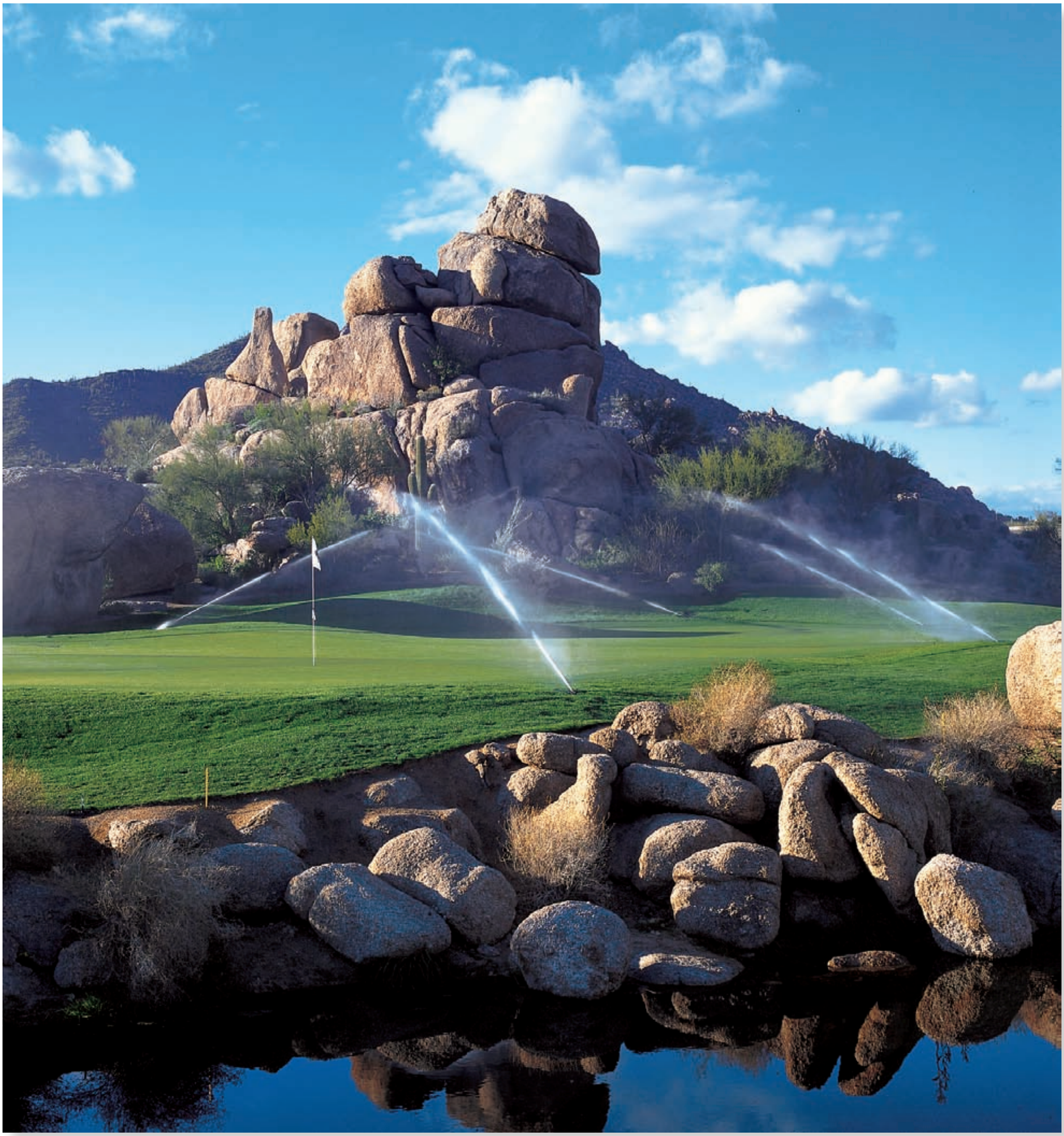
Using Recycled Water On Golf Courses



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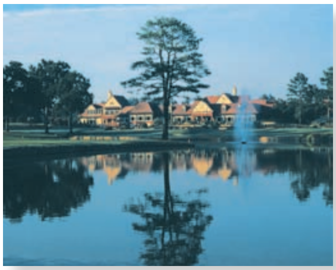
As more restrictions are placed on water use, it becomes increasingly important for superintendents to learn the ins and outs of irrigating with recycled water.



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Environmental Institute for Golf

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GCM golf course management

Editor's note: The Golf Course Superintendents Association of America's (GCSAA) Water Task Group and Environmental Programs Committee commissioned Ali Harivandi, Ph.D., to write this article in order to provide information about the use of recycled water on golf courses and to enhance communication between golf course superintendents and water providers. Dr. Harivandi is recognized as an expert in the use of recycled water on golf courses through his research and teaching contributions over the years.

More and more golf courses across the United States are using recycled water. What was a novel concept 30 years ago is now viewed as a valuable resource that will play a very important role in supplying more golf courses with their water supplies in the future. This is true not only in the arid West and Southwest, but throughout the U.S.

Attitudes toward using recycled water have changed. Although superintendents must be aware of potential agronomic problems associated with irrigating with recycled water, enough information now exists on the use of recycled water in the landscape to dispel many of the social and environmental concerns of the past.

The information supplied here is designed for use by both purveyors of recycled water and superintendents, with the hope that knowledge of both the benefits and potential problems associated with irrigating with recycled water will improve communication and foster cooperation between the two groups. Both providers and users of recycled water benefit from knowing the basics of water quality important to plant growth and the tools necessary for successful golf course management.

Why use recycled water?

For golf courses located in arid regions of the country and in highly populated metropolitan areas where water is a limited natural resource, irrigating with recycled water is a viable means of coping with water shortages and/or rising water costs. Interest in using recycled water for irrigation continues to increase as more and better-quality recycled water becomes available. In recent years, large quantities of recycled water have been used to irrigate agricultural crops, urban landscape sites and golf course properties.

A number of positions favor the use of recycled water on golf courses.

- Recycled municipal water is a reliable source, particularly during drought cycles, when compared with potable domestic, well, river and lake water sources.
- The large expanses of turfgrass grown on golf courses can absorb relatively large amounts of nitrogen and other nutrients often found in recycled water. This characteristic of turfgrass can minimize the chances of groundwater contamination from recycled irrigation water.
- Because recycled water is produced continuously, its use also needs to be continuous. Turfgrass on golf courses, particularly in southern climates, is considered a permanent planting, and irrigation needs are consistent year after year when compared to food crop production where irrigation use is interrupted by cultivation and harvest activities.
- Most golf courses are located in or adjacent to cities where recycled water is produced, thus minimizing transportation costs.
- Recycled water is generally less expensive than water from other sources.
- And finally, superintendents have access to advanced educational materials that allow them to manage most adverse agronomic conditions that may arise from irrigating with recycled water.

Despite sound reasons for using recycled water as a primary irrigation source, golf course operators and designers often view it with mixed feelings. There are legitimate concerns about possible plant injury, potential problems with irrigation systems and variability in water quality even within the same region. However, recognizing potential problems and having a better understanding of the solutions available to address them will allow water providers and users to take a mutually beneficial approach to this valuable resource.

What is recycled water?

Recycled water is any water that has undergone one cycle of human use, and after treatment, is

Along with many other golf courses in the United States, Ventana Canyon Golf & Racquet Club in Tucson, Ariz., irrigates with recycled water. **Photo by W. Dowe**

suitable for limited reuse, including irrigation. Recycled water is also referred to as reclaimed water, wastewater, effluent water, treated effluent water and treated sewage water. In this document, the term *recycled water* will be used.

Recycled water may be primary, secondary or advanced (also called tertiary) treated municipal or industrial wastewater.

- Primary treatment is generally a screening or settling process that removes organic and inorganic solids.
- Secondary treatment is a biological process in which complex organic matter is broken down and metabolized by simple organisms, which are then removed.
- Advanced or tertiary wastewater treatment consists of processes similar to those used to prepare potable water and may include chemical coagulation and flocculation, sedimentation, filtration or adsorption of compounds by a bed of activated charcoal or polymers.

Advanced treatment processes significantly reduce suspended matter and pathogenic organisms potentially present in secondary effluent. However, many "dissolved" solids, including salts, remain and are of concern if water is to be used for irrigation. Reverse osmosis, a highly effective advanced-treatment method, can remove almost all dissolved solids from water. Unfortunately, it is very expensive and thus rarely available. Regardless of the degree of treatment, all recycled water is heavily disinfected by chlorination or other methods before being discharged from the treatment plant.

Seasonal and annual variations in recycled water quality can be significant, and they can harm growing plants. The variation in quality may be caused by any number of unpredictable factors such as increasing volumes of detergents (and thus increases in boron and phosphorous) in the wastewater of a city experiencing rapid growth or the seasonal increase in a specific mineral discharged into the sewage system from a processing plant. Whatever the cause, variability in water quality can lead to problems in the health and growth of turfgrass plants. Regular, seasonal water-quality testing is essential to prepare superintendents to take appropriate remedial action in response to water-quality fluctuations.

Golf course agronomy

Golf courses in the U.S. range in size from 50 to 200 acres, and the average size of a typical 18-hole golf facility is 150 acres. The maintained turf areas average approximately 100 acres, encompassing an average 3 acres of greens, 3 acres

Atlanta Athletic Club's source for irrigation water is no longer the Chattahoochee River but high-quality recycled water from the Cauley Creek treatment plant. **Photo by Mike Klemme/golfoto.com**

The water used to irrigate this loam soil had an EC of 1.48 to 1.77, and the adjusted SAR was 8 to 10, making it impossible for turf to survive in the salt-encrusted soil. **Photo by Mike Huck**

of tees, 30 acres of fairways, 50 acres of roughs, 9 acres of practice areas and 5 acres of other landscape areas. Non-turf areas at golf facilities include water features such as lakes, ponds or streams; natural areas; buildings; parking lots; and golf car paths. Course design today routinely incorporates natural areas or areas that are not maintained to preserve environmental integrity and to reduce maintenance costs.

Turfgrass is the most important asset of a golf course, and the putting greens represent the area with the highest value. Generally, golf courses in the northern half of the U.S. use cool-season turfgrasses, while the southern half of the country uses predominantly warm-season turf species. A large portion of the central U.S. and most of the coastal areas are considered a transitional zone, where a combination of cool- and warm-season grasses may be grown. Warm-season grasses are generally more drought- and salt-tolerant than cool-season grasses, but there is a considerable variation in tolerance to salinity and to drought within both groups.

Almost all golf courses in the U.S. supplement natural precipitation with irrigation. Sources of irrigation water are: potable water, wells, lakes, rivers, canals and recycled water.

Soil-water-plant-salt relationships

Successful irrigation management at a golf course requires regular monitoring of both soil and water chemistry, especially salt content. It also requires knowledge of local soil conditions, primarily soil texture and drainage characteristics and the salinity tolerance of the plants being grown. The goal is to maintain soil salinity at levels that provide adequate growing conditions for the turf so that the turf provides marketable playing conditions.

Salt accumulation in the soil is the most common cause of plant injury from saline irrigation water, but ordinarily a long period of time must pass before salt in the soil actually injures the plants. Various combinations of saline irrigation water, insufficient natural precipitation, inadequate irrigation and poor drainage will increase the likelihood of saline soil conditions.

As a general rule, if the amount of water applied to soil, including irrigation and natural precipitation, exceeds evapotranspiration (which is evaporation of water from the soil surface and transpiration of water through plants), salt movement is downward through the soil profile. Conversely, salts move upward in soils if evapotranspiration exceeds the amount of water applied. In the latter case, salt drawn to the soil surface gradually accumulates to levels that are toxic to plants. The combination of this basic process along with the type of grass grown determines how severe the problem will become and ultimately affects the quality of the playing conditions.

Recycled waters usually contain higher amounts of dissolved salts than other irrigation water sources within a specific geographic region. In some rare cases, however, ground or surface water can be higher in dissolved salts than local recycled water. Depending on local climate — including precipitation and temperature, soil type and type of grass grown — the amount and type of salts delivered to the golf course in recycled water may eventually injure the grass.

Salt injury to plants is more likely to occur when a combination of the following conditions becomes prevalent:

- low annual precipitation
- high average temperature
- heavy clay or slow-draining soils
- cool-season rather than warm-season turfgrasses are grown on the golf course

The severity of problems associated with salt-laden irrigation water can change significantly because of the diverse conditions at different golf courses. The examples below illustrate the variability that can occur when irrigation water with an identical salt content is applied to a variety of golf course sites.

Salinity problems are *less* likely to develop on golf courses:

- with high rainfall and colder climates
- planted with salt-tolerant, warm-season grasses
- built on well-drained, sandy soils.

Salinity problems are *more* likely to develop on golf courses:

- with low rainfall and warm climates
- planted with salt-sensitive cool-season grasses
- built on slow-draining, clay soils.

Agronomic concerns

Plant response to specific elements of water quality has been tested over many years by scientists through research and field experience. These responses have led to the general guidelines presented in Table 1. Because the values presented combine data from a variety of crops and irrigation sources — including but not restricted to recycled water — they should be used only as an indication of the management level usually associated with the parameter studied.

Local soil and climate considerations as well as water-quality characteristics have a major effect on management requirements. In general, as water quality decreases, management options, regardless of location, also decrease. Furthermore, because water-quality parameters can never be evaluated singly or without considering the specific grass, soil conditions and climate, the lines separating the "Degree of the problem" in Table 1 cannot be ironclad.

Salinity

Some soluble salts are nutrients and beneficial to turfgrass growth, whereas others can cause leaf burn and leaf death when present in high concentrations. The rate at which salts accumulate to undesirable levels in a soil depends on their concentration in the irrigation water, the amount of water applied annually, annual precipitation and the soil's physical and chemical characteristics.

Different laboratories use different scales to report water salinity. It may be reported quantitatively as Total Dissolved Solids (TDS) in units of parts per million (ppm) or milligrams per liter (mg/L), or it may be reported as electrical conductivity of water (EC_w) in terms of millimhos per centimeter (mmhos/cm), micromhos per centimeter (µmhos/cm), deciSiemens per meter (dS/m), or Siemens per meter (S/m). Some labs may also report individual components of salinity (for example, sodium) in milliequivalents per liter (meq/L). Soil salinity is reported primarily as electrical conductivity of the soil water extract (EC_e). As indicated in Table 1, irrigation water with salinity EC_w values between 0.7 and 3.0 dS/m (or 450–2,000 ppm), may cause problems without careful management. Recycled water with an EC_w above 3 dS/m (2,000 ppm) is likely to cause salinity problems and should be avoided or diluted with water that is less saline before being used for irrigation.

Soil physical characteristics and drainage are both important factors and must be considered when determining the root zone's ability to handle salinity. For example, water with an EC_w of 1.5 dS/m may be successfully used on grass grown on sandy soil with good drainage and high natural leaching, but it may prove injurious within a very short time if it is used to irrigate the same grass grown on a clay soil or soil that has limited drainage because of salt buildup in the root zone.

The salt tolerance of turfgrasses and other plants is usually expressed in relation to the salt content of the soil. Table 2 provides a general guide to the salt tolerance of individual turfgrasses, based on EC_e values (electrical conductivity of soil water extract).

As indicated, soils with an EC_e below 3 dS/m are considered satisfactory for growing most turfgrasses. Soils with an EC_e between 3 and 10 dS/m can support a few moderately salt-tolerant turfgrass species. Soils with an EC_e higher than 10 dS/m will support only very salt-tolerant grasses.

Sodium

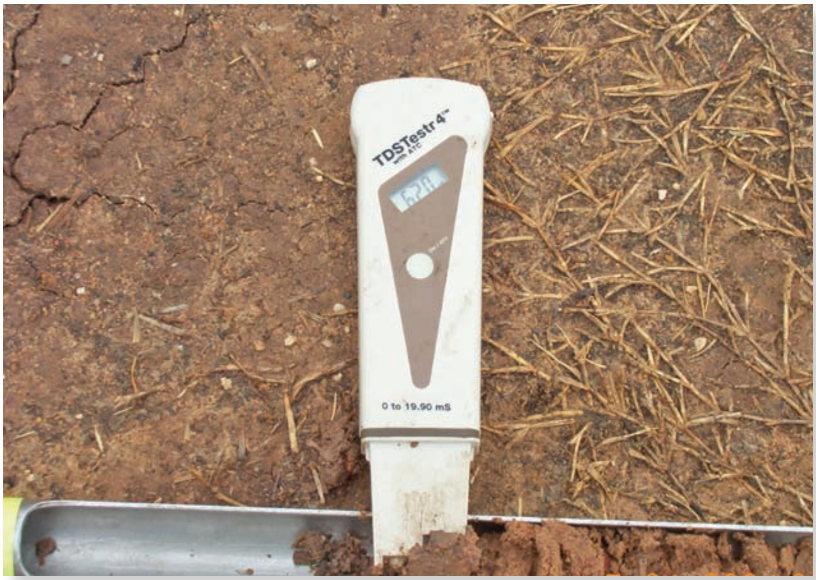
Plant roots absorb sodium and transport it to leaves, where it can accumulate to injurious levels. Symptoms of sodium toxicity resemble those of salt burn on leaves. Recycled irrigation water with high levels of sodium salts can be particularly toxic if it is applied to plants with an overhead sprinkler, because sodium can be absorbed directly by leaves.

Sodium toxicity is often of more concern on plants other than turfgrasses, primarily because accumulated sodium is removed from turfgrasses every time the grass is mowed. On golf courses, annual bluegrass and creeping bentgrass on putting greens are most susceptible to sodium toxicity. Mowing may not provide sufficient protection for

Interpreting water quality

Potential irrigation problem	Unit of measure	Degree of problem: Negligible	Slight to moderate	Severe
Salinity				
Electrical Conductivity (EC_w)	deciSiemens/meter or millimhos/centimeter	<0.7	0.7-3.0	>3.0
Total Dissolved Solids (TDS)	milligrams/liter or parts/million (ppm)	<450	450-2,000	>2,000
Soil water infiltration (evaluate using EC_w [dS/m] and SAR together)				
If SAR = 0-3 & EC_w =		>0.7	0.7-0.2	<0.2
If SAR = 3-6 & EC_w =		>1.2	1.2-0.3	<0.3
If SAR = 6-12 & EC_w =		>1.9	1.9-0.5	<0.5
If SAR = 12-20 & EC_w =		>2.9	2.9-1.3	<1.3
If SAR = 20-40 & EC_w =		>5.0	5.0-2.9	<2.9
Specific ion toxicity				
Sodium (Na)				
Root absorption	sodium adsorption ratio (SAR)	<3	3-9	>9
Foliar absorption	milliequivalents/liter	<3	>3	—
	milligrams/liter	<70	>70	—
Chloride (Cl)				
Root absorption	milliequivalents/liter	<2	2-10	>10
	milligrams/liter	<70	70-355	>355
Foliar absorption	milliequivalents/liter	<3	>3	—
	milligrams/liter	<100	>100	—
Boron (B)	milligrams/liter	<1.0	1.0-2.0	>2.0
Miscellaneous effects				
Bicarbonate (HCO_3)	milliequivalents/liter	<1.5	1.5-8.5	>8.5
(unsightly foliar deposits)	milligrams/liter	<90	90-500	>500
pH		common range	6.5-8.4	
Residual chlorine (Cl_2)	milligrams/liter	<1.0	1-5	>5
Note. This table was adapted from previously published information (1,4).				

Table 1. Guidelines for the interpretation of water quality for golf course irrigation.



The salinity of this Texas loam soil was measured in the field. The 6.2 soil EC reading on the meter equals approximately 17.5 deciSeimens/meter (11,200 ppm TDS) according to a lab test with the saturated paste method. **Photo by Mike Huck**

these grasses, because they are generally stressed by being cut very short and because sodium accumulation will affect a large portion of the remaining leaf tissue.

Table 1 provides general guidelines for assessing the effect of sodium in irrigation water. As indicated, the level of sodium tolerated by non-turf plants varies with the method of irrigation application. Most landscape plants will tolerate up to 70 ppm sodium when irrigated by overhead sprinkler.

SAR (sodium adsorption ratio)

Although sodium can be directly toxic to plants, its most common deleterious effects on plant growth are indirect. Sodium primarily affects soil structure, which directly affects drainage and the rooting environment for turf (Table 1). The *sodium adsorption ratio* (SAR) is the best indicator of the potential sodium effect of recycled water. The sodium adsorption ratio is the proportion of sodium compared to calcium and magnesium present in the water and should be provided in all laboratory water analyses. In general, water with a sodium adsorption ratio value below 3 is considered safe for turf and other ornamental plants.

The high sodium content common to recycled water can cause deflocculation or breakdown of soil clay particles, reducing soil aeration, water infiltration and percolation. In other words, soil permeability is reduced by using recycled irrigation water with a high sodium adsorption ratio. Generally, recycled water with a sodium adsorption ratio above 9 can cause severe permeability problems when applied to fine-textured soils such as clay over a period of time. In coarse-textured soils like those with high sand content, permeability problems are less severe, and a sodium adsorption ratio value of this magnitude may be tolerated, as long as adequate drainage is provided.

For recycled water high in salts and bicarbonate, some laboratories “adjust” the calculation of the sodium adsorption ratio, which yields a number called “adjusted SAR” or “Adj. SAR.” In simplest terms, the adjusted sodium adsorption ratio reflects the water content of calcium, magnesium, sodium and bicarbonate, as well as the water’s total salinity.

Interaction of salinity and SAR

The likely effect of irrigation water on soil permeability is best gauged by its sodium adsorption ratio in combination with its EC_w. Because salts and sodium do not act independently, the effect of sodium on soil particle dispersion and therefore permeability is counteracted by high concentrations of electrolytes or soluble salts. Therefore, the water’s sodium hazard cannot be assessed independently of its salinity. The combined effect of water EC_w and sodium adsorption ratio on soil permeability is given in Table 1. Note that the table provides general guidelines only. Soil properties,

Tolerance to soil salinity

Sensitive (<3 dS/m)	Moderately sensitive (3-6 dS/m)	Moderately tolerant (6-10 dS/m)	Tolerant (>10 dS/m)
Annual bluegrass	Annual ryegrass	Perennial ryegrass	Alkaligrass
Bahiagrass	Buffalograss	Creeping bentgrass (Mariner and Seaside cultivars)	Bermudagrass
Carpetgrass	Creeping bentgrass	Course-leaf (*Japonica* type) zoysiagrasses	Fine-leaf (*Matrella* type) zoysiagrasses
Centipedegrass	Slender creeping, red and chewings fescues	Tall fescue	Saltgrass
Colonial bentgrass			Seashore paspalum
Hard fescue			St. Augustinegrass
Kentucky bluegrass			
Rough bluegrass			
Note. The information in this table was previously published elsewhere (2,3).			

Table 2. Relative tolerances of turfgrass species to soil salinity EC_e (electrical conductivity of soil water extract).

irrigation management, climate, a plant's natural salt tolerance and cultural practices all interact to affect the behavior of soils and plant growth.

Bicarbonate and carbonate

Recycled water may contain excessive bicarbonate levels. High bicarbonate levels in irrigation water can increase soil pH. In addition, bicarbonate content may become obvious during hot, dry periods in arid climates, when evaporation causes white lime (calcium carbonate, $CaCO_3$) deposits to appear on leaves of plants irrigated by overhead sprinklers.

Although high levels of bicarbonate in water can raise soil pH to undesirable levels, the potential negative impact of bicarbonate on soil permeability is more of a concern. When bicarbonate is present in water in greater amounts than the sum of calcium and magnesium present in water, bicarbonate combines with calcium and/or magnesium in soil and precipitates as calcium carbonate and/or magnesium carbonate. This will increase the sodium adsorption ratio of the soil.

The bicarbonate hazard of recycled water may be expressed and reported as Residual Sodium Carbonate (RSC). Residual sodium carbonate is calculated and expressed in milliequivalents/liter by adding the amount of bicarbonate and carbonate in the water and then subtracting the sum of the amount of calcium and magnesium in the water. Recycled water with a residual sodium carbonate value of 1.25 milliequivalents/liter or lower is safe for irrigation. Water with residual sodium carbonate between 1.25 and 2.5 milliequivalents/liter is marginal, and water with residual sodium carbonate of 2.5 milliequivalents/liter and above is probably not suitable for irrigation in most cases. Water-acidification systems at the golf course can help reduce the residual sodium carbonate.

pH (hydrogen ion activity)

The degree of acidity or alkalinity in the water is the pH, which is measured in pH units. The scale ranges from 0 to 14, with pH 7 representing neutral, that is, neither acidic nor alkaline. Values from pH 7 to pH 0 indicate increasing acidity, and values from pH 7 to pH 14 indicate that the water is increasingly basic or alkaline. Although the pH of the water is seldom a problem in itself, a very high or low pH warns a user to evaluate irrigation water for other chemical constituents. The desirable soil pH for most turfgrass is 5.5 to 7.0. The pH of most irrigation waters, however, ranges from 6.5 to 8.4. (Table 1).

Chloride

In addition to contributing to the total soluble salt concentration of irrigation water, chloride may be directly toxic to plants grown on a golf course. Although chloride is not particularly toxic to turfgrasses, many trees, shrubs and ground covers are sensitive to chloride.

A regular schedule of soil and water testing helps superintendents maintain high-quality turf while irrigating with recycled water. **Photo courtesy of MDS Harris Labs**

Chloride is absorbed by plant roots and translocated to leaves, where it accumulates. In sensitive plant species, this accumulation leads to symptoms such as scorched leaf tips or necrosis. In severe situations, chloride can kill the leaf. Similar symptoms may occur on sensitive plants if overhead sprinklers apply water high in chloride, because leaves also can absorb chloride.

As indicated in Table 1, recycled irrigation water with a chloride content higher than 355 ppm is toxic when absorbed by roots, and water with a chloride content higher than 100 ppm can damage sensitive ornamental plants if it is applied to foliage.

Chlorine

Recycled water may contain excessive residual chlorine, a potential plant toxin. Chlorine toxicity is only associated with recycled waters that have been disinfected with chlorine-containing compounds. Chlorine toxicity will occur only if high levels of chlorine are applied directly onto foliage, a situation that is likely to occur where recycled water goes straight from a treatment plant to an overhead irrigation system.

Free chlorine is very unstable in water, and it will dissipate rapidly in water stored for even a short period between treatment and application to plants. In addition, golf course irrigation heads generally project a large volume of water high into the air and over relatively long distances, allowing sufficient exposure of the water to the air to dissipate the chlorine. Accordingly, chlorine toxicity is rare on golf courses. Nevertheless, as indicated in Table 1, residual chlorine is of concern at levels above 5 ppm.

Boron

Boron is a micronutrient essential for plant growth, though it is required in only very small

Atlanta Athletic Club
Photo by Mike Klemme/golfoto.com

amounts. At concentrations as low as 1 to 2 milligrams/liter in irrigation water, it is toxic to most ornamental plants and capable of causing leaf burn (Table 1). Injury is most obvious as necrosis on the margins of older leaves. Turfgrasses are generally more tolerant of boron than other plants grown on a golf course. Most turfgrass species may tolerate soils with boron levels as high as 10 ppm.

Nutrients

Recycled water generally provides a range of micro or trace elements for most turfgrass species. Frequently, they may contain enough macro or major nutrients, such as nitrogen, phosphorus and potassium, to figure significantly in the fertilization program for the golf course. The economic value of these nutrients can be substantial. Even where the quantities of nutrients are low in the recycled water, plants use the nutrients very efficiently. However, in some cases, such constant nutrient (especially nitrogen) availability makes it difficult to control turfgrass growth and maintain a proper fertility program. For example, excess nitrogen applied to cool-season grasses during hot, dry summer months (that is, during peak water use) or to warm-season grasses after overseeding with cool-season grass in the fall, can cause excess succulent growth that makes the turfgrass more susceptible to pathogens or environmental and traffic stress. As a consequence, the application of plant growth regulators may be required, and additional cultural practices such as mowing and dethatching may be needed on a more frequent basis.

Most laboratories test recycled water for nutrient content and often report nutrients in "lb./acre ft. (pounds/acre-feet) of water applied."

Suspended solids

Suspended solids in irrigation water refers to inorganic particles such as clay, silt and other soil constituents, as well as organic matter such as plant material, algae, bacteria, etc. The amount of suspended solids in most tertiary-treated recycled water is negligible and not a cause for concern. However, suspended solids can be a problem in secondary-treated water and must be removed by filtration. Filtration will help prevent sprinkler heads and valves from becoming plugged with debris and optimizes the efficiency and lifespan of the irrigation system.

In addition to the mechanical problems they cause, suspended solids and algae can seal a soil surface, especially on sand-based putting greens and bunkers. Filling air spaces between sand particles reduces infiltration and drainage and increases compaction. Because the effects of suspended solids in recycled water vary considerably, it is difficult to formulate acceptable values for suspended solids in irrigation water. The complexity and variability of irrigation waters and systems make filtration the most sensible approach to controlling the potential hazards of suspended solids in recycled water.

Irrigation system issues

Water storage facilities

Many recycled water contracts require the user to take a specified amount of water each day regardless of the season or weather. This means that large amounts of recycled water must be stored during periods of the year when the turf requires very limited to no supplemental irrigation. Primarily located in northern climates, storage facilities must be built to store the recycled water delivered to the golf course each day over a period of several months.

If recycled water cannot be stored in existing lakes on the course, additional storage facilities may be required. Covered storage tanks or ponds with liners are options. Storage facilities for recycled water require a high level of maintenance. Generally, storage tanks require less maintenance than lakes because the absence of light eliminates algal growth, particularly if the stored water has only received secondary treatment. However, because the settling of suspended matter is a problem in tanks, storage tanks must be periodically emptied and cleaned.

The initial cost of constructing storage lakes with liners may be less than that of installing covered tanks, yet the maintenance cost of the lakes is generally higher. Because storage lakes have elevated levels of nutrients such as nitrogen and phosphorus, algae and weed growth is a constant problem. Such growth can cause major problems when the water is introduced into an irrigation system. Substantial labor and maintenance are often needed to keep pond water clean and suitable for irrigation. Therefore, the cost of maintaining a storage pond for recycled water could be substantially higher than maintenance costs for

In the late 1990s, the city of Scottsdale, Ariz., mandated that Troon G&CC and other courses in the city begin irrigating with recycled water. **Photo by Mike Klemme/golfoto.com**

a pond of potable water. Local laws may require the use of liners for lakes converted for storage of recycled water to prevent potential groundwater contamination.

Labeling, tagging and painting

On new golf courses, purple irrigation system components generally signify and warn unsuspecting users of the presence of recycled water. On existing golf courses, all buried components of the existing irrigation system are often exempted from the color coding requirements. Generally, a golf course will be required to label all visible irrigation system components with purple tape, tags, paint, etc.

Irrigation water filtration

The potential presence of suspended solids in recycled water, especially secondary-treated water, makes a dependable filtration system essential. If recycled water is stored in ponds, the presence of an algal bloom will require a high-quality filtration system. Without effective filtration, algae and other suspended matter may plug irrigation nozzles, reducing the efficiency and uniformity of the irrigation system. Additional labor will be needed to continually unplug heads. Subsequently, without adequate filtration, the fine, suspended particles delivered in secondary-treated recycled water may plug pore spaces in the root zone of sand-based golf greens, impeding both drainage and leaching. These costly problems can be avoided by investing in an effective and well-maintained filtration system.

Adjacent properties

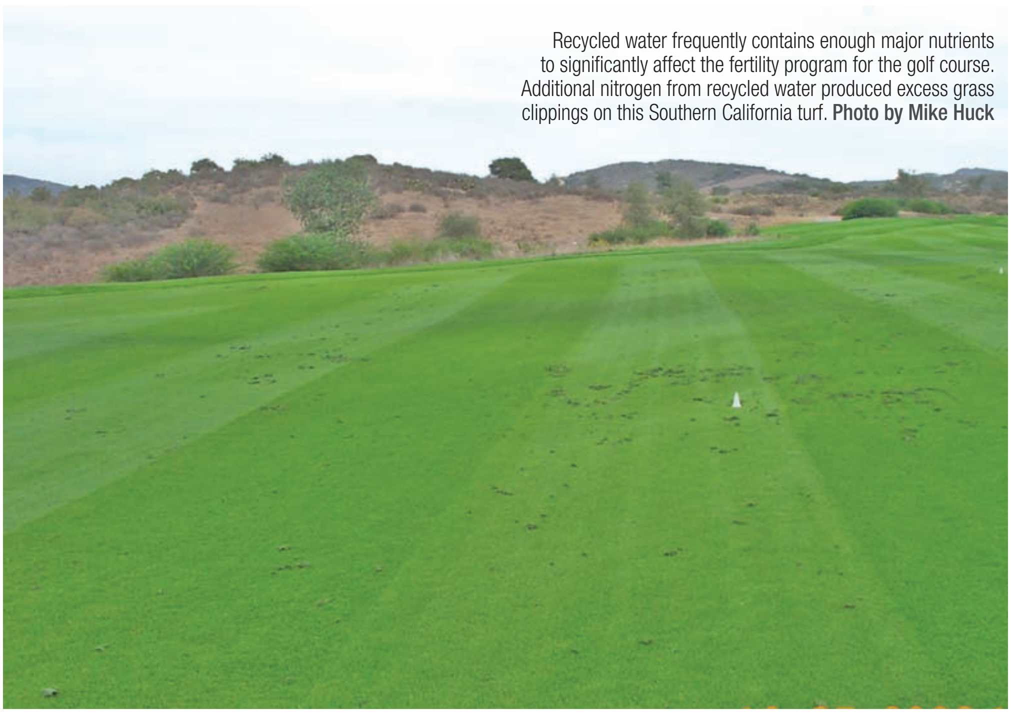
Depending on local regulations, golf courses irrigated with recycled water may be required to protect adjacent properties from runoff or overspray from their irrigation. Compliance with such regulations may mean redesigning the irrigation system to allow irrigation of the perimeter with a source other than recycled water.

Management strategies

When water salinity, sodium and other chemical components are potential problems, the following management practices should be considered.

Drainage

In all cases, good drainage is most essential. Drainage can be improved by installing tile drains, modifying root zones on putting greens and implementing a vigorous aerification program.



Recycled water frequently contains enough major nutrients to significantly affect the fertility program for the golf course. Additional nitrogen from recycled water produced excess grass clippings on this Southern California turf. **Photo by Mike Huck**

Resources

Additional information related to recycled water irrigation is available in the scientific and popular press. The following organizations can provide access to much of this information via print media and the Internet as well as through workshops and educational activities throughout the country.

GCSAA
1421 Research Park Drive
Lawrence, KS 66049
800-472-7878 phone
www.gcsaa.org

TGIF (Turfgrass Information File)
Michigan State University
http://turf.lib.msu.edu

United States Golf Association
P.O. Box 708
Far Hills, NJ 07931
908-234-2300 phone
www.usga.org

WateReuse Association
Alexandria, VA
703-548-0880 phone
www.watereuse.org

Storage lakes on the golf course are often used to store recycled water when the course cannot use the daily water allotment it is required to accept.
Photo by W. Dowe

The research says

- ➔ Recycled municipal water is a relatively inexpensive, reliable, continuous source of irrigation water for golf courses, which have large expanses of turf that can absorb relatively large amounts of nitrogen and other nutrients often found in recycled water.
- ➔ Regular, seasonal monitoring of soil and water chemistry is essential so that superintendents can take appropriate remedial action in response to water-quality fluctuations.
- ➔ Because facilities often must accept recycled water on a continuous basis, golf courses must be prepared to store large amounts of recycled water in storage lakes or tanks.
- ➔ A high-quality filtration system is required to protect an irrigation system that uses recycled water, and irrigation components using recycled water must be labeled appropriately.
- ➔ Management strategies include: providing good drainage, blending poor-quality water with higher-quality water, leaching excess salts from the root zone, applying soil and water amendments, modifying the soil profile to improve water percolation, and installing artificial drainage as necessary.

Plantings

Plant salt-tolerant grass species and other landscape plants.

Blending

Blend poor-quality water with less-salty, higher-quality water. Frequently, poor-quality water can be used for irrigation if better-quality water is also available. The two waters can be pumped into a reservoir to mix before irrigation. Although the resulting salinity will vary according to the type of salts present and climatic conditions, water quality should improve in proportion to the mixing ratio. For example, when equal volumes of two waters, one with an EC_w of 1 dS/m and the other with an EC_w of 5 dS/m are mixed, the salinity of the blend should be approximately 3 dS/m.

Leaching

Apply extra water to leach excess salts. This extra irrigation water, which is needed to leach salts below the turfgrass root zone and to prevent salt building up to toxic levels, is referred to as the *leaching requirement/fraction.* A leaching requirement is based on the recycled water's salt content and the salt-tolerance levels of the grass at the site. Successful leaching requires adequate drainage. Any changes in the system's input, such as leaching caused by rainfall, can greatly affect the amount of water needed for successful leaching.

Amendments

Apply soil and water amendments such as gypsum (calcium sulfate), calcium chloride, sulfur and sulfuric or N-phuric acids. These amendments increase the soil supply of calcium either directly, as in the case of gypsum and calcium chloride, or indirectly, as in the case of sulfur and sulfuric or N-phuric acids.

Sulfur and sulfur-containing fertilizers applied to soils naturally high in calcium may make calcium more soluble. Once available, the calcium can then replace sodium on clay particles, and prevent excess sodium accumulation. Subsequent leaching will flush sodium salts out of the root zone. The amount of sulfur amendment required depends on the soil's sodium content, sodium adsorption ratio of the irrigation water, the quantity of water applied, soil texture and type of amendment.

Bicarbonate

Reduce the damaging effects of the water's bicarbonate content with amendments. The impact of bicarbonate on pH may be reduced by applying an acidifying fertilizer such as ammonium sulfate as part of a regular turf fertilization program, or by acidification of the irrigation water.

Acidification

In some cases, water with a high residual sodium carbonate value may require more drastic measures, such as acidification of the water with sulfuric, N-phuric acid (a type of urea-sulfuric acid), or phosphoric acids, or by using a sulfur burner. Acidification of water, using either acid injection or a sulfur burner, is a specialized procedure, requiring unique measurements and equipment. A superintendent must work closely with a consulting laboratory to determine whether acidification is required and, if it is, how it may best be accomplished.

Water percolation

If a hard or clay pan is present, modify the soil profile to improve water percolation and, thus, leaching. If the soil has become difficult to wet or water-repellent, using a surfactant (wetting agent) can improve uniformity of wetting and therefore leaching.

Artificial drainage

If shallow water tables are a problem, or the soil does not drain well for any reason, install artificial drainage. Leaching does not occur without drainage.

Conclusions

Recycled water is an increasingly attractive alternative to the often high-priced, limited supply of potable water available for irrigating golf courses. Depending on recycled water quality, irrigation with such water is often better tolerated by turfgrasses than by other landscape plants. Golf courses, with their large expanses of turf and their educated and trained maintenance staffs are particularly well-suited to incorporate recycled water in their irrigation programs. Good communication among golf course operators, knowledgeable recycled water purveyors and local regulators is of utmost importance in increasing the use of this valuable resource.

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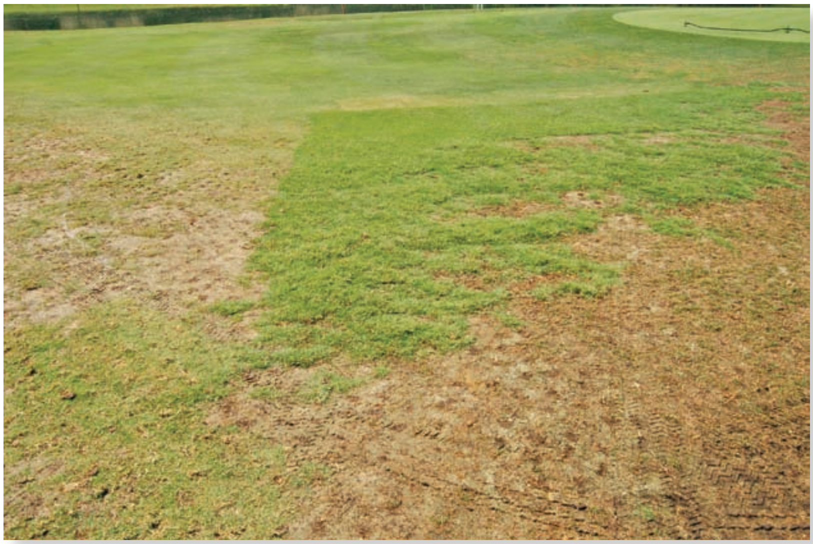
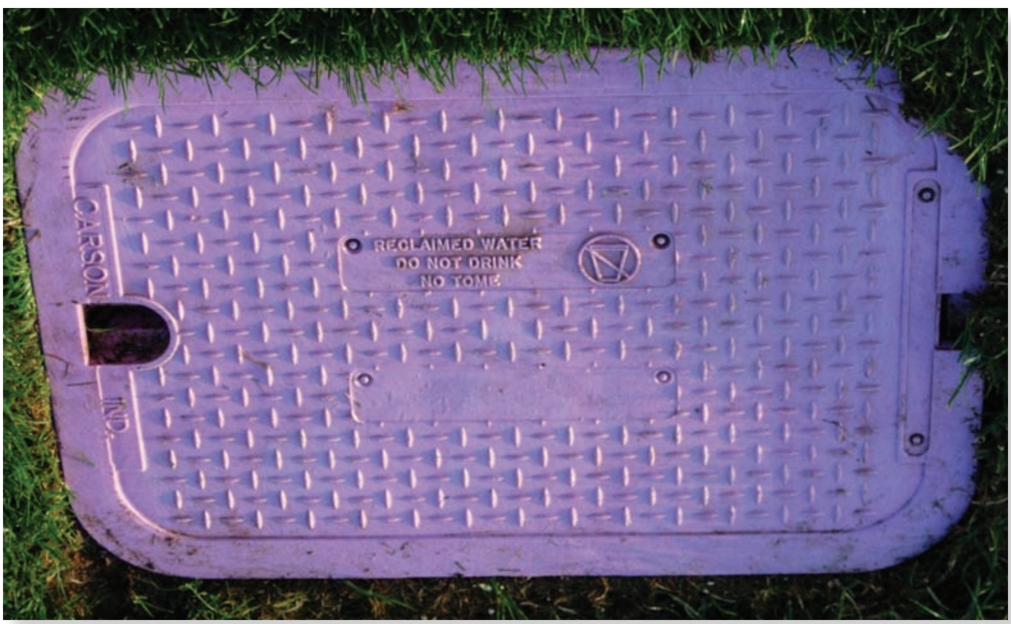


This soil was irrigated with recycled water that was high in salts, and poor drainage compounded the problems caused by the poor-quality water. When the original bermudagrass failed to thrive, some paspalum (center of photo) was sodded into the middle of the area, but the paspalum failed as well. **Photo by Larry Stowell, PACE Turfgrass Research Institute**



Golf courses that use recycled water are generally required to label all visible irrigation system components with purple tape, tags or paint to indicate that the water is recycled and not potable. **Photo by W. Dowe**

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