Best Management Practices for Salt-Affected Golf Courses: Why and How?

Salinity – a dominant challenge.

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Figure 1. Salt accumulation in a green from surface and subsurface runoff from the irrigated rough.

The simple act of broadly applying irrigation containing saline salts over a golf course triggers a number of long-term challenges. Since irrigation is a routine practice, these challenges are ongoing and cannot be ignored (4, 2). Direct on-site effects of salt constituents are exhibited as a combination of: a) salt-induced drought by total soluble salt accumulation in the grass rootzone that inhibits water uptake (saline soils); b) sodium-induced deterioration of soil physical properties that limit water movement and aeration in the soil (sodic soils); c) turfgrass nutrient imbalances that are dynamic in nature; and d) plant shoot and root ion toxicities and other potential problem ion interactions.

Salt mobility after application enhances the potential for adverse on-site and off-site ecosystem impacts. Constant movement of salts occurs: vertically upward (capillary action); downward in the soil profile (infiltration, percolation, drainage); and horizontally as gravity-enhanced surface and subsurface transport. Of particular concern is the potential impact of salts on surface and subsurface groundwater, both onsite and offsite.

The diversity, magnitude, and complexity of salt issues result in a package deal — a package of ongoing turfgrass management, economic (amendments, infrastructure, equipment), environmental, and personnel challenges (degree of expertise, communications). Soil salinity stresses have increased in scope and concern in recent years on golf courses due to: a) political and societal pressures for water conservation, resulting in golf courses increasingly using poorer quality irrigation water to alleviate demand for potable water sources; b) development of salt-tolerant grasses, allowing use of more saline irrigation sources; c) development of coastal or wetland golf courses, resulting in salinity problems from saltwater intrusion in aquifers used for

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irrigation, dredged soils, acid sulfate sites, periodic flooding, high tidal influences, and wind-driven persistent salt spray; and d) increasing environmental concerns over sustainable protection of surface and subsurface waters and soil quality.

SUSTAINABLE SALINITY MANAGEMENT PLAN

Environmental management challenges are an increasing part of routine management on golf courses. With saline irrigation, salinity joins the list of environmental issues that must be addressed along with: water use efficiency and conservation; fate of pesticides, nutrients, and sediment to protect surface and subsurface water quality; wildlife habitat management; and other issues (3). When salinity is present, it is often the most complex environmental challenge. Each issue requires a sustainable management plan. The most successful or gold-standard sustainable plan for any single environmental issue is the Best Management Practice (BMP) approach, whose characteristics have been summarized by Carrow and Duncan (1). Comprehensive BMPs for all environmental issues on a site become the building blocks that are combined to form the overall sustainable golf management program that encompasses the environment, function, and economic viability of the site (golf), and social concerns.

Carrow and Duncan (2) have developed a comprehensive salinity BMPs plan that includes all the possible management strategies or components that potentially could be used by a golf course superintendent managing a salt-affected site and that can be incorporated into an overall sustainable golf course management program on salt-affected sites. This BMP plan is the basis of this article. Not all sites using saline irrigation water require as vigorous BMPs as necessary for courses using highly saline water, with soils sensitive to structural degradation, or on an environmentally sensitive site, but even sites receiving modest salt levels can exhibit major problems over time if proper and timely management is not practiced. Since salinity is a dynamic set of stresses, a comprehensive salinity BMP plan must be aggressively implemented as a working plan and not a document on the shelf.

Figure 2. Salt accumulation and severe salt-induced drought stress on a fairway due to saline irrigation water and limited leaching. Note better leaching in the trenched area due to better physical conditions.

Figure 3. Salt accumulation and salt-induced drought stress on bermudagrass.

Later in this article, different components (i.e., strategies, options) of a salinity BMP plan will be summarized to provide an overall template or grid for those considering a comprehensive and sustainable salinity management plan. But the essential first step of any BMPs plan is a comprehensive site assessment to obtain the necessary initial information to make informed decisions. Then, possible BMP components can be considered based on site-specific conditions as to whether they are needed or necessary in the final golf course-specific salinity BMP. When evaluating potential components, this assessment should be through the lens of site conditions, current and future playability, economics, environmental stewardship, and social aspects.

SITE ASSESSMENT

Site assessment entails a number of factors that may influence salinity management decisions, including possible infrastructure improvements. Many of the initial site assessment factors also will be used for ongoing monitoring on salt-affected areas. Key information includes:

Soil Physical Conditions: These entail impediments to infiltration, percolation, or drainage, such as calcic, clay, or rock layers; deep-ripping or deep cultivation requirements prior to establishment; future cultivation equipment requirements; surface and subsurface drainage improvements; drainage outlets and salt disposal options; irrigation system efficiency requirements; presence of fluctuating or high water tables; sand-capping needs; pre-plant physical and chemical amendments to improve soil physical conditions; soil texture; clay type; and soil physical analyses of rootzone media, including water-holding capacity. Many of these factors influence salt retention and movement.

Identifying Salt Additions: Salt additions must be known, such as those from irrigation water; a fluctuating high water table; capillary rise from salt-rich subsurface horizons; mixing of salt-laden soil during construction or dredging; fertilizers; drainage onto the site.

Soil Chemical Aspects: Critical soil chemical test information is: a) routine soil test information or normal soil fertility data, and b) salt test information — SAR, ESP, ECe, free calcium carbonate content.

Irrigation Water Quality Assessment: This would include: a complete irrigation water quality analyses; human exposure and plant health aspects, if needed; and considering multiple irrigation water sources — blending, drainage water reuse, volume reliability of each source, stability of each source in terms of constituents over time.

Plant Analysis: On existing turfgrass sites where saline irrigation water has been applied, plant tissue analysis can be useful in determining nutrient levels and possible element stresses.

COMPONENTS OF A SALINITY BMP PLAN

The primary salinity management options (strategies, components) that may be incorporated into a salinity BMP plan are:

Plant Selection: Plant selection includes the appropriate turfgrass species and cultivars, landscape plants, and buffer zone plantings. Salinity tolerance is a primary consideration, along with adaptation to climatic, pest, and site-use stresses (mowing height, traffic). Plants must be able to tolerate the irrigation water salinity level and anticipated soil accumulation levels. Salt-tolerant plants provide the manager sufficient time to make adjustments, but that does not mean that whole ecosystem salt management can be omitted.

Irrigation System Design: Irrigation system design for high uniformity of application and flexibility for site-specific application is very important under saline irrigation because: a) non-uniformity will lead to excessive soil salt accumulation areas; and b) lack of uniformity or flexibility for precise application of water greatly hinders a salinity leaching program. Salinity leaching is the single most important salt management strategy, and this depends on the distribution quality of the irrigation system. An irrigation audit is useful in determining the degree of water application efficiency.

Irrigation Scheduling and Salt Leaching: Irrigation scheduling is important for normal irrigation needs in order to avoid salt accumulation by too little water or excessive leaching, but it is also critical for efficient salt leaching. A number of factors (soil, plant, climatic, irrigation water quality, hydrology, and

irrigation system design) influence an effective maintenance leaching program, but proper scheduling of irrigation is the determining factor in success — i.e., especially proper leaching fraction, timing, and pulse irrigation applications.

Identification of Water and Soil Amendments for the Specific Site Conditions: If appreciable sodium (Na) is present, various water and soil amendments will be required on a periodic and ongoing basis to counteract the adverse effects on soil physical properties by the Na ion. Amendments include a combination of: a) water acidification acids for bicarbonate and carbonate control; b) soil application of calcium (Ca) sources such as gypsum or sulphur + lime to create gypsum; and c) possible addition of organic amendments. There are a host of products marketed for salt-affected sites that range from essential to completely ineffective. Thus, care must be taken to select the materials that are targeted to site-specific needs.

Proper Amendment Application Protocols for Site-Specific Problems: Once amendment selections are made, the appropriate application equipment must be obtained and maintained. Also, rates, timing, and frequency of amendment applications have to be determined, where these are usually dependent on quantity and timing of irrigation water, as well as a number of other factors that make amendment needs variable over time. Blending of irrigation water sources will influence amendment requirements.

Cultivation, Topdressing, and Soil Modification: Maintenance of water infiltration, percolation, and drainage, as well as good soil aeration, is essential to maximize salt leaching and to compensate for Na deterioration of soil structure. Creation of macropores for good water movement and aeration requires the combination of cultivation, topdressing, and soil modification on selected areas. Cultivation operations are often twice as frequent compared to non-salt-affected sites, and both surface and subsurface cultivation devices are necessary. Equipment capable of injecting sand, gypsum, or pelletized organic matter as part of cultivation operations are normally required. Aggressive topdressing to create a surface sand layer up to three inches is common on fine-textured soils to allow better surface conditions for infiltration and to reduce surface soil compaction or structure degradation.

Figure 4. Saline (whitish salt deposits) and sodic (black area) conditions from saline and sodic irrigation water. If this continues, the result will be what is shown in Figure 5 — i.e., sodic scald areas.

Drainage and Sand-Capping: Surface and subsurface drainage techniques are very important for salt management by salt removal and to control undesirable salt movement. If water cannot move through the soil, neither can salts. For high-clay-content soils that contain highly expansive clay types, sand-capping for 3 to 12 inches depth may be necessary, especially with irrigation water that contains high total soluble salts and appreciable Na.

Nutritional Practices on Saline and Sodic Sites: Nutritional challenges, potential shoot or root toxic ions, and specific problem ions are part of the overall salinity stress. Golf courses that receive saline irrigation water will exhibit much more complex and dynamic soil fertility and plant nutrition conditions in response to the combination of: high levels of nutrient and ion constituents in the water; variability of quality of irrigation water applied over the year; irrigation water and soil amendment applications; and leaching programs. Proactive monitoring of soil, water, and plant nutritional status is important. Careful selection of fertilizers based on detailed fully disclosed label information is required to properly offset the ongoing nutritional stresses. Certain nutrients (Ca, Mg, K, Mn, Zn) are especially important due to interactions with Na and other soluble salts or because they are important for activation of salinity tolerance mechanisms in plants.

Additional Cultural Practices: A number of other cultural practices in addition to those previously noted should be considered depending on site-specific conditions. These include:

- Additional management related to environmental stresses (drought, high temperature) and traffic stresses (wear, soil compaction) that are enhanced by total soluble salts or Na accumulation.
- Supplemental amendments that may aid in salinity management on many sites, such as wetting agents, zeolite, cytokinins, Lassenite, and others.

Figure 5. Sodic scald areas that are very high in sodium and total soluble salts. These take several years to remediate and the best approach is preventative measures.

- Green management considerations, such as black layer, grooming and vertical mowing practices, reel mower and rollers, flushing of greens with a perched water table, and other items.
- Defining the role, cautions, and limitations of various organic, inorganic, microbial, and bionutritional products marketed for salt-affected sites. Some key guidelines (2) are: a) Determine the specific reason for the product rather than a general need, such as to improve soil structure. b) Does the current turfgrass ecosystem already produce the product at an ample or higher quantity than the marketed products? c) If the label does not fully disclose the product chemistry and rate, then do not apply. d) Does the product add considerable quantities of micropores to the soil that could retain salts and hinder leaching? e) If a microbial product, does it have potential for photosynthetic activity by the organism that could result in undesirable biomass production in the surface soil zone that inhibits gas and water movement?
- Consider the various additional requirements in the biotic stress x salinity interactions with respect to weeds, predisposition to diseases, insects, and nematodes (2).

Proactive Monitoring of Progress. Progress must be monitored in a proactive fashion to avoid excessive soil accumulation of salts or Na. Many of the techniques used during the initial, benchmark site assessment are applicable to ongoing monitoring. Practical suggestions are:

- The goal is an acceptable and sustainable level of saline and sodic site conditions and not total removal, which is impossible when saline irrigation water is routinely used.
- Over time, some difficult micro-sites will appear that require more vigorous assessment and remediation actions.
- Use sample areas to demonstrate what can be achieved with a more comprehensive management plan.
- Look at the turfgrass shoot and root systems, soil for any indications of Na-induced black layer, soil test by soil depth, or use soil sensors to indicate soil levels and movement.

CONCLUDING COMMENTS

When a BMP template for site assessment and management of saline or sodic golf courses is viewed, it can initially appear daunting. However, salts must be managed or the golf course will not be sustainable. Acquiring sufficient knowledge on salt-affected issues is a starting point. Obtaining the appropriate site assessment information will aid in the decision-making process, especially with respect to grass needs and various infrastructure requirements. Individual salinity BMP components can then be systematically evaluated to define what the final salinity BMP plan will become.

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