Gypsum in Land Application and Phosphorus Remediation

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What is FGD Gypsum?

Gypsum is Calcium Sulfate Dihydrate CaSO4•2H2O

FGD Gypsum is gypsum formed from “Fluidized Gas Desulfurization”

Coal-Fired Power Plant

Gypsum Stockpile

Benefits of Gypsum

• Improve soil properties
  – Improve water infiltration
  – Control soil erosion and crusting
  – Nutrients for crop production (Ca and S)
  – Alleviate the effects of subsoil acidity (Al Toxicity)

• Reduce contaminants in water runoff.
Soil Structure

- Complex process developed over time where soil is bound together in soil aggregates.
- Finer clay components (colloidal particles) form negative charges in soil that provide attractive force for positively charged cations and the formation of soil aggregates.

Dispersion

Extreme cases such as the formation of sodic soils from the build up of Na in soil leads to the complete loss of soil productivity.

Dispersion is also a nature process driven from rainwater addition which is natural distilled and low in electrolytes. Process leads to slow degradation of soil structure.

Dispersion

Soil structure is disrupted by the forces of dispersion

(Illustration kindly provided by Dr. Jerry Bigham, The Ohio State University).

Dispersion

- Soil particles clog soil pores
- Soil crusting
- Reduced water flow in soil and infiltration
- Reduce water redistribution to subsoil
- Increased runoff and Erosion
- Increased surface waterlogging
Dispersion of soil particles and then surface drying creates a crust that impedes seedling emergence.

From "Gypsum as a Agriculture Amendment" - The Ohio State University

**Gypsum**

Addition of soluble Ca can reverse the dispersion effects and help promote flocculation and structure development in dispersed soils.

Illustration kindly provided by Dr. Jerry Bigham, The Ohio State University.

Clay dispersion and collapse of structure at the soil-air interface is a major contributor to surface sealing in both sodic and non-sodic soils.

Illustration kindly provided by Dr. Jerry Bigham, The Ohio State University.

Natural rainwater is erosive, in part, because of its low electrolyte (salt) content.

Work at the NSERL (Norton et al.) has shown that soil and chemical loss due to crusting, poor infiltration of rainfall, and runoff can be reduced by managing the calcium (Ca) status of the topsoil.

Traditional sources of Ca are:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone (CaCO₃)</td>
<td>0.015 g/L</td>
</tr>
<tr>
<td>Dolomite (CaMg(CO₃)₂)</td>
<td>0.32 g/L</td>
</tr>
<tr>
<td>Gypsum (CaSO₄)</td>
<td>2.41 g/L</td>
</tr>
</tbody>
</table>

Illustration kindly provided by Dr. Jerry Bigham, The Ohio State University.
Figure 2-4. Infiltration rate for a Blount soil with and without surface-applied gypsum. FGD gypsum as soil amendment to improve soil physical properties and water infiltration and percolation (illustration kindly provided by Dr. Jerry Bigham, The Ohio State University).

Application of FGD gypsum increases water infiltration and percolation. Foreground is the gypsum application section, and background is the control section. (Norton and Rhoton, 2007.)
ARS Multi Location Gypsum study
Use of FGD Gypsum to Improve Crop and Forage Production and reduce P loss on Erodible Soils of the South

Research Goals
• Establish rates of FGD gypsum and poultry litter
• Document improvements in water quality
• Develop guidelines for use of FGD gypsum

USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA
Harry Schomberg - Pasture

USDA-ARS National Soil Dynamics Laboratory, Auburn, AL
Dexter Watts - Pasture

USDA-ARS National Sedimentation Laboratory, Oxford, MS
Martin Locke - Row Cropping Systems

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Comments: Calcium and sulfur distributions with soil depth indicate that three consecutive years of surface applied FGD gypsum amendments on no-till cotton have resulted in significant increases in these essential plant nutrients at depth.

Note: 0, 2.24, 4.48, and 6.72 Mg ha-1 correspond to 0, 1, 2, and 3 tons/acre.

Soil water content during the 2009 growing season Verona, MS

- Water content was measured with TDR.
- CT plots showed little difference until end of the growing season, when 3 tons/acre FGD held more water.
- NT showed a more consistent advantage for the 3 tons/acre FGD treatment, with the difference starting earlier in the growing season.
- Slightly higher soybean yields in NT may have resulted from the increased moisture.

Fred Rhoton - unpublished data
Soil penetration resistance, 2012
Milan, TN

- Cone penetrometer measured integrated total force required to reach a 12-inch depth
- Crop row and middle of row (wheel track and non-wheel track)
- In all row positions, resistance tended to decrease in plots treated with FGD gypsum,

<table>
<thead>
<tr>
<th>Tillage</th>
<th>FGD gypsum rate</th>
<th>Non-wheel track middle</th>
<th>Crop row</th>
<th>Wheel track middle</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>tons/acre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional</td>
<td>0</td>
<td>79.4</td>
<td>76.0</td>
<td>94.8</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>71.2</td>
<td>73.3</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>68.7</td>
<td>75.0</td>
<td>84.2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>72.2</td>
<td>71.3</td>
<td>89.0</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>73.4</td>
<td>69.9</td>
<td>86.4</td>
</tr>
<tr>
<td>No-Nil</td>
<td>0</td>
<td>80.8</td>
<td>72.5</td>
<td>90.6</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>68.4</td>
<td>68.9</td>
<td>83.0</td>
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<tr>
<td></td>
<td>2</td>
<td>84.0</td>
<td>75.5</td>
<td>92.1</td>
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<tr>
<td></td>
<td>3</td>
<td>71.4</td>
<td>71.4</td>
<td>84.1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>79.1</td>
<td>70.1</td>
<td>88.1</td>
</tr>
</tbody>
</table>

Fred Rhoton - unpublished data

Soil water content, Milan, TN

- TDR soil water content, 2011
- Rainfall and mean volumetric soil water content for the top 45 cm as affected by tillage and gypsum
- With exception of two dates, 3 tons/acre NT plots consistently had higher soil moisture
- NT cotton yields were higher in 2011

Fred Rhoton - unpublished data

FGD-Gypsum & Poultry Litter

Poultry Litter (tons/acre)

<table>
<thead>
<tr>
<th>Gypsum (tons/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

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**Watkinsville**

**Bermudagrass**

**Yield Average**

- **Gypsum (tons/acre)**
  - 0
  - 1
  - 2
  - 4

- **Bermudagrass (lb/acre)**
  - 500
  - 1000
  - 1500
  - 2000

**Water Quality**

- What is quality of water in the U.S.?
  - 45% of river miles are impaired
  - 47% of lake acres,
  - 32% of estuarine water is impaired.

- Agriculture is considered to be one of the major contributors to water quality

- Phosphorus loss from agriculture

- Poultry Industry
  - Improper disposal of waste from poultry industry
Gypsum Ties Up Soluble P

• Formation of an insoluble Ca-phosphate complex

• Insoluble hydroxyapatite and fluorapatite
Time samples - 0, 10, 20, 30, 40, 50, 60
Cumulative samples
Unfiltered – Total nutrient
Filtered - Dissolved

Runoff as % of Rainfall

Runoff

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Soluble P in Runoff

| Poultry Litter | 0 | 0 | 6 | 6 | 6 | 6 |
| Gypsum        | 0 | 4 | 0 | 1 | 2 | 4 |

Soluble Reactive Phosphorus (mg L\(^{-1}\))

<table>
<thead>
<tr>
<th>FGD Gypsum (Mg ha(^{-1}))</th>
<th>1.0</th>
<th>6.0</th>
<th>11.0</th>
<th>16.0</th>
<th>21.0</th>
<th>26.0</th>
<th>31.0</th>
<th>36.0</th>
<th>41.0</th>
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</thead>
<tbody>
<tr>
<td>Soluble Reactive Phosphorus (mg L(^{-1}))</td>
<td>0</td>
<td>2.2</td>
<td>4.4</td>
<td>8.9</td>
<td>10</td>
<td>26.0</td>
<td>31.0</td>
<td>36.0</td>
<td>41.0</td>
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</tbody>
</table>

Cumulative

\( r^2 = 0.642 \)

58% reduction
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Not Detected

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>&lt;0.50</td>
</tr>
<tr>
<td>Cobalt</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td></td>
</tr>
<tr>
<td>Antimony</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td></td>
</tr>
<tr>
<td>Beryllium</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td></td>
</tr>
<tr>
<td>Thallium</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td></td>
</tr>
<tr>
<td>Vanadium</td>
<td></td>
</tr>
<tr>
<td>Hexavalent Chromium</td>
<td>≈ &lt;50 µg/L</td>
</tr>
</tbody>
</table>

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Dissolved Arsenic
Dissolved Aluminum
Dissolved Antimony
Dissolved Barium
Dissolved Beryllium
Dissolved Cadmium
Dissolved Chromium
Dissolved Cobalt
Dissolved Copper
Not Detected

Dissolved Lead
Dissolved Potassium
Dissolved Selenium
Dissolved Silver
Dissolved Sodium
Dissolved Thallium
Dissolved Vanadium
Dissolved Zinc
Kitchen Sink

≈ <50 µg/L

• Gypsum can improve soil physical properties
• Improve aggregation
• Increase Water Infiltration
• Reduce runoff
• Improve water holding capacity
• Reduce erosion losses and nutrient losses