ANR-20-05

Extension FactSheet

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Gypsum for Agricultural Use in Ohio—Sources and Quality of Available Products

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The Role of Gypsum as a Soil Amendment

Gypsum is hydrated calcium sulfate ($CaSO_4 \cdot 2H_2O$), and is often marketed as a soil "conditioner" for improving soil "tilth." Compared to most other calcium-rich soil amendments, such as limestone, gypsum is relatively soluble in water, dissolving up to 2 g per liter. The solubility of gypsum, when either incorporated or surface applied, permits a quick release of calcium (Ca^{2+}) and sulfate (SO_4^{2-}) ions into the soil solution. The supply of dissolved salt and Ca^{2+} ions, in particular, may reduce soil crusting (Figure 1) and otherwise benefit soil structure. The aggregation of clay particles that help to form and stabilize soil structure is clearly enhanced by the presence of calcium on clay exchange sites.

It is important to note that pure gypsum is not a liming agent, and it cannot be used to raise soil pH. However, gypsum has the potential to relieve aluminum (Al^{3+}) toxicity in acid soils and to supply calcium and sulfur (S) for plant nutrition. Some natural and synthetic sources of gypsum also contain other chemical compounds, such as calcium carbonate (agricultural lime), calcium oxide (burned lime), or calcium hydroxide (hydrated lime). These materials *do* have a liming effect when applied to soil, but are not discussed further in this publication.

The objectives of this fact sheet are to review possible sources of gypsum for agricultural use in Ohio, and to report results from chemical and mineral analyses of representative samples.

Figure 1. Inhibition of soybean seedling emergence by severe surface crusting.

Sources and Mineral Composition of Gypsum Materials

There are several possible sources of gypsum currently available for agricultural use in Ohio.

These include:

- Natural gypsum mined from geologic deposits
- Synthetic gypsum produced as a by-product of electricity generation
- Recycled casting gypsum from various manufacturing processes
- Recycled drywall gypsum

Natural Gypsum

Gypsum has been obtained by mining geologic deposits in northern Ohio, Michigan, and other locations for many years. Mineral purity of natural samples varies with the local geology and the mining technology employed at the site. Samples obtained from northern Ohio mines near Port Clinton were predominantly gypsum, but also contained dolomite [$CaMg(CO_3)_2$] and quartz (SiO_2) (Table 1). Small quantities of quartz have no effect on soil properties, whereas dolomite is a liming agent and is a good source of magnesium (Mg).

Table 1. Mineralogical composition of gypsum samples.

Source	Minerals* present
Synthetic gypsum[1]	gypsum, quartz
Natural gypsum[2]	gypsum, quartz, dolomite
Cast gypsum[3]	gypsum, quartz, anhydrite
Drywall gypsum[4]	gypsum, quartz, portlandite, calcite

[1] Samples obtained from the W.H. Zimmer Station in Moscow, OH, owned by Cinergy Corporation
[2] Samples obtained from the Kwest Group at Port Clinton, OH
[3] Samples obtained from Mansfield Plumbing Products, LLC of Mansfield, OH
[4] Samples obtained from Transfer Services, LLC of Columbus, OH
* gypsum = $CaSO_4•2H_2O$, quartz = SiO_2, dolomite = $CaMg(CO_3)_2$, anhydrite = $CaSO_4$, portlandite = $Ca(OH)_2$, calcite = $CaCO_3$

Synthetic Gypsum

Synthetic gypsum is produced at some coal-fired power plants as a by-product of pollution control measures. The Clean Air Act Amendments of 1990 mandate that electrical utilities install systems for removal (“scrubbing”) of sulfur dioxide (SO_2) from flue gases that are generated during the burning of coal. The resulting materials are termed *flue gas desulfurization* (FGD) by-products. Depending on the process, these by-products can have a variety of mineral constituents. The forced oxidation procedure used at the W.H. Zimmer Station in Moscow, Ohio, results in a high purity product (Table 1), and the material is marketed as synthetic gypsum.

In the process used at Zimmer Station, the flue gases are first exposed to a slurry of hydrated lime, and calcium sulfite ($CaSO_3•0.5H_2O$) is initially formed by capture of SO_2 (Figure 2). The calcium sulfite is then oxidized to form gypsum. During the oxidation process, washing of the by-product with water removes undesirable chemical contaminants such as boron (B) and mercury (Hg). The final step of the process involves partial removal of water by a combination of centrifugation and vacuum filtration.

The final product is available for drywall manufacturing or for agricultural applications. To be acceptable for drywall manufacture, the material must have less than 600 parts per million (ppm) of total dissolved solids in the pore water, and a water content of less than 15% by weight. Material that does not meet these criteria is marketed as agricultural gypsum, and total dissolved solids is the major

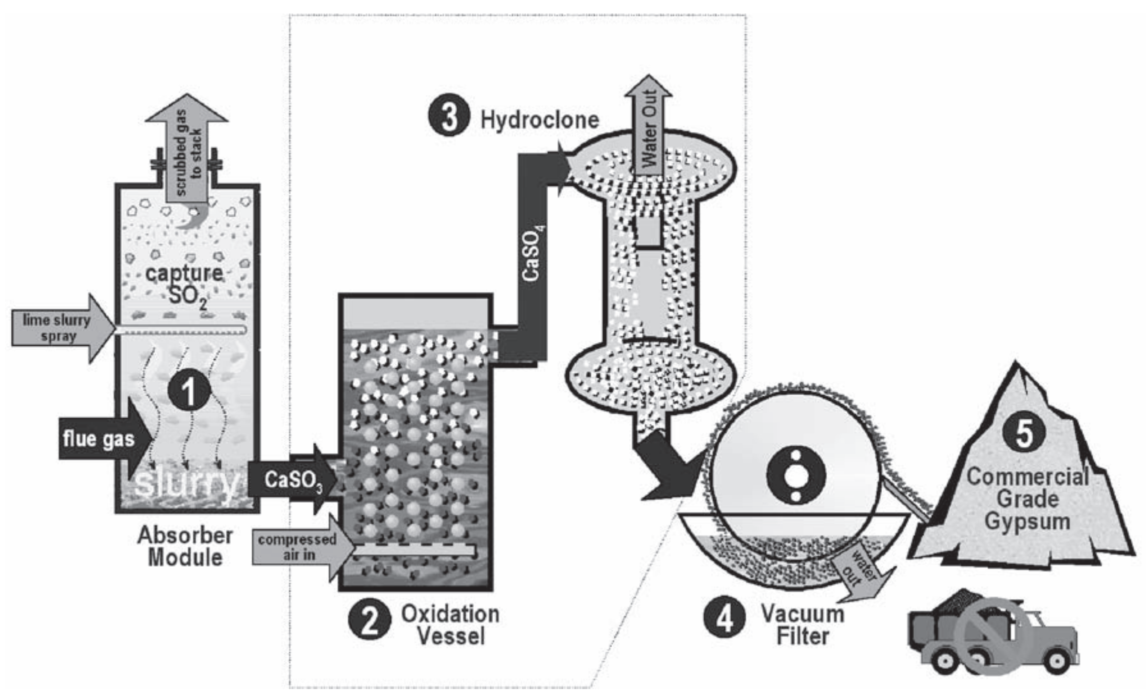

Figure 2. The scrubbing process and gypsum production at Zimmer Station (Figure courtesy of CINERGY Corp.).

criterion for diverting material to agricultural uses. Power plant gypsum in Ohio is permitted as a fertilizer material through the Ohio Environmental Protection Agency, and is monitored by the Ohio Department of Agriculture for Ca and S contents.

Cast gypsum

The manufacture of some products, such as plumbing fixtures, requires gypsum casts or molds. The used molds can potentially be ground and recycled for other uses. The recycled material analyzed for this report contained mostly gypsum with a small admixture of the mineral anhydrite (Table 1), probably due to the dehydration of gypsum during the casting process. Anhydrite ($CaSO_4$) is calcium sulfate without water of hydration, and is usually similar in behavior to gypsum when applied to soils.

Drywall gypsum

Drywall consists of gypsum with a thin paper backing. About 30 billion square feet of gypsum wallboard are manufactured each year in North America, and a considerable quantity is discarded during the construction of homes, offices, and other structures. Up to 25% of the waste produced at new construction sites is drywall material. The recycled drywall analyzed in this study was obtained entirely from new construction projects and is regularly monitored by the Ohio Department of Agriculture as a fertilizer. The samples contained quartz, calcium hydroxide [$Ca(OH)_2$] or portlandite, and calcium carbonate ($CaCO_3$) or calcite (Table 1). Demolition drywall is another possible source of gypsum but should probably be avoided for land application because of potential chemical contamination from paint or other wall coverings.

Physical Properties of Gypsum Materials

The cost and ease of land application are heavily dependent on factors such as water content, particle size, and purity of the gypsum product. The samples collected for this study included products taken directly from the sources as well as materials stockpiled in the field in preparation for land application (Figure 3). As a result, the water contents varied considerably (Table 2). Water content was consistently small (< 1%) for the mined gypsum and the recycled cast material, neither of which were exposed to rainfall. Water contents of the synthetic FGD-gypsum were below 10%, even though the manufacturer reports that the product has an average water content of 12%. Drywall gypsum contained 1% water at the recycling facility, whereas contents were as high as 19% after storage in the field.

Figure 3. Gypsum stockpiled in the field for post-harvest application.

The waste drywall material was crushed and sorted through a 0.5-inch screen at the recycling center. For agricultural uses, this material is best spread with a wet lime spreader. Fertilizer spreaders do not work well because the feeder holes are not sufficiently large to pass larger particles. The synthetic FGD-gypsum, by contrast, generally has excellent spreading characteristics.

Most products sampled for this study were high purity and yielded < 3% water insoluble residues (Table 2). The mined gypsum, on the other hand, contained up to 19% undissolved residue after 3 days equilibration in acidified water. Much of the residue was dolomite, which did not dissolve due to large particle size and relatively low solubility.

Table 2. Physical properties and price (as of 12/2004) of gypsum.

Material	Water content[1]	Particle size	Price $/ton	Insoluble residue[2]
	%			%
Synthetic gypsum	5.55 (3.04)[3]	120 μm	7.00	0.4 (0.2)
Natural gypsum	0.38 (0.48)	NA	12.75	12.9 (8.1)
Cast gypsum[4]	0.15 (0.21)	NA	NA	0.2
Drywall gypsum	10.1 (12.8)	<0.5 inch	11.00	2.2 (0.3)

[1] Dried overnight at 60 degrees Celsius.
[2] Following dissolution for three days at pH <3.
[3] Standard deviation included in parentheses.
[4] Material is not yet available for sale for agricultural application.
NA = not available

Table 3. Selected macro- and micronutrient[1] concentrations in the gypsum samples.

Measure	Units	Museum specimen[2]	Synthetic gypsum	Natural gypsum	Cast gypsum	Drywall gypsum	Ideal analysis[3]
Calcium	%	22.6	23.0 (0.0)[4]	19.1 (2.2)	22.4 (0.0)	21.9 (0.2)	23.3
Magnesium	%	0.01	0.03 (0.01)	1.35 (0.30)	0.05 (0.00)	0.22 (0.01)	
Sulfur	%	18.6	18.7 (0.1)	15.1 (1.2)	19.3 (0.2)	18.1 (0.3)	18.6
Boron	ppm	<13.1	26.7 (8.7)	9.4 (0.9)	0.4 (0,4)	7.3 (4.5)	
Iron	ppm	<1	264 (129)	1045 (148)	44 (7)	547 (92)	
Manganese	ppm	0.1	5.5 (2.3)	14.6 (2.9)	9.1 (0.0)	9.4 (1.6)	
Phosphorus	ppm	3.8	16.7 (9.4)	30.6 (7.6)	7.5 (0.3)	51.6 (3.5)	

[1] Micronutrient data obtained by EPA method 3050 (USEPA, 1996).
[2] The museum specimen is included as a pure sample of gypsum.
[3] Calculated content in a 100% pure product.
[4] Standard deviation included in parentheses.

Table 4. Trace metal content[1] of gypsum from different sources compared with U.S. EPA Part 503 pollutant concentration limits for excellent quality biosolids.

Pollutant (ppm = $mg\ kg^{-1}$)	Museum specimen	Synthetic gypsum	Natural gypsum	Cast gypsum	Drywall gypsum	Part 503 Table 3[2]
Arsenic	<0.52	0.56 (0.05)[3]	<0.52	<0.52	0.98 (0.11)	41
Cadmium	<0.48	<0.48	<0.48	<0.48	<0.48	39
Chromium	0.01	1.30 (0.85)	1.38 (0.32)	0.07 (0.00)	1.09 (0.09)	1200
Cobalt	<0.48	<0.48	0.53 (0.04)	<0.48	<0.48	NR[4]
Copper	<0.48	1.16 (0.66)	1.33 (0.30)	1.40 (0.21)	0.95 (0.14)	1500
Lead	< 0.48	0.80 (.30)	2.92 (0.30)	0.57 (0.08)	0.70 (0.02)	300
Mercury	<0.26	<0.26	<0.26	<0.26	<0.26	17
Molybdenum	<0.24	0.51 (0.26)	1.28 (0.04)	<0.24	<0.24	—[5]
Nickel	<0.24	0.73 (0.18)	1.42 (0.23)	< 0.24	0.83 (0.12)	420
Selenium	<1.45	5.51 (3.47)	<1.45	<1.45	1.85 (0.04)	36
Zinc	<0.24	3.88 (2.78)	0.91 (0.49)	<0.24	3.08 (0.45)	2800

[1] Data obtained by EPA method 3050 (USEPA, 1996).
[2] Part 503—Standards for the Use or Disposal of Sewage Sludge; 503.13, Table 3. (USEPA, 1993).
[3] Standard deviation included in parentheses.
[4] NR = not regulated.
[5] Ceiling concentration limit for molybdenum is 75 ppm; 503.13, Table 1. (USEPA, 1993).

Plant Nutrient Content of Gypsum Samples

All the materials tested would be excellent sources of Ca and S for plant nutrition (Table 3). Because of its dolomite content, the mined gypsum is also a source of Mg.

Boron is a plant micronutrient and some crops have a relatively high demand for B; however, others can be sensitive to elevated levels. Unwashed FGD by-products can have levels of B sufficiently high to result in toxicity to corn. Washing of the by-product in the process of gypsum formation lowers B contents to safe levels if recommended application rates are used.

Trace Metal Content of Gypsum Samples

Chemical analyses of the gypsum materials collected in this study showed that trace metals were present at low concentrations in all samples (Table 4). As a point of reference, the metal contents were much lower than concentration limits identified by government regulations for land application of excellent quality biosolids (USEPA, 1993), and calculated metal loadings with application rates of 2.23 ton $ac^{-1}yr^{-1}$ (5 Mg $ha^{-1}yr^{-1}$) were 100 to 10,000x lower than annual loading rates permitted by these same regulations (see Part 503—Standards for the Use or Disposal of Sewage Sludge; 503.13, Tables 1–4, for details). Gypsum from any of the sources examined could thus be applied without restriction for trace metal loading; however, *samples from a given source should always be tested prior to application*. There is also no demonstrated benefit of application rates greater than 2 ton $ac^{-1}yr^{-1}$ for agronomic or horticultural crop production in Ohio, and biennial applications are probably adequate. Greater quantities could result in seedling damage to salt intolerant species, especially if applied near the time of planting. Autumn applications are recommended.

References

U.S. EPA. 1993. 40 CFR Part 503—Standards for the use and disposal of sewage sludge: Final rule. Federal Register 58:9248–9415. Washington, DC.

U.S. EPA. 1996. Method 3050. Acid Digestion of Sediments, Sludges, Soils and Oils. SW-846. Washington, DC.

Acknowledgement

This publication was produced through a cooperative effort between Ohio State University Extension and the College of Food, Agricultural, and Environmental Sciences.