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MEMO

DT: April 27, 2016
TO: District Commissioners
FR: District Director
RE: FGD Group Meeting at HOVMSD

Attendees: Representatives from:
- Electric Power Research Institute
- Sand County Foundation
- Outagamie County Land Conservation
- HOV Commissioners and Staff

Members of the above groups met at HOV to consider a research program on the use of Flue Gas Desulfurization (FGD) gypsum, recovered from electric power plants, in agricultural applications.

The group is considering the use of the Districts' agricultural land, and that of adjoining neighbors, for a research study. The potential study would involve the addition of FGD gypsum to agricultural lands. The runoff from these fields would be monitored with sampling and analysis of samples.

The gypsum addition can provide the benefits of improved soil health, crop yields, and water quality in nearby waterways. A research program could show that the addition of gypsum aids in the mitigation of P concentrations in runoff and tile drainage from agricultural land. And that gypsum can be an effective tool in controlling soluble P contributions to surface waterways.

In this case, the District may be able to use this measured reduction in P runoff from its fields to obtain a Water Quality Trading P credit toward meeting the Districts' next NPDES Wastewater Permit limits.

A copy of a research report prepared by Ken Ladwig, of the EPRI, is included for your information.

EPRI RESEARCH ON THE USE OF FGD GYPSUM IN AGRICULTURAL APPLICATIONS

Ken Ladwig, Land and Water Science, Electric Power Research Institute

The Electric Power Research Institute (EPRI) maintains a robust research program on the use of flue gas desulfurization (FGD) gypsum in agricultural applications. The research is driven by the benefits gypsum can provide to soil health, crop yield, and water quality in nearby waterways. In addition, the quantity of FGD gypsum produced by the electric power industry has nearly tripled since 2006 as power plants remove more sulfur dioxide from the flue gas to meet new air emissions requirements, resulting in a large resource supply. EPRI research over the last ten years shows that the application of FGD gypsum to farm fields, as an alternative to mined gypsum, does not result in significant environmental impacts and that FGD gypsum can be an effective tool in controlling phosphorous runoff.

Gypsum ($CaSO_4 \cdot 2H_2O$) mined from native rock sources has been used to improve soil quality and crop yields in the United States for more than two centuries (Table 1). In the 1990s, power plants began to produce FGD gypsum as plants installed wet FGD systems using forced oxidation technology. Forced oxidation changes calcium sulfite ($CaSO_3 \cdot 0.5H_2O$) initially produced in the scrubber to calcium sulfate (gypsum, $CaSO_4 \cdot 2H_2O$). These systems produce fine-grained gypsum with fewer mineral impurities than mined gypsum[1], making it an attractive alternative to mined gypsum for many applications, such as wallboard and agriculture.

Table 1. Known Agricultural Benefits of Gypsum Application

Improvement in Soil Health/Soil Quality
Reduced Subsoil Acidity
Plant Nutrients (Calcium and Sulfate)
Improved Water Infiltration and Soil Aeration
Reduced Phosphorus in Runoff and Drainage
Remediation of Sodic Soils
Improved Crop Yield and Quality

Gypsum Agricultural Network

In 2006, EPRI and The Ohio State University (OSU) initiated research on a network of sites across the United States to evaluate use of FGD gypsum on field plots. Dr. Warren Dick led a research team that included the United States Department of Agriculture – Agricultural Research Service (USDA-ARS) and several universities performing the field tests (Table 2). The primary purpose of the research was to evaluate the potential for environmental impacts to soil, water, and plant quality associated with the FGD gypsum application.

Network field sites were established in seven states, with each following similar protocols for consistency. The field tests used a randomized block design for statistical analyses. Seven treatments were used—FGD gypsum and commercially available mined gypsum products at three application rates each, and one control plot. Each treatment was replicated four times for a total of 28 plots. Agronomic application rates were used depending on the crop and soil types, ranging up to five tons per acre.

Samples were collected and analyzed during a two-year period to evaluate changes to soil, water, and plant quality. Plant yield was also measured. For each site, the results were analyzed statistically to assess possible changes due to the treatments. Table 2 lists the locations, crop types, and final EPRI report number for each of the field studies.

Overall, the field studies found no evidence of significant environmental impacts to any media (i.e., soil, plant, water) on the FGD gypsum treated plots when compared to the plots treated with commercial gypsum products and the controls. These results are consistent with data on the composition of FGD gypsum, which has few mineral impurities and low levels of trace constituents[1].

The results with respect to crop yield were mixed. In many cases the gypsum plot yields were similar to the controls. This likely reflects the fact that yield was a secondary consideration in the network research, and field sites were not selected to target specific soil and crop types that would benefit from gypsum application. Also, the short time over which the study was conducted (i.e. two years) is often not long enough to see significant changes occur in soil quality that then impact crop yield. This suggests that soil and crop types should be carefully evaluated when considering gypsum amendments in order to maximize the yield benefit.

An earthworm study was also conducted as part of the network research to determine the environmental fate of metals in the FGD gypsum. Bioaccumulation factors, defined as the ratio of the concentration of an element in an earthworm living in a soil treated with gypsum to the concentration of the metal in the soil itself were calculated. The values determined were found to be statistically similar or lower for the FGD gypsum treatments compared with the controls, suggesting no significant concentration impacts to earthworms at normal agronomic application rates[2].

Additional EPRI studies were performed specifically to assess mercury due its presence in FGD gypsum by Dr. Mae Gustin at the University of Nevada-Reno. Greenhouse studies with 66 tubs were set-up with field soils and FGD gypsum and commercial gypsum products, and perennial rye grass. Mercury and methylmercury were measured in soil, water, plants, and flux to air. The use of FGD gypsum amendments did not significantly affect any media, including flux to air[3]. The mercury and sulfur in the FGD gypsum also did not enhance methylmercury production under these test conditions.

Mitigating Phosphorous in Agricultural Runoff

Runoff and tile drainage from agricultural fields represent non-point sources of nutrients (phosphorus and nitrogen) that can significantly degrade surface water quality. Phosphorus is a primary limiting nutrient for a variety of terrestrial plants and aquatic algae, and transport of excess phosphorous applied as fertilizer can lead to algal blooms in freshwater systems. The increasing frequency of algal blooms in the United States and elsewhere has made nutrient management in agriculture a high priority. High profile incidents of algal blooms include the recent degradation of the City of Toledo drinking water on the western end of Lake Erie[4], and creation of ecologically "dead zones" (such as in the Gulf of Mexico and Green Bay, WI) due to the depletion of dissolved oxygen as the unusually large numbers of algae decompose[5].

Table 2. Gypsum Agricultural Network Sites
EPRI reports can be downloaded from the EPRI website (www.epri.com)

State	Crop	Local Researchers	EPRI Report
North Dakota	Canola	North Dakota State Univ.	1021794 (2011)
North Dakota	Wheat	North Dakota State Univ.	1021817 (2011)
Ohio	Hay/Corn	Ohio State Univ.	1025354 (2012)
New Mexico	Alfalfa	New Mexico State Univ.	1025355 (2012)
Wisconsin	Alfalfa	Univ. of Wisconsin	3002001309 (2013)
Indiana	Corn/Soybeans	USDA-ARS (Purdue Univ.)	3002001236 (2013)
Arkansas	Cotton	Univ. of Arkansas	3002001310 (2013)
Alabama	Cotton	USDA-ARS (Auburn Univ.)	3002003265 (2014)
Alabama	Bermudagrass	USDA-ARS (Auburn Univ.)	3002006090 (2015)

Several laboratory and plot-scale studies in the past few years have shown the potential for FGD gypsum to help mitigate loss of phosphorus from agricultural fields (for example, see reference 6). These studies have generally suggested that a 40 to 70 percent reduction in phosphorus loading is possible using gypsum. EPRI has teamed with researchers at OSU and the University of Wisconsin (UW) to assess the phosphorus mitigation benefits at a field scale and to create greater confidence around the best agricultural practices that can provide both water quality and crop yield (quality) benefits. This research is supported by several power companies located in the Midwest.

Ohio Study

OSU's Dr. Warren Dick is leading the research in the Maumee River Basin in Ohio on the west end of Lake Erie. The Maumee River has been shown to be a major contributor to phosphorus in Lake Erie.[7] Field identification, management and sampling are supported by Nester Ag LLC, Beneficial Reuse Management LLC (Gypsoil), and Greenleaf LLC.

Each field site consists of paired fields, one field receiving gypsum treatment while the other serves as a control (no gypsum). Eight sites were established in the Maumee River Watershed and have been monitored since 2012 or 2013. Water samples were manually collected at "edge-of-field" locations from drain tiles and tested for phosphorus (P) concentrations during or after rainfall events. From June 2012 to June 2015, soluble P concentrations were obtained for 87 sampling events. In addition, nearly 200 soil samples were collected and crop yield response was monitored. Most of the fields were planted in a corn-soybean rotation.

Mean soil P concentrations ranged from 20 to 200 mg/kg for the eight paired fields. Soluble P concentrations varied from below detection to 0.4 mg/L. Figure 1 shows the percent reduction in soluble P between the treated field and the control for each event. Positive percent reduction indicates that P concentration was lower on the gypsum-treated field than the control, and a negative percent reduction indicates the concentration was higher on the gypsum treated field than the control.

Below 0.1 mg/L, the data are randomly scattered indicating no effect of the gypsum treatment. However, at higher concentrations the gypsum benefit is clearly evident, with all but one sampling event yielding a P reduction; reductions ranged from 20% to 93%. The photo in Figure 2 visually shows the difference in tile drainage from a treated field and control field. Annual sampling suggest the benefits of the gypsum decreases with time. Thus a reapplication will probably be needed every other year or every third year to maintain water quality until soil levels decrease to a point where they no longer pose a threat to water quality.

In addition, field plot trials evaluating the interaction of nitrogen application rates and gypsum application rates on soil properties and corn productivity were established at two sites controlled by The Ohio Agricultural and Research Center (OARDC) operated by OSU. Results from these plots are expected to be available in 2016.

In 2016, the project team plans to collaborate with the USDA-ARS to perform automated monitoring at two to four USDA sites in northwestern Ohio. These sites also use an edge-of-field monitoring approach, but employ automated flow monitoring and sampling of both surface runoff and drain tiles.

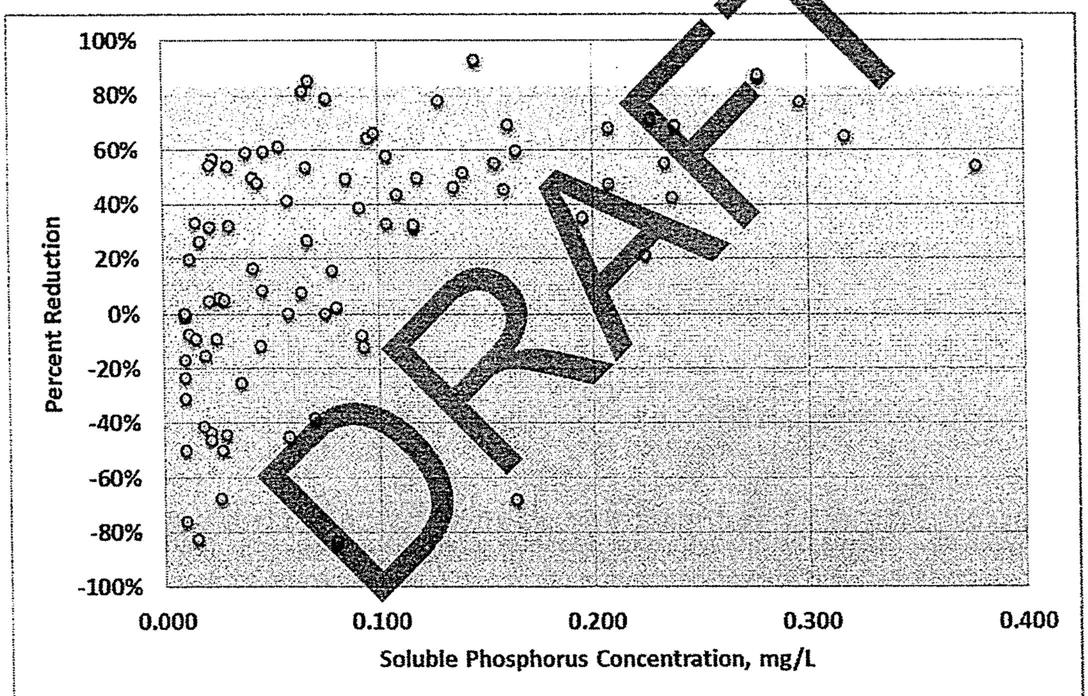

Figure 1
Percent reduction in soluble P on the gypsum treated fields as a function of soluble concentration

Figure 2
Tile drains at paired field and samples collected as part of this study

Wisconsin Study

In parallel with the Ohio study, UW's Dr. Francisco Arriaga is leading research in the Milwaukee River Basin in southeastern Wisconsin. Field identification, management, and sampling are supported by Sand County Foundation and Beneficial Reuse Management LLC (Gypsoil).

The Wisconsin study is also using an edge-of-field sampling approach on three paired sites. These three sites have surface runoff only (no drain tiles), and automated flow/sampling equipment is being used. In general, soil P concentrations were much lower than in the Ohio study. The initial FGD gypsum treatment was in 2014, but large rainfall events immediately after the treatments confounded the 2014 results. FGD gypsum was reapplied in late 2014 and monitoring has continued since then. Results are expected in early 2016.

Laboratory incubation studies are also being performed by UW. Soil samples were spiked to obtain samples with low (≈45 mg/kg), medium (≈175 mg/kg) and high (≈380 mg/kg) soil P levels. Gypsum was then applied to the soils at application rates of 0.5 to 4.0 tons/acre. To date, soluble P reductions ranging from 21% to 67% have been observed relative to the controls. Percent reductions increased with increasing gypsum application rate. Importantly, plant available P was not affected by the gypsum treatments. The objective of the incubation study is to quantify the impact of gypsum application rates on soluble P concentrations, and eventually adjust the P index for sites that apply FGD gypsum.

Summary

FGD gypsum is a valuable product for many agricultural applications, including improving soil properties, increasing crop yields, and mitigating P concentrations in runoff and tile drainage. Ten years of EPRI research has shown that the application of FGD gypsum to farm fields does not result in any significant environmental impacts to soil, water, and plant quality, and that FGD gypsum can be an effective tool in controlling soluble P contributions to surface waterways. During these ten years, use of FGD gypsum in agriculture has increased by more than ten times, a trend that is expected to continue. In 2015, USDA-Natural Resources Conservation Services (NRCS) established a national Practice Standard for use of gypsum[8], which will allow state NRCS programs to reimburse producers for use of gypsum as a Best Management Practice (BMP). State BMPs may also facilitate the use of FGD gypsum in nutrient water quality trading programs.

References

1. EPRI, 2011. *Composition and Leaching of FGD Gypsum and Mined Gypsum*. EPRI, Palo Alto, CA: 2011. 1022146.
2. Chen, L., Kost, D., Tian, Y., Guo, X., Watts, D., Norton, D., Wolkowski, R., and Dick, W., 2014. *Effects of Gypsum on Trace Metals in Soils and Earthworms*. Journal of Environmental Quality, 43 (1), 263-272.
3. Briggs, C., Fine, R., Markee, M., and Gustin, M., 2014. *Investigation of the Potential for Mercury Release from Flue Gas Desulfurization Solids Applied as an Agricultural Amendment*. Journal of Environmental Quality, 43 (1), 253-262.
4. National Geographic (2014). http://news.nationalgeographic.com/news/2014/08/140804-harmful-algal-bloom-lake-erie-climate-change-science/ Accessed December 8, 2015.
5. United States Geological Survey (USGS) (2015). http://toxics.usgs.gov/hypoxia/hypoxic_zone.html Accessed December 8, 2015.
6. Torbert, H. A. and Watts, D. B. (2014). *Impact of Flue Gas Desulfurization Gypsum Application on Water Quality in a Coastal Plain Soil*. Journal of Environmental Quality, 43 (1), 273-280.
7. United States Department of Agriculture (USDA) (2015). http://www.nrcs.usda.gov/wps/portal/nrcs/detail/in/programs/landscape/?cid=nrcs144p2_031032. Accessed December 8, 2015.
8. USDA-Natural Resources Conservation Service. 2015. *Amending Soil Properties with Gypsum Products*. Conservation Practice Standard Code 333. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849 Accessed February 4, 2016.