VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

Soil Genesis and Mined Land Reclamation
Dept. of Crop and Soil Environ. Sciences
244 Smyth Hall, Blacksburg, VA 24061-0404
540-231-7175; Fax: -7630; wdaniels@vt.edu

Memorandum

To: Any Waste Producer

From: W. Lee Daniels

Re: Soil Testing Procedures for Waste Products

Date: January 10, 2004

At your request, I have prepared this memo to describe the procedures that we use to test various waste by-products for utilization as (1) soil amendments or (2) in manufactured soil mixes. In this memo I am summarizing the approach that our research team (which also includes Drs. Mike Beck, Greg Evanylo, and Lucian Zelazny) currently employs for this purpose. We have been involved in this area of work since the early 1990's, and over that period of time, we have screened a wide range of municipal and industrial residuals for potential beneficial reuse including composts, biosolids, papermill sludges, coal fly ash, wood ash, soybean processing wastes, foundry sands, ground construction debris, and a wide array of mining and mineral processing wastes.

A scientifically defensible demonstration that a given waste can actually be beneficially reused in any such application is specifically required for the Virginia Department of Environmental Quality (DEQ) to "delist" a given waste product from regulation as solid waste. As discussed below, any such waste proposed for beneficial use must pass all applicable USEPA/DEQ procedures such as the TCLP test, etc.. In 1995, the Virginia Department of Agriculture and Consumer Services (VDACS) issued a set of guidelines for this purpose, which I am sending you separately along with some associated correspondence. Since that time, we have worked cooperatively with a wide array of industrial product suppliers and their regulators in screening various waste products, and where appropriate, developing safe, marketable topsoils or soil amendments.

Following is general summary of the approach and tests that we run. It is important for you to understand, however, that since many wastes are unique and have not been studied before, that more intensive analyses than those described here may be actually required once we get into a given screening program. On the other hand, many potentially viable waste produces (e.g. coal fly ash) have been widely characterized and studied to date, and require a more limited amount of testing for a narrower range of parameters. The following procedures are presented as documentation of our general approach along with as specific a listing of procedures as is possible. We can provide you with citations for all analytical procedures utilized upon request, but I have not listed them here for the sake of brevity.

Industrial By-Product Testing Procedures by Virginia Tech

I. Initial Certification by Provider:

Any product that is to be considered as a component of manufactured topsoil or as a soil

amendment or conditioner must be shown to be non-toxic and non-hazardous with respect to RCRA subtitle C criteria via the appropriate test(s). For example, coal fly ash must pass the Toxicity Characteristic Leachate Procedure (TCLP) test. Organic wastes and sludges must be tested for USEPA designated Priority Pollutants and shown to be under any current risk-based action levels. Similarly, water treatment sludges that are being considered must meet the USEPA 503 guidelines for heavy metal content for land application. In fact, the 503 guidance levels for heavy metals in biosolids are commonly utilized as a general screening tool for all organic wastes applied to soils since similar guidance for other organic wastes is currently not available. *However, we **do not** consider the 503 levels to be directly applicable as a proof-positive decision criterion for land-applied non-biosolids materials.*

II. Baseline Characterization Analyses:

Assuming the waste product is dominantly inorganic (e.g. Coal Combustion Products - CCP's) a conventional basic soil analysis for pH, extractable P, Ca, Mg, K, and Na and soluble salts should be run by the Virginia Tech Extension Soil Testing Lab and/or a suitable private lab such as A&L Eastern Laboratories in Richmond. Additionally, a total analysis for total As, Al, B, Ba, C, Ca, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Si, Ti, Zn, should be performed, along with a calcium carbonate equivalence analysis.

If the material is a water treatment residual (WTR), biosolids (wastewater sewage sludge) product, or some other primarily organic matrix, the following tests should be run: Complete nutrient and metal elemental analysis (i.e., solids content, pH, $CaCO_3$ equivalent, TKN, NO_3-N +NO_2-N, NH_4-N, total P, K, Ca, Mg, S, As, Cd, Cu, Hg, Mo, Ni, Pb, Se, and Zn). Again, these analyses can be performed by a reputable soil testing laboratory such as A&L Eastern Labs, Richmond, VA.

For "designer mixtures" of soil, CCP's, WTR's and biosolids, these amendments/substitutes should be analyzed for routine soil test analysis (i.e., pH, electrical conductivity/soluble salt concentration, plant-available P, K, Ca, Mg, Mn, Zn, B, and Mo; and total As and Se). These analyses can be performed by a reputable soil testing laboratory. Note: these recommended procedures assume that all waste components in the blend have been pre-tested and approved for such use as specified above. The tests specified above need to be re-run on the blended products, however.

For all inorganic materials or mixtures of mineral and organic materials, the particle size analysis (texture) and plant-available water holding capacity should also be determined.

Once the appropriate suite of analyses (based on the nature of the material or mix) has been performed, the results of these analyses are compared with standard and acceptable ranges for soils as defined in the literature and by our collective research experience. Additional analyses such as sequential extraction/fractionation of a given metal (e.g. As or Cd) may also be required if the preliminary testing levels indicated by total elemental analysis are of concern.

Once this data set of chemical and physical properties of the material (or blended materials) has been completed and analyzed, we generally make a decision to (1) support the material by letter to VDACS for the use requested, (2) reject the material due to one or more adverse soil properties, or (3) recommend further confirmation of beneficial reuse potential via greenhouse bioassays. In general, if a material is from a well-characterized source and has been well-documented with respect to beneficial reuse potential in either the scientific literature or by research screening programs similar to our own, we will proceed with option 1. However, we strongly believe that all "unknown" materials need to be specifically run through a greenhouse phytotoxicity screen, due to the fact that we have worked with several different residual materials that "tested clean" in the lab, but subsequently proceeded to be quite toxic to plants when applied to soil.

III. Greenhouse Bioassay for Phytotoxicity and Loading Rate Specification

In our experience, most residual waste products need to be evaluated in a greenhouse setting to (1) ensure that they are not potentially phytotoxic and (2) develop loading rate or mixing rate guidance. The procedures that we follow are typically modified to some extent based upon our analysis of the preliminary data sets and any other research and testing information available for similar materials.

If we are testing a soil amendment product like fly ash or an organic waste, we utilize a standard agricultural topsoil product from a documented location in Virginia, and then mix the amendment into the soil at a range of loading rates that bracket what we believe to be reasonable and economic. All treatment combinations are replicated three to four times. Based on conventional soil test analyses, lime and additional fertilizers may be added to balance nutrients supplied by the amendment. The treated pots are then planted to (1) tall fescue and (2) soybeans and maintained under optimal water and temperature conditions. Tall fescue is quite tolerant of salts, metals and adverse soil conditions while soybeans are relatively sensitive to soluble salts and many other toxicants.

The response of the two plant materials is then observed over time; usually 30 to 60 days. Specifically, in order for a material to meet beneficial reuse criteria as a "***soil amendment***", it must show some statistically significant benefit to plant growth when compared with untreated control pots. If a material is being proposed as a "***soil conditioner***", previous testing as outlined in section II above must show that it has the desired effect (e.g. improves water holding capacity), and it must not show any statistically significant adverse effect on plant growth when compared with untreated soils.

When the material tested is a blended soil product, a similar approach to that outlined above is utilized, typically with various alternative mixes compared with control treatments grown in appropriate native soil treatments. We also usually compare soil blends with other commercial topsoil or greenhouse media products for comparison.

As a part of this greenhouse bioassay screening process, it is common for a given material (e.g. fly ash) to show increasingly beneficial plant growth effects up to a certain level of application, and then either (a) no effect, or (b) phytotoxic effects above that level. When this is observed, these data are then used to constrain application rate recommendations for VDACS labeling or other agency oversight of how the materials are used.

III. Field Test Plot Verification

Occasionally, for a variety of reasons, we work with materials that require field test plot confirmation of their suitability and verification of their beneficial reuse potential. Reasons to proceed to field test plot work include (1) mixed results in greenhouse bioassays, (2) public and/or agency concerns over the utilization of the material, (3) industry needs to have actual yield data sets for marketing, or (4) the material is a complete unknown with respect to use on/in soils. All field testing is conducted utilizing appropriate statistical designs and agronomic plot techniques, including soil, tissue, and ground water testing as necessary. Field plot research usually requires at least one full growing season and is considerably more expensive to conduct than greenhouse testing. In certain instance, field plot trials may be run for multiple seasons with multiple cropping systems before final recommendations can be developed.

IV. Sponsor and Agency Reporting

Once we have gathered sufficient evidence on the suitability of a product as a soil amendment or as a soil blend component, we prepare a fully documented report with proposed recommendations and VDACS label restrictions. If the sponsor concurs with our proposed language and application restrictions, we then forward our recommendations to VDACS for their utilization in label development and product regulation. Negative results are generally reported directly to the sponsor, with a specific request from us that the material not be submitted for consideration in Virginia (or elsewhere!).

Once a label for a soil amendment or a soil-blended product is developed by VDACS, it is the responsibility of the waste generator to comply with label restrictions over time and to ensure that the properties of the product do not vary significantly from those of the materials that we tested. Any significant change in process and/or waste product properties requires additional testing and label modification as necessary.

Finally, it is important to point out that VDACS does not **require** that Virginia Tech perform these services in order for a product to be approved and labeled for beneficial use. Appropriate data and research results from private laboratories and other universities can and have been submitted to VDACS for approval of such requests. We also occasionally test and report on various properties of other waste materials of interest to DEQ, the Virginia Department of Health, and the Virginia Department of Mines Minerals and Energy and their various environmental and land-use regulatory programs. ***We hope this extended document answers most of your questions!***