United States Department of Agriculture
Research, Education, and Economics
Agricultural Research Service

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Mr. Matt Hale
Director, Office of Resource Conservation and Recovery
US Environmental Protection Agency
Potomac Yard North
2733 South Crystal Drive
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Dear Mr. Hale:

The purpose of this letter is to express USDA-Agricultural Research Service (ARS) interest in current information and research on beneficial uses of industrial byproducts such as coal combustion products (CCPs) in agricultural settings. Some CCPs have chemical and physical properties that could ameliorate natural resource concerns. Only CCPs that do not pose unacceptable risks to public health or the environment can be considered for agricultural uses. The intent of ARS research activities is to contribute science-based information for risk assessment of CCPs, develop guidelines for specific uses of CCPs, and develop decision tools that can be used to support management, policy and regulatory decisions relative to agricultural uses of CCPs. The attached article (Haynes, 2007) is provided as an earlier, published summary of many issues addressed in this letter. An annotated bibliography of publications on agricultural applications of CCPs, compiled by the National Agricultural Library, is also enclosed to illustrate the range of research that has been conducted on these materials.

Materials and Characteristics for Agricultural Uses

During combustion of coal in coal-fired power plants, several byproducts are generated. Bottom ash and boiler slag remain at the base of the furnace and are collected and disposed as solid waste. Other solids enter the exhaust gases which must be treated to remove contaminants from the exhaust. Electrostatic precipitators have been used for decades to remove most solids from the stack exhaust, generating fly ash (FA). More recently, power plants began to add lime in wet or dry treatment processes to remove sulfur dioxide (SO_2) from exhaust gas - forming flue gas desulfurization products (FGDs). The final product generated using wet scrubbers and forced oxidation is calcium sulfate, referred to as FGD-gypsum. The American Coal Ash Association (ACAA) estimated that approximately 115 million metric tons of CCPs were produced in the United States in 2007. The percentage distribution of CCPs by weight in 2007 was: 54.7% FA, 13.8% bottom ash, 1.6% boiler slag and 25.2% FGDs. FA and FGD production are expected to increase over time (ACAA, 2008; EPA 2008). CCPs are already being used to a limited extent in agriculture.

Increased use of appropriate CCPs in agriculture could have several benefits including: improved soil properties for increased crop production and environmental protection; removal of contaminants from runoff, drainage water and wastewater; promotion of increased recycling; reduced energy costs; and low-cost materials for agricultural producers. To be useful in agriculture, CCPs must have several key characteristics: (1) low concentration and bioavailability of toxic trace elements; (2) physical and chemical properties that confer distinct benefits, such as reduce soil erosion, improve water infiltration, remediate saline and high-sodium (sodic) soils, remediate acidic soils, serve as a nutrient source for crops, and/or reduce movement of nutrients, sediment and agricultural chemicals to water and air; (3) consistent composition so that performance is predictable; (4) availability in large amounts at numerous points around the country so transportation costs to sites where the materials would be used are manageable; and (5) cost-effectiveness or profitability for the generator and the agricultural user of the material.

Beneficial Uses of Coal Combustion Products in Agriculture

Historically, utilization of CCPs in agriculture has been low. Much of the early research studied rates of application that could be reasonably achieved for disposal purposes (e.g., more than 200 tons per acre, T/A) rather than fertilizer or soil amendment application rates (typically 1-10 T/A/year). Three principal uses have been considered beneficial: 1) as an alternative to limestone to increase pH; 2) as a fertilizer providing essential plant nutrients such as calcium, sulfur, magnesium, potassium, phosphorus, boron, iron, manganese, copper and zinc; and 3) as a soil amendment to improve soil structure in fine- and course-textured soils to improve water infiltration and root growth (Norton et al., 1993; Brauer et al., 2005).

An example of application to provide plant nutrients is use of FGD-gypsum from a power plant in Minnesota, which was tested as an alternative to limestone to establish alfalfa. Alfalfa is grown as a perennial crop for 3-5 years before crop rotation, and soil is adjusted to pH 7 or greater when the crop is established. In addition, both boron and sulfate fertilizers are needed for maximum crop production. Application of FGD-gypsum containing 50% limestone equivalent in addition to moderate levels of boron and selenium was appropriate to produce alfalfa. Elements such as boron or selenium, which would be supplied to excess if the FGD were applied at disposal rates, became important fertilizers that improved yield and quality of the alfalfa for feeding to livestock (Sloan, et al., 1999).

An important use of FGD-gypsum is as a replacement for commercial gypsum applied to peanuts on Coastal Plain soils in the southeastern US. Gypsum must be applied to the coarse textured soils to support grain filling of peanut, and the FGD applied at a few T/A fully satisfies requirements for plant nutrition (Dick, 2008; Larrimore, 2008). Recently available FGD-gypsum is very similar to mined gypsum normally used for fertilizing peanuts. It has also been shown that application of FGD gypsum improves crop production and crop quality for a number of other crops, including tomatoes and corn (Dick, 2008; Larrimore, 2008).

Revegetation of acidic coal mined land has been shown to be a beneficial use of alkaline fly ash and FGD products. Many areas of disturbed coal mine land remain highly acidic and nearly barren of plant growth due to the toxicity of natural soil constituents such as aluminum and manganese in the mine spoil material, as well as a lack of essential plant nutrients. Technologies have been developed to revegetate such land by neutralizing the soil acidity and applying required nutrients. Very effective revegetation demonstration programs have been conducted in several states, in which combinations of CCPs and other byproducts such as manure, compost or biosolids are used; the amended land may become as productive as it was before mining (Stehouwer et al., 1995; 1996).

Of all the CCPs, FGDs generated by removing sulfur dioxide from the flue gases of coal-fired power plants probably is the most promising material for agricultural use. This material is essentially identical to mined gypsum that has been used for centuries in agriculture as a soil amendment to supply plant nutrients and improve soil properties. A considerable amount of information is available about the beneficial impact of FGD gypsum application on crop yield and crop quality. The solubility of gypsum makes it an excellent source of calcium and sulfur, both essential nutrients for plant growth. Sulfur deficiency in crops is becoming more common since sulfur deposition in rainfall has decreased significantly over the past 20 years.

Evaluation of Potential Environmental Risks of Land Application of CCP

The long-term effects of CCP use in agricultural applications remain a subject of research. For example, new technology to reduce greenhouse gases and remove sulfur dioxide, mercury and particulates from power plant emissions also increases the metal content, such as mercury and arsenic, in the CCPs. The use of these materials in agriculture may create risks to the environment depending on coal source, technology used, and the land application rate.

Unwashed or unleached fly ash could increase the salt content of the soils; for example application of 80 tons of unwashed fly ash from the Nevada Power Plant increased soil salinity 500 to 600 percent and resulted in excessively high concentrations of plant-available boron, calcium and magnesium, while washed fly ash did not have these adverse effects. For parts of the western US, salinity aspects of fly ash must be managed carefully. In this same part of the country, sodicity (excessive sodium accumulation that causes sealing of the soil surface) can be counteracted by application of gypsum and irrigation water. FDG gypsum should be equally as effective as mined gypsum in recovery of sodic soils caused by mismanagement of irrigation waters.

There have been few reports of adverse effects of application of fly ash, especially when it is used at fertilizer rather than disposal rates. Nutrients available from fly ash are chemically and functionally equivalent to fertilizer-based nutrients and are processed in the same ways in organisms and soils (Langmuir et al., 2005). Additional research can clarify remaining questions about potential risks from rare trace elements in fly ash, for which little research has been reported.

When FGD gypsum was applied to soil, low levels of metals were measured in soil and plant tissue (Clark et al., 1999). These results suggested that such FGD could be applied to soil for a long period of time without becoming an environmental risk. Further research could verify this finding. The alkaline CCPs could also be used to stabilize biosolids or manure before land application, which will reduce pathogen levels in the treated biosolids or manure.

Recent ARS Research on CCPs

ARS has conducted research on CCPs for decades (Armiger et al., 1976; Korcak, 1995; Ritchey et al., 1995; Stout et al., 1979; Vona et al., 1992; Wright et al., 1998). The ARS work includes study of revegetation/remediation of coal mine land and acidic soils, and beneficial use of fly ash, bottom ash and FGD products. ARS has investigated other beneficial use of CCPs such as removal of contaminants (such as nutrients, trace elements, pesticides, and hormones) from surface water and subsurface artificial drainage systems. ARS scientists are evaluating different types of CCP (fly ash, bottom ash, and FGD gypsum) for potential benefits and risks.

ARS scientists have worked with EPA to conduct risk assessments for agricultural uses of materials such as biosolids and foundry sand. Benefits and risks of agricultural uses of FGD gypsum, including fate and transport of trace elements such as mercury, arsenic and selenium, are subjects of current investigations. Preliminary studies in Georgia have demonstrated that soil application of FGD gypsum reduced movement of mercury in runoff to surface waters compared to control plots without FGD gypsum. ARS researchers and cooperators in Kentucky are studying volatile losses of mercury from land application of FGD gypsum to determine the extent of mercury release by this mechanism and to develop methods to reduce these losses if necessary.

Since a great deal is known about plant nutrition attributes of FGD gypsum, recent ARS research has focused on use of FGD gypsum for soil and water improvements. The research approach for FGD gypsum or any other industrial byproduct involves: (1) evaluating benefits and risks of the material for agricultural uses, (2) evaluating the effectiveness and economic outcomes of management practices and control technologies using industrial byproducts to improve soil and water resources, (3) documenting the environmental impacts of these management practices and control technologies for relevance to USDA Conservation Programs, and (4) developing guidelines for specific agricultural uses of the material.

Many agricultural areas in the United States require surface (ditches) or subsurface (tile drains) artificial drainage systems to control the height of the water-table so agricultural production can occur. However, these drainage systems can serve as conduits for movement of contaminants from agricultural fields to sensitive bodies of water (Chesapeake Bay, Gulf of Mexico). ARS scientists in Pennsylvania are developing technologies using CCPs and other byproducts to remove nutrients, trace elements, pesticides and hormones from surface and subsurface drainage systems. The drainage water, from a tile drain outflow or a surface ditch, is routed through reactors containing CCPs or other materials to remove the contaminants. Reactors installed in surface drainage ditches on the Eastern Shore of Maryland have removed approximately 70 percent of the phosphorus flowing through the reactor. This technology also could be used to clean up wastewater for subsequent use in agriculture.

An additional proposed application is reduction of phosphate in runoff or drainage waters from fields with excessive phosphate accumulation. Many fields where livestock manure was repeatedly applied as a fertilizer have accumulated excessive phosphate. Runoff, leaching and erosion of this phosphate are an eutrophication risk that is being addressed by both field treatments and water treatments. Because calcium can combine with phosphate to produce compounds with low solubility, FGD-gypsum is being studied for possible use in treating phosphate in runoff water. Annual surface application of FGD may also contribute to lowering phosphate in runoff (Torbert et al., 2005). Using FGD-gypsum to limit phosphate in surface runoff has been studied for only a short period, and additional studies are ongoing.

A large cooperative study has begun in which several ARS locations, The Ohio State University, the Southern Company, the Electric Power Research Institute and US-EPA are cooperating in field evaluation of benefits and risks from application of FGD-gypsum at fertilizer rates. Documentation of agronomic benefits arising from utilization of such byproducts is a key product of the research. In addition, extensive planning has been implemented to address issues of importance to regulation of such beneficial uses, and the quality assurance processes for the analytical methods are designed to ensure that the data obtained will support risk assessments.

ARS scientists in Mississippi have investigated the effects of FGD gypsum on soil properties and erosion in the southeastern United States. Soils in this part of the country are of poor quality and do not capture and store water effectively. Therefore, rainfall runoff exacerbates soil erosion, and adjacent water bodies are impaired by sediment and nutrients. Approximately 11 million acres of agricultural land in the southeastern United States are already eroded or are highly susceptible to erosion. ARS scientists have demonstrated that FGD gypsum applied at the rate of 3 T/A to a no-till cotton production site significantly improved soil aggregation and limited erosion. FGD gypsum application is compatible with widely used reduced tillage practices because the high solubility of FGD gypsum allows it to be effective even if it is applied only to the soil surface without disturbance. Results showed that FGD gypsum improved rainfall infiltration, decreased runoff, and reduced erosion on a degraded soil with high sodium content. Such improved water infiltration and storage would be a major benefit to crop production especially in an area like the southeastern United States, which is subject to severe droughts in some years. In many cases, a 15 percent improvement in rainwater infiltration following FGD gypsum application could help overcome the crop water deficit caused by drought.

Future Research

Research completed to date indicates that much FGD-gypsum and even much fly ash do not present unacceptable risks to humans or the environment when applied at fertilizer rates. Nevertheless, additional research on use of CCPs in the environment is warranted on the basis of both analytical approaches and industrial changes in the materials themselves. Ecological risk assessments continue to become increasingly sophisticated, and new data are required to quantify risks in new models, for new assessment endpoints, and to provide a basis for risk management recommendations. Recent questions about risks and benefits may concern elements that were not evaluated in earlier research or for which detection limits have improved. Furthermore, changes in the industry's processes, such as those leading to production of the purer FGD-gypsum, provide new materials for which current information needs updating to support risk assessments. None of these considerations invalidates completed research; however, further investigations are justified to address such issues.

Accordingly, ARS has planned additional research and has begun to obtain information needed to conduct risk assessments at current standards for agronomic uses of these materials. (A recently completed risk assessment conducted for agricultural uses of spent foundry sand is a good example of cooperation between USDA and US-EPA on an industrial byproduct; see Dungan et al., 2009). Wise management of CCPs by industry and new beneficial uses will minimize the quantities of CCPs that must be disposed of, and sequestered long-term in, landfills and impoundment ponds. Such disposal of large quantities, concentrated in small areas, leads to a different suite of environmental risks that must be managed.

Conclusion

Research has demonstrated that certain CCPs, particularly FGD gypsum, can be used in agriculture to provide necessary trace elements, improve soil properties, increase water infiltration and storage in soil, and protect water quality. Additional research is needed to assess the risks, effectiveness and environmental benefits of FGD gypsum and other CCPs across a range of agricultural uses and systems. Documentation of environmental benefits (erosion reduction, water quality improvements, increased soil carbon sequestration) resulting from agricultural uses of FGD gypsum will be an important component of ARS research on these materials.

In general, FGD gypsum has many promising agricultural uses. It has many desirable characteristics from an agricultural standpoint: wide availability, consistent composition and properties that allow national scale soil and water problems to be addressed. There is more than enough land area of degraded soils (approximately 100 million acres) in the United States that can potentially benefit from applications of FGD gypsum produced in excess of that required for wallboard production.

ARS will continue to conduct research that can provide a scientific basis to assess risks associated with agricultural uses of FGD gypsum. We anticipate that research on a particular use of FGD gypsum will either lead to new practices that overcome significant limitations, or reliably justify eliminating that particular use of the material. Moreover, we advocate such research on risks and benefits as the best foundation for acceptance or rejection of future applications of FGD gypsum in agriculture.

In addition to information reviewed herein, you may be interested in a broader overview of this and other ARS research conducted under our Manure and Byproduct National Program. You can find documentation of this National Program's vision, mission, action plan, individual projects, multi-year assessment reports, program annual reports, and leadership on the ARS website at http://www.ars.usda.gov/research/programs/programs.htm?NP_CODE=206.

Please feel free to contact me if you believe I can provide additional information or answer any questions you may have concerning ARS research.

Sincerely,

Steven R Shafer

STEVEN R. SHAFER
Deputy Administrator

cc:
John Sager, USEPA

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Attachments

1. Haynes, C. 2007. FGD gypsum's place in American agriculture. Ash at Work, Issue 2: 22-25.
2. Bibliography of CCP research.