Project Title: USE OF FLUIDIZED BED COMBUSTION BY-PRODUCTS FOR LINERS AND ALKALI SUBSTITUTES

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ABSTRACT

An impermeable liner was built over an area of seven acres using 10,000 tons of FBC ash and native soils and utilizing conventional construction equipment. Construction of this type is competitive with clay liners based on costs actually incurred in the field. Establishment of the liner potential of FBC ash should provide a market outlet for the material and reduce the risk of costly environmental requirements for monofills accepting FBC ash.

Dust generation was monitored over a two-month period using four high volume air samplers. Dust levels were found to pose no health risk to the general public, though equipment operators in close proximity could face health risks if no protective or preventative measures were taken. Successful control of dust formation from FBC fly ash dumping was demonstrated in this project. The major dust source, however, is the passage of heavy equipment across layers of spread fly ash. Control of this dust will require treatment of the ash itself beyond containment during dumping. Several approaches were investigated and follow-up demonstrations will be proposed by the investigator.

“Pages 6 through 22 contain proprietary information.”
EXECUTIVE SUMMARY

The Thunderbird field demonstration project involved the placement of 10,000 tons of FBC fly and bed ash together with native soil materials to create an impermeable liner over an area of seven acres. The project represents a joint effort of Archer Daniels Midland Corporation, the Illinois Abandoned Mined Land Reclamation Division, and Southern Illinois University at Carbondale with ICCI support. Commercial scale field construction equipment and techniques were utilized and the liner was successfully built. The earthwork contractor completed the work with a viable profit margin and within the contract bid price for the work.

The objective of the work was the creation of a market outlet for FBC ash products for use in liners. Liners are currently required for landfills and many special waste monofills. They are typically constructed of compacted clay and/or geomembranes. At the onset of this project, it was believed that economics favored the use of FBC fly ash as a reagent to treat native soils to produce low permeability rather than to import clay from an outside source. It also was felt that establishing the self-lining properties of FBC fly ash would reduce the need for expensive specially built liners at monofills accepting FBC fly ash.

Actual costs from the Thunderbird project or unit operations costs from other similar projects were utilized to determine if FBC ash was cost competitive for clay liners. Depending on the scenario, the cost of a liner made of soil amended with FBC fly ash is estimated at $2.70 to $12.87/ton. To build a similar liner using clay imported to the site is estimated to cost $16.50 to $36.50/ton. It, therefore, seems that FBC fly ash should be a viable alternative to clay liners from an economics standpoint.

The problem of dust generation and dust control was studied over a two-month period using four high volume air samplers. It was found that the dust concentrations for all operations are low enough to pose no threat to the general public health. Equipment operators in close contact with ash dust clouds would be expected to face negative health effects unless protective measures or dust prevention were practiced. Dust concentrations generated by uncontrolled FBC fly ash handling are similar to dust levels generated by haul road traffic. Since EPA does require dust control for haul road traffic, it can be inferred that FBC ash handling also will be regulated.

The most dust prone operations with FBC fly ash involve the passage of heavy equipment across layers of spread ash. Simply preventing or containing dust clouds from dumping operations will not control this problem and some form of ash treatment will almost certainly be necessary to comply with environmental regulations. Several approaches were tested as part of this project and follow-up demonstrations will be proposed by the investigator. The type of technology to control this dust problem is available in commercial scale, although specific configurations and applications must be tested before control can be demonstrated.

Control of dust formation during dumping operations was successfully demonstrated in this project. Mechanization of the approach will provide substantial cost savings over the manual approach used as part of the ICCI demonstration. The manual approach does appear to be
economically viable. Several alternative approaches are available and also appear to be economically viable and practicable with existing technology.

This project was successful in establishing that FBC fly ash can be used to amend soils and produce liners. Monitoring work now ongoing, as part of a two-year ICCI project, should establish long-term performance and environmental safety of this type of construction.

"Pages 6 through 22 contain proprietary information."
OBJECTIVES

The objective of this study was to demonstrate at a full commercial scale, that FBC fly ash could be used in conjunction with regular soils to form water infiltration barriers. Specifically, the study was aimed at showing that:

1- FBC fly ash could be mixed with soils and placed in the field using commercially viable construction equipment and techniques.

2- FBC fly ash and soil mixtures would function as a long lived infiltration barrier, even when constructed in the field where macro-scale features, excluded at the laboratory scale, could be present.

3- FBC fly ash and soil mixtures would be benign from a ground and surface water quality impact relative to untreated soils and alternate materials.

To fully satisfy objectives 2 and 3, it will take long-term monitoring work currently ongoing in an additional two-year project funded by ICCI. Objective 1 can be satisfied by the on-site construction project that formed the core of the ICCI project now being reported.

Forming an effective infiltration barrier using FBC fly ash and soil is valuable to industry because:

1- Native soils need only amendments of about 25% FBC fly ash to produce a material as impermeable as a clay liner. Because transportation is the major cost in building liners from non-native materials, significant savings can result when only 25% of the material needs to be imported as opposed to all the material in the case a full clay liner. This market penetrating advantage offers opportunities for beneficial use and recycling of what might otherwise be a high volume waste material.

2- FBC fly ash has still not been cleared from regulation under RCRA and if cap and liner requirements were imposed on FBC fly ash, the estimated cost of ash disposal would be equal to a $7.50/ton surcharge on the price of coal. Nonutility generators are expected to meet a large part of the nations future electric power demands and fluidized bed combustion is an economically and environmentally favored SO₂ control method for these companies. Since coal sulfur content is not an issue for FBC units, they form an important part of the growth market for Illinois coal. The $7.50/ton effective surcharge from regulations on FBC fly ash could be devastating to the market for Illinois coal. If it is demonstrable that FBC fly ash is self lining, the risk of excessively costly regulation would be much reduced.

Quarterly progress reports issued earlier on this project have each identified and discussed specific aspects of the research in terms of meeting the objectives given above. This
concluding report emphasizes the fugitive dust issue, and a proof of potential economic viability based on construction costs actually incurred in the field.

INTRODUCTION AND BACKGROUND

Ash from the combustion of coal has been considered for regulation as a dangerous solid waste for over ten years. During the review period, coal combustion ash was exempted from stringent regulations under the Resource Conservation and Recovery Act (RCRA) by the Bellville Amendment. In 1993, the EPA ruled that coal combustion ash from regular power plants was non-hazardous and exempted from RCRA regulation. No ruling has been made on FBC power plant ashes, which continue their uncertain future under the Bellville Amendment.

FBC power plants are a key market for the Illinois Coal Industry. There is no doubt that the Clean Air Act Amendments will cause a loss of market for Illinois Coal with conventional power plants that must face expensive scrubber retrofits or continuing SO₂ allowance purchases. Non-Utility Generators (NUGs) are not under the SO₂ cap and are required only to use the best available control technology to eliminate as much SO₂ emission as possible.

FBC is the most frequent control technology of choice amongst the NUGs. Non-Utility Generators are expected to build most of the new units needed to meet U.S. power needs. Archer Daniels Midland (ADM) (one of the cooperating organizations for this project) is projecting to double their production by just after the year 2000, and enough capacity addition to increase production by 50% has already been contracted. The existing boilers at ADM already are the equivalent of a 280 megawatt generating station, but coal consumption is far higher than needed for electricity alone, since the boilers also provide heat for grain processing.

If Illinois is to capture the new growth market for power and steam production, protecting and promoting FBC technology will be crucial. FBC power plants produce 250% of the solid by-products of conventional pulverized coal units and RCRA regulations requiring disposal in lined and capped landfills at seven times the price of conventional monofill disposal would render the technology economically infeasible. FBC units directly fire limestone with coal to adsorb SO₂ as it is created and thus have a larger volume of non-combustible material. At the heart of the issue of whether FBC by-products are environmentally hazardous are their high content of calcium oxides (created by exposing limestone to boiler temperatures). The portlandite formed in this way is responsible for the same high pH values seen during the curing of concrete. In previous laboratory and small scale field studies by the P.I., these reactions also allowed FBC fly ash to act as a soil stabilizer, just as cement does, and for FBC soil mixtures to achieve the same low permeabilities as clay liners used for landfills. In fact, one of the problems in many percolation tests conducted by the P.I. in previous work has been that FBC by-products are so impermeable that they produce no leachate to analyze.
Thus, one of the prospects to be explored in this study is whether FBC by-products can be used as a soil additive to substitute for clay in landfill liners.

For many low value bulk materials, the cost of transportation approaches exceeds the value of the material itself. FBC ash can be used to amend natural soils and degraded rock material to produce a substance as impermeable as the clay liners used in landfills. The cap and seepage barrier at the Thunderbird site will be made from about 20% FBC ash and 80% on-site soil materials. This ratio would mean that companies planning to build impermeable lines would only have to haul in 20% of the liner material instead of 100% as is the case with clays. The ability of FBC ash to amend on-site soils would give it potentially significant market penetration advantages.

Demonstrating a bonafide potential use of FBC ash would aid in deregulating the material as a waste, and demonstrating that the material can be used to produce almost impermeable liners when used as an amendment to existing site soils would aid in market penetration. Still FBC ash would find barriers to use in terms of handling problems, particularly issues related to dust. Sites now receiving FBC ash for disposal must either dump ash in totally enclosed spray fogged buildings (not available at construction sites where liners are developed over large land areas), or have variances that allow for large scale fugitive dust release (not available in many of the near suburban areas where lined landfills are needed). Some FBC generators have had to resort to pelletization of the ash to reduce dusting to acceptable levels.

ADM is considering such a system, but the cost would be high, and the pelletized material probably would not be suitable for preparation of liners.

This demonstration is to show that dust problems can be managed, materials can be mixed and placed, and the liners created would be effective.

**EXPERIMENTAL PROCEDURES**

**Dust Control Monitoring Procedures and Network**

FBC fly ash is considered a highly dusty material that produces a highly visible dust plume. Materials handling for FBC fly ash in construction is not a problem from a mixing and placement standpoint; however, dust management is a potentially significant issue and control procedures may significantly alter handling procedures and costs. For this reason a dust monitoring network was set up on the construction site and operated during placement of the seven-acre 10,000 ton cap and infiltration barrier. The period of operation for the network was from late August 1995 to late October 1995.

The dust monitoring network consisted of four high-volume sampler stations. The position of the stations relative to the construction site is shown schematically in figure 1. The high volume samplers were equipped and calibrated for total dust collection rather than PM-10 particles only. The decision to collect total dust concentration rather than PM-10 is warranted because FBC fly ash can produce caustic reactions with the skin, and human health
risk is not restricted to respiration of dust particles. The rate of air draw was calibrated using magnahelic gages at the Illinois Environmental Protection Agency air lab in Springfield. The high-volume samples in the field were placed on wooden platforms standing 5 ft in the air to avoid problems of high-volume air suction drawing dirt from the ground surface into the filters. Thus, measurements taken represent true air dust concentrations taken near the level from which an erect adult would breath.

The stations were kept at fixed locations during the construction process while equipment worked across adjacent areas of several acres. No procedures were used to hold or place the high-volume samplers at a fixed and steady distance from the work or to make sure that the dust samplers were "inside" the dust clouds produced. The high-volume samplers were run continuously for an average sampling interval of 3.5 hrs. The exact sampling time for each filter was measured by recording the time at which the filter was placed and the high-volume sampler started and then recording the time at which the sampler was shutdown to remove the filter. The time intervals ranged from 2 hrs to 4.5 hrs but most values were 3 to 3.5 hrs. Similarly the inches of water gage draw pressure was measured using a magnahelic gage when the sampler was started and again just before the sampler was shut-down for filter collection. The two water-gage values were averaged and compared to the calibration curve for each high volume sampler to determine the average rate of air draw. The total volume of air drawn through the filter was assumed to be equal to the estimated rate of air draw times the time interval over which the sample was collected. Each filter was weighed in the laboratory using a four-place gram electric balance before being taken to the field and again after the filter was used in the field. Each filter was individually labeled. Changes in weight were assumed to be equal to the mass of dust collected. Dust concentrations that are reported represent the mass of dust collected divided by the air volume estimated to have been drawn through the sampler. Measurements represent the general quality of air in the immediate vicinity of work with FBC fly ash and not the dust concentrations a few feet from the equipment and within the dust clouds themselves or short-term peak dust concentrations.

The trailer was equipped with a wind vain and anemometer connected to a data logger. The system was used to accumulate data on wind speed and direction during the construction time period. During all measurement time intervals, wind speeds were low with peaks of only 1 to 2.5 miles per hour. Work was not performed during periods on high wind. The principle wind direction at the site was from south to north as shown in the figure, and monitoring stations were placed to best use this wind direction.

High-volume Station Number 4 was originally intended to represent the background concentration of dust in the air coming into the construction area. As can be seen from Figure 1, it was placed well out of the construction zone. The station was close enough to the trailer to be powered by regular 120 volt power from the commercial electric lines and delivered through about 200 ft of heavy duty out-door extension chord. In practice the station was located too close to the county road and actually measured the impact of passenger and/or construction vehicle traffic on dust concentration. The baseline measurements actually used for background air quality came from the high volume samplers at the field construction site operated during the evening or during nonworking days when there was no activity at the site.
Figure 1. Location of Air Monitoring Stations at Thunderbird Demonstration Site
(Demonstration Plots are Approximately 150 x 300 Feet)
The road running adjacent to the actual construction area was a temporary construction road and did not carry traffic when construction was shutdown.

High-volume stations numbers 1 to 3 were placed near the corners of the construction plots. Because there were no nearby electric power lines, these stations were operated using gasoline fired electric generators underneath the platforms on which the high-volume samplers were placed. Construction work and equipment approached the platforms to within distances of 10 to 15 ft, but the far side of the construction plots were located about 150 ft away. The adjacent construction road was located about 70 ft from the air monitoring stations so that the average distance from construction was similar to the average distance from the construction road. Since dust settling is generally not found to be a linear function of distance, the idea of average distance may not be relevant in a quantitative sense. The activities occurring in the field during dust sampling were recorded in a field notebook by a researcher assigned to coordinate construction activities and operate the high-volume samplers. Because sampling occurred over time intervals several hours long, it was frequently the case that more than one activity occurred in the field during a particular sampling interval. The data collected was grouped according to the activity or activities occurring in the field as recorded in the field notebook. Individual dust concentration measurements differ from each other by an order of magnitude in the extreme, even for the same activity, with about 25% difference in individual measurements being typical. Results in this report represent the numeric average of all measurements for a particular activity or group of activities. Examination of the distribution of individual dust concentration values do not show sufficient evidence of lognormality to warrant the use of geometric means as opposed to numeric averages. Indeed the reported averages are near the modal values.

RESULTS AND DISCUSSION - Proprietary

Except in nonattainment areas, EPA does not have dust regulations specifying specific concentrations of dust resulting from various activities. In the absence of quantitative measures of environmentally acceptable dust concentrations initial comparisons in this report are based on dust concentrations relative to other activities and to health and safety limitations on workplace exposure of humans to dust concentrations (threshold limit values), (see Figure 2).

The initial observation on dust concentrations is that FBC fly ash dustiness appears highly overrated. Dust concentrations from FBC fly ash are an order of magnitude lower than air from an electrostatic precipitator, two orders of magnitude lower than the threshold limit values for mercury vapor, two to three orders of magnitude lower than dust concentrations for pollen laden air and three to four orders of magnitude lower than dust concentrations in city and suburban air. An interpretation that FBC fly ash handling is not a health risk to the general public is probably warranted, since most construction sites pursue active operations only during a limited number of hours per day and dust concentrations even 100 ft away are far below the threshold limit values for human health.