salt-tolerant grass must be used in conjunction with adoption of management options such as salt leaching, a possible need for water and/or soil treatments, drainage improvements, fertilization adjustments, to name a few, for long-term turfgrass sustainability and performance. Do not create an environment to grow grass that is worse than the one you started with or inherited. Mismanagement of salts can result in this problem, which is both expensive and difficult to remediate.

Even low levels of salts can accumulate in soils because salt is added with each irrigation application, i.e., 500 parts per million (ppm) irrigation water dispersing 1 ton of salt over the irrigated acreage with one 500,000 gallon application (Table 1).

Low-level salinity might not initially cause problems, but if the salts are not managed properly to minimize accumulation and layering in the soil over years, turf quality traits will eventually deteriorate. Ocean water irrigation (at 34,500 ppm TDS) is not recommended in any situation because of the massive salt-loading potential.

Development of certain seashore paspalum ecotypes that can tolerate ocean-water salinity is important, and not just because superintendents would want to use ocean water for irrigation. There are two more reasons salinity tolerance is beneficial. First, it allows the turf manager time to make management adjustments under normal high-saline irrigation practices with saline water at lower salt levels than ocean water. Second, on sites susceptible to ocean flooding, storm surge, or persistent salt spray, a tolerant variety would allow survival and recovery from periodic catastrophic events.

Additional limitations

When excess sodium, chlorides, sulfates, boron and bicarbonates/carbonates accumulate in the soil, they impact soil and turf nutritional stability. When high levels of sodium (concern levels greater than 200 ppm or greater than 5 percent cation base saturation) build up in the soil to the level of displacing calcium in the colloids, soil structural breakdown can occur, leading eventually to sodic soils.

Sodium can dominate the cation exchange sites, and granular fertilizer utilization efficiency can be decreased. Excess chlorides greater than 355 ppm can affect nitrogen nutrition. Excess sulfate levels greater than 180 ppm can accumulate and layer in the soil profile, leading to potential black layer problems in conjunction with anaerobic conditions.

Excess boron levels greater than 3 ppm can lead to additional nutritional imbalances. Bicarbonate levels greater than 120 ppm and carbonate levels greater than 15 ppm have a propensity to complex with calcium, magnesium and phosphates to form insoluble precipitates, layer in the soil and reduce the availability of these key nutritional elements for turf uptake. Infiltration/percolation rates are good indicators of increasing problems.

Actual levels of Ca and Mg are key concentrations that must be balanced in the soil and the plant to maintain turf health.

The increasing use of poorer quality irrigation water dramatically affects the soil's chemical and physical properties, which in turn can adversely affect turfgrass performance — and these challenges will be persistent. The level of turfgrass management skills to deal with the diverse direct and indirect effects of poor water quality will be substantially greater than for the same site with good (lower salinity) irrigation water.

The whole plant-soil-water-climatic system becomes much more dynamic and the changes must be systematically monitored. Site-specific management must be the norm. Turf managers must resist the temptation to look for a magic-bullet solution — such as a salt-tolerant grass, irrigation water acidification, sand-capping and other management options.

All of these options are potential tools that require strategically planned implementation in conjunction with grass management adjustments made across the whole ecosystem for long-term success.

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