ELECTRIC POWER RESEARCH INSTITUTE

# Use of Flue Gas Desulfurization Products in Agricultural Applications

*2006 Workshop*

**1012698**

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Technical Update, March 2007

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# ABSTRACT

The use of flue gas desulfurization (FGD) systems to reduce sulfur dioxide ($SO_2$) emissions from power plants is expected to increase significantly, resulting in a concomitant increase in FGD products. Agricultural applications hold great promise for increasing the use of FGD products, while enhancing productivity for a variety of crops and improving marginal soils. In specific, when properly applied, FGD products can be used to favorably modify both the chemical and physical characteristics of soils, resulting in healthier growing environments and increased crop yields. The use of FGD gypsum to enhance no-tillage crop production along with the use of FGD materials as nutrient sources (primarily calcium and sulfur) are the most mature applications at present. Future research will examine surface applications after tillage for increasing crop production in heavy clay soils.

In 2006, EPRI initiated a multiyear research effort to help close data gaps identified in a literature review and to support increased use of various FGD products in appropriate agricultural applications (EPRI report 1010385). A two-day workshop on research and demonstration of agricultural uses of gypsum and other FGD materials was held in St. Louis, Missouri, September 10-12, 2006. This report summarizes workshop presentations and discussions and describes development of a network for demonstrating agricultural applications of FGD products.

# CONTENTS

# 1
# INTRODUCTION

The use of flue gas desulfurization (FGD) systems to reduce $SO_2$ emissions from power plants is expected to increase significantly, resulting in a concomitant increase in FGD products. Agricultural applications hold great promise for increasing the use of FGD products while increasing productivity for a variety of crops and improving marginal soils. In 2006, EPRI initiated a multiyear research effort to help close data gaps identified in a literature review (EPRI, 2006), and to support the increased use of the various FGD products in appropriate agricultural applications.

For the purpose of this report, an FGD product is any material produced when $SO_2$ is captured during or after the combustion of coal. The chemical composition of an FGD product is influenced by the type of coal, desulfurization process, sorbent used in the desulfurization process, and any other air emissions controls in place at the plant. FGD product types can be broadly divided into five types: (1) FGD gypsum – derived from wet limestone FGD systems with forced oxidation; (2) FGD scrubber solids – derived from wet FGD systems with inhibited or natural oxidation; (3) spray dryer absorber (SDA) solids – derived from spray dryer absorber systems; (4) sorbent injection solids – derived from dry injection of sorbents into the furnace (FSI) or flue gas ducts (DSI); and (5) fluidized bed combustor (FBC) bed material – derived from fluidized bed combustion systems.

A two day workshop on research and demonstration of agricultural uses of gypsum and other FGD materials was held in St. Louis, MO in September 2006. The general goal of the workshop was to bring together interested parties to discuss agricultural uses of FGD materials and plan implementation of a network of research and demonstration sites for beneficial land application uses of FGD materials. Sessions of the workshop included several presentations on the agricultural benefits of FGD materials, a discussion of FGD agricultural uses from the electric utility, policy, and regulatory perspectives, and presentation of the views of marketers of FGD products for agricultural uses.

This report summarizes presentations and discussions at the workshop, and development of a network for demonstrating the use of FGD materials in agriculture. All presentations made at the workshop are included on the FGD in agriculture network web site (http://www.oardc.ohio-state.edu/agriculturalfgdnetwork/) under the link “2006 workshop”. An agenda for the workshop is provided in Appendix A.

# 2

# WORKSHOP SUMMARY

## Agricultural Benefits of Using FGD Products

Beneficial land application of FGD gypsum and other products involves using the materials to improve the soil (primarily) and also the total environment. The intended benefit often relates to plant growth, but there may be other benefits to soil or water such as reduction of erosion, improved quality of runoff and/or leachate water, or improved internal drainage.

The primary benefits of FGD products in agriculture are summarized in Table 2-1 and then described in more detail in the paragraphs that follow.

**Table 2-1**
**Summary of Potential Benefits when FGD Products are used in Agriculture**

| FGD Product Property | Agricultural Benefit |
|---|---|
| Unreacted alkalinity | Liming substitute for improving productivity of acid soils. |
| Presence of required plant nutrients | Increased crop growth due to overcoming nutrient limitations. FGD products contain major and minor required plant nutrients. |
| Greater solubility for gypsum than agricultural lime | Movement of the sulfate to acid subsoils permits complexation of the sulfate with soluble $Al^{3+}$ and thus improves crop rooting and overall crop performance. |
| High levels of available Ca | (1) Displaces Na on soil exchange sites, thus facilitating the reclamation of sodic soils.<br>(2) Enhances aggregation of soil particles, thus inhibiting particle dispersion. The result is improved water infiltration and soil aeration. |

### *Soil pH*

The pH of soil is one of its most important properties that affect all types of soil functions. Before plants can use a nutrient, it must be dissolved in the soil solution. Most nutrients are more soluble or available in neutral or slightly alkaline soils. Strongly acid soils (pH 3.0-5.0) can have high concentrations of soluble aluminum, iron and manganese that may be toxic to the growth of plants. The soil pH can also influence plant growth by its effect on activity of beneficial microorganisms. Bacteria that decompose soil organic matter are hindered in strongly acid soils. This prevents organic matter from breaking down, resulting in an accumulation of organic matter and the tie-up of nutrients, particularly nitrogen, that are held in the organic matter.

Soils tend to become acidic as a result of (1) rainwater leaching away basic cations (i.e. calcium, magnesium, potassium and sodium), (2) formation of carbon dioxide from decomposing organic matter and root respiration that dissolves in soil water to form a weak organic acid, and (3) formation of strong organic and inorganic acids, such as nitric and sulfuric acid, from decaying organic matter and the oxidation of ammonium and sulfur fertilizers and metal sulfides. Strongly acid soils are most often the result of the action of these strong organic and inorganic acids.

To correct for low pH, lime is added to acid soils to neutralize acidity and increase soil pH. Some FGD products can be highly alkaline and have significant neutralization potential because they contain excess unreacted sorbent that did not react with the flue gas. Thus, one benefit of FGD products is that they can serve as replacements for agricultural lime (ag-lime). However, FGD products generally have less than 100% of total neutralizing power compared to agricultural lime. This means that FGD product application rates required to correct for acid soil conditions must be higher than that for ag-lime to achieve a similar soil response. However, several studies have shown that FGD products can be effectively used as alkaline amendments for agricultural soils (Terman et al., 1978; Stout et al., 1979; Korcak, 1980; Ritchey et al., 1996; Stehouwer et al., 1995; 1996, 1999; Chen et al., 2001).

### *Plant Nutrients*

A second benefit of FGD products is their ability to serve as sources of essential plant nutrients. Gypsum is one of the earliest forms of fertilizer used in the United States, having been applied to agricultural soils for more than 250 years (Tisdale et al., 1985). FGD gypsum is a quality source of both calcium and sulfur for plant nutrition. Sulfur is a macronutrient and must be available in relatively large amounts for good crop growth. Sulfur is a constituent of the amino acids cysteine and methionine and hence of protein. When deficient, it decreases the synthesis of proteins and the photosynthetic rate in plants (Marschner, 1986). Cysteine and methionine are also precursors of other sulfur-containing compounds such as coenzymes and secondary plant products. Sulfur is a structural constituent of these compounds or acts as a functional group directly involved in metabolic reactions.

Deficiencies of sulfur in crops are increasing (McGrath and Zhao, 1995). This is attributed to use of highly concentrated fertilizers containing little or no sulfur, intensive cropping systems, increased crop yield that results in more sulfur removal from fields, less sulfur deposition from the atmosphere, and less use of sulfur-containing pesticides. Alfalfa has a relative high requirement for sulfur and harvested yields greater than15 Mg $ha^{-1}$ remove approximately 40 kg of sulfur from the soil each year (Troeh and Thompson, 1993). Alfalfa yields were increased by gypsum application in sandy loams in Minnesota (O'Leary and Rehm, 1989). Sulfur deficiencies not only decrease yield, but also influence the feeding value of forage (Sexton et al., 1997).

In Wooster, Ohio, annual sulfate deposition gradually decreased from 34.8 kg/ha in 1979 to 22.0 kg/ha in 2005 (National Atmospheric Deposition Program, 2006) (Figure 2-1). A sulfur status model (Dick et al., 2006) for Ohio uses soil characteristics, atmospheric sulfur deposition, meteorological data, and sulfur requirements of crops to predict crop response to S fertilization. Based on this model, 296 of 475 soil series in Ohio were rated at least moderately deficient for alfalfa in one or more Ohio counties. Therefore, crop response to sulfur application on agriculture soils will occur with even greater frequency in the future. Chen et al. (2005) recently reported that alfalfa yields were increased by applying FGD products to soils in Ohio.

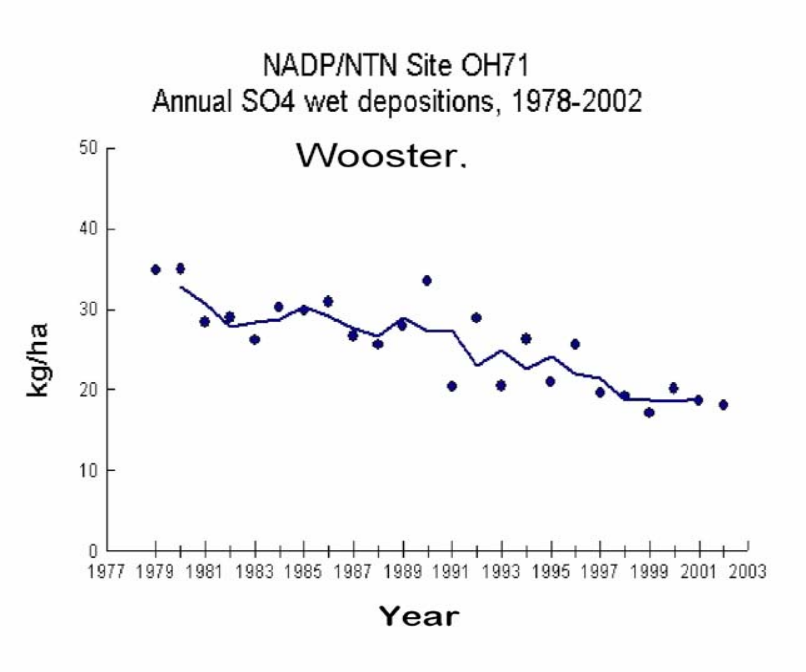


**Figure 2-1**
**Change in amount of sulfur deposited by rainfall at Wooster, OH from 1978 to 2002**

Ammonium sulfate is a common, although not widely used, nitrogen fertilizer due to its higher cost compared to other nitrogen fertilizer sources. It contains 21% nitrogen and is especially valuable where sulfur is also likely to be deficient. Fertilizer grade ammonium sulfate is produced by a few scrubbers that use ammonia as sorbent. Soil processes that act on ammonium sulfate will acidify the soil and, where this fertilizer is widely used, it is important to watch for changes in soil pH. However, provided the ammonium sulfate created by utility scrubbers is sufficiently pure and free of unwanted metals, it would seem to be a valued product for agricultural use.

Calcium serves as a nutrient for several crops. FGD gypsum has been widely used as a calcium source for peanut crops in the Southeast. Other crops that benefit from calcium include sweet potatoes, blueberries and Irish potatoes. Calcium addition has also been shown to increase the shelf life of several fruits and vegetables, including tomatoes and melons.

Phosphorus is an important plant nutrient, but runoff from agricultural fields can result in phosphorus loadings that are harmful to aquatic systems. Calcium from applied gypsum can help tie up reactive phosphorus, and reduce the amount of phosphorus in runoff.

### *Subsoil Acidity Amelioration*

FGD gypsum is much more soluble (Table 2-2) than soil liming agents such as dolomite ($CaMg(CO_3)_2$) or calcite ($CaCO_3$). This is a third benefit of FGD products that can be captured for agriculture. Whereas the beneficial effects of calcite or dolomite are mostly limited to the zone of incorporation, surface application of gypsum affects soil physical and chemical properties at depth (Hammel et al., 1985; Pavan and Bingham, 1982; Pavan et al., 1984; Farina and Channon, 1988). An associated effect of gypsum application to agricultural soils is thus the amelioration of phytotoxic conditions arising from excess soluble aluminum in acid soils, especially in acid subsoils (Sumner, 1970; Reeve and Sumner, 1972).

**Table 2-2**
**Solubility of Materials Used as Soil Liming Agents**

| Liming Material Name | Chemical Form | Solubility (g/L) |
|---|---|---|
| Gypsum | $CaSO_4{\bullet}2H_2O$ | 2.1 |
| Calcite | $CaCO_3$ | 0.01 |
| Dolomite | $CaMg(CO_3)_2$ | 0.32 |

One of the major soil types in Ohio where agriculture is practiced is Blount soil. Blount soil is often acidic below the plow layer (i.e. below about 20 cm depth). This acid subsoil restricts root growth and ultimately crop production because roots of corn in other soils commonly extend much deeper than 20 cm in search of water and nutrients. The addition of gypsum leads to improved corn root growth when applied with limestone (i.e. ag-lime) as compared to addition of limestone alone (Figure 2-2). This is because the soluble sulfate binds with the toxic aluminum ($Al^{3+}$), thus rendering it less harmful to plants and improving overall crop production. Blount soils total more than 2.5 million acres in the upper region of the cornbelt and there are many other soils east of the Mississippi River with properties similar to Blount soil.

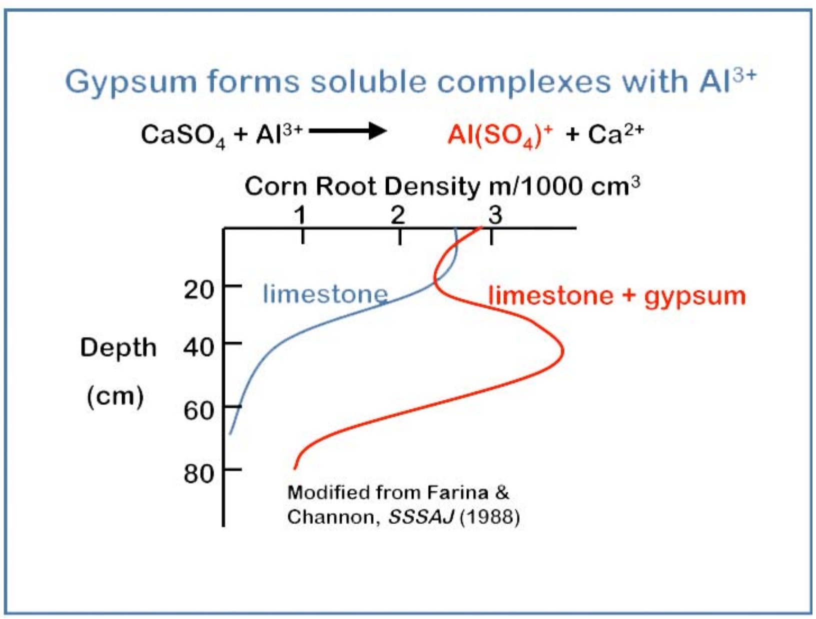


**Figure 2-2**
**Improved Rooting of Corn Plants When Gypsum is Applied to Soil**

In a separate study, Ritchey et al. (1996) reported that applications of FGD-gypsum to the plow layer reduced subsurface Al toxicity and improved deep rooting so that water and nutrient uptake by various crops was dramatically improved. For example, the percentage of corn roots found below 45-cm depth increased at least 600% with the addition of 6 Mg/ha or more of gypsum. Corn, wheat, soybean, sorghum and leuceana yields were increased by 45, 50, 24, and 50% over the control, respectively. Ritchey et al. (1996) also concluded that improved corn yields were due, in part, to increased nitrogen uptake in the gypsum treated soils.

### *Soil Structure and Infiltration*

A fourth major benefit of FGD products such as gypsum is also related to its solubility. Soils with high sodium and magnesium contents have poor structure because the sodium and magnesium tend to hydrate and disperse soil particles. Soil structure is defined as the arrangement of primary mineral particles and organic substances into larger units known as aggregates with their inter-aggregate pore system (Horn et al., 1994). Thus instead of the soil particles remaining in aggregates, around which water and air movement is easily facilitated, the dispersed soil particles clog soil pores. Soil structure has been shown to influence a wide variety of soil processes including water and chemical transport, soil aeration and thermal regime, erosion by wind and water, soil response to mechanical stress, seed germination, and root penetration (Dexter, 1988; Kay, 1990, Horn et al., 1994). Soil crusting is the destruction of surface soil structure by raindrop impact, resulting in a surface layer enriched with individual soil particles and micro-aggregates. Surface sealing reduces water infiltration and gaseous exchange with the atmosphere. The benefit of applying gypsum to soil is that the calcium is mobilized by dissolution of gypsum and replaces sodium and/or magnesium on the soil cation exchange complex, thus promoting flocculation and structure development in these highly dispersed soils (Oster, 1982; Shainberg et al., 1989). Gypsum has been shown to improve soil infiltration of water into soil (Norton, 1995; Norton and Dontsova, 1998; Zhang et. al., 1998).

There is developing an increasing awareness among farmers of the benefits of applying gypsum to no-tillage soils. The benefits seem especially noticeable when gypsum and no-tillage are applied to heavier soils (i.e. soils containing a substantial amount of clay) where no-tillage has traditionally not been practiced. When no-tillage is continuously practiced, major changes in soil organic matter quantity and quality occur (Dick et al., 1991). The amount of carbon stored in the top 20 cm of a no-tillage soil under continuous corn was 6.0 Mg/ha (2.7 tons/ac) greater than in plow tillage plots. Organic matter accumulated in the surface 7.5-cm soil layer at levels 3 to 6 times higher than when the soil was tilled each year (Dick and Durkalski, 1997). Properties of soil that benefit from the maintenance of organic carbon include increased water retention, metal chelation, buffering activity, plant nutrient storage, microbial activity, and cation exchange capacity (Dick and McCoy, 1993). Recently, the issue of global warming has emerged as a national and international issue. Global warming is caused, in part, by carbon dioxide buildup in the atmosphere through the conversion of natural ecosystems to agriculture. This accumulation can be slowed by adoption of no-tillage, which removes carbon dioxide from the air and returns it to the soil where it is stored in the form of soil organic matter.

No-tillage technology is well advanced, but it has not been fully adapted to all soils. Somewhat poorly drained soils with seasonal high water tables can only be no-tilled with careful management (Ohio Cooperative Extension, 1990). These soils produce optimum yields under no-till if they are systematically drained and crops are rotated. If adequate drainage and residue are present, no-tillage yields should be equal, on average, to those obtained by plowing. Poorly drained soils that respond to tile drainage may also be adapted to no-till crop production with tile drainage and crop rotation (Ohio Cooperative Extension, 1990). If drainage and rotation are not used, yields under no-till may be lower than had the field been plowed.

In Ohio alone, approximately 57% (5.9 million acres) of the soils used for cropland have a natural drainage limitation (Ohio State University Extension, 1995). This is the cropland that is not widely no-tilled but could be if surface and internal drainage were improved. Gypsum can increase water penetration and improve internal soil drainage because it dissolves quickly and releases electrolytes that aggregate soil clay particles, i.e. gypsum releases calcium which replaces exchangeable magnesium and sodium that naturally tend to disperse soil clays (Shainberg et al., 1989). Therefore, applications of FGD-gypsum could significantly increase the amount of land suitable for no-tillage, including soils where tile drainage is needed for good crop performance.

Finally, increased no-tillage leads to increased carbon sequestration in soil (Lal, 1998), and increased organic carbon concentrations in soils have many crop production and environmental/ecological benefits. While this will improve soil quality and benefit farmers, the increased carbon sequestration can also lead to agriculture being an important source of low cost carbon credits to producers of carbon dioxide.

## Potential Barriers and Opportunities

In addition to the many benefits presented in the previous section, several other important points and questions for promoting the use of FGD products in agriculture were discussed at the workshop. Some of these are summarized below.

### *Trace Elements*

FGD products contain trace elements of environmental concern such as arsenic, barium, cadmium, chromium, lead, mercury and selenium (Kost et al., 2005; Clark et al., 2001; Korcak, 1995; Carlson and Adriano, 1993). Trace element concentrations in FGD products are variable and depend on many factors, including coal source, combustion conditions, FGD technology, and other air emissions controls at a power plant. Concentrations in FGD gypsum are typically low. Since trace elements can have a direct impact on the potential agricultural utilization of these materials, the concentrations should be determined prior to use.

The concentration of boron is sometimes found to be high in some FGD products. Plants require boron for good growth, but the range for optimum growth is very narrow. High available boron levels could induce toxicity. However, where boron is deficient, addition of boron on deficient soils may be beneficial.

Recent reports have raised concern that by removing mercury from flue gases, the environmental burden is shifted from the flue gases to the solids formed as by-products of the coal combustion and flue gas scrubbing processes. If mercury is substantially concentrated in FGD product, this could inhibit the use of FGD product for agricultural applications. Little information exists as to the effect of current levels of mercury in FGD on soil processes and plant uptake. Recently Schroeder and Kairies (2005) have shown that mercury in FGD products may be associated with a relatively small iron-rich fraction of the material, while EPRI and others have shown that it may be concentrated in the gypsum fines. This research suggests that by modifying the FGD product recovery process, or by adding a processing step after recovery, the levels of mercury in the FGD may be substantially reduced.

### Terminology and Classification

Developing clearly defined terminology and classification standards for FGD products to be used in agriculture will be important. Classification could involve ASTM designations similar to class C and class F fly ashes, or agricultural use standards could be developed in conjunction with the USDA. There is a question of how broad the standards should be. If there is a 10% change in the fuel mix used by a power plant, will the resulting FGD material still be within standards? Upsets in dewatering or scrubbing will have large effects on quality assurance and quality control for FGD gypsum. How often should materials be analyzed for quality control?

Ordinary mined gypsum is generally classified as a soil amendment, but some states regulate it as a fertilizer. A national standard for use of FGD gypsum in agriculture would be valuable, but state-by-state registration will probably be the norm. Because FGD products are classified as solid wastes in some states, its importation into a different state may sometimes by restricted. It is important to move away from the idea of FGD gypsum and other FGD products used in agriculture as solid wastes. To that end, power plants that generate FGD gypsum and other materials should be aware of the importance of producing a consistent material that can be marketed as a product and not labeled a solid waste.

### End-User Education

Development of new markets for agricultural uses of FGD products will depend on educating the agricultural community on the value of the products. Marketers of FGD products must deal at a local level with growers and farm associations. Agriculture extension agents, word of mouth, and local experts are the best means for obtaining buy-in by the growers. New agricultural uses of FGD materials should be announced in agricultural trade publications. Adoption of new practices take time in the farming industry, on the order of ten to twenty years. The power industry and marketers should not promise more material than can be readily supplied to farmers on a consistent basis. Development of a local market for FGD gypsum before a new generating plant comes online may be problematic because the FGD gypsum would not yet be available for use in agricultural demonstrations. In such cases it may be necessary to transport other FGD gypsum by truck to the potential market area for use in demonstrations to jump-start the market demand.

### Material Handling and Transportation

All participants at the workshop affirmed that transportation cost is critical. Material handling adds cost each time the product is moved. Cost of over the road transportation is about $0.10 per ton per mile. As a rule of thumb, workshop participants thought that trucking was limited to a range of 30 to 100 miles from the power plant. However, instances are known where delivery as far as 200 miles from the source has been made. Rail and barge transportation are not extensively used, but may be economical once adequate markets are developed.

There may be a need for equipment designed specifically for applying FGD gypsum and other specific FGD materials, although it is possible to spread FGD gypsum with conventional farm equipment. Some considerations in equipment design are moisture content and particle size of the FGD product, and angle of repose of piled material.

### *Market Size*

The size of the agricultural market is immense. Row crops alone account for more than 200 million acres in the United States, and that figure remains relatively constant from year to year. Use of FGD gypsum on 5 percent of available row crops, at an average rate of 1 on per acre, would utilize more than 10 million tons.

## Research Needs

Highest priority research needs were discussed at the workshop. Particular needs at the present time are: (1) to demonstrate FGD gypsum use in several different geographic locations; (2) to investigate newer or less researched types of FGD products, such as calcium sulfite and ammonium sulfate, for agricultural use; and (3) to answer questions related to potential environmental impacts of FGD use in agriculture.

# 3

# NATIONAL NETWORK FOR RESEARCH ON LAND APPLICATION USES OF FGD PRODUCTS

To promote use of FGD products, especially FGD gypsum, a national network of agricultural demonstration and research sites is under development for the United States. Development of this network is funded by EPRI, the DOE Combustion By-product Recycling Consortium (CBRC), and The Ohio State University (OSU). Workshop participants discussed the purpose of such a network, and implementation of the research plan.

Network sites, strategically located in the United States, will be available to producers, users and marketers of FGD products. They will provide a place where observations can be made as to the benefits of FGD product use under regional agricultural conditions. In addition, data on crop yields, environmental impacts and economic benefits will aid in the marketing of the FGD products.

To obtain maximum benefit from such a network, it is important that a common set of research protocols be established. This ensures that valid comparisons can be made not only for treatments at a single site, but also to provide information across a much larger scale (e.g.. national or even international). OSU will take the technical lead in developing experimental protocols, coordinating research at network sites, analyzing the results, and preparing reports and other documentation. In addition, all analytical work will be performed at OSU laboratories.

A standard field experiment for the FGD research network would use two materials (an FGD material plus a commercially available substitute) at three rates plus an untreated control. The three rates would include a perceived optimum rate plus one rate greater than and one rate less than the optimum rate. Using two materials multiplied by three rates yields six treatments that, in combination with an untreated control, produce a total of seven treatments. These treatments will be arranged in a randomized complete block design with four replications as shown below in Figure 3-1. Other arrangements can be easily accommodated including strip tests in full-scale farmer fields.

| | |
|---|---|
| **Replicate 1** | **Replicate 2** |
| **Replicate 3** | **Replicate 4** |

**Figure 3-1**
**Randomized block field plot design**

In the standard field experiment, combining seven treatments with four replicates requires a total of 28 plots. Replicate 1 will have seven plots with each treatment assigned to a plot. This arrangement is repeated for Replicates 2, Replicate 3, and Replicate 4. The seven plots in each block should be as uniform as possible in terms of perceived site conditions such as previous land use history, slope, drainage, soil texture, or other recognizable field characteristics. For example, if the experimental site has a uniform slope in one direction, a block of seven plots should be located across the slope contour at the same slope position (Figure 3-2) to eliminate variation caused by, for example, moisture differences across the slope.

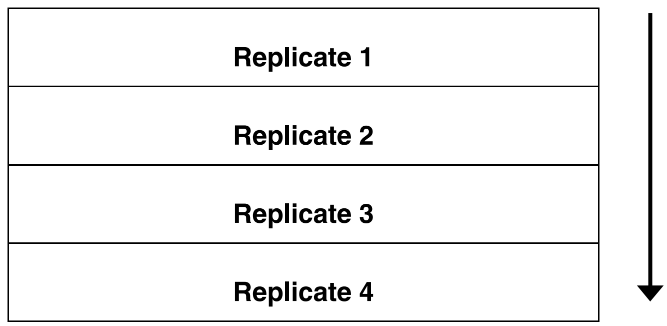


**Figure 3-2**
**Randomized block field plot design located on slope in one direction**

Plot size will vary depending on the crop to be grown, the type of FGD benefits that is being tested, space available, and equipment. Initial plots will be established in Spring 2007. It is anticipated that all field plots will be maintained and monitored for a minimum of two growing seasons.

The plots will be extensively monitored for a wide range of environmental and performance criteria. Crop yields and quality will be measured to evaluate the effectiveness of the FGD gypsum product application. Environmental testing will also include soil composition before and after treatments, soil water quality, and plant uptake of trace metals. To address unique concerns with respect to mercury, mercury emissions from emissions from treated soils will also be measured.

It was suggested at the workshop that the FGD research network should focus on FGD gypsum in view of its expected increase in production volume over the next two decades, as well as its proven success in agricultural applications. Other materials to be studied will include scrubber solids, spray dryer absorber solids, and possibly FBC material. These materials have significantly different chemical and physical properties than FGD gypsum. However, they may be beneficial in certain agricultural applications. In reality, there is probably a productive agricultural (or land application) use for almost all FGD products, limited only by the ingenuity to recognize the suitability of a material for a particular use.

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# A
# WORKSHOP AGENDA

## SESSION I - Review of Agricultural Benefits

*Workshop Introduction and Statement of Workshop Goals*
Ken Ladwig, Electric Power Research Institute

*What is Gypsum and What is Its Value for Agriculture?*
Dave Kost, The Ohio State University

*Benefits of Gypsum for Soil and Water Management*
Darrell Norton, United States Department of Agriculture

*Turfgrass Growth and Water Use in Gypsum-Treated Ultisols*
Max Schlossberg , Penn State University

*Effects of Various Soil Amendments on Soil Test P Values*
Dave Brauer, United States Department of Agriculture

*Use of Gypsum for Crop Production on Southeastern Soils*
Lamar Larrimore, Southern Company

*Soil Reclamation Using FGD Byproduct in China*
Xuchang Xu, Tsinghua University, Beijing, China

*Research on Use of FGD Gypsum in Ohio*
Warren Dick, The Ohio State University

## SESSION II - Utility, Policy and Regulatory Perspectives

*EPRI Perspective on Using FGD Gypsum in Agriculture*
Ken Ladwig, Electric Power Research Institute

*DOE's Perspectives and R&D Related to FGD Products*
Bill Aljoe, National Energy Technology Lab

*FGD Gypsum: An Important Resource for the CCP Industry*
Dave Goss, American Coal Ash Association

*USWAG's Perspective on Use of FGD Products in Agriculture*
Jim Roewer, Utility Solid Waste Activities Group

*Value to Utilities of Agronomic Uses for Gypsum*
Lamar Larrimore, Southern Company

*Flue Gas Desulfurization Gypsum Production, Processing, and Disposal*
Cheri Miller, Tennessee Valley Authority

*Evaluating Life-Cycle Environmental Trade-Offs from Use of FGD Gypsum*
Susan Thorneloe, US Environmental Protection Agency

*Mercury Speciation in FGD: Assessing Transport and Bioavailability Risk*
Kirk Scheckel , US Environmental Protection Agency

## SESSION III - Marketer's Perspectives

*US Gypsum's Perspective on Marketing to Agriculture*
Doug Snyder, US Gypsum

*Opportunities and Challenges of Marketing FGD-Gypsum to Agriculture*
David Flack, AgSpectrum

*Using Calcium Sulfate as a Soil Management Tool*
Bob Hecht, Soil Solutions

*Service and Product Pitfalls to Avoid in the Agricultural Market*
Vern Dearth, Headwater Resources

## SESSION IV - National Research and Demonstration Network

*Where Are We Now and Where Do We Go?*
Warren Dick, The Ohio State University

*Presentation and Discussion of National Network*
Warren Dick, The Ohio State University
Ken Ladwig, Electric Power Research Institute

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