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Agricultural Uses for Flue Gas Desulfurization (FGD) Gypsum

What Is Gypsum?

Gypsum is calcium sulfate dihydrate, or $CaSO_4 \cdot 2H_2O$, which can come from a number of sources. Mined gypsum is a common mineral found around the world in sedimentary rock formations, from which it is mined or quarried. FGD gypsum is a synthetic material of identical chemical structure produced as a byproduct from coal-fired electric utilities. Other sources of gypsum include phosphogypsum, citrogypsum and fluorogypsum, which are byproducts of different chemical manufacturing processes[1].

Gypsum has many beneficial uses, including agricultural applications, wallboard products for residential and commercial buildings, as an ingredient in portland cement manufacturing, and as a filler ingredient in some foods and toothpaste. Because of its relatively high degree of purity, FGD gypsum can be used as a substitute for mined gypsum in many uses, while also realizing important environmental benefits that result from recycling this byproduct material.

Gypsum in Agriculture

Both mined and FGD gypsum can be used as a soil amendment in a range of soil and hydrogeologic conditions. Gypsum can be used as a nutrient source for crops; as a conditioner to improve soil physical properties, and water infiltration and storage; to remediate sodic (high sodium) soils; and to reduce nutrient and sediment movement to surface waters, among other uses. The United States Environmental Protection Agency (USEPA) and the United States Department of Agriculture (USDA) support the use of FGD gypsum in appropriate soil and hydrogeologic conditions as an effective method of soil conservation and industrial material recycling. However, before applying any fertilizer or other soil amendment, including FGD gypsum, it is important to first assess the amendment material and soil conditions to determine compatibility and appropriate application rates.

1 This brochure does not address these sources of gypsum.

FGD Gypsum

FGD gypsum is created by forced oxidation scrubbers attached to coal-fired power plants to limit emissions of the sulfur which is released when coal is burned. The scrubbers spray liquid lime or limestone slurry into the flue gas path, where it reacts with sulfur in the gas to form calcium sulfite, an intermediate product with little practical value. However, when the chemical reaction is pushed further by the introduction of air into the FGD absorber tank, the calcium sulfite reacts to become gypsum. The material is then dewatered and processed; the end product is a consistent, finely divided powder. This process is known as flue gas desulfurization (FGD), and the gypsum produced is known as FGD gypsum.

The term FGD gypsum is the name most often used by generators of the material. Other names include recaptured gypsum, byproduct gypsum, and synthetic gypsum. All of these terms refer to the same material produced by the forced oxidation process. The gypsum in both FGD gypsum and mined gypsum has the same basic chemical makeup— $CaSO_4 \cdot 2H_2O$; however, the amount and types of trace materials and unreacted sorbents found in the gypsum can vary among power plants and among mines[2]. If you are considering using FGD gypsum products as a soil amendment, it is appropriate that the chemical analysis of the material be provided by all commercial sources to support decision-making in their use, as States may have regulations and standards that need to be followed. To this end, it is advisable to contact your State's department of agriculture or State extension service before FGD gypsum is used as a soil amendment.

The Future of FGD Gypsum

According to the American Coal Ash Association's annual Coal Combustion Product Production and Use Survey, total production of FGD gypsum in 2006 was approximately 12 million tons. Close to 9 million tons of FGD gypsum was put to beneficial use, while the remainder was landfilled. Of the amount used, approximately 80 percent was used in wallboard products, and about 2 percent (168,190 tons) was used in agriculture, with most of the rest being used in concrete and cement applications. In the future, FGD gypsum may find more use as filler in plastics and fiberglass, as well as in reducing mine subsidence, re-contouring landforms, and improving soil conditions at mining sites.

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2 Information about constituent concentrations in mined and FGD gypsum may be found at http://www.epa.gov/epaoswer/osw/conserve/c2p2/ccps/fgd.htm.

Over the next ten years, annual production of FGD gypsum may double as more coal-fired power plants come online, and as scrubbers are added to existing power plants to comply with the EPA's Clean Air Interstate Rule and other requirements. It is anticipated that the majority of the new scrubbers will produce FGD gypsum, although in some parts of the country power plants may select dry scrubbers, resulting in materials other than FGD gypsum. This increased supply is an opportunity to explore the expanded use of FGD gypsum as a soil amendment. Ongoing and future research and demonstration projects will be able to assist people in making decisions about the use of FGD gypsum.

Agricultural Applications of Gypsum

There are three general uses of gypsum in agricultural applications:

- A source of nutrients for plants
- Improvement of soil physical and chemical properties
- Reduction in the transport of nutrients, sediment, pesticides and other contaminants to surface waters

Current Uses of Gypsum in Agriculture

Nutrient Source

Gypsum is rich in calcium and sulfur, two nutrients essential to all crops. The most common application of gypsum is to crops that have high calcium requirements, or to areas that have calcium-poor soils. Peanuts have particularly high calcium requirements, and gypsum often is added to peanut fields to increase yield and quality of the crop. Many fruits, vegetables, and cereals also can benefit from increased calcium availability; in particular, fruits such as tomatoes and cantaloupes need calcium for skin strength, and growers may add calcium to produce fewer blemishes and a longer shelf life.

Sulfur fertilization also is required for many crops, and gypsum can be an effective sulfur source. There is a growing need for sulfur addition to soils, since atmospheric deposition of sulfur has decreased, and most nitrogen and phosphorus fertilizers no longer contain significant amounts of sulfur. Sulfur is sometimes a constituent of nitrogen and phosphorus fertilizers, but gypsum also can be an effective sulfur source for some crops. In addition to calcium and sulfur, gypsum, depending on its source, may provide essential micronutrients to plants.

Soil Improvement

Gypsum is helpful in treating sodic soils and soils suffering from crusting and other structural problems. Gypsum is more readily soluble in water than other calcium-rich soil amendments such as limestone, and therefore moves throughout the soil column more easily. Calcium ions from gypsum displace excess sodium and other ions, which then become mobile and diffuse. The calcium ions reduce dispersion of soil particles by promoting the aggregation of clay particles. This improves soil structure and stability and prevents soil crusting. Reduced crusting and better particle aggregation allow for greater water infiltration and storage in soil, thereby reducing runoff and erosion. These soil structural improvements also ease the emergence of seedlings and allow roots to penetrate further into the soil to take advantage of the additional stored moisture.

Mitigation of Contaminant Transport to Surface Water

In addition to water quality benefits associated with reduced runoff and erosion, FGD gypsum application can reduce the solubility of nutrients such as phosphorus in livestock and poultry manure and soils treated with manure. Gypsum converts readily soluble phosphorus to less-soluble forms, which can reduce the runoff of phosphorus into adjacent streams, lakes, or ground water. Excess phosphorus in runoff leads to water quality problems, including algal blooms and eutrophication of water bodies.

Gypsum Decisions in Agriculture

Recycling coal combustion products (CCPs) and other industrial materials can result in significant environmental benefits, including reduced greenhouse gas emissions, less use of virgin materials, and decreased use of landfills. The USEPA's Coal Combustion Products Partnership (C2P2) (http://www.epa.gov/epaoswer/osw/conserve/c2p2/) aims to increase recycling of CCPs, including FGD gypsum. In addition to its environmental benefits, FGD gypsum may be less expensive for users than mined gypsum, although transportation costs can be a factor in evaluating the practicality of using FGD gypsum as a gypsum source.

As with any fertilizer or chemical additive, there are a range of considerations that should be kept in mind when deciding whether to apply gypsum. Gypsum is not suitable for all soil types, soil conditions or crops. Appropriate application rates should be determined to accomplish specific soil improvement goals, while not exceeding state limits on the use of individual constituents. In general, application rates of up to two tons per acre should be sufficient to accomplish most agronomic and horticultural objectives[3].

In situations where there is excess sulfur in the soil, the amount of gypsum to be added should be balanced against copper nutrition in animals, as high levels of sulfur in feed can interfere with copper absorption. Boron concentrations in FGD gypsum typically are higher than in natural gypsum sources; therefore, crops sensitive to boron uptake such as cherry, peach and kidney bean may require lower application rates. The high calcium and sulfur content of gypsum can cause an imbalance in other soil nutrients, such as magnesium; therefore, soil nutrient characteristics, and potential plant and animal uptake, of these and other constituents should be understood and considered before deciding whether to use any gypsum product.

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3 Donstova et al. and other sources

In determining the environmental suitability of FGD gypsum for a particular location, you may find the USEPA's Industrial Waste Management Evaluation Model (IWEM) and the chapter on land application (Chapter 7) in the associated *Guide for Industrial Waste Management* (http://www.epa.gov/epaoswer/non-hw/industd/guide/index.htm) to be useful resources. You should also consult with your State's department of environmental protection to comply with any regulations pertaining to the management of CCPs. You may also find it helpful to consult with your State's department of agriculture and agricultural extension service, and with the USDA Natural Resources Conservation Service.

FGD Gypsum Beneficial Use Considerations

Decision	Things to Consider	Resources
1. Is gypsum a good choice for my needs?	• Types of crops • Nutrient requirements of crops • Soil structure • Soil chemical profile	• State department of agriculture/ag. extension agency • USDA Natural Resources Conservation Service
2. If gypsum is a good choice, should I use FGD gypsum?	• Trace element sensitivity of crops • Purity of available FGD gypsum • Cost differential	• State department of agriculture/ag. extension agency • Fertilizer supplier
3. Is the use of FGD gypsum environmentally protective?	• Ground water • Direct exposure • Ecosystem impacts • Surface waters	• State departments of environmental protection • EPA's *Guide for Industrial Waste Management*

References and Websites

The references and Websites below provide additional information and studies about the uses of gypsum in agriculture.

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EPA (2003) *Guide for Industrial Waste Management.* U.S. Environmental Protection Agency. EPA530-R-03-001. February.

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USGS (2005) *Major- and Trace-Element Concentrations in Soils from Two Continental-Scale Transects of the United States and Canada*. Open-File Report 2005-1253, U.S. Geological Survey. Available online at: http://pubs.usgs.gov/of/2005/1253/. Accessed September 13, 2007.

For More Information

--USDA Natural Resources Conservation Service:

http://www.nrcs.usda.gov/partners/for_farmers.html

--USEPA C2P2 Website: http://www.epa.gov/epaoswer/osw/conserve/c2p2

--USEPA Industrial Waste Management Website:

http://www.epa.gov/epaoswer/non-hw/industd/guide/index.htm

--FGD Products Website: http://www.fgdproducts.org/

--Information sheets on agricultural gypsum use from a leading distributor:

http://www.gypsumsales.com/gyp_whitepapers.html

--A paper on agricultural gypsum use from a distributor:

http://www.dktgypsum.com/news_content7.html

--Information sheet on FGD gypsum from the American Coal Ash Association: http://www.acaa-usa.org/PDF/EnvFocusFinal3g2.pdf

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