Saline and Sodic Soils: Characteristics and Properties

DOUGLAS D. MALO, PRESENTING TODAY

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SALINE/SODIC SOIL MANAGEMENT WORKSHOP
REDFIELD, SD
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Outline

• Definition of the problem
• Causes of the problem
• Salt affected classes of soils
• Lab tests used to identify salt and sodicity problems
• Current research results
Why Salt Problems Now?

- Changes in climate
- Changes in management
  - More corn and soybeans
  - No-till adoption
- Source of the salts - the soil parent materials
- In typical, normal conditions salts are deeper in soil profiles
Climate Changes

• Changes in precipitation from 1900 to 2010 in the Northern Great Plains

Next factor that adds to problem: Seasonal water use of tall grass prairie greater than that of corn, soybeans, or wheat.

Deep roots of the tall grass that remove water from deeper in the soil profile.

Photo, Jim Millar
Changes in Tillage Practices

- Shift from Conventional to No-till
- Impacts
Source of the Salts

Spink County: Areas with till, and lacustrine deposits from Pierre shale

Daniels 1987
Glacial Lake Plain
Typical Eastern SD Soil

- Appearance
- Horizons
- Organic Matter distribution
- Salt location
Evaporation losses from the rim areas are greater than from the pond surface. Capillary and osmotic forces pull water to rim area. Dissolved salts move with the water. Water and salts move to rim.
Genesis of Salt Affected Soils – Saline Seep

Water

Excess water and soluble salts move down in soil until reach impermeable layer.

Permeable parent material with soluble salts present

Precipitation

Summer Fallow

Salinity

Saline seep area

Impermeable parent material with high salt content (e.g., shale)

Stream
Development of Salt Sites in Fields

1. Abundance of precipitation in the 1980’s and throughout the 2010’s.

2. Water tables have risen bringing deep old geologic salt concentrations to the surface.

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex167
High Water Table and Salts

• Saline = Calcium / Magnesium Salts \rightarrow Plants will not grow

• Sodic = Sodium Salts \rightarrow Plants will not grow and soil is dispersed.

• Commonality between saline and sodic problems is a high water table.

Source – Reese, 2015
Saline or Sodic?

- **Note solubility**
- **Saline** – Calcium (Ca) or Magnesium (Mg) Salts (2+) dominate
- **Sodic** – Sodium Salts (1+) dominate

### Table 1. Composition and solubility of some common evaporite minerals (salts).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Composition</th>
<th>Solubility (moles/liter)</th>
<th>Chemical Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcite (lime)</td>
<td>CaCO₃</td>
<td>0.00014</td>
<td>Calcium Carbonate</td>
</tr>
<tr>
<td>Gypsum</td>
<td>CaSO₄ • 2H₂O</td>
<td>0.0154</td>
<td>Calcium Sulfate</td>
</tr>
<tr>
<td>----</td>
<td>CaCl₂ • 6H₂O</td>
<td>7.38</td>
<td>Calcium Chloride</td>
</tr>
<tr>
<td>Magnesite</td>
<td>MgCO₃</td>
<td>0.001</td>
<td>Magnesium Carbonate</td>
</tr>
<tr>
<td>Hexahydrate</td>
<td>MgSO₄ • 6H₂O</td>
<td>4.15</td>
<td>Magnesium Sulfate</td>
</tr>
<tr>
<td>Epsomite</td>
<td>MgSO₄ • 7H₂O</td>
<td>3.07</td>
<td>Magnesium Sulfate</td>
</tr>
<tr>
<td>Bischofite</td>
<td>MgCl₂ • 6H₂O</td>
<td>5.84</td>
<td>Magnesium Chloride</td>
</tr>
<tr>
<td>(Washing soda)</td>
<td>Na₂CO₃ • 10H₂O</td>
<td>2.77</td>
<td>Sodium Carbonate</td>
</tr>
<tr>
<td>(Baking soda)</td>
<td>NaHCO₃</td>
<td>1.22</td>
<td>Sodium Bicarbonate</td>
</tr>
<tr>
<td>Mirabilite</td>
<td>Na₂SO₄ • 10H₂O</td>
<td>1.96</td>
<td>Sodium Sulfate</td>
</tr>
<tr>
<td>Thenardite</td>
<td>NaSO₄</td>
<td>3.45</td>
<td>Sodium Sulfate</td>
</tr>
<tr>
<td>Halite</td>
<td>NaCl</td>
<td>6.15</td>
<td>Sodium Chloride</td>
</tr>
</tbody>
</table>

Source – Reese, 2015
Saline Stress: Calcium (Ca) + Magnesium (Mg)

• Moderately high pH
• Drought like conditions
• Poor germination and growth
• Low nutrient availability

Source – Reese, 2015
Sodic Stress: Sodium (Na)

- Dispersion
- High pH >8.4
- No water movement
- Erosion
- Root limitation

Source – Reese, 2015
Terms to Know

- **EC (Electrical Conductivity):**
  - Measurement of total salts, critical value is 4 dS/m

- **CEC (Cation Exchange Capacity):**
  - Soils’ ability to hold positively charged cations

- **ESP (Exchangeable Sodium Percentage):**
  - Sodium (Na+) on soil exchange sites (% Na+ compared to Ca^{2+} + Mg^{2+} on CEC)
  - ESP > 5 = is considered sodic in SD (previously ESP >15)

- **SAR (Sodium Adsorption Ratio):**
  - Measurement of the relative amount of sodium, when compared to total amount of salts (from saturated extracts)
  - Attention – SAR > 4 is considered sodic in SD! (previously > 13)

- **NOTE ABOUT SAR:** Not as commonly used as ESP because more difficult to do

Source – Reese, 2015
# Soil Testing Lab Survey

<table>
<thead>
<tr>
<th>Testing Lab</th>
<th>Location</th>
<th>EC</th>
<th>Cation Concentration</th>
<th>Sodium Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa State University</td>
<td>Ames, IA</td>
<td>SP</td>
<td>NH(_4)OAc</td>
<td>SAR</td>
</tr>
<tr>
<td>North Dakota State University</td>
<td>Fargo, ND</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>SAR</td>
</tr>
<tr>
<td>University of Minnesota</td>
<td>St. Paul, MN</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>SAR</td>
</tr>
<tr>
<td>AgLab Express</td>
<td>Sioux Falls, SD</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>ESP</td>
</tr>
<tr>
<td>AgVise Laboratory</td>
<td>Northwood, ND</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>ESP</td>
</tr>
<tr>
<td>Minnesota Valley Testing Lab</td>
<td>New Ulm, MN</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>ESP</td>
</tr>
<tr>
<td>Ward Laboratories</td>
<td>Kearney, NE</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>ESP</td>
</tr>
<tr>
<td>ServiTech</td>
<td>Hastings, NE</td>
<td>1:1</td>
<td>NH(_4)OAc</td>
<td>SAR</td>
</tr>
</tbody>
</table>

Source - Owen, 2014
Results

Overall Relationship between EC and TSC

\[ y = 13.54x - 0.29 \]

\[ R^2 = 0.88 \]

\[ n = 1245 \]

\[ p\text{-value} < 0.0001 \]

Source - Owen, 2014
Results

Established a linear relationship between EC and TSC:

- \( TSC = 13.5 \times EC \)

Provides a simple way to relate EC to TSC and allows users to more efficiently assess salt-affected soils.

Allows users to calculate SAR using only EC and Na\(^+\).

\[
[(EC \times 13.5) - Na^+] = [Ca^{2+} + Mg^{2+}]
\]

Source - Owen, 2014
Question to ask a soil testing lab

• How is sodium determined?
  • Saturated paste (SAR) or Ammonium Acetate Extraction (ESP)

• How was EC determined?
  • Saturated paste or 1:1 extract?

• Why is this important?

• Because the EC is used to estimate the total soluble cations (TSC).

• The TSC is required for the SAR calculation.

Source – Reese, 2015
Salt Affected Soil Classes

- **Saline**
  - pH < 8.4
  - EC > 4 mmhos cm\(^{-1}\)
  - SAR < 13, ESP < 15% (Arid)
  - SAR < 4, ESP < 5% (Midwest/Great Plains)*

- Problem – excess soluble salts, reduce water/nutrient availability, *plasmolysis*, and osmotic forces
Salt Affected Soil Classes

- Sodic
  - pH > 8.4
  - EC < 4 mmhos cm\(^{-1}\)
  - SAR > 13, ESP > 15% (arid)
  - SAR > 4, ESP > 5% (Midwest/Great Plains)*

- Problem is high pH due to excess sodium, soluble salts are low, dispersion, reduced air and water movement and reduced nutrient availability
Salt Affected Soil Classes

- Saline-sodic
  - EC > 4 mmhos cm$^{-1}$
  - pH < 8.4 (excess soluble salts keep pH low)
  - SAR > 13, ESP > 15% in arid areas
  - SAR > 4, ESP > 5% (Midwest/Great Plains)
- Soil has both high soluble salts and sodium. Soil will become sodic if excess soluble salts are removed.

www.r5.fs.fed.us/ecoregions/photos/cd1-031.jpg
Salt Affected Soil Classes

• Normal
  • pH < 8.4
  • EC < 4 mmhos cm
  • SAR < 13, ESP < 15% (arid)
  • SAR < 4, ESP < 5% (Midwest/Great Plains)
  • No salt problems for most crop and other plants
Extent of Salinity

A map of the Northern Great Plains soils with a high risk potential for excessive soil salinity. Soils with EC > 4 dS/m constitute the high risk areas. Source: http://www.soilsci.ndsu.nodak.edu/DeSutter/TomDeSutter.html.
Extent of Sodicity

Map: Jim Millar

Economic Impact

Upper James River — Salinity Impact

- Percent Productivity Decrease
- Total Acres Impacted (Acres)

- Beadle County: 70,504 acres, 27%
- Brown County: 94,265 acres, 33%
- Spink County: 115,290 acres, 31%
- Upper James River: 280,059 acres, 30%

Annual Economic Loss (millions)

- Beadle County: Spring Wheat $12.7 million, Winter Wheat $2.4 million
- Brown County: Corn for Grain $13.1 million, Soybeans $1.7 million
- Spink County: Spring Wheat $11.8 million, Winter Wheat $1.8 million
- Upper James River: Corn for Grain $27.6 million, Soybeans $1.7 million

Source - NRCS 2012

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Summary

- Discussed how saline/sodic soils form
- Causes for increased areas of saline/sodic soils
- Basic properties of saline/sodic soils
- Basic soil properties measured to classify and identify saline/sodic soils
Funding Acknowledgements / Cooperators

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• South Dakota State University

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  • David Gillen, White Lake, SD
Questions?