Irrigation Water Quality Problems

NC STATE EXTENSION

Water is a colorless, odorless, tasteless liquid with a unique set of physical and chemical properties (e.g., water generally freezes at 32°F, it generally boils at 212°F, etc.). Most of what we call "water" is not water per se; it is a solution of materials dissolved or suspended in water. The suitability of water for turfgrass irrigation is a affected by what is dissolved or suspended in it. An irrigation problem that is becoming increasingly more difficult to avoid is the presence of salts in the irrigation water, or salinity. Irrigation water salinity is a problem because there is a negative correlation between salt concentration in the soil solution and the rate of plant growth in the soil. High soil salt levels can interfere with plant water absorption because high concentrations of solutes in soil water can prevent plants from absorbing water by osmosis (physiological drought). High soil salinity can also create nutritional imbalances and mineral toxicities in plants.

Measuring Salinity

Because soluble salts in a water solution will conduct an electric current, changes in electrical conductivity (EC) can be used to measure the water's salt content in electrical resistance units (decisiemens per meter, or dS m^{-1}). This EC measurement can be converted to parts per million (ppm) or milligrams per liter (mg L^{-1}) relationships. Water salinity, reported as total dissolved solids (TDS), is approximated as follows:

ECw [dS m^{-1}] × 640 = TDS [ppm or mg L^{-1}]

This is an approximation because the exact relationship is determined by the composition of the salt. The ions of individual elements conduct electrical current at slightly different rates.

Based on salt concentration and EC conductance, water can be classified for irrigation use as follows:

Electrical Conductivity	Classification for Irrigation Use
< 0.25 dS m^{-1}	Low hazard
0.25 – 0.75 dS m^{-1}	Usable with moderate leaching
0.75 – 2.25 dS m^{-1}	Avoid use on poorly drained soils and salt-sensitive plants
> 2.25 dS m^{-1}	Not suitable for irrigation

Not all turfgrass species have the same tolerance for salinity. **Table 1** ranks turf species for salinity tolerance based on research and eld experience with saline irrigation.

Table 1. Estimated salt tolerance of common turfgrass species (adapted from Carrow and Duncan, 1998).

Turfgrass Type	Name	Rating
Cool-Season Turfgrass	Tall fescue (*Festuca arundinacea*)	T
	Perennial ryegrass (*Lolium perenne*)	T
	Hard fescue (*Festuca longifolia*)	MT
	Creeping red fescue (*Festuca rubra ssp. rubra*)	MT
	Creeping bentgrass (*Agrostis palustris*)	MT
	Kentucky bluegrass (*Poa pratensis*)	MS
	Annual bluegrass (*Poa annua*)	VS
	Colonial bentgrass (*Agrostis tenuis*)	VS
	Rough bluegrass (*Poa trivialis*)	VS
Warm-Season Turfgrass	Seashore paspalum (*Paspalum vaginatum*)	VT
	St. Augustinegrass (*Stenotaphrum secundatum*)	T
	Buffalograss (*Buchloe dactyloides*)	MT
	Bermudagrass (*Cynodon* dactylon and hybrids)	MT
	Zoysiagrass (*Zoysia* spp.)	MT
	Centipedegrass (*Eremochloa ophiuroides*)	VS
	Bahiagrass (*Paspalum notatum*)	VS

Note: VS = very sensitive; MS = moderately sensitive; MT = moderately tolerant; T = tolerant; VT = very tolerant. Turfgrass ratings reflect the general difficulty of establishing and maintaining a species at various salinity levels. Ratings in no way indicate that a grass will not tolerate higher salinity levels under good growing conditions and with optimum care. The ratings are based on soil salt levels (ECe) as follows: VS ≤ 1.5 dS m-1; MS = 1.6 – 3.0 dS m^{-1}; MT = 3.1 – 6.0 dS m^{-1}; T = 6.1 – 10.0 dS m^{-1}; and VT > 10.1 dS m^{-1}.

Even relatively salt-tolerant grasses can have their salt tolerance reduced if they are subjected to adverse growing conditions. Stress caused by climatic conditions and soil properties may make the turf more prone to salinity problem.

Sodium is especially injurious to turf areas because of its salt effects on both the plant and on the physical and chemical properties of the soil. Sodium can compete with potassium for absorption by the plant, and reduced potassium uptake creates a less stress-tolerant plant because sodium does not play the same role as potassium in metabolism. The relative concentrations of sodium (Na), calcium (Ca), and magnesium (Mg) in irrigation water are used to calculate the sodium absorption ratio (SAR), as follows:

SAR = (Na)÷ [square root of: (Ca + Mg) ÷ 2)]

where the values are given in milliequivalents per liter (meq L^{-1}). A high water SAR can reduce permeability when applied to more finely textured soils, such as silts or clays, over an extended period of time. The SAR interacts with the EC to determine the suitability of irrigation water.

In soil, the exchangeable sodium percentage (ESP) determines sodium-related impermeability problems. Sodium itself does not usually cause direct injury, but if the ESP exceeds 15%, a turf may be damaged by soil impermeability to air and water. Typical symptoms of reduced permeability include poor aeration, surface ponding, slow water in filtration, and problems with weeds and disease. Table 2 presents guidelines the combined effect of salinity and sodium content (sodicity) on the degree of impermeability that can result from use of irrigation water with a given salt content.

Table 2. Guidelines for suitability of water for turfgrass irrigation (adapted from Harivandi, 1994).

Problem Type	Potential Irrigation Problem	Degree of Restriction on Use of Water		
		None	**Slight to Moderate**	**Severe**
Salinity and Electrical Conductivity	Salinity, dS m^{-1}	< 0.7	0.7 – 3.0	> 3.0
	ECw TDS, mg L^{-1}	< 450	450 – 2000	> 2000
Infiltration[a]	SAR = 0 – 3 and ECw, dS m^{-1}	> 0.7	0.7 – 0.2	< 0.2
	SAR = 3 – 6 and ECw, dS m^{-1}	> 1.2	1.2 – 0.3	< 0.3
	SAR = 6 – 12 and ECw, dS m^{-1}	> 1.9	1.9 – 0.5	< 0.5
	SAR = 12 – 20 and ECw, dS m^{-1}	> 2.9	2.9 – 1.3	< 1.3
	SAR = 20 – 40 and ECw, dS m^{-1}	> 5.0	5.0 – 2.9	< 2.9

Problem Type	Potential Irrigation Problem	Degree of Restriction on Use of Water		
		None	Slight to Moderate	Severe
Specific Ion Toxicity	Sodium (Na^+) root absorption, SAR	< 3	3 – 9	> 9
	Sodium (Na^+) foliar absorption, meq L^{-1}	< 3	> 3	
	Sodium (Na^+) foliar absorption, mg L^{-1}	< 70	> 70	
	Chloride (Cl^-) root absorption, meq L^{-1}	< 2	2 – 10	> 10
	Chloride (Cl^-) root absorption, mg L^{-1}	< 70	70 – 355	> 355
	Chloride (Cl-) foliar absorption, meq L^{-1}	< 3	> 3	
	Chloride (Cl-) foliar absorption, mg L^{-1}	< 100	> 100	
	Boron (B), meq L-[1]	< 1.0	1.0 – 2.0	> 2.0
	Bicarbonate (HCO_3^-)[b], meq L^{-1}	< 1.5	1.5 – 8.5	> 8.5
	Bicarbonate (HCO_3^-)[b], mg L^{-1}	< 90	90 – 500	> 500
	pH	6.5 – 8.4 (normal range)	5.0 – 8.5	< 5.0 or > 8.5

[a] SAR and Ecw both affect the rate at which water infiltrates into soil. Use ECw and SAR together to evaluate the potential for infiltration problems.

[b] Excess levels of HCO_3^- can cause unsightly foliar deposits.

Guidelines for Using Reclaimed Water for Irrigation

Use of reclaimed water for irrigation should include close scrutiny of water quality, edaphic interactions, and plant growth. Irrigation with reclaimed water can present problems, but that does not necessarily mean that irrigation with reclaimed water cannot be "managed." Rather, managing these problems requires having a sound understanding of how soils interact with plant growth and development and how the environment influences management decisions.

The use of recycled water affects turf management in three major areas:

- **Turf and soils management.** The greatest effect in this area is on regulation of growth and prevention of unwanted changes in soil conditions that may adversely affect growth.
- **Irrigation system.** The use of recycled water affects system operation and maintenance because regulations may require changes in where, when, and how recycled water will be used.
- **Natural phenomena.** This includes everything from the weather to health considerations.

Following are some key factors to evaluate when considering or managing the use of reclaimed water for irrigation.

Water Conservation

Water conservation is one of the primary motives for irrigating with reclaimed water. However, any area developed for recycled water application must take into account certain design considerations. These include soil type and topography; characterization of the recycled water, including rate of ow, nutrient loads, organic loads, and concentration of any toxic materials; and the assimilative capacity of the site, which is related to soil type, type of vegetation planted, and environmental conditions to which the site is exposed.

Recycled use advantages: Paramount in this category is the fact that there is water available for irrigation use rather than none at all. Additionally, because this supply is dependent on human consumption and supply, it is available based on demand rather than being rationed during short- or long-term droughts. Another distinct advantage is the benefit of using a natural filtration system for effluent disposal from sewage treatment facilities. Benefits of this system have long been known, and this is much more desirable than surface water or ocean dumping or deep-well injection.

Recycled use disadvantages: Water supply may vary such that it is either excessive or deficient in volume. In resort areas where populations shift seasonally, the sanitary waste stream may fluctuate greatly. If the facility supplying recycled water is a minimum-capacity system serving a small seasonal community, recycled water flows could change significantly from month to month. This would mean having to use a supplemental source that may have poor quality or high cost.

Site Suitability for Use of Recycled Water

A more prevalent problem is whether the site is engineered as a recycled water disposal system. If not, overapplication can easily occur. The assimilative capacity of the site, including hydraulic loading (the amount of water the site can infiltrate and percolate), is not necessarily a measure of the ideal relationship for optimum irrigation of turf. While turf growth may be manageable under excess irrigation, the impact of traffic and play on these areas may be costly when revenues and increased maintenance factors are considered. Irrigation amounts and rates should be matched to turf demands, not to site capacity. This includes allowing periods of resting from irrigation to allow for reaeration of the soil. Enough flexibility must be engineered into the site design to allow for rainy periods when no recycled water will be needed and for an adequate recovery period for drainage and aeration.

Typical hydraulic loading rates based on soil grouping are listed in Table 3. However, even the soil group with the lowest application rate (IVa) may not necessarily correlate with turf use, even under semiarid or arid conditions that at maximum only approach 0.5 inch/day. Low soil oxygen from overirrigation or poor drainage may result in anaerobic production of lactic acid, ethanol, and acetaldehyde, all of which are toxic to root cells. is condition also favors the growth of saprophytic fungi, which affect overall turf vigor partly due to ethanol exudates from root systems.

Table 3. Hydraulic loading rates commonly used in site design, by soil group.

Soil Group	Texture	Application Rate (inches/day)
I	Sandy	1.5 – 2.0
II	Coarse loamy	1.0 – 1.5
III	Fine loamy	0.75 – 1.0
IVa	Clayey (1:1 type)	0.3 – 0.75
IVb	Clayey (2:1 type)	Unsuitable

An area that has not been adequately addressed in research or engineering is the potential for surface or ground water contamination from runoff or percolation of recycled water. Some states regulate where effluent can be applied relative to potable drinking water supplies, but application of recycled water and the potential for negatively affecting surface and ground water supplies depend on the quality of the effluent and the potential of the turf/ soil system to provide adequate filtration. Adequate soil depth is essential to achieve filtration of the recycled water, and sites that have ground water supplies closer to the soil surface are more vulnerable.

Nutrient Content

Recycled water contains both dissolved and suspended materials. is loading of materials can have a significant nutrient impact over an extended time, depending upon the total volume of water that is applied.

Recycled water advantages: The water may have an appreciable nutrient content. Forms of nitrogen (N) present may include NH_4^+-N, NO_3^--N, and organic N. Other macronutrients present may include phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S). These vary seasonally, and concentration will depend on the source of the water and the type of treatment facility. Several micronutrients may also be found in recycled water; boron (B), chlorine (Cl), copper (Cu), and zinc (Zn) are o en present. All of these may provide some turf fertilization.

Recycled water disadvantages: One of the biggest challenges is proper timing of nutrient applications. Excess nutrients may be applied to cool-season grasses at the peak time of water use under hot and dry weather conditions, when they are not needed, or to warm-season grasses at fall overseeding transition. In each case, stress tolerance and pest management effectiveness may be adversely affected.

Recycled water may provide significant amounts of nitrogen, especially if large volumes of recycled water are being applied. However, this may be seasonally dependent. A major concern with the application of nitrogen is that the site's assimilative capacity may change over time. With most turf areas, nitrogen — which is not volatilized — is not actually removed from the plant/soil system except in areas where clippings are removed. Permanent storage will occur in the soil as organic matter accumulates, but every soil has a dynamic point at which soil organic matter accumulation changes. Once this equilibrium of nitrogen loading, fixation, and mineralization occurs, the soil's assimilative capacity changes. The time required to reach this point varies depending on soil texture, turf species, and environmental influences. Close monitoring is required to determine if nitrogen is moving off site or downward into groundwater.

Water Quality

A number of parameters must be considered in dealing with recycled water quality. Although the nutrient content of applied water has been listed as an advantage of using recycled water, many of the nutrients may be salts that will influence total soluble salts (TSS), TDS, or salinity. The most desirable situation is for recycled water to have as little residual dissolved or suspended material as possible.

Recycled water disadvantages: Water quality varies greatly depending on the source of the water and the efficiency of the treatment system. Water quality can range from good to poor, depending upon its composition, and additional inputs to the management program may be required to compensate for this impact.

Water quality analysis should evaluate the following characteristics: concentrations of suspended solids, specific ions and pH, total soluble salts and calculation of a leaching requirement, SAR, biological oxygen demand (BOD), chemical oxygen demand (COD), toxic materials (particularly volatile organic compounds [VOCs]), and total or fecal coliforms (Table 4). Local regulations may also dictate additional analysis. Problems associated with each of these characteristics and their potential effects on turf management are described below.

- **Suspended solids.** These can accumulate on the surface and cause sealing of the soil. This is especially critical if the ac- cumulation includes a substantial mineral component. If the solids are organic, they may be decomposed by soil microorganisms if soil temperatures favor microorganism activity. Accumulations of materials in surface zones during cooler weather with subsequent decomposition during warmer weather may lead to periods of extreme oxygen depletion in the soil if (as is the usual situation) decomposition occurs at very shallow depths where the root system may be concentrated. Rooting and turf vigor then would be adversely affected. Suspended solids are filtered and potentially decomposed at the soil surface if soil temperatures are greater than 60°F and if the soil is unsaturated and permits good oxygen exchange.

  Another consideration is the effect of suspended solids on highly modified soils. Where root zone mixes consist of a high sand content specifically to ensure good drainage and compaction resistance, an increase in the amount of both organic and mineral suspended materials may potentially plug macropores, thereby reducing in filtration and percolation rate. One management strategy to overcome the effects of suspended solids is to increase the number of corings (aerifications). The presence of suspended solids can also affect irrigation system operation by plugging sprinkler head openings and valves and by abrading plastic and metal components. is may affect irrigation system component life expectancy and could lead to substantial additional cost.

- **Nitrogen loading.** All inorganic nitrogen is immediately available for turf uptake. If it is not taken in by the plant or used by the microbial population, it may leach. The management program will be affected if the plants are overstimulated and become so and succulent. With organic nitrogen, as little as 20% or as much as 50% may be mineralized in the first year.

This means a significant amount of nitrogen could build up and then be released during the warmest time of the year, when soil temperatures allow for unlimited microorganism activity. This makes it very difficult to control turf fertility, especially after a few years of organic nitrogen accumulation.

- **Phosphorus and potassium.** These nutrients do not normally pose a problem unless the recycled water is being held in a retention lake for an extended length of time. If so, phosphorus and nitrogen favor algal blooms that become a significant lake management problem. The amount of phosphorus and potassium added seldom exceed what the soil can assimilate and the turf requires; in fact, it is rare that the effluent can add, and that the soil can retain, adequate potassium for the annual requirement. Similarly, the amount of phosphorus typically added will not affect the availability of other nutrients in most soils and may add enough under certain situations for suitable turf growth.
- **Calcium, magnesium, sodium.** The major concern with calcium and magnesium is not the total amounts of these elements but their relationship to sodium content and the resultant SAR. Excess sodium displaces calcium on the soil exchange sites, causing deflocculation of the soil structure, or soil dispersal. is can result in increased compaction, thereby limiting oxygen exchange and affecting rooting and turf vigor. When the SAR exceeds 10, a recommendation normally is made to apply calcium, usually as gypsum, and to apply excess irrigation to displace and leach the sodium. However, there are costs involved. For example, gypsum requirements and costs may be high, and there will be a requirement for excess irrigation to leach. All of this requires labor, electricity for pump operation, and increased wear on the irrigation system.
- **pH and total carbonates.** Bicarbonates and carbonates both affect the pH of the recycled water and potentially the chemical properties of the soil. These are measured in milliequivalents per liter and are a source of alkalinity that may affect the water and soil. Water quality analysis commonly reports total carbonates (bicarbonates and carbonates) because both carbonates affect pH levels. If the amount is significant — greater than 2.5 meq/l (150 ppm) — the pH of the soil may be affected by long-term use of recycled water. This in turn affects nutrient availability. To offset this effect, one may use acid-forming nitrogen fertilizers, inject acid into the irrigation water, or apply sulfur to the soil.
- **BOD/COD.** These measurements are functions of the organic and microbiological load in the effluent. They represent the amount of oxygen required for decomposition to occur. The most accurate analysis is the COD because it represents the maximum potential oxygen requirement once the organic materials are deposited in the soil. Because the microorganism population in the soil is so diverse, organic materials added in the recycled water stream become an energy source for microorganisms and therefore possess an oxygen requirement for their metabolism. This can result in subtle but measurable reductions

in growth under low BOD/COD concentrations. If organic loading creates a situation where the microorganisms use oxygen at a greater rate than the exchange capacity of the soil, oxygen depletion and an interruption in root function may result.

- **Conductivity (total soluble salts).** Salinity problems primarily manifest in three ways: osmotic effects, accumulations of specific ions, and their effect on soil physical conditions. The relative salinity tolerance of grasses and plants used in the landscape may cause a shift in the components as saline irrigation favors one species over another. Leaching of salts from the root zone is critical to maintaining turf under saline irrigation. The conductivity of soils can be two to ten times higher than that of the irrigation water. Saline irrigation requires constant attention to ensure that adequate leaching occurs. On sandy soils, leaching of salts is easily accomplished with excess irrigation. On more heavily textured soils, larger volumes and longer irrigation times are required, making leaching more difficult. Also, many of these salts may become attached to the colloidal complex of the soil, making their leaching potential is lower and requiring more intensive irrigation.
- **Specific ions.** Boron, chlorine, and sulfur as sulfates may all become toxic to the plant if concentrations in the irrigation water are excessive. Recent information suggests that because boron accumulates in leaf tips in situations where clippings are removed, high boron levels do not create severe problems. However, where clippings are returned, there is concern about leaf burn and boron buildup in the soil. Boron concentrations are excessive when they exceed 1 to 2 ppm. Boron is difficult to leach, requiring twice as much water to leach as other soluble salts. Boron also is of critical concern to other landscape plantings, such as woody ornamentals, which may not be as boron-tolerant as turfgrasses. Some plants are sensitive to boron levels as low as 0.33 ppm. Where good drainage is available and the leach- ing potential is high, there is less concern with chlorides and sulfates because both of these salts have good water solubility. However, for some salt-sensitive grasses and other plants, levels of 250 to 400 ppm are considered undesirable for irrigation.
- **Heavy metals.** These include copper, nickel, zinc, lead, chromium, mercury, and arsenic. The exact levels at which these become a problem (either separately or collectively) are unknown. However, levels of heavy metals should be monitored periodically both in the water and in the soil. Many of these metals complex with phosphorous and other elements to make them biologically unavailable. As soil levels build, it may be necessary to increase phosphorus applications to complex these ions and keep them unavailable.
- **Toxic organics.** Many of these are also known as volatile organic compounds (VOCs), such as toluene and xylene. ey may create direct toxicity problems if present in high concentrations.
- **Fecal coliforms.** These are a health concern related to human exposure and are not an agronomic consideration.

All of these recycled water quality factors can affect the turf cultural program. Water quality affects turf fertility because more potassium may be needed to off set the effects of sodium and it may be difficult to control nitrogen levels. It is easy to overirrigate, especially if leaching is required, and excess suspended solids, organics, bicarbonates, and sodium may then present soil problems.

Use of recycled water for turfgrass irrigation presents a unique set of advantages and disadvantages that might affect many decisions the turf manager must make. However, despite increased problems, concerns, and costs, these impacts are not necessarily insurmountable; rather, they present a challenge that demands attention to every agronomic and management detail.

Table 4. Recycled water quality parameters that may affect turf management.

Parameter Analyzed	**Potential Impact**	**Effect on Turf Management**
Suspended solids	Soil sealing	Increase coring
Total-N, NH_4^+-N, NO_3^--N, organic-N	Buildup of nitrogen; untimely availability	Control nitrogen fertility
P and K	Contaminated runoff to lakes	Control runoff; monitor soil levels
Ca, Mg, Na	High SAR; soil sealing	Increase calcium applications
pH, carbonates, bicarbonates	Increased soil pH; effect on nutrient availability	Acidify water or nitrogen sources
BOD/COD	Organic loading; depletion of soil oxygen	Increase coring; improve root growth
Conductivity (TSS, TDS)	Accumulation of salts in root zone	Leach with irrigation
B, Cl^-, SO_4^{2-}	Potential specific ion toxicity	Monitor and offset with fertilization
Heavy metals	Toxicity to plant roots	Monitor and precipitate with P
Toxic materials	Toxicity to plant	Monitor and leach or treat with charcoal
Total/fecal coliforms	Human exposure	Monitor and isolate

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Authors

Charles Peacock
Professor and Extension Turfgrass Specialist Crop and Soil Sciences

Grady Miller
Professor Crop and Soil Sciences

Matt Martin
Extension Associate - Turfgrass, NCSU Crop Science Dept Crop and Soil Sciences

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