Quality of reclaimed water for turfgrass irrigation

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<table>
<thead>
<tr>
<th>Option</th>
<th>Cost (acre-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination</td>
<td>$1,400</td>
</tr>
<tr>
<td>Recycling for Drinking Water</td>
<td>$1,230</td>
</tr>
<tr>
<td>Imperial Valley Imports</td>
<td>$800</td>
</tr>
<tr>
<td>Current Costs</td>
<td>$500</td>
</tr>
<tr>
<td>Landscape Reuse</td>
<td>$70</td>
</tr>
</tbody>
</table>
Water Quality Problems

- **Salinity**
  - Salts reduce water availability through osmotic effects

- **Water Infiltration Rate**
  - Relatively high sodium or low calcium content of soil or water reduces the infiltration rate

- **Specific Ion Toxicity**
  - Certain ions (sodium, chloride, or boron) from soil or water accumulate and cause damage

- **Miscellaneous**
  - Excessive corrosion of equipment
Salinity

Precipitation

Precipitation (cm)
- < 12.70
- 12.71 – 30.50
- 30.51 – 50.80
- 50.81 – 76.20
- 76.21 – 101.60
- 101.61 – 127.00

Temperature

Temperature (C)
- 0 – 4.40
- 4.41 – 7.20
- 7.21 – 10.00
- 10.01 – 12.80
- 12.81 – 15.60
- 15.61 – 18.30
- 18.31 – 21.10
- > 22.11

Evaporative Demand > Precipitation
Salt River

0.8 maf/yr @ 500 mg L$^{-1}$
imports 620,000 metric tons annually
Central Arizona Project

1.2 maf/yr @ 650 mg L$^{-1}$
imports 960,000 metric tons annually
Salt Accumulation

- Groundwater: 39%
- Vadose Zone: 22%
- Salt Sinks: 8%
- Other: 31%
Units for Salinity

- **TDS** – Total dissolved solids (mg L\(^{-1}\))
  - Measured by filtering then evaporating a sample and weighing the residue
  - Common measurement at sewer treatment plants

- **EC** – Electrical conductivity
  - Measured by passing a current through a water sample
  - Most management criteria based on EC
Converting between TDS and EC

\[ \text{EC} \left( \frac{dS}{m} \right) = \frac{\text{TDS} \left( \frac{mg}{L} \right)}{\text{Conversion Factor}} \]

\[ \text{TDS} \left( \frac{mg}{L} \right) = \text{EC} \left( \frac{dS}{m} \right) \cdot \text{(Conversion Factor)} \]

Conversion factor usually 500 – 1000 depending on solution
Conversion factor = 900

Conversion factor = 500

Calculated EC from TDS
For most irrigation waters conversion factor $\approx 640$

- $\approx 640$
- $1$
- $1.5$
- $2$
- $2.5$
- $3$
- $3.5$
- $4$
- $4.5$
- $5$

Calculated EC from TDS
Units for EC

Conversion for EC units

\[
\frac{dS}{m} = \frac{\mu S}{cm} = \frac{mmho}{cm} = \frac{\mu mho}{cm} \times 1000
\]
Irrigation with Saline Water

The diagram illustrates the relationship between EC<sub>W</sub> (Electrical Conductivity of Water) and Relative Yield. The graph shows that different crop types have varying tolerances to saline water, with:

- **Sensitive** crops: Unsuitable for crops.
- **Moderately Sensitive**
- **Moderately Tolerant**
- **Tolerant**

The x-axis represents EC<sub>W</sub> values ranging from 0 to 35, while the y-axis represents Relative Yield, ranging from 0% to 100%. The lines indicate the relative yield percentage for each crop type based on the EC<sub>W</sub> value.
## Irrigation Water Quality – Salinity

<table>
<thead>
<tr>
<th>Units</th>
<th>Degree of Restriction on Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>$\text{EC}_w$ (or) TDS</td>
<td>$\text{dS/m}$</td>
</tr>
<tr>
<td></td>
<td>$\text{mg/l}$</td>
</tr>
</tbody>
</table>
Data Collection Rate

EC (dS m⁻¹)

3/11/06 3/13/06 3/15/06 3/17/06 3/19/06
Measure salinity often

- EC meters range in price from $50 - $1000
- Results are instant
- Track results
Irrigation Water Quality – Sodicity

Potential Infiltration Problems

<table>
<thead>
<tr>
<th>SAR = 0-3 and EC&lt;sub&gt;W&lt;/sub&gt; =</th>
<th>None</th>
<th>Slight to Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0.7</td>
<td>0.7 – 0.2</td>
<td>&lt;0.2</td>
<td></td>
</tr>
<tr>
<td>&gt; 1.2</td>
<td>1.2 – 0.3</td>
<td>&lt;0.3</td>
<td></td>
</tr>
<tr>
<td>&gt; 1.9</td>
<td>1.9 – 0.5</td>
<td>&lt;0.5</td>
<td></td>
</tr>
<tr>
<td>&gt; 2.9</td>
<td>2.9 – 1.3</td>
<td>&lt;1.3</td>
<td></td>
</tr>
<tr>
<td>&gt; 5.0</td>
<td>5.0 – 2.9</td>
<td>&lt;2.9</td>
<td></td>
</tr>
</tbody>
</table>

SAR = \left[ \frac{\left[ \text{Na}^+ \right]}{\sqrt{\left( \frac{\text{Ca}^{2+} + \text{Mg}^{2+} \right)/2}} \right]; \text{ Conc} \Rightarrow \left[ \frac{\text{meq}}{l} \right]
## Irrigation Water Quality – Toxicity

### Boron (ppm)

<table>
<thead>
<tr>
<th>Class of Water</th>
<th>Sensitive</th>
<th>Semi-tolerant</th>
<th>Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&lt; 0.33</td>
<td>&lt; 0.67</td>
<td>&lt; 1.00</td>
</tr>
<tr>
<td>Good</td>
<td>0.33 to 0.67</td>
<td>0.67 to 1.33</td>
<td>1.00 to 2.00</td>
</tr>
<tr>
<td>Permissible</td>
<td>0.67 to 1.00</td>
<td>1.33 to 2.00</td>
<td>2.00 to 3.00</td>
</tr>
<tr>
<td>Doubtful</td>
<td>1.00 to 1.25</td>
<td>2.00 to 2.50</td>
<td>3.00 to 3.75</td>
</tr>
<tr>
<td>Unsuitable</td>
<td>&gt; 1.25</td>
<td>&gt; 2.50</td>
<td>&gt; 3.75</td>
</tr>
</tbody>
</table>

Boron accumulates in leaf tips – removal in clippings

Problem for trees and shrubs
Salinity and wastewater reuse

- Power plant has zero discharge permit for spent cooling water.
Salinity and wastewater reuse

- Waste water is used to irrigate 250 acre farm.
Salinity and wastewater reuse

- Ongoing monitoring to determine if salt is leaching out of root zone and the effective life of the farm for waste water disposal.
Experimental Design

Two line source sprinkler systems.
- One waste water
- One fresh water
Six irrigation levels on either side of line source.
Water level 4 is approximately equal to no leaching beyond the root zone.
Experimental Design

- Water level 5 = LF 0.075
- Water level 6 = LF 0.15
## Properties of Waste Water

<table>
<thead>
<tr>
<th></th>
<th>Concentration (mg L(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>410</td>
</tr>
<tr>
<td>Mg</td>
<td>158</td>
</tr>
<tr>
<td>Na</td>
<td>268</td>
</tr>
<tr>
<td>K</td>
<td>13.2</td>
</tr>
<tr>
<td>SO(_4)</td>
<td>1629</td>
</tr>
<tr>
<td>Cl</td>
<td>276</td>
</tr>
<tr>
<td>B</td>
<td>317</td>
</tr>
<tr>
<td>EC</td>
<td>4.3 dS m(^{-1})</td>
</tr>
</tbody>
</table>
LF = 0.0066

EC₀ = 4.3 dS m⁻¹
LF₀ = 1.00

EC₁ = 7.1 dS m⁻¹
LF₁ = 0.602

EC₂ = 23.2 dS m⁻¹
LF₂ = 0.300

EC₃ = 221 dS m⁻¹
LF₃ = 0.110

EC₄ = 33,000 dS m⁻¹
LF₄ = 0.0066

ARZS 6650 dS m⁻¹

LF = 0.075

EC₀ = 4.3 dS m⁻¹
LF₀ = 1.00

EC₁ = 6.83 dS m⁻¹
LF₁ = 0.63

EC₂ = 19.4 dS m⁻¹
LF₂ = 0.353

EC₃ = 71.0 dS m⁻¹
LF₃ = 0.23

EC₄ = 472 dS m⁻¹
LF₄ = 0.15

ARZS 338 dS m⁻¹

LF = 0.150

EC₀ = 4.3 dS m⁻¹
LF₀ = 1.00

EC₁ = 6.5 dS m⁻¹
LF₁ = 0.66

EC₂ = 16.3 dS m⁻¹
LF₂ = 0.40

EC₃ = 71.0 dS m⁻¹
LF₃ = 0.23

EC₄ = 472 dS m⁻¹
LF₄ = 0.15

ARZS 114 dS m⁻¹
Electrical Conductivity
(dS m⁻¹)

Depth (ft)

2000

- LF 0.0066
- LF 0.075
- LF 0.150
Results

- Salts in solution are not accumulating as fast as predicted.
- CaSO$_4$ precipitation.
- Potential B, Cl, and Na toxicity.
Managing Salinity and SAR

- Measure salinity often
- Monthly samples for SAR
  - Sodium, Calcium, Magnesium
- Quarterly sampling for toxicity
  - Boron, Sodium and Chloride
- Proper leaching fraction
- Replace sodium with polyvalent ions (Ca^{2+})
Managing Salinity and SAR

- Record Keeping
Diagnosis and Improvement of Saline and Alkali Soils

United States Salinity Laboratory Staff

Agriculture Handbook No. 60
UNITED STATES DEPARTMENT OF AGRICULTURE

http://www.ars.usda.gov/SP2UserFiles/Place/53102000/hb60_pdf/hb60complete.pdf