Chloride in Crop Production

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Chloride and Plant Nutrition

Fate of Chloride in Soils

Sources of Chloride in the Soil

Fertilizer Sales in Minnesota as a Proxy for Chloride

Assessment of Chloride in MN Agricultural Soil and Water
Chloride is a plant **micro-nutrient**

- Macro-nutrients: N, P, Potassium (K)
- Micro-nutrients: Chlorine (Cl), B, Cu, Mn, Mo and Zn
- Crop requirement: 3.5-7 lb/ac for average crop

**HOWEVER**

*Chloride* is applied at **comparable rates to potassium (K)** because *Potassium Chloride (KCl)* is the dominant fertilizer source for K **AND** has **equal amounts** of K and Cl (nearly 50% K and 50% Cl)
Role of chloride in plants:

- Photosynthesis
- Disease control
- Plant vigor and volume

Deficiency is very rare

- Reduced leaf growth
- Wilting
- Necrosis and stunted roots
Chloride and Plant Nutrition, Cont.

Plant **tolerance** to chloride **varies**

- 4-7 mg.g\(^{-1}\) **Sensitive** plant species
- 15-50 mg.g\(^{-1}\) **Tolerant** plant species

Chloride **toxicity** is most common in irrigated and dry regions
• Uptake form: Plant uptake in **chloride** form (Cl⁻)

• **Distribution** in plant: Chloride is found mostly in the **crop residue**, not in crop grain

• A typical corn yield (150-200 bu/ac) will have about **4 lbs in corn grain** and **68 lbs in corn stover**

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Table 1. Chloride removal by selected crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Plant part</th>
<th>CI content</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Shoot</td>
<td>7.6 lb/ton (dry wt)</td>
<td>NRC, 1981</td>
</tr>
<tr>
<td>Barley</td>
<td>Grain</td>
<td>0.024 lb/bu¹</td>
<td>Fixen, 1993</td>
</tr>
<tr>
<td>Potatoes</td>
<td>Tuber</td>
<td>0.06 lb/cwt</td>
<td>Saffigna et al., 1977</td>
</tr>
<tr>
<td>Sweet clover</td>
<td>Shoot</td>
<td>7.4 lb/ton (dry wt)</td>
<td>NRC, 1981</td>
</tr>
<tr>
<td>Wheat</td>
<td>Grain</td>
<td>0.026 lb/bu</td>
<td>Fixen, 1993</td>
</tr>
<tr>
<td>Wheat</td>
<td>Grain + straw Low soil Cl</td>
<td>0.17 lb/bu</td>
<td>Schumacher, 1988</td>
</tr>
<tr>
<td></td>
<td>High soil Cl</td>
<td>0.44 lb/bu</td>
<td></td>
</tr>
</tbody>
</table>

Fixen, 1993
• Chloride movement from soil solution to plant root mainly via mass flow

• Chloride is negatively charged: Potential to leach below the root zone

• Chloride is not altered by soil microbes: Often used for soil water flow tracing

• Chloride movement in the soil profile controlled by ET and precipitation with the potential to buildup in soils where ET>Precipitation (not from carry over)
Sources of Chloride in the Soil

Natural sources

• Atmospheric deposition
• Parent material/shallow water table (capillarity forces)

Other sources

• **Crop residue** decomposition
• **Manure** amendment
• Commercial fertilizer (**Potash**)
Chloride is applied to soils mainly as Potassium Chloride KCl (Muriate of Potash: MOP):

- Chloride is a “byproduct” of potash
- **Cost effective** (provides both K, and Cl)
- Logistics: **available** at local coops
- Potash is 50% **Chloride** and 50% K (58-62% K2O)
- **Alternative K fertilizer** sources: Potassium sulfate (SOP), potassium Mg. Sulfate
Field Application (MOP):

- Applied **before or at planting**
- Broadcasted or banded
- **No soil test for chloride**
- Rate **dictated by K soil test**
- KCl rate can be **reduced by half** if fertilizer is banded
Chloride from Statewide Commercial Fertilizer Sales

Procedure for estimating chloride from fertilizer

• MDA annual **fertilizer sale** records of KCl (2010-2017)

• Converting KCl mass to **chloride mass**

• **Averaging** over **eight years** to reduce bias due to inter-annual storage

• Spatial aggregation (**counties to districts**) to reduce bias due to cross-county purchases
Chloride from Statewide Commercial Fertilizer Sales

Statewide chloride use from fertilizer estimate: **245,362 tons/year**

- More in SE MN (low native soil K)
- Less in NW MN: Wheat requires lower amounts of K
- **9194 tons/year** in the seven metro counties
Comparing Chloride from Fertilizer to Road Salt Chloride in the Metropolitan Area

In the **Metropolitan Area** where the majority of chloride impairments are located (39/50):

- Farm fertilizer chloride estimate: **9,194 tons/yr**
- Road salt chloride estimate: **210,000 tons/yr** (Novetny et al., 2008)
- **Chloride fertilizer** is not applied to impervious surfaces unlike road salts
- Chloride from fertilizer have a different fate in the environment
Assessment of Chloride in MN Agricultural Soil and Water

Chloride in soils:

- Based on Agvise soil analysis
  - Residual soil test (taken after harvest)
  - 2 feet soil sample (0-24”)
- Majority of soils in **central MN** have less than **5ppm** of chloride (40lb/ac)
- Soils in **NW MN** have more chloride likely due to a combination of soil and weather conditions (salinity)
Water Quality Assessment: Edge of Field Monitoring

• **Discovery Farm Minnesota:**
  - Led by the **MAWRC** in partnership with the MDA
  - Long term monitoring of agricultural water quality attributes
  - Chloride in **tile** and **surface runoff**
  - Different cropping systems/management

• **Root River Field to Stream Partnership**
  - Edge of field monitoring
  - Stream monitoring
Monthly chloride concentration (FWMC) from 10 agricultural sites in MN between 2011 and 2019

- Site 1
- Site 2
- Site 3
- Site 4
- Site 5
- Site 6
- Site 7
- Site 8
- Site 9
- Site 10
Monthly chloride concentration (FWMC) from 10 agricultural sites in MN between 2011 and 2019
Water Quality: Edge of Field Monitoring (Discovery Farm)

• Significant variability between sites
• Significant interannual variability
  • Higher concentration (early spring and late fall)
• Chloride mean concentration (FWMM):
  • 31.4 mg/l
Annual chloride yield (tile and surface runoff)

- Tile Drainage loss: **35 lb/ac/yr**
- Surface runoff: **5.8 lb/ac/yr**
- Large **variability** between sites/years: **19-53 lb/ac/year**
- Annual average loss: **40.8 lb/ac/year**
- Tile loss accounts for **86%** of the loss
Field to **stream dilution**

- **Field** drainage water chloride: **21 mg/l**
- Stream chloride (**Headwaters**): **17.2 mg/l**
- Stream chloride (**Downstream**): **6.6 mg/l**
Conclusion

• Chloride is a by product of Potash

• Over 245,000 tons used every year

• Leaching occur with significant spatial and temporal variability

• Improvement to potassium fertilizer management can help reduce chloride use

• Soil test for K, variable rate K application, promote use of non-chloride K fertilizer
Thank you!

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