Advances in our Knowledge of Dispersion and Swelling with Soil Sodium and the Interaction of Sodium Chemistry with Soluble Salts

Tom DeSutter and Yangbo ‘Kathy’ He
Department of Soil Science
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Soil and Soil-Water Workshop
Current/Upcoming Studies Focused on Sodic Soils

- NRCS-USDA Conservation Innovation Grant
  - Two locations (near Wyndmere and Thompson)
  - Tiled and non-tiled
  - Amendments
  - Soil, crop response, econ, Extension, engineering
- North Dakota Soybean Council
  - Tiled and non-tiled soils near Milnor
  - Alfalfa and amendments
Yangbo He
PhD candidate
Soil Science Department
Sodic soil cause problems
Why do we care?

- Slaking (\( \text{H}_2\text{O}-\text{induced} \) )
- Dispersion
- Swelling

\[ \text{Na-induced} \]
Dispersion

- Soil is separated into individual particles (opposite of flocculation)

At beginning by $H_2O$

After 6 h

Letcher-Lemert sodic soil
Theory of dispersion

- Guoy-Chapman theory

\[ k^{-1} = \frac{3.042(10^{-10})}{Z\sqrt{I}} \]

If the double layer is small, no dispersion.

At low EC, thickness of double layer is large, Double layers of adjacent particles will overlap, causing electrostatic repulsion (Essington, 2004)
Swelling

- Expansion of soil volume in spacing
- Na pushes the individual clay particles in an aggregate without actually dissociating from it

Interlayer space increase when water enter inside, cause swelling

Shrink, cracks at dry;
Swell at wet

(http://www.regyp.com.au/tag/gypsum-recycling/)
Lab data of dispersion

• **Purpose**
  – Identify the dispersion limits of sodic soils for management

• **Sodic soil criteria** *(U.S. Salinity Laboratory Staff, 1954)*
  – EC <4 dS/m, SAR >13, pH>8.5
Lab data of dispersion

• **Materials and Methods**
  – Clay Minerals
    • Kaolinite, Montmorillonite, and Illite purchased from Clay Minerals Society
  – SAR
    • 1, 5, 12, and 24
  – EC
    • 0, 0.5, 2, 4, 6, 8, 12, and 16 dS/m (mmoh/cm)
  – Dispersion measurement (clay was calibrated, then 1g:30mL; shake 16 h and settle down by Stoke’s law for a depth of 2 cm and then pipette)
  – Using a Spectrophotometer (640 nm) for ABS
  – The clay dispersion determined by standard line
Lab data of dispersion

Mont SAR = 12
Mont SAR = 24
Kaolinite SAR = 12

EC = 0.5, 2, 4, 6, 8, 12, and 16 dS/m
Montmorillonite

Clay dispersion decreases with a decrease in SAR and an increase in EC.
Lab data of dispersion

SAR=24 Montmorillonite

SAR=24 Illite

SAR=24 Kaolinite
Lab data of dispersion

- Dispersion is as a function of both amount of Na and EC
- Dispersion increase with SAR and decrease with increase of EC for 2:1 type clays (Mont. & Illite)
- Adverse effects of dispersion can be alleviated by increasing the solution EC (but plants may suffer)
Swelling---another important mechanism on sodic soil

- Water net \((H_2O)\) functions with clay mineral in the interlayer of soil

(Grim, 1968)
Swelling theory

- Hydration radius: $Na^+ = 8\text{Å}$; $Ca^{2+} = 12\text{Å}$
- $Na^+$ has little interruption on water net in interlayer, the water is retained and fluidity is reduced
- When more $H_2O$ enter into interlayer, the cation chemical potential is reduced, cation diffuse into bulk solution (repulsive force)

[Diagram showing the hydration of cations and the increase in interlayer space]

Repulsion > attraction force, interlayer space increase, clay swell

(Grim, 1968)
Swelling

- Materials and methods
  - Soils from Richland county site: Exline (Fine, smectitic, frigid Leptic Natrudolls)
  - Solution EC: 0, 0.5, 1, 2, 4, 8, and 15 dS/m
  - Soils were treated and determined at 1/3 bar for water content (field capacity)
  - The excess of water imbibed by soil compared to reference is the swelling
  - Reference line is “normal soil”
Lab data for swelling

- Effect of EC

Water adsorbed by sodic soil are almost doubled from high EC solution to low EC solution
Lab data for swelling

- **Effect of SAR**
Swelling and/or dispersion

- Trafficability of sodic soil in field is poor when wet
- Very hard when dry
Potential impact of sodic soils on drainage and water movement

H₂O Flow

GW

A
E
Btn

A
E
Btn

Drainage tile

EC may decrease

After 6 h

Start

(Quirk and Schofield, 1955)
Adverse effects on water movement

Sodium Na and EC

Control swelling and dispersion

Reduced soil pores and clogged soil pores by clay particles

Slow down water movement (Ksat)
Adverse effects on water movement

- $K_{sat}$ (Saturated hydraulic conductivity) no treatment

![Bar chart showing hydraulic conductivity (cm/h) for different SAR values. The chart shows a significant drop in conductivity at SAR 7 compared to other SAR values.]
Now what?

• Steps to remediation a sodic soil
  – Need Ca amendment
  – Need water for leaching
  – Need drainage to get Na out
Ca is provided—water movement

The Ksat value increased about 10 to 100X.
Adverse effects on water movement

- $K_{sat}$ (Saturated hydraulic conductivity) no treatment

![Bar chart showing hydraulic conductivity (cm/h) for SAR values 7, 14, 24, and 28.]
Adverse effects on water movement

• As SAR increased, Ksat decreased
• As repeated, water movement is a function of EC and SAR (amount Na)
• Effluent was clear indicating no dispersion
Summary

• Swelling and dispersion are the major mechanisms controlling soil structure and H$_2$O movement
• Closely related with soil Na and solution EC
• SAR between 0-8 should be acceptable for H$_2$O movement
• If SAR $>8$, EC will be needed to be $\geq 2$
Summary

- Gypsum required for SAR to be reduced to 8 (tons/acre foot) (includes 25% overage)

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<th>Gypsum of tons/unit change SAR</th>
<th>Quantity of gypsum</th>
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Author of The Demon Under the Microscope