Issues in the Use of Reclaimed Water on Golf Courses

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Bottom line: Production of reclaimed water is a popular approach for conserving one of our most important resources. With growing supplies now available, pressure on golf courses to accept reclaimed water is increasing. But because reclaimed water usually contains higher levels of dissolved salts than typical domestic water sources, its use can result in damage to plants and soil. A variety of agronomic and business strategies can mitigate the negative effects of reclaimed water, but in extreme cases, a change to more salt tolerant turf varieties is the only feasible approach.

Reclaimed water and dissolved salts

Dissolved salts (including sodium, chlorine, boron, bicarbonate, sulfate, calcium, potassium, magnesium, etc.) that are present in irrigation water ultimately end up in the soil. If they are allowed to accumulate to high levels in the soil, serious damage to turf and other plants, as well as to the soil itself will occur. In many regions, the struggle to avoid damage from excessive dissolved salts in the soil is one of the primary challenges that golf course superintendents face. The problem is exacerbated when reclaimed water is used to irrigate golf course fairways. This is because the reclamation process does not remove all of the dissolved salts that are added to the water during its first use by the community, resulting in about a 10% increase in total dissolved salts (Pettygrove and Asano, 1984). As a result, reclaimed water usually is of inferior quality to the domestic water source that it replaces (Table 1).

Table 1. Comparison between average domestic water and reclaimed water quality from sources used at several Southern California golf courses. Electrical conductivity (EC) is reported in dS/m. Bicarbonate (HCO3), boron (B), chloride (Cl), and sodium (Na) are reported in parts per million (ppm, mg/l). SAR and SARadj are ratios that are reported without units of measure. Red shading indicates that reclaimed water exceeds recommended guidelines (see table 5). Yellow shading indicates the value is within 10%, and green shading that the value falls within, recommended guidelines. Note the dramatic differences in reclaimed water quality from different sources.

Factor	Average Domestic	Big Canyon	Dove Canyon	Laguna Hills	Bear Creek	El Niguel	Oakmont
EC (dS/m)	0.8	1.6	1.0	1.2	1.0	1.6	1.1
SAR	1.9	5.3	2.8	3.6	4.6	3.7	3.4
SARadj	3.4	11.2	5.3	6.1	7.5	6.6	6.12
HCO3	173.8	243	134	125	156	134	203
B	0.17	0.52	0.26	0.41	0.62	0.42	0.64
Cl	81.7	244	122	228	158	211	106
Na	70.0	194	112	151	147	168	115

Figure 1. Dove Canyon Country Club (photo on left) where reclaimed water severely damaged bentgrass fairways, despite a variety of management practices that were implemented to reverse this trend. To correct the problem, the turfgrass variety was changed to a more salt tolerant hybrid bermudagrass that now thrives under the same water and soil conditions. At El Niguel Country Club (photo on right), the kikuyugrass fairways could not tolerate the high soil salinity levels due to low quality reclaimed water. The fairway was converted to a salt tolerant paspalum and is also now thriving.

Reclaimed water: is it all bad?

The statement, "everything is relative" applies well when conducting an evaluation of reclaimed water. Although reclaimed water is usually of inferior quality compared to the domestic source, at some golf courses, the quality of well water is so low that reclaimed water can represent an improvement (Table 2). For this reason, each situation should be evaluated on a case-by-case basis.

Table 2. Comparison between domestic and well water sources used at several golf courses in Southern California. Note the dramatic differences in reclaimed water quality from different sources. Electrical conductivity (EC) is reported in dS/m. Bicarbonate (HCO3), boron (B), chloride (Cl), and sodium (Na) are reported in parts per million (ppm, mg/l). SAR and SARadj are ratios that are reported without units of measure. Red shading indicates that reclaimed water exceeds recommended guidelines (see table 5). Yellow shading indicates the value is within 10%, and green shading that the value falls within, recommended guidelines.

Factor	Average Domestic	Fairbanks Ranch	Vista Valley	San Diego	Arrowhead	Friendly Hills	Oakmont
EC (dS/m)	0.8	2.8	2.8	4.0	0.5	0.7	0.9
SAR	1.9	3.2	2.8	5.2	0.8	1.2	1.6
SARadj	3.4	8.2	6.7	13.3	1.4	2.4	3.1
HCO3	173.8	366.1	389.5	363.9	189.5	244.1	185.4
B	0.17	0.05	0.21	0.41	0.15	0.13	0.13
Cl	81.7	322.7	609.3	1004.2	9.8	59.6	73.2
Na	70.0	195.0	194.8	406.5	24.6	44.4	65.3

The role of increased water volumes in dealing with reclaimed water

To prevent accumulation of salts to plant and soil damaging levels, irrigation volumes must be sufficient to move the salts from the surface of the soil to deeper in the soil profile. If you have bermudagrass fairways, it is relatively easy to calculate how much additional water you will need to prevent soil salt accumulation from exceeding the limits for bermudagrass.

1. Compare the total dissolved salts (TDS) content of your current domestic water source to that of the proposed reclaimed water source.
2. For every increase of 640 ppm TDS (640 ppm TDS is equivalent to 1 dS/m of electrical conductivity, or EC), you will need an approximate increase of 12.5% in water volume applied, in order to move the dissolved salts beyond the root zone.

In other words, if your current water source has a TDS of 320 ppm and the reclaimed water source has a TDS of 960 ppm (an increase of 640 ppm or 1 dS/m), you will need to use 12.5% more reclaimed water than you currently use to prevent accumulation of salts to turf damaging levels. An increase in water volume will also have the undesirable effect of producing more wet spots and bare areas – something you will need to prepare yourselves and your membership for.

In addition to helping you determine how current agronomic practices might change when reclaimed water is used, the formula above can also help you estimate the economic costs of reclaimed water. The cost of reclaimed water is frequently coupled to current domestic water costs, with a discount of about 15%. In the example above, where a 12.5% increase in water is required, you would therefore only be saving 2.5% (15% - 12.5%) of the current cost of water. The "discount" offered on reclaimed water therefore needs to be closely examined, especially since hidden costs, in the form of additional inputs (more aggressive and expensive soil management and irrigation practices, for example) are typically required to help relieve the problems associated with reclaimed water.

Water management guidelines

- Implement a periodic irrigation distribution monitoring program to insure that optimum distribution is maintained at the course (greater than 80% DU).
- Implement a leaching fraction for all areas where the reclaimed water is used to prevent accumulation of salts to turf damaging levels. Increase this value in areas where uniformity is inadequate and salts are accumulating.
- Install a water flow meter on one fairway to enable an accurate leaching fraction calculation to be derived from the weather station ET data and actual water applied to the fairway. This baseline leaching fraction will help determine if the recommended leaching fraction is being applied.
- If negative trends in soil chemistry (electrical conductivity, percent extractable sodium, boron or other factors) are observed, increased leaching will be needed. These effects may not be observed

until up to three to five years have passed, depending upon annual rainfall conditions.

- The water district should provide access to daily, weekly and monthly summary values for water quality indicators. Of particular interest are water electrical conductivity, sodium, chloride and boron levels. Independent water testing may be conducted by the golf courses for more complete periodic evaluations of the reclaimed water. The guidelines in Table 3, with special attention paid to the "Recommended Maximum" values, should be of use, both in negotiating your contract as well as tracking trends in water quality.

Soil sampling program guidelines

- Implement an annual aerial photography program to aid in identification of turf "hot-spots" and declining trees. Photographs should be obtained in August when turfgrass stress is at its maximum.
- Initiate an annual soil sampling and laboratory analysis program that entails collecting pairs of samples from 10 fairways that represent good performing turf and poor performing turf as identified in aerial photographs. Parameters to be measured and maintained in a data base include: salinity, pH, organic matter, sulfur, exchangeable Ca-Mg-K-Na, Bray II phosphorous, manganese, zinc, boron, copper, iron and aluminum.
- Monitor soil salinity using a TDS-4 EC meter (or equivalent) in-house using golf course personnel during the growing season. Apply leaching irrigation to prevent accumulation of salts above an EC of 8 dS/m, or when turf stress can be linked to elevated salinity. This will require adjustment of the irrigation system and also use of manually placed sprinklers where needed throughout the course.

Table 3. Comparison of water quality parameters. Desired range is a compilation from values published in the scientific literature and experience at PACE Consulting. The average domestic and reclaimed values were compiled from the PACE soil and water database for golf courses. Values shaded in green indicate that values fall within desired ranges, yellow shading that the value is within 10%, and red shading that the value exceeds the desired range. The "Recommended Maximum" column suggests values to be used in contractual limits for use on sand based bermudagrass fairways. While these limits do not insure that the water may be used in a sustainable fashion for turfgrass irrigation, they will prevent the reclaimed water quality from exceeding reasonable guidelines and will reduce the hidden costs of using reclaimed water. Reclaimed water values that fall within these guidelines may still not provide a high quality golfing experience.

Parameter	Desired range	Average Domestic	Average Reclaimed	**Recommended Maximum**
Electrical Conductivity EC (dS/m)	< 1.2	0.8	1.1	**1.5**
Sodium Absorption Ratio SAR	< 6.0	1.9	3.1	**5.7**
Adjusted SAR	<11	3.4	5.7	**11.6**
Bicarbonate HCO3 (ppm)	<90 (1.5 meq/l)	173.8	194.4	**250.0**
Boron B (ppm)	<0.50	0.17	0.44	**0.50**
Chloride Cl (ppm)	<100 (2.8 meq/l)	81.7	129.6	**250.0**
Sodium Na (ppm)	<160 (7 meq/l)	70.0	114.2	**200.0**
pH	6.5 - 8.4	7.7	7.1	
Total Dissolved Salts TDS (ppm)	<768	616.7	729.2	
Calcium Ca (ppm)	<100 (5.0 meq/l)	67.3	63.9	
Magnesium Mg (ppm)	<40 (3.0 meq/l)	24.4	22.9	
Potassium K (ppm)	<160 (4.1 meq/l)	3.9	25.5	
Carbonate CO3 (ppm)	<50	2.7	0.0	
Sulfate SO4 (ppm)	<200 (4.2 meq/l)	171.3	196.0	
Iron Fe (ppm)	<0.30	0.16	0.20	
Manganese Mn (ppm)	<0.15	0.01	0.03	
Copper Cu (ppm)	<0.05	0.04	0.03	
Zinc Zn (ppm)	<2.00	0.12	0.08	

Cultural practices guidelines

- Based upon soil testing results, apply amendments to compensate for accumulation of sodium or other elemental deficits that may occur during leaching (possibly potassium leaching). For example, gypsum applications will almost surely be needed to maintain soil sodium at levels below 8% of the total extractable cations.
- Aerate fairways twice annually (after first fall rainfall of 1 inch and in the spring) using a vertidrain to 9 inches. Apply amendments in the fall only in conjunction with aeration.
- Tree foliage may need to be trimmed to prevent contact with the irrigation spray if detrimental effects on the foliage are observed. This will prevent most foliar damage caused by the elevated chlorine content in reclaimed water. Some plants may be damaged after multi-year use of reclaimed water and the resulting accumulation of boron in the soil. These plants should be replaced with boron and salt tolerant varieties. Trends in tree and horticultural plant decline can also be identified using aerial photographs.

Changing the turf variety: the last resort

If the above management program does not provide effective salinity management for the soil-turfgrass system, it may be necessary to switch fairway turfgrass varieties to more salt tolerant paspalum (5 - 10 years in the future). As illustrated in Figure 1, a change in turf variety is sometimes the only way to alleviate the problems caused by low quality reclaimed water. The varying ways in which different turfgrass varieties respond to high salinity is illustrated in Table 4.

Economic and contract guidelines

- Exclude greens in all discussions on reclaimed water unless the current source of greens irrigation water is worse than reclaimed water and no better source is available.
- Water price should be keyed to current water prices and also water quality factors. Expect a 15 – 25% cost per unit reduction compared to current domestic water sources.
- Set maximum acceptable water quality limits (Table 3). If limits are exceeded, the contract may be voided without penalty to the golf course.
- Delivery guarantees should be included in the contract – include access to pump area to allow restarts and guaranteed pump repair times. Determine what happens if the pumps stops working – can you use domestic water and how will it be plumbed for use?
- Include costs of fairway cultivation and amendment to prevent soil damage from long term use of the reclaimed water.
- Include the costs of monitoring equipment – in-line conductivity monitoring and flow meters and the costs of soil testing and management consultation.

Table 4. Relative tolerance of turfgrasses to soil salinity (Harivandi et. al. 1992).

Sensitive < 3 dS/m	Moderately Sensitive 3-6 dS/m	Moderately Tolerant 6-10 dS/m	Tolerant > 10 dS/m
Annual bluegrass	Annual ryegrass	Bent. cv. Seaside	Alkaligrass
Colonial bentgrass	Chewings fescue	Perennial ryegrass	Bermudagrass
Kentucky bluegrass	Creeping bentgrass	Tall fescue	Seashore paspalum
Rough bluegrass	Hard fescue	Buffalograss	St. Augustinegrass
Centipedegrass	Bahiagrass	Zoysiagrass	

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