

Clean Coal Technology By-Products as Treatment Chemicals for Hazardous Wastes

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Introduction

In the fall of 1994 the University of Pittsburgh (Pitt) embarked upon a two-phase program for the evaluation of the use of by-products from three advanced clean coal technologies, which have been installed recently at U.S. coal-fired utility and cogeneration plants, as treatment chemicals for metal-laden hazardous wastes. Treaters of metal-laden hazardous wastes generally use inexpensive chemical by-products, such as the calcium oxide manufactured in the production of acetylene from calcium carbide, to provide alkalinity for stabilizing metal ions which are mobile under the more acidic conditions present in the untreated wastes. They may also include a cementitious material, such as portland cement, to encapsulate small particles of concentrated hazardous species. By-products from advanced clean coal technologies, which are now being installed throughout the electric power sector, contain high levels of both alkalinity and pozzolanicity.

Objective

The objectives of this program are:

1. To provide pertinent data on the properties of these new treatment chemicals;
2. To acquire useful information on the ability of these new treatment chemicals to stabilize solid waste streams of commercial interest;
3. To demonstrate the performance of several waste/by-product mixtures at commercial scale.

The program's goal is the development of a new niche market for this emerging class of coal combustion by-products, namely, their sale to hazardous waste treaters.

Approach

During the first two years of the program, Dravo Lime Company (DLC) collected and thoroughly analyzed multiple samples of three by-products [1,2]. Bench-scale treatability studies were performed by the University and by the Mill Service Yukon Plant (MSYP) of MAX Environmental Technologies, Inc., to show the effectiveness of the three by-products as treatment chemicals for seven metal-laden wastes [3,4]. Solidification studies were conducted on successful products of treatment [5]. The successful products of treatment of one of the wastes by two by-products were viewed by x-ray diffraction and scanning electron microscopy to demonstrate the project team's ability to discover the method of stabilization [6].

For a variety of reasons (discussed below) a period of two years was required following successful completion of the benchscale tests before a commercial demonstration could be initiated [5]. Currently the Mill Service Yukon Plant is designing modifications that will allow it to regularly store and transport large quantities of these new dusty chemicals and to use them to stabilize and solidify wastes in its treatment pits. The installation of these modifications is scheduled for this fall. Once they are in place, the demonstration can begin.

Project Description

ADVANCED CLEAN-COAL TECHNOLOGY BY-PRODUCTS

Advanced clean-coal technology by-products generally are produced in systems where a calcium-based sorbent (usually slaked lime, limestone, or dolomite) is injected directly into a furnace, ductwork, precipitator, or scrubber vessel to capture sulfur dioxide. The sulfur-laden sorbent leaves the system as a dry powdered or granular product, as opposed to the slurry associated with a traditional wet scrubbers. The dry by-products have neutralizing, sorptive and cementitious properties that make them interesting as potential reagents for hazardous waste stabilization because they contain large amounts of free quicklime (CaO), anhydrous calcium sulfate (CaSO_4) or sulfite (CaSO_3), and pozzolanic ash.

Three advanced clean-coal technology by-products were used in the bench-scale portion of the program, (1) dry scrubber residue, (2) residue from a coal-fired pressurized fluid bed combustor (PFBC), and (3) residue from a coal-waste-fired circulating fluid bed combustor (CFBC).

The dry scrubber residue was produced in a spray drier at the outlet of a pulverized coal boiler burning high-sulfur eastern coal. In this unit ash-laden flue gas enters the bottom of the spray drier and a lime slurry enters the top. All of the sulfur-capture residue rises through the upper port with the fly ash.

Residue from a coal-fired PFBC was obtained from the Tidd Station of Ohio Power Company. In this demonstration facility (which has ceased operation) dolomite was co-fed with coal to the

combustor. Dolomite, instead of limestone, was used as the sorbent because it was both more porous (and thus more reactive) and easier to handle without bridging in the piping system.

Residue from a coal-waste-fired CFBC was obtained from a commercial cogeneration plant in western Pennsylvania. The coal waste fed to the combustor has a sulfur content between 1.4 and 2.0 percent. The limestone, which is co-fed with the coal, is 83% CaCO₃. The fly ash from the combustor is removed in a ten-segment baghouse and conveyed to a silo. Approximately 70% of the by-product in the silo is baghouse ash; 30% is bottom ash.

Dravo Lime Company collected ten dry samples from each of the three by-product sources. In general, samples came from a homogeneous by-product matrix produced under stable, well-defined plant operating conditions. Samples of the first by-product, the dry scrubber residue, were obtained at the terminus in western Pennsylvania of the bulk transport of this material back from the power plant in New Jersey, where it was produced. The other two by-products were sampled at the points of their production. For each sample, ten 5-gallon plastic buckets (with lids) of material were collected. These were distributed among the three project partners — DLC, MSYP and Pitt — for their respective analysis and use. All containers were filled as full as possible and tightly sealed to minimize sample contact with air and moisture. A clear chain of custody and QC procedure was established and utilized.

METAL-LADEN HAZARDOUS WASTES

The seven metal-laden hazardous wastes used in the bench-scale portion of the program were selected from among the materials processed commercially by Mill Service Yukon Plant, a centralized hazardous waste treater in southwestern Pennsylvania. The selected wastes were:

1. Sludge from lead-acid storage battery production
2. Contaminated soil from a munitions depot
3. Contaminated soil from a multi-use industrial site
4. Baghouse dust from basic oxygen furnace steelmaking
5. Ash from a municipal solid waste incinerator
6. Contaminated soil from a former waste water treatment plant
7. Sandblast dust from a paint-removal operation.

MSYP collected approximately 250 pounds of material for a sample of each of these wastes. The samples were drawn from the bulk containers (20 to 60 cubic yards) delivering the wastes to MSYP. Samples were obtained at a minimum of three locations distributed evenly along the length of the container. Moist materials with a relatively even distribution of small particles, such as wastewater treatment plant residues, were sampled with a trier forced into the material. Dry materials, such as dusts and sandblast wastes, and materials with large or uneven particle sizes, such as soils, were sampled using a shovel or scoop. The individual samples of each waste were composited into a clean sample container.

Samples of the wastes were obtained for analysis and for use in the extraction procedure by the quartering method detailed in ASTM C702-87. Waste samples were characterized to determine

the total concentration of each of fifteen metals by SW-846 Methods, using inductively coupled plasma-atomic emission spectroscopy (ICP) or atomic absorption spectroscopy. MSYP performed TCLP extractions at its on-site laboratory. These extracts were analyzed for the same fifteen metals as the wastes.

TREATMENT STUDIES

Bench-scale stabilization experiments consisted of mixing by-products with hazardous wastes at weight ratios of 1:10, 1:3 and 1:2 with minimal moisture addition. Sampling of the stabilized mass was done immediately after treatment for evaluation of TCLP leachate compositions. Preliminary solidification studies were conducted on samples of the treated masses, as described below.

MICROSTRUCTURAL ANALYSES OF TREATMENT PRODUCTS

Two sandblast waste aliquots, one treated with a 30% aliquot of spray drier residue and the other with a 30% aliquot of PFBC residue, were each blended with water to approximately a 1.5 inch slump. The composition and morphology of the two resulting solidified products after 28 days, as well as the sandblast waste itself, were evaluated by scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques.

Results

ADVANCED CLEAN-COAL TECHNOLOGY BY-PRODUCTS

Average values of Dravo Lime Company's standard analyses of ten samples of each of these three by-products are given in Tables 1, 2 and 3.

Geochemical analysis shows that each of the three CCT by-products contains a significant amount of free lime (CaO). The spray dry scrubber residue contains the highest percentage of CaO, at 28.9%, while the PFBC and CFBC residues contain 20.9% and 10.6%, respectively. These high percentages of CaO represent beneficial properties for hazardous waste stabilization. Each of these by-products also contain appreciable amounts of inorganic compounds, such as SiO₂, Al₂O₃, and Fe₂O₃, which are commonly found in coal fly ash. The CFBC residue contains the highest percentages of silica and alumina, which is a result of burning low grade, high ash fuel. The presence of these pozzolanic compounds represents desirable characteristics for waste treatment, as they have the potential to produce a highly solidified material which may help limit the leaching of contaminants into the environment. The PFBC residue contains the highest percentage of MgO, which is expected as the sorbent fed to the boiler was dolomite instead of lime or limestone. These by-products also contain appreciable amounts of sulfur (both as sulfite and sulfate), which is expected as sulfur sorption was the primary purpose for the utilization of the CCT processes employed. The sulfur present in the spray dry scrubber residue is mostly in the form of sulfite, as opposed to sulfate found in both the FBC residues. This difference is mainly due to sulfur sorption at lower temperatures in the spray dry scrubber process. The presence of sulfur in treated waste mixtures could be detrimental to the development of compressive strength over time, and may therefore be responsible for increased contaminant leaching, as a result of

Table 1
Mean Comparison of By-Product Geochemical Properties

Geochemical Analysis (%)	Spray Dryer Residue	PFBC Residue	CFBC Residue
CaO	28.91	20.94	10.61
MgO	0.70	12.89	1.26
SiO ₂	20.18	21.75	48.56
Fe ₂ O ₃	6.39	10.78	6.92
Al ₂ O ₃	10.24	9.39	18.45
CO ₂	3.94	9.98	0.68
Total Sulfur as S	10.03	4.47	2.3
SO ₃	3.11	10.58	5.23
SO ₂	17.55	0.47	0.41
LOI @ 1100 °C	13.13	11.23	5.28
Total of Elements Determined	100.21	98.03	96.69
Reactivity			
Temperature Rise (°F)	2	5	8
Calcium Carbonate Equivalency (% CaCO ₃)	43.8	52.6	11.6
Available Lime Index (% CaO)	3.7	0.9	4.0
pH	12.36	11.92	12.52
Mixed Ratio (lbs/gal)	13	20	16
Physical Properties			
Specific Gravity (g/cc)	2.41	2.83	2.7
Bulk Density - Loose (lb/ft ³)	36	59	52
Bulk Density - Tamped (lb/ft ³)	42	70	60
Blaine Fineness (cm ² /g)	10,700	5,588	8,506
Passing 200 Mesh (%)	93	88	57
Passing 325 Mesh (%)	84	81	48
Specific Surface Area (m ² /g)	6.87	2.93	10.64
Particle Size Distribution			
Passing 80 Mesh (%)	98.9	94.2	49.8
10% passing (µm)	2.0	2.6	3.4
50% passing (µm)	11.88	10.95	26.59
90% passing (µm)	42.17	55.49	110.49
Average Particle Size (µm)	17.74	21.39	42.67

sulfur expansion. Finally, these by-products contain varying amounts of unburned organic material, as measured by the percent of material by weight that is lost on ignition at 1100 °C. The spray dry scrubber residue contains the highest percentage of unburned organic material, at

19.8%, followed by the PFBC and CFBC residues, at 11.2% and 5.3%, respectively. The presence of unburned organic material in treated waste mixtures could hinder the development of significant compressive strength.

Reactivity of the by-products was determined by measuring temperature rise, calcium carbonate equivalency (CCE), available lime index, pH, and mixed ratio. The temperature rise indicates the amount of heat generated by the hydration of quicklime and anhydrite. A higher temperature rise indicates that more lime is present in the anhydrous (quicklime) state. The spray dry scrubber residue has the lowest temperature rise among the three by-products. This indicates that the free lime is in the hydrated form, which is expected as slaked lime (a slurry of lime in water) was used as the sorbent in this process. The calcium carbonate equivalency measures the acid-neutralizing capacity of the material and is expressed as weight percent of calcium carbonate present. Both the PFBC and spray dry scrubber residues have higher calcium carbonate equivalencies, at 52.6% and 43.8% CaCO_3 , respectively, as compared to the CFBC residue, which contains 11.6% CaCO_3 . Although the CFBC residue contains less CaCO_3 , the high temperature rise of this by-product indicates that the lime is present in a form that is more reactive than the more abundant slaked lime found in the spray dry scrubber residue, which has a relatively low temperature rise. The available lime index gives a measure of the amount of constituents available to enter into reaction. The spray dry scrubber and CFBC residues both have significantly higher values for the available lime index, at 3.7% and 4.0% CaO , respectively, as compared to the PFBC residue which has an available lime index of 0.9% CaO . The pH of the three CCT by-products is very similar, with the pH of the CFBC residue being slightly higher than that of the PFBC residue. Finally, the mixed ratio of the spray dry scrubber residue is the lowest among the three by-products. This indicates that the material has the ability to absorb large amounts of water, thus having a high stabilization potential.

The physical properties reported in Table 1 include measurements of density, fineness, and surface area. The bulk density of the spray dry scrubber residue is significantly less than that of either of the two FBC residues. Fineness, measured either through the use of the Blaine air permeability apparatus or a sieve analysis, gives an important indication of reactivity. Fineness affects the rate of hydration and the heat released. Greater fineness increases the rate of hydration and thus accelerates compressive strength development. All three of the CCT by-products analyzed have a greater fineness than either Portland cement or fly ash, two materials commonly used as reagents in waste stabilization. Among the three by-products, the spray dry scrubber residue has a significantly higher fineness than either of the two FBC residues. The CFBC residue was found to have a significantly smaller percentage passing the 325 mesh sieve. This corresponds to the significantly larger average particle size of the CFBC residue, which is primarily due to its bed ash content. In contrast, the spray dry scrubber residue has the smallest average particle size of 17.74 μm . Thus, the finer spray dry scrubber residue is more reactive, a good property for hazardous waste stabilization.

The results of this by-product characterization are consistent with what was expected from a review of the literature. Examination of the aforementioned by-product properties reveals differences due to the CCT process employed, composition of coal burned, and composition of specific sulfur sorbent utilized. Overall, however, the high fineness and small particle sizes of

these by-products indicate that they should have the potential to rapidly enter into hydration reactions, which would make them useful reagents in stabilization/solidification applications. In addition, they also contain high percentages of CaO, another beneficial property for waste stabilization. The spray dry scrubber residue, specifically, has the highest percentage of CaO, lowest mixed ratio, smallest average particle size, and highest fineness. The properties characteristic to this by-product could provide for superior stabilization.

A comprehensive metals analysis of each of the three CCT by-products utilized for the purposes of this treatability study was performed in order to demonstrate that the by-products were not inherently hazardous in their own right and that they would not contribute to the leachable metals concentrations of the resulting treated waste mixtures. The metals analyzed included the eight RCRA metals (As, Ba, Cd, Cr, Pb, Hg, Se, and Ag), which are currently regulated under the U.S. EPA's Toxicity Characteristic Program, and seven other metals (Sb, Be, Cu, Ni, Tl, V, and Zn) which are currently considered underlying constituents under the Uniform Treatment Standards (40 CFR Section 268.48). Although the Uniform Treatment Standards (UTS) do not currently apply to characteristic hazardous wastes, there is potential that these metals could be regulated in the future.

A total constituent analysis (TCA) was performed in order to determine which metals were present and in what concentration. Total metals concentrations, however, do not indicate whether a material is considered hazardous or not. The presence of high concentrations of metals in a material does not necessarily mean that the metals are in a form that will leach, or that the metals will have the opportunity to come into contact with the leaching solution. Total metals concentrations do, however, give some insight into the potential for a material to be considered hazardous.

In order to determine which of the metals present in the material have the potential to exceed the TCLP limit (as established by the current BDAT Standards) assuming that 100% of the metal present were to leach, it is necessary to correlate the TCLP limits expressed in mg/L to total metals concentrations expressed in mg/kg. In the TCLP test, a liquid to solids ratio of 20:1 (volume:weight) is utilized. Therefore, multiplying the TCLP limit by 20 will give the concentrations on a mg/kg basis for comparison. To provide for a margin of error, a multiplying factor of 80% (0.8 times the mg/kg metal concentration) was used as the threshold value above which the metal would be of concern. Any metal which has a concentration greater than that of the threshold value has the potential to leach in excess of the TCLP limit given 100% leachability. The results of the total constituent analysis of each of the three CCT by-products, as well as the corresponding limits for concern, are given below in Table 2.

Table 2 reveals that there are a number of heavy metals present in each of the three CCT by-products. This is expected as trace metals are commonly found in coal fly. Table 2 shows that arsenic was found to be the only metal of concern under the current BDAT standards when utilizing either of the two FBC residues in stabilization applications, as it has the potential to leach at levels that exceed the current BDAT standards. If the UTS eventually replace the current BDAT standards, then beryllium and vanadium would also become metals of concern for all three by-products, as these two metals have the potential to leach at levels that exceed the UTS.

Table 2
Total Constituent Analysis of the CCT By-Products

Metal	Limits for Concern (mg/kg)	TCA (mg/kg)		
		Spray Dryer Residue	PFBC Residue	CFBC Residue
Antimony (Sb)	33.6*	<4.0	<4.0	<4.0
Arsenic (As)	80.0	41.0	140.0	95.0
Barium (Ba)	1600.0	97.0	150.0	160.0
Beryllium (Be)	0.224*	2.22	2.60	2.00
Cadmium (Cd)	16.0	6.6	4.8	10.0
Chromium (Cr)	80.0	29.0	15.0	50.0
Copper (Cu)	NR [#]	20.0	17.0	35.0
Lead (Pb)	80.0	3.0	4.6	3.6
Mercury (Hg)	3.2	0.55	<0.10	1.10
Nickel (Ni)	81.6*	23.0	12.0	21.0
Selenium (Se)	16.0	<0.2	<0.2	<0.2
Silver (Ag)	80.0	<2.0	<2.0	<2.0
Thallium (Tl)	1.248*	<0.5	<4.0	<4.0
Vanadium (V)	3.68*	54.15	26.10	55.25
Zinc (Zn)	84.8*	34.0	78.0	52.0

*As these metals are not currently regulated under the U.S. EPA Toxicity Characteristic Program, the Uniform Treatment Standards for underlying constituents were used instead of the BDAT standards in calculating the threshold limits for concern.

[#]NR: This metal is not currently regulated under the U.S. EPA Toxicity Characteristic Program or as an underlying constituent under the Uniform Treatment Standards.

In addition to determining the total metals concentrations in the by-products and which of those metals are present at concentrations of concern, the actual leachable (TCLP) metals concentrations were also measured. The results of the TCLP metals analysis are given in Table 3. Although the total concentration of arsenic was found to be of concern in the FBC residues, it did not leach significantly during the TCLP test. Table 3 demonstrates that the by-products are not inherently hazardous in their own right, nor are they expected to contribute to the leaching of heavy metals in the treated waste mixtures, as none of their TCLP metals concentrations exceed the current BDAT standards. As these by-products do not contain highly mobile constituents, they are suitable materials for stabilization applications. If the UTS eventually replace the current BDAT standards, however, the CFBC residue may no longer be suitable material for hazardous

waste stabilization as its leachable vanadium concentration exceeds the projected future standard of 0.23 mg/L.

Table 3
TCLP Metals Concentrations of the CCT By-Products

Metal	Regulatory Standards (mg/L)		TCLP Concentrations (mg/L)		
	BDAT Standards	UTS	Spray Dryer Residue	PFBC Residue	CFBC Residue
Antimony (Sb)	NR*	2.1	<0.020	0.022	0.024
Arsenic (As)	5.0	5.0	<0.01	<0.1	0.89
Barium (Ba)	100.0	7.6	<5.0	<5.0	<5.0
Beryllium (Be)	NR	0.014	<0.001	<0.001	<0.001
Cadmium (Cd)	1.0	0.19	<0.1	<0.1	<0.1
Chromium (Cr)	5.0	0.86	<0.1	<0.1	<0.1
Copper (Cu)	NR	NR	<1.0	<1.0	<1.0
Lead (Pb)	5.0	0.37	<0.1	<0.1	<0.1
Mercury (Hg)	0.2	0.20/0.0025	<0.01	<0.01	<0.01
Nickel (Ni)	NR	5.1	<0.1	<0.1	<0.1
Selenium (Se)	1.0	0.16	<0.1	<0.1	<0.1
Silver (Ag)	80.0	0.3	<0.1	<0.1	<0.1
Thallium (Tl)	NR	0.078	<0.005	<0.005	<0.005
Vanadium (V)	NR	0.23	0.074	0.013	0.316
Zinc (Zn)	NR	5.3	<1.0	<1.0	<1.0

*NR: Not currently regulated under the applicable treatment standards

METAL-LADEN HAZARDOUS WASTES

The principal hazardous constituent of concern for all seven wastes was found from total metals concentrations to be lead. The range of total lead concentration in these seven wastes was from 750 to 43,000 mg/kg solids as received. Other hazardous constituents were found, but when the seven wastes were extracted by the TCLP protocol, only the lead concentrations fell above RCRA regulatory limits.

Those other hazardous constituents, found in the seven wastes, included three other RCRA hazardous constituents of concern — cadmium and chromium (five wastes) and barium (one waste). Four wastes contained other constituents which, although not currently regulated under EPA's TC program, are considered underlying constituents in the Universal Treatment Standards for non-characteristic wastes. All four of these were contaminated with copper and zinc and one, in addition, with nickel and vanadium.

TREATMENT STUDIES

The metals content of the TCLP extracts of the treated samples were evaluated to determine 1) if the by-product/waste mixture continued to exhibit the hazardous waste characteristic(s) exhibited by the untreated waste, 2) if the by-product/waste mixture exhibited any other hazardous waste characteristic, based on the parameters of concern identified from the total metals analyses performed on the waste and by-product, and 3) if the by-product/waste mixture achieved the LDR treatment standards.

The analytic data generated from the stabilized waste testing was reviewed jointly by MSYP and Pitt to determine which of the by-product/waste dosages most effectively treated the wastes. Effectiveness is defined as resulting in a non-hazardous treatment residue capable of land disposal under RCRA regulation. In the event multiple dosages achieved comparable results, the most economical dosage was judged to be the best.

Table 4 summarizes the results of this review. In the table the minimum weight ratio of by-product to waste, that successfully stabilizes the waste, is shown. A blank space indicates that even the 1:2 treatment ratio failed to stabilize the waste.

Six of the ten successful treatments were evaluated for solidification. For each evaluation, aliquots of the hazardous waste and the by-product were blended in the ratios shown in Table 5. For the PFBC and CFBC residues, these were in the same ratio as shown in Table 4 — namely 1:2. For the spray dryer residue, the ratios were shifted to 1:3 and 1:2 for the two treatments, respectively. The optimal amounts of moisture to be added to each mixture were determined to be that at which the wetted mass would produce an immediate “slump” in the neighborhood of 1.25 inches to 2 inches. Table 5 presents the 90-day unconfined compressive strength developed by the treated product (in pounds per square inch).

The mixtures with PFBC and CFBC residues yielded products of satisfactory unconfined compressive strength. These products are of interest for use in structural fills and road bases. The mixtures with the spray drier residue yielded unsatisfactory products.

Table 4
Success of By-product/Waste Combinations

Waste	Spray-Drier Residue	PFBC Residue	CFBC Residue
Battery sludge	1:10		
Munitions soil	1:10	1:2	
Industrial soil	1:10	1:2	
BOF dust			
Incinerator ash			
WWTP soil	1:10	1:2	1:2
Sandblast waste	1:10	1:2	

Table 5
Strength Developed by Treatment Products

By-product	Waste	By-Product/ Waste Ratio	90-Day Strength (Pounds per Inch ²)
Spray drier residue	Battery sludge	1:3	46
Spray drier residue	Munitions soil	1:2	31
PFBC residue	Industrial soil	1:2	378
PFBC residue	Munitions soil	1:2	188
PFBC residue	WWTP soil	1:2	364
CFBC residue	WWTP soil	1:2	539

MICROSTRUCTURAL ANALYSES OF TREATMENT PRODUCTS

The speciation of the hazardous constituent within the raw waste was found to be a basic lead carbonate, as determined by XRD analysis. Phase characterization by XRD also indicated that the metal speciation of the raw waste remained unchanged in the resulting treated waste mixtures. Microstructure characterization by SEM revealed that the particles of basic lead carbonate scattered throughout the treated waste mixtures were surrounded by or encapsulated in a matrix of very fine material consisting of calcium, sulfur, and silicon. The results of the XRD analysis, when interpreted in conjunction with the results of the SEM analysis, imply that physical encapsulation on a microscopic scale is the principal mechanism responsible for stabilization.

COMMERCIAL DEMONSTRATION

The results of the bench-scale treatments, shown in Table 4, are very encouraging. In particular, the spray drier residue shows excellent ability to stabilize metal-laden hazardous waste. As a consequence, in the third quarter of 1995 the University of Pittsburgh began to seek a commercial partner for a demonstration of this technology. The partner built into the project from the outset was MSYP. However, an unforeseen regulatory requirement forced MSYP to resign from the project. The project team searched for over a year for a replacement. That search continued through mid-1997, when the regulatory requirement, which had caused the MSYP to leave the project, appears to have been rescinded. MSYP then returned to the project. Since that time, the MSYP has been adjusting its operation (as noted earlier) in a changing business and regulatory climate to accommodate the project. Active work on the commercial phase of the project is expected to begin in the fall of 1998.

The next portion of this paper offers a brief history of the search and of barriers to its success, which were experienced.

The initial commercial hazardous waste treater for this project, MSYP, was already considering the use of coal combustion by-products (CCBs) as treatment chemicals when first approached by the university to join the project at its outset. They were very enthusiastic about a demonstration until told that the program's sponsor had determined, after lengthy consideration of the presence of hazardous wastes in the work of the project, that a federal environmental assessment (EA) would be required for this project. An EA would open another avenue for public scrutiny of the company's operation. The company had been exposed to public scrutiny at the state level on a number of occasions in the past and felt that the cost of further scrutiny at the federal level for this project would not be repaid sufficiently. It therefore with disappointment withdrew from negotiations early in the second quarter of 1996.

The second company approached quickly decided not to consider participating in the demonstration because of the general intrusiveness they felt of an EA.

The third company approached declined to participate at the time they were contacted (late in the second quarter of 1996). This company's decision was at first based principally on their desire not to be distracted by an EA while their Part B permit was being considered for renewal. A little

later in the discussions they indicated that they would be open to considering participation after the renewal was received, although they admitted that the presence of a federal sponsor of the program was a concern. They questioned whether having such a sponsor might expose them to future scrutiny.

As the approach to a fourth company was being developed, the program's sponsor reconsidered its requirement for an environmental assessment. In consideration of the fact that hazardous waste treaters are fully scrutinized at the state level and operate only under carefully reviewed permits, the level of environmental scrutiny was expected to shift to the review of the project's response to an environmental questionnaire. Consideration of the questionnaire does not include the opportunity for redundant review by the local affected population.

The fourth company approached was located outside the Appalachian coal province. The other three had been located well within that province. After a lengthy, thorough analysis, in the middle of the fourth quarter of 1996 they concluded that, while the project was of technical interest and their plant was permitted for an operation of this type, they could find no economic benefit for their company to join with the university to conduct this demonstration. Not only were there no apparent sources of this type of treatment chemical within an economic range of their plant, but also the general availability of the results of the demonstration would be an asset more to hazardous waste treaters in the Appalachian coal province than to themselves. They offered to examine closely any revised proposal for conducting the project at their plant that would provide a positive change in the economic outlook for long-term commercialization there.

The university, in consultation with the program sponsor, decided to refocus its search on a close-by company in the Appalachian coal province. In the first quarter of 1997 it recontacted MSYP and found that, a year having passed since breaking off earlier discussions and the requirement for an EA having been taken away, the company was open to negotiations to return to the project, which were successful. As noted earlier, plans are progressing for conducting the demonstration at MSYP.

Application

A successful conclusion to the demonstration will be reported to the two interested technical communities — the coal-fired utility sector and the hazardous waste treatment sector. The university envisions that entities in these two sectors will establish sales/purchase agreements, and advanced clean coal technology (CCT) by-products will be used to treat metal-laden hazardous wastes on a wide commercial basis. The amounts of CCT by-products that will be utilized in this manner likely will never come up to the quantities that can be utilized in the construction sector. However, any amount utilized by waste treaters will be a welcome sale economically for those utilities that establish them as customers.

Whether utilities will welcome potential sales to waste treaters from the standpoint of liability, is another matter. Significant barriers exist, which have been examined recently by the U.S. Department of Energy. These will now be reviewed in some detail.

BARRIERS TO BENEFICIAL USE OF CCBs

Before embarking upon a discussion of the barriers to beneficial use of CCBs, a report of one other specific experience, which the University of Pittsburgh had while conducting this project, will be instructive.

It will be noted that the original clean coal technology by-product is not among the three examined in this project, namely, residue from a coal-fired fluid bed combustor (FBC). Many of these units are in operation across the United States and their by-product has moved into the mainstream of CCBs in the marketplace. Ash brokers have been engaged by the operators of the cogeneration plants which utilize coal-fired FBCs to aggressively market this by-product and carefully dispose of that which can't be sold. While planning and conducting the bench-scale tests of this project, the university engaged in extensive negotiations with a major CCB broker to obtain a sample of coal-fired FBC residue to include in the program. It was unsuccessful in doing so. Generators of CCBs retain the right of approval on all by-product uses, suggested to them by their brokers. Testing of their by-product as a hazardous waste treatment chemical in a publicly reported program such as this one, failed to receive generator approval because of concern for potential liability for cleanup of sites "contaminated" with hazardous materials, even though (1) the wastes treated with their by-product would be rendered non-hazardous and (2) the generator is once or twice removed from the by-product sale — once if the broker takes ownership of the by-product as a product of commerce and twice if the transporter of the by-product takes ownership first before it passes to the broker.

The barriers that have been experienced by this project are typical of those being encountered across the nation by all who are trying to increase the utilization of CCBs. This problem is sufficiently pronounced that Congress asked for a special report from the DOE on it. The report was provided to Congress in July 1994 [7]. The appendix of this paper contains the statement of the barriers, contained in the Executive Summary of the report.

Here are barriers, which were identified in the report, that the University of Pittsburgh has encountered in conducting this project. The immediately preceding paragraphs and section have already given the background for much of this discussion.

1. This project was initiated to provide data to the public domain on the use of clean coal technology by-products as treatment chemicals for hazardous wastes. *Inadequate information* is available in the literature on this byproduct use technology.
2. Coupled with the first barrier is *inefficient technology/information transfer* in the case of residue from coal-fired FBCs for this use technology.
3. The data from this project can be used by the E-50 Committee of the American Society for Testing and Materials to create a *specification for byproduct use* in this technology. The university has already met with this committee and it intends to participate in standards development when the demonstration is complete.

4. *Attitudinal barriers* have been encountered. The initial decision to require an environmental assessment for this project arose in a climate of concern for the legal definition of a non-hazardous product of a permitted hazardous waste stabilization process. The resulting hesitance of three companies to participate in the commercial phase of the project could be considered to some extent to be a product of “public misconception of the risk” of hazardous waste stabilization, a misconception which results in acrimonious public meetings when permit applications and environmental assessments are opened for public review.

5. The “lack of discrimination between beneficial reuse application and disposal” contributes strongly to an economic barrier. In general, if a material is disposed to a waste treatment plant and carries a tipping fee, even if it is used beneficially — in this case as a treatment chemical — it is still legally defined as a waste and is regulated as such. However, if it is purchased by the plant, it generally can be claimed as a product of commerce and used as a treatment chemical. The requirement that a by-product must be sold to a hazardous waste treatment plant in order for it to be considered not a waste, severely limits the ash dilution of the alkaline components in the by-product. Ash is essentially an inert which takes up relatively expensive landfill space in ultimate disposal. A hazardous waste treater cannot afford to “purchase” much ash accompanying the alkaline component. If the seller of the active ingredient in the by-product could provide the funds (through a tipping fee) to landfill the ash component which is just along for the ride, a better economic case could be made for more use of this by-product for hazardous waste treatment.

6. The basic concern over “the potential for liability associated with the use of a material designated as a waste material” has had a generally chilling effect on the interest of by-product producers to participate in this project. It should be noted that the last paragraph of the Appendix, from which the quotation in the preceding sentence is taken, was actually directed at the complex of issues related to Bevill wastes [8]. Advanced clean coal technology by-products fall into this category. A full discussion of this topic and its impact on their use as a treatment chemical is a subject for an extensive paper of its own.

Future Activities

The University of Pittsburgh and the Mill Service Yukon Plant are committed to conducting the demonstration during FY 1999. A time extension on the original contract has been requested for this purpose. Following a successful demonstration, the university will encourage commercialization of this concept.

Contract Information

This work is being performed under Contract No. DE-FC21-94MC31175. The Contractor is the University of Pittsburgh. The Principal Investigator is James T. Cobb, Jr., 1137 Benedum Hall, Pittsburgh, PA 15261, FAX 412-624-9639. The FETC Contracting Officer’s Representative is Scott Renninger. The initial period of performance was October 1994 through September 1996.

Two one-year no-cost contract extensions have been necessary and another final one has been requested for next year. MAX Environmental Technologies, Inc. (the parent company of the Mill Service Yukon Plant) and Dravo Lime Company have been the primary subcontractors. Several companies have provided by-products.

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Appendix

Barriers to Increased By-product Utilization

The following is reproduced from the Executive Summary of “Report to Congress. Barriers to the Increased Utilization of Coal Combustion/Desulfurization Byproducts by Governmental and Commercial Sectors” [7].

The findings of the study suggest that institutional, regulatory, and legal barriers are very much interrelated. The institutional barriers can be summarized into the following major areas:

Inefficient Technology/Information Transfer. Available information is not transferred or is not transferred in a timely fashion to regulators or potential users of byproduct utilization technology. There is an apparent information or communications gap among the producers of byproducts, end users, and regulators.

Lack of Coordination/Leadership in Development and Promotion of Coal Byproduct Utilization. There is a national industry group for promotion of coal byproduct reuse. However, an organization is needed within the Federal Government to support that promotional role within the governmental sector.

Inadequacies of State Programs to Promote Beneficial Reuse. Coal byproduct disposal and beneficial reuse are regulated by the States. Across the States there is inconsistency in State regulations for what constitutes beneficial reuse and how it should be regulated. Few State procurement programs support use of recovered materials such as coal byproducts.

Non-Existent or Inadequate Specifications for Byproduct Use. There is a lack of recognized technical specifications for use of coal byproducts even in proven technology.

Existence of Attitudinal Barriers. Designation of coal byproducts as a solid waste, while fostering public misconception about the risk of these materials, stymies attempts to develop or expand markets for their use.

The lack of discrimination in the Federal and State regulatory systems between coal byproducts for beneficial reuse application and disposal is central to the regulatory barriers to increased byproduct utilization. Without this discrimination, the “waste” designation can trigger case-by-case approval which makes utilization impractical.

There is also the need in the regulatory field to develop environmental compliance tests which determine realistic environmental impacts.

The chief legal barrier to increased coal byproduct use is the potential for liability associated with use of a material designated as a waste material. It is a concern of producers and users of coal byproducts that their liability is unacceptably extended beyond that normally associated with use of a commercial material.