**TREATMENT OF METAL-LADEN HAZARDOUS WASTES
WITH
ADVANCED CLEAN COAL TECHNOLOGY BY-PRODUCTS**

DRAFT FINAL REPORT

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ABSTRACT

Metal-laden wastes can be stabilized and solidified using advanced clean coal technology by-products (CCTBs) – fluid bed combustor ash and spray drier solids. These utility-generated treatment chemicals are available for purchase through brokers, and commercial applications of this process are being practiced by treaters of metal-laden hazardous waste. A complex of regulations governs this industry, and sensitivities to this complex has discouraged public documentation of treatment of metal-laden hazardous wastes with CCTBs.

This report provides a comprehensive public documentation of laboratory studies that show the efficacy of the stabilization and solidification of metal-laden hazardous wastes – such as lead-contaminated soils and sandblast residues – through treatment with CCTBs. It then describes the extensive efforts that were made to obtain the permits allowing a commercial hazardous waste treater to utilize CCTBs as treatment chemicals and to install the equipment required to do so. It concludes with the effect of this lengthy process on the ability of the treatment company to realize the practical, physical outcome of this effort, leading to premature termination of the project.

EXECUTIVE SUMMARY

Environmental Approvals and Plant Modifications

1996. The Waste Management Division, Southwest Region, Pennsylvania Department of Environmental Protection (PADEP) approved the field work for Phase 2 at the Mill Service Yukon Plant (MSYP). The Air Pollution Control Division, Southwest Region, PADEP exempted the field work at MSYP from its Plan Approval/Operating Permit. However, a decision by the U.S. Department of Energy (USDOE) that an environmental evaluation of the work of Phase 2 at MSYP must be conducted, led that firm to withdraw from Phase 2.

A search began for a new subcontractor. The Bedford, Ohio plant of Republic Environmental Systems was approached first, but they declined the invitation. A second candidate, the Canton, Ohio plant of Envirite Corporation, was approached, but they declined the invitation. A third candidate, EQ Company, Ypsilanti, Michigan, was visited. The project team decided not to continue discussions with them. A fourth candidate, Heritage Environmental Services, Inc., was sent information about the project but did not consider an invitation to join.

1997. When the USDOE decided not to require an environmental evaluation of the work of Phase 2, MSYP was contacted to rejoin the project team. MSYP responded positively and begin planning for installation of equipment to allow Phase 2 to be conducted there. The cost of equipment, financial arrangements for its purchase and installation, and preparation of requests for permit modifications were addressed. MSYP received a market survey of the demand for hazardous metal-laden dust stabilization, and its principal owner authorized the seeking of funds to purchase and install equipment to allow dusty wastes and treatment chemicals to be used at the plant.

1998. Work was carried out on the detailed design of that portion of the new system to handle dusty treatment chemicals and on the minor permit modification applications needed to carry out the installation.

Staff of MSYP met with staff of the PADEP to discuss new equipment installation at the plant. MSYP received a modification of its principal solid waste permit to allow the commercial use of dusty, dry clean coal technology by-products as stabilization/solidification treatment chemicals at the plant. The staff of MSYP submitted to the PADEP applications (1) for a minor permit modification for the installation of a new silo and new storage pads and (2) for a revision to the air permit to operate the baghouse on the new silo.

New federal Universal Treatment Standards were issued on August 24. Operating parameters at MSYP were adjusted accordingly.

1999. MSYP filed a response to the PADEP concerning two administrative deficiencies in its August 1998 application for a minor modification to its air permit to allow installation of

the new silo. It also filed an application for modification to its solid waste permit to allow disposal of wastes treated with clean coal technology byproducts in its current impoundment. MSYP received approval from the PADEP for installation of the silo to store dusty clean coal technology byproducts. MSYP provided a reply to comments received from the PADEP on its application for a modification to its solid waste permit.

Work began on the Test Plan for Phase 2 was prepared by the University. Work also began on the Environmental Questionnaires for Phase 2 at both the University and at MSYP.

2000. The Environmental Questionnaires for Phase 2 at the University of Pittsburgh and the MSYP were submitted in January.

The Test Plan for Phase 2 was also submitted in January, and subsequently approved.

MSYP received final solid waste permit modifications allowing wastes stabilized with clean coal technology by-products to be disposed on site.

2001. The detailed design for silo foundation and supports was prepared and the silo was sand blasted, primed and painted. The concrete mix was designed the concrete mix, and the rebar and lining for the construction of the foundation of the silo was ordered. The stormwater sump, the stormwater discharge line, the aggregate base and the liner were installed and interviews of concrete companies to pour the foundation were begun.

Several by-product brokers were contacted to determine the availability of candidate by-products to be evaluated at MSYP for use in the field test. The Tennessee Valley Authority (TVA), ReUse Technology, Inc. (ReUse), and Mineral Solutions, Inc. (MSI) offered to provide samples.

In September MSYP submitted an application for renewal of its Hazardous Waste Permit. The first round of comments took place in December.

2002. Both MSI and ReUse provided several samples of advanced clean coal technology by-products to MSYP to use in conducting treatability studies with soils contaminated with hexavalent chrome that were expected to be sent to MSYP for treatment during 2002 and 2003.

Unfortunately, because of other projects and the fact that the renewal of the Hazardous Waste Permit, that had been applied for in September 2001, still had not arrived by the end of the 2002 construction season, MSYP deferred the construction of the silo's pad until Spring 2003.

2003. By late Spring 2003 it became clear that other work at MSYP continued to have higher priority than the field test. So, considering all of the delays and with no end in sight, the project was terminated on June 30, 2003.

Laboratory Studies

Final Analyses of Phase 1 Samples. Final analyses for arsenic, selenium and mercury were completed for the extracts of the three by-products collected in Phase 1. All metals concentrations in the extracts were below the current BDAT (Best Demonstrated Available Technology) standard and only selenium in the TCLP extract of two samples of the residues from the Ebensburg Power Company (EBP) exceeded the potential future BDAT standard of 0.16 mg/L.

Final analyses for arsenic, beryllium, copper, mercury, selenium, antimony, thallium and vanadium were completed for the extracts of the eight immediately successful by-product/waste mixtures and the five mixtures which were not immediately successful, prepared during Phase 1. All concentrations were below both the current and potential future BDAT standards.

Mercury analyses were completed for the extracts of the three by-products, the unused fourth by-product, and eleven treated waste mixtures. All were well below both current and potential future standards.

Analysis and Treatment of a Seventh Waste. The seventh waste, a sandblast residue, was analyzed and found to yield hazardous levels of lead when extracted. Six other metals were found to be present in sufficient quantities in the waste to be potentially a problem if completely leached, but were not present in significant amounts in the standard leachate. The lead in this waste was found to be stabilized by a 30% dosage of CONSOL by-product and a 50% dosage of the Tidd by-product. The EPC by-product was not effective for this waste.

Solidification studies on the sandblast residue were conducted on the successful stabilization recipes of the 30% dosage of CONSOL by-product and the 50% dosage of the Tidd by-product. The product of treatment with the CONSOL by-product exhibited no unconfined compressive strength. That with the Tidd by-product yielded very modest strength. Good stabilization accompanied the solidification with the CONSOL by-product but the (aged) Tidd by-product failed to stabilize the solidified sandblast residue.

Long-Term Stabilization. Two of the graduate students assigned to this project examined the long-term stabilization of the solidification samples prepared a year ago. The first found a general trend toward destabilization was found. The second prepared a literature review on stabilization/solidification and found in the laboratory that after two years, the leachability of lead decreased or remained nearly constant in both the TCLP and ASTM leaching tests. In contrast, while the leachability of zinc in the TCLP leaching test also decreased or remained nearly constant, its leachability in the ASTM leaching test increased.. She also found that cadmium and chromium remained tightly bound within the s/s matrix after two years. The leachability of lead and zinc from the s/s matrices varied among the six samples after two years of curing.

Evaluations of the Solidified Sandblast Residue Using X-Ray Diffraction and the Scanning Electron Microscope. A third graduate student assigned to this project evaluated the solidified sandblast residue using x-ray diffraction and the scanning electron microscope.

1.0 INTRODUCTION

This report documents the work conducted under Award Number DE-FC21-94MC31175 on "Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology By-Products." The project was defined in two phases. The first phase was a laboratory evaluation of the stabilization and solidification of six metal-laden wastes using four clean coal technology by-products. A topical report describing Phase I, covering work during the period August 18, 1994 to August 18, 1995, was presented to the U.S. Department of Energy (U.S.DOE) on March 1, 1996. This report is reproduced in Appendix A.

The results of the work of Phase I and follow-on laboratory work, that continued in parallel with the early portion of Phase II, was reported in an article, entitled "Stabilization of Heavy Metal Containing Hazardous Wastes with By-Products from Advanced Clean Coal Technology Systems," published in the October 1999 issue of the *Journal of the Air & Waste Management Association*. This article is reproduced in Appendix B.

The work in Phase II was aimed at organizing and conducting a commercial field test of the stabilization of a metal-laden waste with a clean coal technology by-product at the Mill Service Yukon Plant (MSYP) of Max Environmental Technologies, Inc. The plan for Phase II called for environmental approvals to be provided by the U.S.DOE, and then by the Pennsylvania Department of Environmental Protection through its normal regulatory actions. With all environmental approvals in place, the plan called for the installation of new equipment at MSYP to receive dry, dusty clean coal technology by-product (such a treatment chemical not previously in use at MSYP) and to feed it to and mix it with the metal-laden waste.

This report first describes the recently completed eight-year effort to obtain the environmental approvals required before the new equipment could begin to be installed at MSYP. Throughout this description are noted the first steps taken to install the equipment and prepare the procedure for treating a waste with a by-product. The report then provides details of laboratory work conducted after August 18, 1995 that were not included in the topical report. A condensed version of this data was included in the article in the *Journal of the Air & Waste Management Association*.

It has been decided to end this extraordinarily lengthy project in June 2003 at a point where the principal by-product-receiving equipment is ready to install, the foundation for the receiving equipment is in place, and several candidate by-products are in hand to use in treatability studies of the next available appropriate metal-laden waste. In obtaining the candidate by-products, it has been learned that clean coal technology by-products are being quietly used for stabilization of metal-laden wastes. It was the hope of this project to document publically one such use at MSYP, as these other commercial projects have not to this time been so documented. It is to be hoped that the MSYP project, when it goes on-line, or one of the other commercial projects, will be documented in the open literature for the benefit of the electric utilities and hazardous waste treaters of the United States.

2.0 ENVIRONMENTAL APPROVALS AND PLANT MODIFICATIONS

2.1 Permission for the Field Tests. On November 30, 1995 the Mill Service Yukon Plant (MSYP) wrote to the Southwest Regional Manager for Waste Management of the Pennsylvania Department of Environmental Protection (PADEP), requesting the Department's permission to conduct the field tests of Phase 2 of this project. MSYP had earlier requested a modification to its Hazardous Waste Permit to do so on a permanent basis, but had neither received the modification at that time nor had the expectation that it would be granted before the field work of Phase 2 must proceed.

MSYP also asked the Air Pollution Control Division of the Southwest Regional Office of PADEP for an exemption from its Plan Approval/Operating Permit for an anticipated increase in fugitive emissions when clean coal technology by-products were used in Phase 2 to treat commercial hazardous waste batches at MSYP.

On December 27, 1995, the Southwest Regional Manager for Waste Management of the PADEP wrote to MSYP, giving that division's approval for the field work of Phase 2.

In early January 1996 MSYP was requested by the Air Pollution Control Division to provide additional information in support of MSYP's request for an exemption from its Plan Approval/Operating Permit. The request appeared to have been initiated in response to information obtained by PADEP during the preparation of the environmental information report by the Center for Hazardous Materials Research last summer as part of Phase 1 of this project. Soon after the requested information was provided by MSYP, on February 20, 1996 one of the Southwest Regional Air Pollution Control Engineers — Air Quality — of PADEP wrote to MSYP, giving the requested exemption.

2.2 Effect of an Environmental Assessment on MSYP's Participation. In anticipation of the decision by the Morgantown Energy Technology Center (METC) on whether an environmental assessment (EA) would be necessary or a categorical exclusion would be granted under NEPA, MSYP in early Spring 1996 prepared an elementary plan for conducting the field tests at MSYP. This plan would become a significant portion of the Test Plan for Phase 2.

In further anticipation of the decision by METC on whether an EA would be necessary or a categorical exclusion would be granted under NEPA, MSYP in early April 1996 prepared a plan to handle the collection of the CONSOL and EPC by-products. This plan involved engaging another company to haul each by-product to MSYP from its point of availability. The EPC material would have been delivered directly to the plant, while the CONSOL material would have been stored in one of the silos owned by the hauling company. A cost estimate for this service was prepared.

Unfortunately, the elementary plan for conducting the field tests and the by-product

handling plan became moot as a result of the decision, announced by telephone to the project team on April 1, 1996 by the project's Contracting Officer's Representative (COR), that METC had decided to perform an EA of Phase 2 of the project, if it were conducted at MSYP.

After much consideration of this decision, MSYP on April 26, 1996 formally withdrew from Phase 2. Had the categorical exclusion been invoked, MSYP would have been able to have continued to participate in Phase 2. MSYP's reason for withdrawing centers on that aspect of an EA which would have provided an opportunity for public input. The project team understood that it was MSYP's position that it (MSYP) would likely have been required to devote considerable resources — in time spent by its professionals, staff and officers; in direct funds expended; and in undefinable costs to meet unnecessary, increased regulations which frequently result from overreaction by the PADEP to uninformed, emotional testimony — to participate in a public review of the project. The project's budget did not include reimbursement of these ill-defined expenses. These unreimbursable, somewhat undefinable, increased expenses caused MSYP to withdraw from the project.

2.3 Search for an Alternate Site. Following MSYP's withdrawal, a search began for an alternative site and partner for the field tests of Phase 2. In late May 1996 discussions were held with the Bedford, Ohio plant of Republic Environmental Systems (Republic), the closest hazardous waste treatment facility (geographically) to Pittsburgh — other than MSYP, of course. Although the technical director of the facility at first was very interested in the technical aspects of the project, its general managers declined to participate, citing concerns for the intrusiveness and magnitude of an EA of the project.

At that time — May 31, 1996 — the project team anticipated that an EA would be required of any site agreeing to participate in Phase 2. During discussions with METC immediately following the decision by Republic's Bedford plant not to participate, the project team learned that the decision to perform an EA at MSYP had been based apparently solely upon the substantial, acrimonious public scrutiny which that plant has received over the years. If that scrutiny had not been so vigorous, the categorical exclusion under NEPA would likely have been granted. Subsequent contacts with other potential participants were and continued to be made with the advice to them out front that an EA was unlikely if little public scrutiny had been previously applied to the plant being considered.

With this in mind, discussions were opened in mid-June 1996 with the Canton, Ohio plant of Envirote Corporation (Envirote). This plant was a treatment facility only — no material was stored there. The flow of hazardous waste to the plant was relatively constant year-round. Occasionally, the plant had been open to public review when permit modifications were sought. However, no members of the public had come forward at those times, the permits were granted and no controversy was ever present. The plant currently was nearing the conclusion of the process of obtaining a Part B permit. Envirote indicated that, when this permit was received, it would be very interested in the possibility of using advanced clean coal technology by-products as treatment chemicals. However, they wished absolutely nothing to interfere with their Part B application. The project team indicated that the circumstances of the plant were such that an EA

would not anticipated. On this basis the plant asked for documentation describing the project, an idea of the role Envirite would play in it, and the format of the NEPA Checklist in order that they could consider whether to join the project team for Phase 2. This material was sent to Envirite on July 1, 1996, along with an invitation to join the project team. On July 10, 1996 Envirite formally declined to participate. In a telephone conversation it was noted that the reasons for rejection were:

- incomplete cycle of approval of Part B permit;
- lack of operational, economic or business advantage;
- concern for federal involvement.

On July 25, 1996 a letter similar to the one to Envirite was sent to EQ Company (EQ) in Ypsilanti, Michigan, and on September 10, 1996 another was sent to Heritage Environmental Services, Inc. (Heritage), in Indianapolis, Indiana. The principal investigator (PI) for this project paid a visit to EQ on November 12, 1996, meeting with the Vice President for Hazardous Waste Operations and the General Manager. Here are the points that were covered in the discussion.

1. EQ had a basic interest in the project. They were looking for inexpensive treatment chemicals. If certain conditions could be met, they would participate, even though those chemicals might have been useful for only a small fraction of their wastes. If it turned out that the chemicals could not be used with their wastes for any reason, the outcome of the project would be more to the advantage of their competitors to the east, where there were more obvious sources of by-product. So, EQ, as a business, would have had a success in the project only if EQ used the process on a competitive playing field that was at least level.
2. The principal condition, therefore, was that there would be sufficient usable by-product within 50 miles of EQ in Ypsilanti, Michigan, to serve as a commercial source. A second condition was that the by-products instantly bring the concentrations to UTS levels (for example 0.37 ppm for lead, NOT 5 ppm). This is a relatively difficult task for the treatment chemicals being examined in this project.
3. EQ treated batches an order of magnitude larger than MSYP. Typically, 220 yards of treated waste were produced per batch. However, at off-peak hours, batches of about 100 yards probably could be used.
4. EQ would line up the wastes to be treated.
5. EQ felt that the data in the topical report describing Phase 1 was very robust, much more so than similar studies they had seen.
6. EQ had filed for using their hazardous (RCRA) fill as a toxic (TOSCA) fill. For the past six months the site had been a lightning rod for public assessment of this request. Even so, the

project team hoped that, because the site was fully permitted as a RCRA fill, an EA would not be required by USDOE.

7. EQ wanted the project team to find the by-products in their area. They provided names of contacts at GM Worldwide Powerhouse Operation, Wayne County Air Quality Management, and the Air Quality Division of the Michigan Department of Environmental Quality. They also suggested getting in touch with Detroit Edison.

8. EQ felt that the project team should have had an easier time lining up a treater farther east, where by-product was more available. If USDOE were less likely to require an EA, they suggested going back to others that the project team had spoken with earlier.

As a result of this visit, the project team decided not to continue discussions with EQ.

2.4 Reentry of MSYP to Project. In mid-January 1997 the PI and the COR discussed options for field work of Phase 2. After nine months of effort it had become apparent that a number of barriers were present to identifying a replacement for MSYP, as the subcontractor for the field work:

- distance from and inexperience with the prime contractor
- lack of technical or economic incentives
- regulatory concerns
- press of competing projects.

The COR suggested recontacting MSYP. The PI did so and the response was very encouraging. The current business plan for the plant continued to call for adding treatment technologies utilizing dusty chemicals, and the permit modification application to allow this was still active with the PADEP.

On February 11, 1997 the project team visited MSYP. It was told that MSYP was then experiencing major shifts in the waste streams that were being offered to them for treatment or that they might seek out for treatment. They also noted that they were always looking for new inexpensive treatment chemicals. A key handlability property of clean coal technology by-products as treatment chemicals is their dustiness, but that was also a principal property of a growing percentage of wastes that were likely to become available for treatment in the future. MSYP was beginning an examination of this situation, because the permit application for the use of dusty chemicals had been under review for some time and the permit was expected to be issued soon. The MSYP staff said that they would give careful consideration to returning to the project team. They expressed appreciation for this discussion, because it stimulated many good ideas about the direction their business might take.

Following the meeting on February 11, MSYP sought and obtained several cost estimates for handling finely divided, dry chemicals and wastes. It also began to estimate the market in the surrounding ten states for treatment of finely divided, dry wastes. This information was

necessary for MSYP to make a decision on this new line of business and on rejoining the project. MSYP also initiated a survey of financing options for installing this long-term commercial system for treating metal-laden wastes with dusty chemicals.

On May 29, 1997 the PI met for several hours with the owner and key staff members. He outlined the project and presented the expectations the University had for Phase 2. The owner emphasized his general, strong support for this and similar projects in the future with the University. He authorized planning for Phase 2 at MSYP. He stated that, as soon as MSYP's financial situation allowed, it would move forward on the acquisition and installation of equipment at MSYP, required to conduct treatment with dry, dusty materials. The University would assist in permitting as appropriate.

On June 12, 1997 the PI met for several hours with one of the key staff member at MSYP for the project. A number of issues were covered.

1. The business potential for MSYP of treatment using dry, dusty chemicals was summarized .
2. The cost of equipment for a comprehensive installation to receive wastes, treat them, and load out the product was reviewed. Financial arrangements for equipment purchase and installation were discussed.
3. MSYP must prepare a request for a permit modification to install and operate the new equipment, based upon a requirement from the Pennsylvania Department of Environmental Protection to solve an existing dust problem at the Yukon Plant. It was hoped that the modification could be reviewed quickly, because it was a solution to an existing problem.
4. The files from Phase 1 were surveyed, and key documents for review were identified.

On June 13, 1997 the PI queried CONSOL in regard to the availability of its byproduct for Phase 2.

On June 24, 1997 the PI discussed the costs of treatment chemicals with the key staff member at MSYP. The PI learned that a large window of costs existed. One byproduct used for treatment at MSYP was purchased in a considerably competitive market for over \$20 per ton plus transportation cost. A second byproduct in the past had been purchased for an "ownership transfer cost" of \$1 per ton plus transportation cost. A third treatment chemical was a non-hazardous waste which was provided at the plant gate along with a \$6 per ton tipping fee. Most of this material was being utilized in a disposal pond closure program, but some of it was being used as a treatment chemical. It was clear that the economic evaluation of a clean coal technology byproduct as a treatment chemical at the Yukon Plant would be based upon its quality and purchase cost, as well as its location (which sets the transportation cost), in

comparison to competing materials.

In late August 1997 the key staff member at MSYP received from an outside firm a market survey of the demand for hazardous metal-laden dust stabilization. A careful analysis of the report revealed that the market for this sector of hazardous waste treatment was very good. A preliminary technical evaluation of the equipment needed (unloading facilities, silos, conveyors, a plug mill and product loading facilities) factored favorably into the overall economics of this sector. The principal owner of MSYP authorized the application for low-interest financing to seek the funds for this large, ambitious installation.

In mid-November 1997 the key staff member at MSYP reported that MSYP had just hired a new Vice President of Sales, which added considerably to its management capability. He anticipated that the application for a low-interest loan to fund the installation of the equipment needed to carry out this project to utilize dusty by-products to treat metal-laden hazardous waste at the Yukon Plant would be completed early in 1998.

MSYP formally rejoined the project team via a letter of recommitment dated January 22, 1998.

2.5 Design, Permitting, Equipment Purchasing and Initial Construction at MSYP. Work began in late Winter 1998 at MSYP on the detailed design of one portion of the new system. When fully installed, the new system would allow MSYP to treat dusty wastes with dusty chemicals (including advanced clean coal technology by-products). At the beginning of the design work it was expected that the entire system would be acquired immediately. However, a major investment at another corporate site required that the installation at MSYP be scaled back to include just the equipment to handle dusty treatment chemicals and to allow these to be used at the existing treatment pits.

The steps to engaging this partial installation in the project were:

- detailed design of treatment chemical unloading section, silo, chemical transfer section and dust management system at the treatment pits
- preparation of the air and solid waste permit applications for construction and operation of the partial system
- review of permit applications and issuance of permits
- construction of the partial system
- preparation of the task plan for Phase 2 of the project

The task plan would describe the acquisition of chemicals and wastes, the treatability and solidification study for each chemical/waste pair, the treatment of 20-30 tons of waste with 2-6

tons of chemicals in each batch in the treatment pits, and the stabilization/solidification characterization of treated products.

During the second week of April 1998 the staff of MSYP met with staff of PADEP to discuss MSYP's plan to install among other items a silo and new storage pads near the treatment pits. This portion of the planned new installation would allow MSYP to regularly use dry dusty treatment chemicals, such as advanced clean coal technology by-products, to stabilize large volumes of solid, metal-laden hazardous waste. PADEP agreed to allow MSYP to submit an application for a minor permit modification for the new installation.

MSYP's staff worked throughout the late Spring 1998 on the application for the minor permit modification for the new installation, along with several other applications, including (1) a revision to the air permit to operate the baghouse on the silo and (2) a modification to the solid waste permit to dispose of the solid waste produced by treatment with the new chemicals.

It should be noted that PADEP at the time was in the process of consolidating all air permits on a given site. Currently, MSYP had five active air permits. It had already submitted the consolidation application in November 1997 for a new general air permit under the Pennsylvania State Only Facility-Wide Minor Source Air Quality program and was awaiting approval. MSYP hoped that the air permit application for the silo's baghouse would be issued quickly and separately from the consolidated permit.

It should also be noted that the solidification characteristics of the wastes stabilized by advanced clean coal technology by-products at that moment were important to MSYP. MSYP wished to use this stabilized waste stream as a portion of the cap on Impoundment #5, which was scheduled to be closed at the end of 1998 and capped by the end of 1999.

During the early summer 1998 MSYP's staff sought and received quotes on specific items of equipment for the new installation to handle dry dusty treatment chemicals.

On July 8, 1998 the permit modification was finally issued to MSYP's principal solid waste permit (PAD004835146) to allow the commercial use of dusty, dry clean coal technology by-products as stabilization/solidification treatment chemicals at the plant.

On August 3, 1998 MSYP submitted its application for a minor permit modification to PADEP for the installation, among other pieces of equipment, of the new silo and new storage pads near the treatment pits at MSYP in order to conduct the field test of this project. This portion of the planned new installation would allow MSYP to regularly use dry dusty treatment chemicals, such as advanced clean coal technology by-products, to stabilize large volumes of solid, metal-laden hazardous waste.

In late August 1998 MSYP submitted a request to PADEP for a revision to the air permit to operate the baghouse on the silo. The revision was expected to be approved early in 1999. As soon as it was approved, a modification would be requested to the solid waste permit to dispose

of the solid waste produced by treatment with the new chemicals. This modification was expected to be issued within eight weeks of the request. The project team was hopeful that MSYP could begin construction of the modifications in early spring 1999 and be ready to conduct the field work of Phase 2 soon thereafter.

Because of a major regulatory revision that occurred during this quarter, it is appropriate to revisit the subject of land disposal restrictions (i.e., Universal Treatment Standards — UTS) for metal constituents in hazardous wastes. Appendix C provides the summary, history and applicability of the new federal UTS regulations from pages 28559-28561 of the Federal Register (volume 63, number 100, May 26, 1998). It also shows both the (then) current and new standards for K061 from 40 CFR 268.40(f). These newest regulations became effective on August 24, 1998. In Phase 1 the project team compared the stabilization results, which it obtained during that phase, to the then existing and proposed UTS. At that time the existing UTS for lead was 5.0 ppm and the proposed UTS for lead was 0.37 ppm. The UTS for lead in mid-1998 was 0.37 ppm and the new UTS for lead (after August 24, 1998) was 0.75 ppm.

The Tidd by-product, that had been stored at Dravo Lime Company for several years, was moved to MSYP on September 16, 1998.

On December 29, 1998, PADEP identified two administrative deficiencies in the application for minor modification to MSYP's air permit to allow installation of the new silo for handling dusty treatment chemicals, such as clean coal technology byproducts (CCTBs), that had been filed with PADEP on August 3, 1998. On April 26, 1999, MSYP responded to PADEP concerning the deficiencies.

In April 1999 MSYP filed the last of the permit applications to allow work on Phase 2 to be initiated, namely, an application for a modification to the plant's solid waste permit to allow it to dispose of the waste treated with CCTBs in its current impoundment.

In July 1999 MSYP received comments from PADEP on its application for a modification to its solid waste permit.

On August 31, 1999, MSYP received a letter from PADEP exempting the silo for the storage of dusty treatment reagents from Plan Approval requirements. This cleared the way regulatorily for installation of the silo. However, MSYP still needed the approval of the PADEP for its modification to MSYP's solid waste permit before MSYP was allowed to operate the treatment system using clean coal technology byproducts. Receipt of this final permit modification was necessary before MSYP could be authorized by its owners to spend the funds to rehabilitate the silo, install it and connect it to the treatment pits.

In October 1999 MSYP completed work on its reply to comments it received in July 1999 from PADEP on its application for a modification to its solid waste permit. The reply was forwarded to PADEP later that month.

On January 18, 2000 executed copies of the Environmental Questionnaires for Phase 2 at the University of Pittsburgh and at MSYP was submitted to the Environmental Officer at the National Energy Technology Laboratory (NETL). On that same date the Test Plan for Phase 2 was submitted to the COR. These three documents are reproduced in Appendices D, E and F.

In late April 2000 the project team received approval of the Test Plan for Phase 2 from the project's COR.

The detailed design for the silo's reinforced concrete foundation and for its supports was prepared in May 2000. In June 2000 the silo was sand blasted, primed and painted.

On June 6, 2000 MSYP received its final solid waste permit modifications allowing wastes stabilized with clean coal technology by-products to be disposed on site.

However, at this point, work on the by-product feed system was interrupted by other needs at the plant. It was not until a year later, at the end of June 2001 that MSYP finally continued to prepare for the field test in earnest. During that summer, the concrete mix was designed, the rebar and lining was ordered, the stormwater sump, the stormwater discharge line, the aggregate base and the liner were installed and interviews of concrete companies to pour the foundation was begun.

Given this activity, the PI contacted several by-product brokers in July 2001 to determine the availability of candidate by-products to be evaluated at MSYP for use in the field test. Those contacted were the Tennessee Valley Authority (TVA), ReUse Technology, Inc. (ReUse), and Mineral Solutions, Inc. (MSI). TVA replied that they could provide spent material from its atmospheric fluid bed combustor at the Shawnee Fossil Plant for waste stabilization. ReUse replied that it would be interested in supplying various by-products for the field test at MSYP, including (1) FBC ash, (2) spray dryer FBC ash separated from fly ash and bottom ash, (3) spray dryer FBC ash combined with stoker fly ash and bottom ash, (4) spray dryer FBC ash combined with stoker fly ash only, and (5) spray dryer FBC ash combined with PC fly ash. MSI offered to provide samples of materials from two sources in Pennsylvania and a plant in Minnesota. The two plants in Pennsylvania are both circulating fluidized bed units, one combusting anthracite culm and the other bituminous coal waste. The plant in Minnesota combusts western coal and has a dry scrubber.

The search for by-product samples was suspended when, again, work on the silo's foundation was interrupted later in Summer 2001, this time for two reasons. The first was the fact that the silo's pad abutted the foundation of a new building also being constructed. The footers for that building had to be poured before the silo's pad could be poured. The second reason was the regulatory need for MSYP to submit an application for renewal of its Hazardous Waste Permit. The application was submitted in September 2001. The first round of comments took place in December 2001.

It was not until April 2002 that MSYP stated that it would resume construction, using its

own summer construction crew, rather than an outside company. That month the PI resumed contacting by-product suppliers to obtain samples for MSYP to use in conducting treatability studies with soils contaminated with hexavalent chrome that were expected to be sent to MSYP for treatment during the coming year. MSI arranged for the circulating fluidized bed combustor, feeding bituminous coal waste, to send several 5-gallon samples of its spent bed material to MSYP. This material would be the most likely for commercial use at MSYP, as it is relatively close to Yukon. ReUse arranged for several 5-gallon samples of by-products from three units in Virginia and North Carolina. These materials would be less likely to be of commercial interest at MSYP, but ReUse was particularly interested in gaining experience in waste stabilization with a wider range of by-products than it currently had tested before.

In late June 2002 MSYP began to assemble their summer construction crew, but experienced great difficulty in finding employable workers. Once the crew was assembled, their first task was closure of a 7-acre cell. This task required much of the summer. When the renewal of the Hazardous Waste Permit, that had been applied for in September 2001, still had not arrived by the end of the 2002 construction season, MSYP deferred the construction of the silo's pad until Spring 2003, assuring the project team that it could complete the field test by September 30, 2003.

However, by late Spring 2003 it became clear that other work at MSYP continued to have higher priority than the field test. So, considering all of the delays and with no end in sight, the project was terminated on June 30, 2003.

3.0 LABORATORY STUDIES

The topical report, reproduced in Appendix A, provided the results and conclusions of laboratory studies conducted during the first year and three months of the project (September 30, 1994 – December 30, 1995). Laboratory studies continued through the next three years (1996, 1997 and 1998) while field work was being developed. This chapter provides the details of those laboratory studies. The article in the October 1999 issue of the *Journal of the Air & Waste Management Association*, reproduced in Appendix B, provides a summary and analysis of all of the laboratory studies during the first four years and three months of the project (September 30, 1994 – December 30, 1998).

3.1 Analyses for Metals, including Arsenic, Selenium and Mercury

At the close of 1995, the final analyses by atomic absorption spectroscopy for arsenic, selenium and mercury had not been completed for the ASTM and TCLP extracts of by-products, nor had the final analyses of all metals for the ASTM and TCLP extracts of by-product/waste mixtures. Those analyses were performed in early 1996.

3.1.1 By-Product Analyses

Analysis of all ASTM extracts of the by-products was completed with measurement of the concentrations of the following three metals: As, Se and Hg. In addition, the TCLP extracts of all the by-products were analyzed for As and Se. It should be noted that As was analyzed by USEPA SW-846 Method 7060A (Atomic Absorption, Furnace Technique) instead of Method 7061 (Atomic Absorption, Gaseous Hydride) as previously stated in the Phase 1 Test Plan. In addition, Se was analyzed by USEPA SW-846 Method 7740 (Atomic Absorption, Furnace Technique) instead of Method 7741 (Atomic Absorption, Gaseous Hydride) as previously stated in the Phase 1 Test Plan. A summary of the metals analysis completed on ASTM and TCLP extracts of the by-products is given in Tables 1 and 2, respectively.

All metals concentrations of the ASTM and TCLP by-product extracts were found to be below the current BDAT standards. In addition, all metals concentrations of the ASTM and TCLP by-product extracts were found to be below the potential future standards except for the Se concentration of the TCLP extracts of EPC #4 and 5, which exceeded the potential future standard of 0.16 mg/L.

TABLE 1: METAL ANALYSIS OF ASTM EXTRACTS OF BY-PRODUCTS^

Metal	CONSOL #1	CONSOL # 5	CONSOL #7	Tidd #2	Tidd #8	Tidd #10	EPC #2	EPC #3	EPC #4	EPC #5	Thames River #2	Thames River #4
As	<0.01	<0.01	<0.01	0.020	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.012
Hg	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
Se	<0.01	<0.01	<0.01	0.011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

^ All concentrations are in units of mg/L

TABLE 2: METAL ANALYSIS OF TCLP EXTRACTS OF BY-PRODUCTS^

Metal	Current BDAT Standard	Potential Future Standard	CONSOL #5	CONSOL #7	Tidd #8	Tidd #10	EPC #2	EPC #4	EPC #5	Thames River #2	Thames River #7
As	5.0	5.0	0.046	<0.01	0.019	<0.01	0.165	0.134	0.158	0.015	<0.01
Se	1.0	0.16	0.016	0.013	<0.01	<0.01	0.078	0.254	0.201	0.025	0.025

^ All concentrations are in units of mg/L

3.1.2 Analyses of By-Product/Waste Mixtures

Analysis of all ASTM extracts of immediately successful by-product/waste mixtures was completed with measurement of the concentrations of the following eight metals: As, Be, Cu, Hg, Se, Sb, Tl and V. In addition, the TCLP extracts of immediately successful by-product/waste mixtures were analyzed for the following seven metals: As, Be, Cu, Se, Sb, Tl and V. A summary of the metals analysis completed on 24-hour ASTM and 90-day TCLP extracts of the immediately successful treated wastes is given in Tables 3 and 4, respectively.

TABLE 3: METAL ANALYSIS OF 24-HOUR ASTM EXTRACTS OF BY-PRODUCT/WASTE MIXTURES[^]

Metal	CONSOL/ Battery Sludge	CONSOL /Muni- tions Soil	Tidd/ Battery Sludge	Tidd/ Indust- rial Soil	Tidd/ Muni- tions Soil	Tidd/ WWTP Soil	EPC/ Muni- tions Soil	EPC/ WWTP Soil
As	<0.01	<0.01	<0.01	0.012	0.012	0.012	<0.01	<0.01
Be	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	<0.05	0.06	<0.05	<0.05	0.06	<0.05	<0.05	<0.05
Hg	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
Sb	<0.020	<0.020	0.101	0.056	<0.020	<0.020	<0.020	<0.020
Se	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	<0.010	<0.010	<0.010	<0.010	0.021	0.017	0.016	0.024

[^] All concentrations are in units of mg/L

All metals concentrations of the ASTM and TCLP extracts of the by-product/waste mixtures were found to be below both the current BDAT standards and the potential future standards (where applicable).

TABLE 4: METAL ANALYSIS OF 90-DAY TCLP EXTRACTS OF BY-PRODUCT/WASTE MIXTURES[^]

Metal	Current BDAT Standard	Potential Future Standard	CONSOL/ Battery Sludge	CONSOL/ Munitions Soil	Tidd/ Battery Sludge	Tidd/ Industrial Soil	Tidd/ Munitions Soil	Tidd/ WWTP Soil	EPC/ Munitions Soil	EPC/ WWTP Soil
As	5.0	5.0	0.012	0.041	<0.01	<0.01	<0.01	<0.01	0.069	0.124
Be	---	0.014	<0.001	0.0040	<0.001	<0.001	<0.001	<0.001	0.0025	0.0027
Cu	---	---	0.08	0.97	<0.05	0.13	0.09	<0.05	0.82	0.09
Sb	---	2.1	0.242	0.024	0.107	0.238	0.026	<0.020	<0.020	<0.020
Se	5.7	0.16	0.028	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tl	---	0.078	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
V	---	0.23	0.074	0.101	0.011	<0.010	0.013	<0.010	0.019	0.032

[^] All concentrations are in units of mg/L

For those treatments that did not prove immediately successful, the 28 and 90-day TCLP extracts were analyzed for the same seven metals as mentioned above. A summary of the metals analysis completed on the TCLP extracts of the by-product/waste mixtures prepared by the Proctor method is given in Tables 5 and 6.

TABLE 5: METAL ANALYSIS OF 28-DAY TCLP EXTRACTS OF BY-PRODUCT/WASTE MIXTURES PREPARED BY THE PROCTOR METHOD[^]

Metal	Current BDAT Standard	Potential Future Standard	CONSOL/ Industrial Soil	Tidd/ Munitions Soil	EPC/ WWTP Soil
As	5.0	5.0	0.030	<0.01	0.071
Be	---	0.014	0.0114	<0.001	0.0029
Cu	---	---	0.52	0.14	0.20
Sb	---	2.1	<0.020	0.102	<0.020
Se	5.7	0.16	<0.01	<0.01	<0.01
Tl	---	0.078	<0.005	<0.005	<0.005
V	---	0.23	0.097	<0.010	0.020

[^] All concentrations are in units of mg/L

All metals concentrations of the ASTM and TCLP extracts of the by-product/waste mixtures prepared by the Proctor method were found to be below both the current BDAT standards and the potential future standards (where applicable).

3.1.3 Mercury Analyses

A number of samples were analyzed in order to determine the concentration of mercury present. These samples included TCLP extracts of a number of by-product samples and treated wastes. The method used to analyze for mercury was based on EPA SW-846 Method 7470A - Mercury in Liquid Waste (Manual Cold-Vapor Technique). The method stated in the test plan was Method 7470. Method 7470A is simply a more recent revision of Method 7470. Method 7470A was modified to use a Varian VGA-76 Vapor Generation Accessory in place of the cold-vapor generator described in the procedure. This modification was used in order to simplify the analysis.

The results of the mercury analysis performed on the by-product samples and the treated wastes is shown in Table 7. All of the samples analyzed were below the current standard of 200 : g/L, as well as the UTS level of 25 : g/L.

TABLE 6: METAL ANALYSIS OF 90-DAY TCLP EXTRACTS OF BY-PRODUCT/WASTE MIXTURES PREPARED BY THE PROCTOR METHOD[^]

Metal	Current BDAT Standard	Potential Future Standard	CONSOL/ Industrial Soil	Tidd/ Munitions Soil	EPC/ WWTP Soil
As	5.0	5.0	0.013	<0.01	<0.01
Be	---	0.014	0.0072	<0.001	<0.001
Cu	---	---	4.32	0.07	0.06
Sb	---	2.1	0.101	<0.020	<0.020
Se	5.7	0.16	<0.01	<0.01	0.021
Tl	---	0.078	<0.005	<0.005	<0.005
V	---	0.23	0.045	<0.010	0.014

[^] All concentrations are in units of mg/L

3.2 Analysis and Treatment of an Additional Waste

In the spring of 1996 MSYP received a sandblast waste for evaluation.

3.2.1 Waste Analysis

MSYP analyzed many of the total metals in a digestate of the untreated sandblast waste and in a TCLP extract of this waste. Those in the latter that are above minimum detectible levels are as follows: antimony, 0.051 mg/l; copper, 0.28 mg/l; lead, 350 mg/l; zinc, 1.7 mg/l. MSYP also sent the digestate and the extract to Pitt where the final four metals were measured (see Table 8). These results led MSYP to determine that the treated sandblast waste had to be analyzed for the following parameters — As, Ba, Cd, Cr, Pb, Hg and Ni.

In addition to the digestate and extract, an analytical sample of the waste itself was provided to Pitt for XRD and SEM analyses. These analyses are reported in the internal white paper referred to in the next subsection and provided in Appendix H.

3.2.2 Waste Treatment

The sandblast waste was treated at MSYP at laboratory scale with each of the three by-products at dosages of 10, 30 and 50%. The results of metals analyses of TCLP extracts of the treated wastes are shown in Appendix G (Table 2 of the Seventh Quarterly Report) for those metals evaluated by MSYP and in Table 9 for those metals evaluated by Pitt.

TABLE 7: MERCURY CONCENTRATION IN BY-PRODUCTS AND TREATED WASTES

Sample	Mercury Conc. (: g/L)	Sample	Mercury Conc. (: g/L)
CONSOL #5	1.2	Battery Sludge w/ 33% CONSOL	3.1
CONSOL #7	0.8	Battery Sludge w/ 72% Tidd	0.2
Tidd #8	1.0	Munitions Soil w/ 100% Ebensburg	0.6
Tidd #10	0.6	Munitions Soil w/ 50% CONSOL	3.9
Ebensburg #2	1.0	Munitions Soil w/ 50% Tidd	0.8
Ebensburg #4	0.2	Industrial Soil w/ 50% Tidd	1.7
Ebensburg #5	0.8	WWTP Soil w/ 50% Tidd	1.4
Thames River #2	0.8	WWTP Soil w/ 50% Ebensburg	0.6
Thames River #7	0.4	Munitions Soil w/ 50% Tidd (28-Days, Proctor Method)	0.8
WWTP Soil w/ 50% Ebensburg (28-Days, Proctor Method)	1.0	Munitions Soil w/ 50% Tidd (90-Days, Proctor Method)	0.4
WWTP Soil w/ 50% Ebensburg (90-Days, Proctor Method)	0.2	Industrial Soil w/ 100% CONSOL (28-Days, Proctor Method)	11.4

TABLE 8: METALS ANALYSIS OF SANDBLAST WASTE

Parameter	Total Metals (mg/kg)	TCLP (mg/L)
Antimony	5.1	0.0051
Beryllium	<0.089	<0.001
Thallium	<0.045	<0.005
Vanadium	1.29	<0.01

TABLE 9: METALS ANALYSIS OF SANDBLAST WASTE/BY-PRODUCT COMBINATIONS

Immediate TCLP

By-Product	Consol			Tidd			EPC		
Dosage	10%	30%	50%	10%	30%	50%	10%	30%	50%
Antimony (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.023	<0.02	0.028
Beryllium (mg/L)	<0.001	0.0033	0.0042	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium (mg/L)	0.033	0.100	0.134	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

24 Hour TCLP

By-Product	Consol			Tidd			EPC		
Dosage	10%	30%	50%	10%	30%	50%	10%	30%	50%
Antimony (mg/L)	<0.02	<0.02	<0.02	0.03	<0.02	<0.02	0.027	<0.02	<0.02
Beryllium (mg/L)	<0.001	0.0029	0.0039	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium (mg/L)	0.029	0.099	0.119	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Immediate ASTM extraction for heavy metals leachability were performed on the two treated sandblast residue samples according to ASTM D 3987-85 - “Test Method for Shake Extraction of Solid Waste with Water.” The results of the ASTM analyses of all 15 metals are presented in an internal white paper entitled “Treatment of Sandblast Waste With By-Products From Clean Coal Technologies.” A copy of this paper can be found in Appendix H.

In addition to the immediate ASTM metals analyses, TCLP lead analyses were performed on the two treated sandblast residue mixtures after curing for a period of 28 days each. Table 10 gives the resulting TCLP lead concentrations of these two treatments in milligrams of contaminant per liter of leachant.

TABLE 10: TCLP LEAD CONCENTRATIONS OF TREATED SANDBLAST RESIDUE

Sample Identification	Curing Time (days)	TCLP Pb Concentration (mg/L)
Sandblast Residue w/30% CONSOL	28	0.24
Sandblast Residue w/50% Tidd	28	67.80

Table 10 shows that the long term stabilization of the sandblast residue treated with 30% CONSOL was successful in decreasing the leachable lead concentration to well below the current BDAT standard of 5 mg/L. The long term stabilization of the sandblast residue treated with 50% Tidd, however, was not successful as the leachable lead concentration after 28 days was well above the current BDAT standard.

3.2.3 Solidification Testing

Based upon the analytical results just presented, MSYP recommended that solidification testing of treated sandblast residue be conducted with two by-products. Here is their specific analysis:

CONSOL. All of the tests performed with the CONSOL by-product generated a non-hazardous waste that met the current LDR treatment standards and the 30% and 50% dosages achieved the UTS levels. It was suggested that Pitt perform a solidification test at the 30% dosage.

Ebensburg. None of the tests performed with the EPC by-product were successful. TCLP-lead levels exceeded the current LDR treatment standards and the UTS levels at all dosages. No solidification tests were recommended.

Tidd. The test performed with 50% Tidd by-product was the only test that was successful in generating a non-hazardous waste and one that met the current LDR treatment standards. None of the tests achieved the UTS levels. It was suggested that Pitt perform a solidification test at the 50% dosage.

In the summer of 1996, solidification tests were conducted for successful treatments of the sandblast residue. There were two treated waste mixtures which demonstrated immediate stabilization, the sandblast residue w/30% spray drier residue (CONSOL) and the sandblast residue w/50% PFBC residue (Tidd). For these two mixtures, a water-containing blend having a 1-2" slump was prepared out at the Yukon plant of MSYP. Each of these mixtures was prepared by placing a measured weight of by-product into a 32"x21"x9" plastic mortar box. A measured weight of sandblast residue was then added to the mortar box and the mixture blended with a

cement hoe until well mixed. A measured volume of water was then added to the mixture and blended until thoroughly mixed. The slump of the mixture was tested as per the requirements of ASTM C 143-90a - "Test Method for Slump of Hydraulic Cement Concrete." Once the desired slump was obtained, the mixture was compacted into 3"x 6" cardboard cylinders as per ASTM C 192-90a - "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory." The cylinders were then covered with plastic in order to prevent moisture loss and allowed to set up for 24 hours. Following the setup period, the samples were transported back the university campus, the molds were stripped off, and the specimens placed in an environmentally controlled room with a relative humidity of 100%. A summary of the treatments prepared for solidification testing during the quarter using this methodology is given in Table 11.

TABLE 11: TREATMENT OF THE SANDBLAST RESIDUE FOR SOLIDIFICATION TESTING

Sample Identification	Weight of By-Product (lbs)	Weight of Waste (lbs)	Volume of Water (L)	Slump (inches)
Sandblast Waste w/30% CONSOL	20	60	8.5	1.75
Sandblast Waste w/50% Tidd	22	44	5.0	1.5

Following specified curing times of 3, 7, 14, and 28 days, the compressive strength of the treated sandblast residue mixtures was evaluated according to ASTM C 39-86 - "Test Method for Compressive Strength of Cylindrical Concrete Specimens." The sandblast residue w/30% CONSOL did not undergo solidification sufficient enough to conduct compressive strength tests. A summary of the solidification tests performed on the treated sandblast residue w/50% Tidd is given in Table 12.

TABLE 12: COMPRESSIVE STRENGTH OF THE SANDBLAST RESIDUE TREATED WITH 50% TIDD

Curing Time (days)	Compressive Strength (psi)
3	Not Solidified
7	13
14	18
28	20

3.3 Long-term Stability and Leachability of Treated Waste Mixtures

Also during the summer of 1996, long term solidification tests and TCLP lead analyses were performed on ten different treated waste mixtures. A summary of the results of these long term evaluations is given in Table 13.

A comparison of the one-year TCLP with the immediate and 90-day TCLPs is shown in Table 14. It can be seen that in general the stability of the residues treated with CONSOL and Tidd by-products degrades from 90 days to one year, while those treated with EPC by-product are more stable at one year than at 90 days. It should be recalled that the immediate TCLP was determined for small samples treated at MSYP, while the 90-day and one-year TCLPs were performed on fragments of cylinders produced for solidification tests. Thus, it may not be completely valid to compare the immediate TCLP with the other two.

TABLE 13: LONG TERM EVALUATIONS OF SOLIDIFIED WASTES

Sample Identification	Curing Time (days)	Compressive Strength (psi)	TCLP Lead Concentration (mg/L)
CONSOL/Battery Manufacturing Sludge	419	40	3.56
Ebensburg/Munitions Depot Soil	419	165	0.49
Tidd/Industrial Soil	405	312	20.48
CONSOL/Munitions Depot Soil	399	27	1.07
Tidd/Battery Manufacturing Sludge	399	190	4.16
Tidd/Munitions Depot Soil	370	133	1.74
Tidd/WWTP Soil	335	472	1.12
Ebensburg/WWTP Soil	335	120	0.65
Tidd/Munitions Depot Soil Proctor	348	186	3.64
Ebensburg/WWTP Soil Proctor	327	39	0.53

TABLE 14: TCLP HISTORY OF SOLIDIFIED WASTES (CONCENTRATIONS IN MG/L)

Sample Identification	TCLP Lead Immediate	TCLP Lead 90-Day	TCLP Lead One-Year
CONSOL/Battery Manufacturing Sludge	0.2	<0.5	3.6
Ebensburg/Munitions Depot Soil	5.0	9.0	0.5
Tidd/Industrial Soil	1.7	14.0	20.5
CONSOL/Munitions Depot Soil	0.3	0.9	1.1
Tidd/Battery Manufacturing Sludge	4.6	0.7	4.2
Tidd/Munitions Depot Soil	0.8	1.2	1.8
Tidd/WWTP Soil	2.2	0.6	1.1
Ebensburg/WWTP Soil	0.2	6.0	0.7

3.4 Microscopic Evaluation of Treated Sandblast Waste Mixtures

During the summer and fall of 1996 microscopic evaluations were conducted of the treated sandblast waste mixtures after curing times of 1, 3, 7, 14 and 28 days, in addition to the raw materials used, by both x-ray diffraction and scanning electron microscopy. That work was reported in an M.S. thesis by Vourneen Clifford, entitled "The Stabilization of a Hazardous Sandblast Waste with Advanced Clean Coal Technology By-Products." What follows are the sections of her thesis which describe the microscopic evaluations.

Chemistry and Microstructure

Evaluation of chemistry and microstructure was performed on the treated waste mixtures prepared for solidification testing after curing times of 1, 3, 7, 14, and 28 days, as well as on the raw materials. Morphology and elemental composition were evaluated through the use of scanning electron microscopy (SEM), whereas mineralogy was determined through the use of x-ray diffraction (XRD). A detailed description of these two different techniques is provided below.

Scanning Electron Microscopy. SEM was used to create a magnified image of the

sample surface. In this process, a high energy focused beam of electrons, several tens of angstroms in diameter, was used to scan palladium coated samples. Interaction of the beam with the outermost electron shells of the atoms on the surface produced secondary electrons which were collected by a detector and displayed on a cathode ray tube screen, resulting in an image of the surface. Two different scanning electron microscopes, a JEOL 35CF and a Philips XL30 with a field emission source, were used during the course of this investigation. In preparation, all samples were dried in a 60 °C oven, under vacuum, for two hours prior to examination under the SEM. All dried samples were transported and stored in a desiccator. For examination under the JEOL 35CF SEM, all specimens were mounted to sample stubs using conductive carbon tape. As the Philips XL30 SEM was used to detect light elements such as carbon, conductive silver paint was used instead of carbon tape to secure the specimen to the sample stub in order to avoid any interference from the mounting media. All samples were coated with palladium using a Polaron Equipment Limited SEM Coating Unit E5000. Each sample was coated three times for two minutes at 1.0 kV, in order to prevent the sample from charging while in the microscope. While using both microscopes, the secondary electron mode was used to characterize morphology, while the backscatter electron mode was used to locate the lead metal within the specimen. The JOEL 35CF microscope was used in conjunction with a 4B computer system with a DTSA program for elemental analysis. The Philips XL30 microscope was used in conjunction with an EDAX, both eDXi and eDXAUTOp, analytical system with a super-ultra thin window Si-Li detector for elemental analysis. Use of the aforementioned techniques made it possible to analyze small volumes of samples, approximately as small as 1 (: m)³.

X-Ray Diffraction. XRD was used to identify the crystalline phases present in the samples. In preparation, samples were ground into a fine powder using a mortar and pestle. Approximately 2 grams of each powdered sample was then mounted on a glass cover slide in a square sample holder. Each finely ground sample was rotated while being irradiated with a monochromatic beam of x-rays. Mineralogy was determined by XRD using the powder method in an X'Pert diffractometer system (Philips, Almelo, Holland) using Cu K_α radiation. The system was operated using a tube voltage of 40 kV and a tube current of 30 mA. The different crystalline phases diffracted the beam of x-rays at different angles of rotation (2 θ) and produced strong signals which were recorded digitally as counts per seconds versus the 2 θ angle. A 0.5° beam slit and a 0.3° detector slit were used in scanning 2 θ from 3° to 80° at a rate of 2.4°/min. The peak intensities were directly related to the degree of sample crystallinity and the detection limit for well crystallized phases was of the order of 1-3%. The angles at which peaks occurred were then used with Bragg's law to calculate the spacing between the atomic planes of the different crystalline phases. Diffraction patterns were generated using PC-APD (PW1877) Analytical Powder Diffraction software version 3.6. Peaks in the resulting diffraction patterns were identified using PC-Identify software (PW1876) version 1.0 and comparison to a data base of known atomic plane spacings, the Joint Committee on Powder Diffraction Standards (JCPDS) files, in order to determine the nature of the crystalline phases for mineral identification. The presence of the 3 peaks of strongest intensity of a given phase, as given by the reference pattern for that particular phase, was required for positive phase identification.

Results and Discussion

Appendix I contains a copy of those sections of Ms. Clifford's thesis devoted to the presentation of the results and discussion of the chemistry and microstructure studies.

Conclusions and Recommendations

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.

The results of this study indicate several areas worthy of further investigation. The long-term effectiveness of stabilization and solidification should be evaluated. For this purpose, it is recommended that these same evaluations be conducted after curing times of at least 90 days to gain a better understanding of the long term effects. Long-term evaluations may be particularly promising for the CFBC residue as the immediate leachable lead concentration of the waste treated with this by-product significantly decreased after mellowing for 24 hours. It is also recommended that the chemistry and microstructure of this treated waste mixture be evaluated by SEM and XRD analysis. Long-term evaluations may also be of particular interest for the sandblast waste treated with 50% PFBC residue as the first appearance of crystal growth in this treated waste mixture did not occur until 28 days. At this time, it was too early to determine the exact composition of the crystal formation. Long-term evaluations would give further insight into the chemistry and microstructure of the matured crystals, thus determining their composition and related effect upon stabilization and solidification.

It was hypothesized that the PFBC residue did not enter into pozzolanic hydration reactions as readily as it has the potential to due to the fact that it may have become hydrated during storage and subsequent utilization over the last year. Further studies are necessary between fresh and hydrated by-products to determine the resulting effect on stabilization ability. In addition, further experiments could be performed using additional binders and reagents to the FBC residues in order to improve stabilization ability. The use of additives, such as trisodium phosphate (TSP), which is currently used by the local TSD facility as a treatment chemical, to the sandblast waste treated with the PFBC residue may help bring the leachable concentration of lead to below the current BDAT standard of 5 mg/L.

The total porosity and pore size distribution of a solid affects its physiomechanical properties and permeability characteristics. The correlation between porosity and permeability is dependent upon total porosity, pore size distribution, and the morphology and configuration of the pores. The determination of total porosity and pore size distribution may be used as potential indicators of the physiomechanical properties and leaching potential of stabilized/solidified

wastes.

Finally, the degree of encapsulation is enhanced by the type and energy per unit mass of mixing. Bench-scale laboratory samples are generally well blended with a high energy per unit mass as compared to full-scale batches mixed in the field. This gives rise to a greater degree of encapsulation in the laboratory as a larger number of particles become entrapped. Field studies should be conducted mixing 50 ton commercial-scale batches to ensure the same degree of stabilization as was demonstrated in the laboratory.

3.5 Leachability of Aged Samples of Treated Waste Mixtures

Jana Agostini, the graduate student in the Civil and Environmental Engineering Department, continued this special study for her M.S. project, entitled “An Evaluation of the Long-Term Leaching Characteristics of Metals from Solidified/Stabilized Wastes.” As a portion of her project, she completed a literature of “Stabilization/Solidification Technology” which is provided in Appendix J. Here is the abstract of the final report of her special project.

Current hazardous waste treatment standards are based on the premise that the leaching properties of stabilized/solidified (s/s) wastes do not significantly change with time. However, numerous studies have examined the mineralogical changes which occur in s/s wastes with time. Changes in the mineralogy of the s/s matrix could cause changes in the microstructure, which may influence the leachability of hazardous constituents in the s/s matrix. The objective of this research was to evaluate the long-term leaching characteristics of s/s waste samples (originally prepared during [Phase 1 of this project] at the University of Pittsburgh) by analyzing the available s/s waste samples; and to support such results with a review of the literature in this area. Six s/s waste samples, remaining from [Phase 1], were examined to evaluate changes in the leachability of cadmium, chromium, lead and zinc as a result of aging. In order to measure changes, the six original s/s waste samples were retested using the Toxicity Characteristic Leaching Procedure (TCLP) and the Shake Extraction Test (ASTM D 3987-85) after two years of curing. Cadmium, as measured in the TCLP leachates of the six samples, remained immobilized after two years, as expected based on the literature review. Chromium also remained tightly bound within the s/s matrix after two years, in agreement with previously published results. The leachability of lead from the s/s matrices varied among the six samples after two years of curing. This result is expected based on the noted mechanisms for lead immobilization found in the literature. Similar to lead, the concentration of zinc in the TCLP leachates of the two year old samples varied. The varying results for zinc stabilization may be expected according to the mechanisms described for zinc immobilization presented in the literature. In addition, the shake extraction test leachates contained lesser concentrations of cadmium, chromium, lead and zinc than did the TCLP leachates for each of the six s/s wastes examined. This result is expected since the shake extraction test used a less aggressive extraction fluid

(near neutral pH) than does the TCLP.

Chapters 4-7 and Appendix B of Ms. Agostini's thesis are reproduced in Appendix K.

This ends the laboratory studies of this project.

4.0 PRESENTATIONS

Four presentations of particular note have been made during Phase 2 of this project. They are reproduced in Appendices L through O.

1. On March 25, 1996 the Principal Investigator (PI), James T. Cobb, Jr., presented a paper entitled, "Stabilization of Metal-Laden Hazardous Wastes Using Lime-Containing Ash from Two FBC's and a Spray-Drier" at the 211th American Chemical Society National Meeting and Exposition in New Orleans, Louisiana. Coauthors were R. D. Neufeld, J. Pritts and V. Clifford of the University of Pittsburgh, C. Bender of Mill Service, Inc., and J. Beeghly of Dravo Lime Company. A copy of the preprint of the paper is given in Appendix L.
2. On July 14, 1997 the PI presented a paper entitled, "Preparation of a Commercial Test of the Treatment of Metal-Laden Hazardous Wastes with Clean Coal Technologies By-Products," at the 29th Mid-Atlantic Industrial and Hazardous Waste Conference in Roanoke, VA. Coauthors were R. D. Neufeld, C. F. Bender, J. W. Pritts and B. V. Clifford. The paper published in the proceedings is reproduced in Appendix M.
3. On October 21, 1997 the PI presented a paper entitled "Laboratory Evaluation and Commercial Demonstration of Hazardous Waste Treatment Using Clean Coal Technology By-Products," at the 1997 International Ash Utilization Symposium in Lexington, KY. Coauthors were B. V. Clifford, R. D. Neufeld, J. W. Pritts, J. H. Beeghly and C. F. Bender. The paper is reproduced in Appendix N.
4. On July 22, 1998 the PI made a presentation on "Clean Coal Technology By-Products as Treatment Chemicals for Hazardous Wastes" as part of the session titled By-Product Utilization at FETC's Advanced Coal-Based Power and Environmental Systems '98 Conference at the Morgantown (WV) site. An accompanying paper, coauthored by R. D. Neufeld, the Co-Principal Investigator, was published in the proceedings of the conference. A copy of the paper in the proceedings is provided in Appendix O.

5.0 CONCLUSIONS

5.1 Laboratory Studies of the Stabilization and Solidification of Seven Wastes. A set of conclusions drawn from Phase 1 of this project were provided in the Topical Report that is reproduced in Appendix A. General conclusions from the laboratory studies of Phase 1 and those of Phase 2 that examined the sandblast waste were provided in the article from the *Journal of the Air & Waste Management Association* that is reproduced in Appendix B.

5.2 Long-Term Stabilization. In general the mid-term stability of the residues treated with CONSOL and Tidd by-products degrades from 90 days to one year, while those treated with EPC by-product are more stable at one year than at 90 days. In the long term, both cadmium and chromium, as measured by the TCLP, remained immobilized after two years. However, the leachability of lead and zinc from the solid matrices varied among the samples tested after two years of curing.

5.3 Microscopic Evaluations of Raw and Treated Sandblast Waste. The speciation of the hazardous constituent within the raw sandblast 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.

5.4 Field Work. Satisfying environmental regulations for a demonstration project such as this one, that involves hazardous wastes being treated at a state-regulated RCRA facility during the decade from 1994 to 2003, proved to be an extremely lengthy process. Adding in the effect of Title V of the Clean Air Act of 1990, the temporary imposition of an environmental assessment by USDOE and the reluctance of utilities to commingle CCTBs with hazardous wastes, and the required time became extraordinary. Once the regulations were satisfied, the business situation of the industrial partner of this project had so shifted that the project could not get traction within the total set of projects being conducted by MSYP, leading to its termination before completion.

Having said that, the situation currently faced by commercial projects involving treatment of metal-laden wastes with CCTBs at state-regulated RCRA facilities is much more favorable. Most facilities have met the requirements of Title V. Like MSYP, many have enlarged the scope of their approved treatment chemicals to include materials such as CCTBs, have received permission to modify their facilities to utilize them, and have made those modifications. As evidenced by the recent delivery to MSYP of a number of samples of CCTBs from CCTB brokers, utilities are actively selling CCTBs through brokers for use as treatment chemicals for metal-laden wastes at RCRA facilities. It is certainly easily possible for a utility to sell its CCTBs through existing brokers for use as treatment chemicals for metal-laden wastes,

and for a RCRA facility to add CCTBs to its list of active treatment chemicals. And it should be possible for the use of CCTBs as treatment chemicals at one of the RCRA facilities conducting business in this manner to be documented now in the open literature.

6.0 ACKNOWLEDGMENTS

Many at the University of Pittsburgh participated in this project. Professor Ronald D. Neufeld, Department of Civil and Environmental Engineering, served as co-principal investigator. He guided the students in the laboratory work. Three graduate students – Jesse Pritts, Vourneen Clifford and Jana Agostini – and one undergraduate student – Sarah Spencer – performed the laboratory analyses. All contributed significant portions of the written material contained in this report. Jesse Pritts was the key preparer of the article in the *Journal of the Air & Waste Management Association*.

At MSYP Carl Bender guided the laboratory work there during Phase 1, and Henry Springer led the permitting efforts and supervised the equipment preparation that was accomplished.

At Dravo Lime Company Joel Beeghly supervised the analytical work conducted there during Phase 1 and assisted in collecting samples of CCTBs for the project. The project concept was formulated at a meeting in Manny Babu's office in late June 1993, attended by Mr. Beeghly, Mr. Babu and Dr. Cobb.

Three staff members of USDOE served as COR for the project – Steven Bossart, Scott Renninger and Peter Botros.

APPENDIX A

TOPICAL REPORT OF PHASE 1

TREATMENT OF METAL-LADEN HAZARDOUS WASTES
WITH
ADVANCED CLEAN COAL TECHNOLOGY BY-PRODUCTS

TOPICAL REPORT

AUGUST 18, 1994 - AUGUST 18, 1995

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DRAFT
March 1, 1996

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For: U. S. Department of Energy
Office of Fossil Energy
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1.0 EXECUTIVE SUMMARY

The project was initiated on August 18, 1994. This report details the activity of the first year of the two-year period for which it is authorized to run.

1.1 OBJECTIVES AND APPROACH OF THE PROJECT

The project's objectives are:

- generally to provide useful information and data on the ability of new sources of chemical treatment materials, in this case by-products from advanced clean coal technologies, to be used by the hazardous waste community.
- commercially to link the producers of by-products with operators of hazardous waste treatment facilities in a mutually profitable manner.
- specifically to evaluate treatment of up to ten characteristic metal-laden hazardous wastes with up to four by-products, first in laboratory-scale (Phase 1) and then in commercial-scale tests (Phase 2).

Limiting treatment to only characteristic metal-laden hazardous waste in the project is an important constraint. This type of hazardous waste may be disposed as a non-hazardous waste when the hazardous characteristics are eliminated by treatment.

During the first year (Phase 1) of the project, samples of four by-products were collected and characterized by Dravo Lime Company (DLC). Samples of six hazardous wastes were collected, analyzed and evaluated for treatment by Mill Service, Inc. (MSI). Samples of the treated wastes were further analyzed at the University of Pittsburgh (Pitt) which is also coordinating the project.

1.2 BACKGROUND SURVEY

Clean coal technology (CCT) by-products are generated when a dry calcium-based sorbent is used to collect sulfur dioxide and sulfur trioxide from coal combustion gases. Specific processes include fluidized bed combustors and dry scrubbers. The by-products are characterized as ash-diluted mixtures of calcium oxide (lime), calcium sulfite or calcium sulfite hemihydrate, and calcium sulfate (anhydrite). The overall calcium content can be identified as calcium carbonate equivalent (CCE). The anhydrite can be rendered unreactive ("dead-burned") if the combustion temperature is high. When the CCT by-products are exposed to water, the leachate will contain small amounts of toxic metals and

a high pH. None of the levels of these contaminants cause the by-products to be considered hazardous. When small amounts of water are added to mixtures of fly ash and CCT by-products, cementitious hydration reactions occur, including the formation of ettringite.

The metal-laden hazardous waste treatment industry has developed to prevent the release of toxic metals from commercial residues. Regulations governing this industry flow from the Resource Conservation and Recovery Act (RCRA) of 1976. Various types of facilities have evolved to receive RCRA wastes, including recovery/recycling facilities, land disposal facilities, and treatment facilities. Treatment facilities in particular receive manifested wastes, store them temporarily, prepare them for treatment, conduct one or more processes to stabilize and/or solidify the wastes, and finally manage the ultimate disposal of the treated wastes. Processes that may be selected to treat metal-laden hazardous wastes include physical/chemical processes, neutralization/precipitation, membrane processes, chemical reduction and oxidation and thermal methods.

1.3 TESTS APPLIED IN PHASE 1

Four CCT by-products were identified for use in the project:

- dry scrubber residue from the Joy Niro Spray Dryer, produced at the Carneys Point Cogeneration Plant
- pressurized fluid bed residue from the Tidd Station of Ohio Power Company
- circulating fluid bed residue from the coal-waste-fired unit of the Ebensburg Power Company
- circulating fluid bed residue from the coal-fired unit of the Thames River Plant.

The last residue was ultimately not allowed to be used for hazardous waste treatment by its owner. Dravo Lime Company (DLC) collected ten samples of each of these four by-products. DLC, MSI and Pitt all analyzed them for the following:

- elemental chemical analysis
- alkalinity and acid neutralization
- physical properties
- reactivity

- total metals
- TCLP leaching
- ASTM leaching

Six metal-laden hazardous wastes were identified by MSI from among those received at its Yukon Plant for inclusion in Phase 1:

- industrial wastewater treatment residue from a battery manufacturing plant
- contaminated soil from a remediation project conducted at a munitions depot
- contaminated soil from a remediation project conducted at an abandoned industrial site
- contaminated soil from a remediation project conducted at a former sewage treatment plant
- air pollution control dust from basic oxygen furnace steel production
- air pollution control ash from municipal waste incineration.

All six of these wastes contained lead as the principal contaminant. The wastes were analyzed for 15 metals. They were also leached by the TCLP method and the leachates analyzed for these 15 metals. They were then treated with the three approved CCT by-products in the laboratory using three by-product:waste dosages. Larger samples of successful treatment pairs were prepared to evaluate the compressive strength and long-term stability of the final mixtures.

A comprehensive quality assurance/quality control program was followed throughout the analytical portion of Phase 1.

1.4 RESULTS FOUND IN PHASE 1

The totals for the geochemical analyses by DLC of twelve by-product samples ranged between 96.1% and 100.3%, which is the normal variation expected. The variation in physical properties and reactivity appears to be relatively small within each set of by-product samples from the same source. Each of the by-products was produced during steady-state periods and exhibits no variation caused by variation in operating conditions. However, significant differences in total CaO content, CCE, sulfides, sulfites and sulfates

are observed among the average values of each of the four by-product sets themselves. The between-set variations are due to the different processes from which the by-products are generated and the different compositions of sorbents and coals utilized. Metals content of TCLP leachates of the four by-products were below regulatory limits.

The six hazardous wastes all exhibited lead concentrations in TCLP extracts above regulatory levels. In addition, between three and thirteen metals were parameters of concern, based upon their concentration in the total metals analyses. Thirteen of the eighteen waste/by-product combinations were effective for treatment of lead to today's regulatory standards, but only five could meet more severe potential future standards. However, for the municipal waste incinerator dust, zinc and cadmium appeared to be mobilized by the CCT by-products. The by-products from the coal-waste-fired circulating fluid bed combustor and the pressurized fluid bed combustor produced acceptable solidification results. However, this has not been the case to date for the spray dryer by-product in this project, an observation that needs much more work to confirm and understand, as it is contrary to the experience of others.

A preliminary economic evaluation of the use of the spray dryer by-product, which provided the best stabilization in Phase 1 tests, showed that a tipping fee of \$2.55 per ton for this by-product at the Yukon Plant of MSI would make it equivalent to current treatment chemicals.

1.5 PLANS FOR PHASE 2

For those by-product/waste combinations giving immediate successful stabilizations as evaluated during the laboratory studies of Phase 1, one commercial batch of waste will be treated at MSI with by-product. Laboratory tests of portions of these batches will be performed at Pitt to evaluate the solidification achieved by each batch.

Additional laboratory tests at Pitt will examine stabilization and solidification from a microscopic viewpoint, using x-ray diffraction and the scanning electron microscope. Long-term stabilization is an important issue. Placement of treated waste, rendered regulatorily non-hazardous, in structural fills is a societally valuable procedure, but a basic question arises, "Can treated waste be placed in the fill in a timely fashion such that both its short-term and long-term stability can be assured?" Work in Phase 2 will begin to address this question.

2.0 INTRODUCTION

2.1 GOALS, PURPOSE AND PARTICIPANTS OF THIS PROJECT

This project is divided into two phases. The general objective of the laboratory studies in Phase 1 and subsequent field studies in Phase 2 of this project is to provide useful information and data on the ability of new sources of chemical treatment materials, solid by-products from advanced Clean Coal Technologies (CCT), to be used by the hazardous waste management community. These studies fall into two categories: 1) characterization of selected critical properties of the solid by-products and 2) observation of their ability to stabilize and solidify characteristic metal-laden solid hazardous wastes. The characterization studies are designed to assess the chemical, mineralogical, physical and engineering properties of dry combustion/desulfurization by-products. To the extent possible within the limited number of by-product samples collected during this project, how the measured properties are affected by the type of process utilized and how specific operating conditions within the various processes affect the measured properties of the by-products will be examined. The stabilization and solidification studies are designed to assess the ability of these by-products to immobilize the metals present in the wastes and to assess the compressive strength of the resulting non-hazardous products.

A more commercial objective of the project is to link the producers of by-product with operators of hazardous waste treatment facilities in a mutually profitable manner. From the treatment facility operators' side, new sources of treatment material, which can stabilize and solidify their feed wastes, will be added to their material source list. From the producers' side of the equation, new uses for by-products of their advanced coal combustors and desulfurizers will be developed and demonstrated. These producers have implemented various emission control technologies at their coal-fired (and coal-waste-fired) electric power plants and are studying a number of others. The technologies currently in use generate significant amounts of by-products with limited commercial value. Consequently, a majority of the by-products have to be disposed as solid wastes. In particular, companies employing wet scrubber technologies for the desulfurization of flue gases have found few alternatives to disposal for the sludges generated in the processes due to the excess moisture present in the by-product. The development of dry desulfurization technologies offers more promise that the process by-products may have beneficial commercial application, such as that to be studied in this project. An economic analysis is included in both phases to assess the commercial viability of treating metal-laden hazardous waste with solid CCT by-products.

The successful outcome of this research, development and demonstration project offers many benefits. Operators of U.S. coal powered electric plants, who generate about 70,650 kilotons of ash per year [Conner, 1990], would benefit greatly if new utilization of some of the massive amounts of fly ash from these coal-fired plants as reagents could be

defined, as it would reduce the quantity and cost of landfilling these residues as wastes. People in the business of remediation of hazardous wastes could also benefit by seeing how coal fly ash chemistries work to reduce the leachability or mobilities of heavy metals such as lead without resorting to "reagent dilution" to achieve meaningful results. A company involved in waste treatment might also be interested in learning what the differences between general classes of coal fly ash are when it comes to toxic control and waste strength properties after treatment. Coal fly ashes are widely available and if it can be demonstrated that the utilization of CCT by-products can result in successful technical results that are cost effective, then the producers of by-products could be linked with the operators of hazardous waste treatment facilities in a mutually beneficial manner, thus meeting the objectives of this project. [Baldwin, 1993]

Participating with the University of Pittsburgh (Pitt) on this project are Dravo Lime Company (DLC), Mill Service, Inc. (MSI) and the Center for Hazardous Materials Research (CHMR).

2.2 CLEAN COAL TECHNOLOGY BY-PRODUCTS

The 1990 amendments to the Clean Air Act have spurred the development of Clean Coal Technologies, such as fluidized bed combustors and spray dry scrubbers, to reduce atmospheric SO_x and NO_x emissions from coal-fired power plants. In CCT processes, a calcium-based sorbent (usually quick lime, limestone or dolomite) is injected directly into a furnace, ductwork, precipitator, or scrubber vessel which produces a dry, solid by-product material. This by-product material consists of excess sorbent, reaction products containing sulfates and sulfites, and coal fly ash. Presently, most of the dry combustion/desulfurization by-product materials are treated as solid wastes and must be landfilled. It is, therefore, highly desirable to find beneficial reuses for these materials provided the environmental impacts are minimal and socially acceptable. In order to explore the feasibility of the utilization of CCT by-products for the treatment of metal-laden hazardous wastes, the processes from which the by-products are produced, as well as their resulting chemical, mineralogical, physical, and leaching properties, need to be examined so as to enable decisions regarding their interactions with toxic metals.

2.3 CHARACTERISTIC METAL-LADEN HAZARDOUS WASTES

The project focuses on characteristic metal-laden hazardous wastes. Federal regulations and many state regulations require generators of solid wastes to determine if the wastes they produce are hazardous. The determination process often requires the generators to analyze the wastes, or leachates produced when the wastes are mixed with an extraction fluid, and compare the results of that analysis to a published list that defines which parameters are of concern and the extract concentrations at which a waste

containing those parameters is considered hazardous. Wastes that contain extract constituents on the list at concentrations that equal or exceed the published concentrations are considered to be characteristically hazardous (unless they are specifically excluded) and said to exhibit the toxicity characteristic. Among the parameters included on the toxicity characteristic list published in the Federal Regulations¹ are eight metals. These metals, and the concentrations at which a waste extract containing them is considered hazardous, are:

Metal Parameter	Hazardous Concentration (mg/l)
Arsenic (As)	5.0
Barium (Ba)	100.0
Cadmium (Cd)	1.0
Chromium (Cr)	5.0
Lead (Pb)	5.0
Mercury (Hg)	0.2
Selenium (Se)	1.0
Silver (Ag)	5.0

Once a waste is determined to be hazardous, generators are restricted from disposing that waste anywhere in the United States. Prior to disposal, the waste must be treated to an extent equivalent to that which can be achieved by the technology the United States Environmental Protection Agency (USEPA) has determined is demonstrated to be the best and is available to the generator.² This technology is known as the "Best Demonstrated Available Technology" or BDAT. The purpose of the treatment prior to disposal is to reduce the likelihood of migration of hazardous waste constituents from the waste. Wastes that are treated to meet the established standards can then be disposed.

For wastes that exhibit the metal toxicity characteristics, the USEPA has established the BDAT treatment standards as follows³:

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¹ See 40 CFR 261.24.

² The USEPA does not mandate the use of a specific technology, except in certain situations. Rather, the USEPA establishes treatment limits based on the use of the best technology in treating the waste, then allows generators to use any technology they choose, other than impermissible dilution, to achieve the limits.

³ See 40 CFR 268.

Metal Parameter	BDAT Treatment Standard (mg/l) ⁴
Arsenic (As)	5.0
Barium (Ba)	100.0
Cadmium (Cd)	1.0
Chromium (Cr)	5.0
Lead (Pb)	5.0
Mercury (Hg) ⁵	0.20
Selenium (Se)	5.7
Silver (Ag)	5.0

As is apparent, all of the treatment standards (except the standard established for selenium) mimic the concentrations at which the waste is considered to exhibit the toxicity characteristic. Consequently, by treating a waste that exhibits a metal toxicity characteristic to meet the treatment standard (other than selenium), *the waste is no longer considered to exhibit that characteristic and can be disposed as a non-hazardous waste* (unless state law requires otherwise). In the case of selenium, a waste treated to meet the treatment standard may still require disposal as a hazardous waste if the concentration in the treatment residue equals or exceeds the toxicity characteristic level.

In a recent rulemaking⁶, the USEPA expanded the list of BDAT constituents to include several additional metals and established treatment standards for those parameters. Although hazardous wastes that contain these constituents, known as underlying constituents, at concentrations above the treatment standards are not considered hazardous due to their presence, certain treated hazardous wastes must meet the treatment standards for the underlying constituents in addition to the treatment standards for the hazardous constituents of concern before they can be land disposed. Wastes that exhibit the metal toxicity characteristics are currently exempt from this requirement. However, a modification of this rule in the future is anticipated and will likely expand the scope of coverage to these wastes. The new parameters and treatment standards are as follows:

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⁴ The concentrations presented are for the metals present in nonwastewaters, that is, wastes that do not contain less than 1% (by weight) total suspended solids or less than 1% (by weight) total organic carbon. The same metals present in wastewaters or in wastes considered hazardous for other reasons, such as listed wastes, may be subject to different treatment standards.

⁵ The mercury treatment standard applies only to wastes that contain less than 260 mg/kg mercury. Wastes that contain higher mercury concentrations are subject to a different treatment standard.

⁶ This rulemaking was published in the Federal Register on September 19, 1994 and was codified within 40 CFR 268.

Underlying Constituent	BDAT Treatment Standard (mg/l) ⁷
Antimony (Sb)	2.1
Beryllium (Be)	0.014
Nickel (Ni)	5.1
Thallium (Tl)	0.078
Vanadium (V)	0.23
Zinc (Zn)	5.3

In the same rulemaking, the USEPA established a uniform set of treatment standards, known as the Universal Treatment Standards, for the eight metals mentioned previously (As, Ba, Cd, etc.) when these metals are present in wastes other than those that are considered to be metal toxicity characteristic wastes. These treatment standards are as follows:

Metal Parameter	Universal Treatment Standard (mg/l) ⁸
Arsenic (As)	5.0
Barium (Ba)	7.6
Cadmium (Cd)	0.19
Chromium (Cr)	0.86
Lead (Pb)	0.37
Mercury (Hg) - Retort Residues	0.20
Mercury (Hg) - Not Retort Residues	0.025
Selenium (Se)	0.16
Silver (Ag)	0.30

A comparison of the uniform treatment standards and the BDAT standards for the metal toxicity characteristic wastes reveals that the uniform standards generally require treatment to lower concentrations before a waste can be land disposed. Although the uniform treatment standards are not currently applicable to the wastes to be stabilized in this project, future rulemaking by the USEPA will likely make these standards applicable to all wastes in which event they would replace the current standards.

2.4 TREATMENT OF METAL-LADEN HAZARDOUS WASTES

As previously stated, the objective of this project is to examine the treatment of metal-laden hazardous wastes with advanced Clean Coal Technology by-products. The

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⁷ See Footnote 4.

⁸ See Footnote 4.

U.S. EPA has defined treatment as "any method of modifying the chemical, biological, and/or physical character or composition of a waste." [Conner, 1990] In the case of this project, the metal-laden wastes were treated by stabilization/solidification processes. Stabilization/Solidification is a treatment technology used to reduce the surface area over which contaminants can transfer or leach, limit the solubility of the contaminant within a waste and improve the physical characteristics of hazardous waste. Stabilization refers to those techniques that reduce the hazard potential of a waste by converting the contaminants into their least soluble, mobile or toxic form. Solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. Solidification does not necessarily involve a chemical interaction between the wastes and the solidifying reagents, but may mechanically bind the waste into the monolith. Contaminant migration is restricted by vastly decreasing the surface area exposed to leaching and/or by isolating the wastes within an impervious capsule. [Conner, 1990] Thus the goal of stabilization/solidification is to prevent or minimize the release of a contaminant into the environment by decreasing surface area, limiting mobility of the contaminant when exposed to leaching fluids, chemically transforming or bonding the contaminant into a nontoxic form, producing a solid or improving handling characteristics. [Gilliam & Wiles, 1992] The effectiveness of stabilization/solidification as a treatment process is typically evaluated by the results obtained with the Toxicity Characteristic Leaching Procedure (TCLP). [Rinehard, 1993]

Stabilization is the process by which a waste is converted to a chemically and physically more stable material suitable for long term land disposal. Stabilization may include chemical reactions that produce products that are less volatile, soluble and reactive. Solidification by chemical or physical means can be a means of stabilization. The major stabilization processes are chemical fixation and physical fixation (solidification with Portland cement or silicate materials, sorption to a solid matrix material and surface encapsulation) of waste. The stabilization process serves to minimize leaching by isolating the waste from the environment, especially groundwater, so that it has the least possible tendency to migrate. This is accomplished by physically isolating the waste, reducing its solubility and decreasing its surface area.[Manahan, 1990]

Chemical fixation is a process that binds a hazardous waste substance in a less mobile, less toxic form by a chemical reaction that alters the waste chemically. Polymeric inorganic silicates containing calcium, and often some aluminum, are the inorganic materials most widely used as a fixation matrix. Many kinds of heavy metals are chemically bound in such a matrix, as well as being held by it physically. [Manahan, 1990]

Solidification may involve a chemical reaction between the waste and the solidification agent, mechanical isolation in a protective binding matrix or a combination of chemical and physical processes. It can be accomplished by sorption onto solid material, reaction with cement or silicates and encapsulation. Solidification of sludges is often accomplished by the addition of a substance that absorbs water and produces a

solid. For many wastes Portland cement is effective for this purpose. Pozzolanic material consisting of hygroscopic silicates, such as those produced in fly ash, is an effective drying agent for solidification processes. [Manahan, 1990]

Encapsulation, as the name implies, is used to coat wastes with an impervious material so that they do not contact their surroundings. Microencapsulation refers to the coating of individual small particles with an impervious material, whereas imbedding larger aggregates of material in such a matrix is referred to as macroencapsulation. [Manahan, 1990]

The stabilization/solidification process involves the addition of a chemical and/or binder and supplemental water to the waste. Examples of the binders commonly used in stabilization/solidification treatment include Portland cement, lime, fly ash, kiln dust or various combinations of these. Lime is the most common alkali used in stabilization/solidification technology, other than lime-containing cements and pozzolans. Lime products may either be calcium or dolomite. Both quicklime (anhydrous) and hydrated lime are used in the stabilization/solidification process, however, the hydrated form is more common as it is easier and safer to store and handle. Hydration reaction products formed during curing are the basis for the improved physical characteristics and controlling the leaching of contaminants from the waste. Water may need to be added to the mixture if there is inadequate moisture in the waste to meet an acceptable water to binder ratio. The water to binder ratio is significant in the development of the physical properties of the cured solidified waste as insufficient water will prevent complete hydration while excess water will reduce the physical strength of the treated waste.

The effectiveness of stabilization/solidification for permanent treatment of hazardous wastes depends on the relation of the waste to the binder. There are two extreme possibilities: 1) chemical entrapment, when the wastes react with the binder to form new, stable phases or 2) physical entrapment, when the chemical species remain unchanged and the waste is protected from percolating by a coating of the binder. If the waste is chemically entrapped in new phases, then the stability of these phases in different environments must be known in order to predict their long-term behavior. The formation of metastable species may lead to phase changes in the long term, which may make more waste elements available for leaching after long curing times. In contrast, if the entrapment is physical, the distribution of the waste and the degree of encapsulation will control leaching. Both mechanisms are expected to operate, but to different degrees in a particular stabilization/solidification process.

2.5 ROLE OF PARTICIPANTS

DRAVO LIME COMPANY

The primary mission of the Dravo Lime Company's Research Center is to develop and commercialize processes for flue gas treatment. They routinely analyze FGD by-product materials for their own research demands as well as providing service to their many lime and limestone FGD scrubber customers. Their range of analytical capabilities spans a broad continuum, extending from the simplicity of classical wet chemistry to the sophistication of state-of-the-art instrumentation and the capability of performing x-ray fluorescence. For the purposes of this project, DLC was responsible for the collection and chemical and physical characterization (except for the analysis of leachate metals concentrations) of the CCT by-products.

MILL SERVICE, INC.

The Yukon Plant of Mill Service, Inc. is an industrial waste treatment, storage and disposal (TSD) facility authorized by permits from the Commonwealth of Pennsylvania, Department of Environmental Protection (PADEP). The facility is authorized to treat and store certain hazardous wastes by Hazardous Waste Permit No. PAD004835146 and is authorized to treat, store and dispose certain non-hazardous wastes by Solid Waste Permit No. 301071. The facility routinely evaluates metal-bearing wastes from remediation projects and industries such as iron and steel manufacturing, glass manufacturing, and metal finishing to determine if the wastes can be treated to below the applicable treatment standards. The hazardous wastes which can currently be handled at the facility from off-site generators are categorized as follows:

- D002 - Corrosive
- D004 - Containing Arsenic
- D005 - Containing Barium
- D006 - Containing Cadmium
- D007 - Containing Chromium
- D008 - Containing Lead
- D010 - Containing Selenium
- D011 - Containing Silver
- K062 - Spent Pickle Liquor Generated from Steel Finishing Operations of Facilities Within the Iron and Steel Industry (SIC Codes 331 and 332)

Characteristic wastes can only be handled following a demonstration that the materials can be adequately treated at the site. These evaluations are conducted in an on-site laboratory that has filed all of the required notifications.⁹ The PADEP is notified of the

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⁹ See 40 CFR 261.4(f) and 25 Pa Code 261.4(d).

metal toxicity characteristic wastes that the laboratory successfully treats and that MSI intends to manage prior to actual management of the waste. The wastes are then accepted for treatment and disposal. All wastes disposed at the Yukon Plant must be non-hazardous and meet several chemical constraints. In order to meet these restrictions, most wastes received at the facility must be treated prior to disposal. The treatment processes employed include neutralization/precipitation, chemical reduction, chemical oxidation and oil removal. Following treatment, the residues from the treatment processes employed at the facility can be disposed on-site as residual (non-hazardous) wastes, or can be disposed off-site if they do not meet the on-site disposal criteria. For the purposes of this project, MSI was responsible for the collection and analysis of the metal-laden hazardous wastes, treatment of the wastes, and analysis of the treated wastes.

THE UNIVERSITY OF PITTSBURGH

This research project is a cooperative effort within the University of Pittsburgh's School of Engineering between the Energy Resources Program and the Department of Civil and Environmental Engineering. Pitt is responsible for the overall coordination of the project, environmental analysis of the CCT by-products and treated wastes, compressive strength testing of treated by-product/waste combinations and evaluation of the overall ability of Clean Coal Technology by-products to successfully treat metal-laden hazardous wastes.

THE CENTER FOR HAZARDOUS MATERIALS RESEARCH

The Center for Hazardous Materials Research (CHMR) has been subcontracted by the University of Pittsburgh to provide the environmental information needed for the U.S. Department of Energy (DOE) to make an environmental review determination pursuant to DOE's Implementing Procedures (10 CFR 1021, subpart B) under the National Environmental Policy Act (NEPA). Information concerning effects on environmental resources in the proposed project area was provided in the form of a DOE Morgantown Energy Technology Center (METC) Environmental Questionnaire and is necessary for DOE to determine the level of NEPA review required for a proposed action, i.e., whether it can be covered under a Categorical Exclusion or would require an Environmental Assessment (EA). It was the intent of CHMR in the development of this report to go beyond the scope of the Environmental Questionnaire, covering environmental resource topics typically addressed in an EA in addition to covering topics included on the questionnaire. This additional environmental review was provided to address any and all potential environmental concerns with the proposed action in order to facilitate DOE's NEPA determination process.

3.0 LITERATURE REVIEW

3.1 CHARACTERIZATION OF CCT BY-PRODUCTS

The 1990 amendments to the Clean Air Act have spurred the development of Clean Coal Technology (CCT) processes, most of which produce a dry, solid by-product material consisting of excess sorbent, reaction products containing sulfates and sulfites, and coal fly ash. Presently, most of the dry combustion/desulfurization by-product materials are treated as solid wastes and must be landfilled. It is, therefore, highly desirable to find beneficial reuses for these materials provided the environmental impacts are minimal and socially acceptable. One potential opportunity for utilization of the mass quantities of CCT by-products that are being produced is the stabilization/solidification of metal-laden hazardous wastes. In order to explore the feasibility of the utilization of dry combustion/desulfurization by-products for the treatment of metal-laden hazardous wastes, the chemical, mineralogical, physical, and leaching properties of the by-products need to be well defined so as to enable further study of their interactions with toxic metals. The objective of this literature review is to characterize these selected critical properties of typical advanced CCT by-products that are representative of the actual by-products that will be used in this research project and to determine those properties which would enable the by-products to successfully treat metal-laden hazardous wastes. A literature review of previous reports of by-product characterization obtained from various clean coal technologies has yielded the resulting representative characterization of the chemical, mineralogical, physical, and leaching properties described in this section and their potential to treat metal-laden hazardous wastes. A survey of descriptions of the types of power plants producing the four by-products used in this study provides insights into the origin of these properties and variations within them. The information presented here will hopefully lead to the eventual identification and commercial application of beneficial uses of advanced Clean Coal Technology by-products.

The Clean Coal Technology (CCT) Program is a cooperative effort, cofunded by government and industry, to demonstrate a new generation of innovative coal processes, which are environmentally cleaner and more efficient than conventional coal-burning processes. [US DOE, 1991] In dry CCT systems, a calcium-based sorbent (usually slaked lime, limestone, or dolomite) is injected directly into a furnace, ductwork, precipitator, or scrubber vessel that produces powdered or granular by-products, as opposed to the slurries associated with traditional wet scrubber systems. The specific composition of a particular type of by-product may vary widely depending upon the CCT process employed, the coal and sorbent composition and the plant operating conditions. Since the chemical, physical and engineering properties of dry CCT by-products are directly related to their mineralogy, it is essential to accurately determine the mineralogical composition of these wastes if safe and economical uses are to be defined. Vast quantities of dry CCT wastes may be produced in the near future and it is important that beneficial uses be developed

to reduce landfill demands. [Fowler, 1992]

In dry sulfur sorption systems the sorbent is injected directly into the furnace, into the ductwork after the furnace at lower temperature, or into a spray dryer vessel. All these processes produce a by-product which is removed in the particulate control equipment. Dry by-products from lime or limestone injected into the high-temperature furnace, such as in FBC systems, have neutralizing, sorptive, and cementitious properties that make them particularly interesting as potential reagents for hazardous waste stabilization because of their high free quicklime (CaO), anhydrous calcium sulfate (CaSO_4) and (coal) ash contents.

The objective of this section is to review the chemical, mineralogical, physical, and leaching properties that are typical to CCT by-products in order to determine their usefulness in the treatment of metal-laden hazardous wastes. Four advanced clean coal technology combustion/desulfurization by-products have been identified for characterization, of which three were used in laboratory-scale studies of the treatment of metal-laden solid hazardous wastes. The sources of the by-products identified for characterization are described in detail in Section 4.2 under the title "IDENTIFICATION OF BY-PRODUCT SOURCES".

CLEAN COAL TECHNOLOGY PROCESSES

The clean coal technologies which generate these by-products are divided into two main processes, fluidized bed combustion and spray dry scrubbing. These processes are described in detail below.

Fluidized Bed Combustors

Fluidized bed combustion (FBC) technology has been identified as the most promising of the advanced clean coal technologies in terms of economic viability and reduction of air emissions as required by the 1991 Clean Air Act. [Behr-Andres, 1994] FBC is a process of burning crushed coal in a bed of limestone particles held in suspension by the upward flow of combustion air entering a chamber through a perforated air distribution grid below the fluidized bed. Lime is specifically calcium oxide (CaO) and usually contains varying amounts of other alkaline products in small amounts such as sodium and magnesium oxides, as well as calcium carbonate. Commercial chemical grade hydrated lime contains over 92% calcium hydroxide or calcium oxide. [Baldwin, 1993] Crushed limestone is first placed in the bed on the air distribution grid. The bed is then fluidized by injecting air through the grid to form an expanded, suspended mass closely resembling a boiling liquid, hence the name "fluidized." Oil burners are used to heat the bed material to the coal ignition temperature, and then coal feed is started. [Baldwin, 1993]

During operation, coal and limestone are fed continuously into the bed. The tumbling motion of the coal enhances the burning process. Combustion temperatures are held to around 1,400 to 1,600 °F, or almost half the temperature of a conventional boiler. [US DOE, 1991] These lower combustion temperatures, compared to conventional electric-utility systems, decrease the formation of NO_x gases and reduce furnace slagging and fouling. [Behr-Andres, 1994]

During combustion, when acidic gases such as sulfur dioxide are generated, the mineral matter becomes ash and the carbonate minerals are calcined to act as a sorbent for the acidic gases. As the coal burns and sulfur is released as sulfur dioxide, the limestone reacts with the sulfur dioxide and prevents it from escaping into the atmosphere. The chemical process is as follows:

Sulfur-dioxide gas reacts with the sorbent to form alkaline sulfate and sulfite solids, thereby reducing flue-gas emissions. Thus, the limestone basically acts like a chemical "sponge" to capture the sulfur before it can escape the boiler. The amount of limestone added to the combustion chamber is dependent upon the sulfur-dioxide capture efficiency of the limestone and the amount of sulfur in the coal. It is usually much greater than stoichiometric requirements for formation of alkaline sulfate and sulfite solids. As a result, both the fly and bottom ash fractions of FBC by-products consist of varying amounts of spent and unspent sorbent. [Behr-Andres, 1994] More than 90% of the sulfur released from coal can be caught in this manner. The sulfur-laden sorbent and the ash from the coal form a dry waste product. Larger particles of coal ash and spent sorbent are drained from the bottom of the bed. The smaller ash and spent sorbent particles, or "fly ash", are carried out of the boiler and captured with dust collectors. These dry residues are potentially usable, among other things, in stabilizing hazardous wastes and as cement additives.

There are three types of fluidized bed combustion being demonstrated in the Clean Coal Technology Program: atmospheric FBC (AFBC), circulating FBC (CFBC), and pressurized FBC (PFBC). Both AFBC and CFBC operate at normal atmospheric

pressures; whereas PFBC operates at pressures inside the boiler that are 6 to 16 times higher than normal atmospheric pressure. The fundamental distinguishing feature between AFBC and CFBC is the velocity of the air through the unit. The AFBC has lower fluidization velocities, about 5-12 ft/sec, while CFBCs have velocities as high as 30 ft/sec. [Manaker, 1990] The PFBC concept promises the same emission control capabilities as AFBC and CFBC, plus significantly greater thermal efficiency. The flexibility of AFBC and CFBC units to burn low-grade fuels under stringent emissions standards, is superior to that of the flue gas desulfurization systems. [Manaker, 1990]

The two sources from FBC processes examined in this study are residues from circulating FBC and pressurized FBC systems. In circulating FBC all residues collected by the cyclone are recycled as shown in Figure 3.1. There are two main sources of pressurized FBC residues, either from bed-offtake or cyclone discharge, as shown in Figure 3.2.

FIGURE 3.1: Circulating FBC Process Showing Residue Sources

FIGURE 3.2: Pressurized FBC Process Showing Residue Sources

Spray Dry Scrubbers

This technology evolved as an alternative to wet scrubbers and was first used commercially on a coal-fired power station in the U.S. in 1980. Spray dry scrubber processes involve gas/liquid reactions. In spray dry scrubbers an alkaline reagent slurry (usually lime in water) is injected in a finely atomized form into the reaction vessel, which is why these devices are also known as spray dryers. This slurry of alkaline material is mixed with the flue gases at air preheater outlet temperatures. The flue gases are humidified by finely dispersed droplets. The moisture associated with the entering droplets evaporates in hot gas, drying as it reacts with the SO_2 in the flue gases. As the slurry or solution is evaporated, liquid-phase salts are precipitated and the remaining solids are dried, generally to less than a few percent free moisture. The solids and fly ash, entrained in the flue gases, are carried out from the spray dry scrubber to a particulate collection device, either an electrostatic precipitator (ESP) or fabric filter (baghouse), thus leaving only dry particles for collection as waste. Slaked lime is generally used as a sorbent, although sodium carbonate is used in a few installations. Spray dry scrubbers are designed to achieve 70-95% SO_2 removal but the process has the potential to remove up to 98% of SO_2 . The by-product is a dry mixture of calcium sulphite, calcium sulphate, fly ash, and unreacted lime. [Soud, 1994] Figure 3.3 below shows a spray dry scrubber process.

FIGURE 3.3: The Spray Dry Scrubber Process

BY-PRODUCT CHARACTERIZATION

Coal-fired power generation facilities produce high volumes of solid by-products. Fly ash comprises a high percentage of these by-products. The utilization of coal fly ash has significant benefits and expanding fly ash utilization in an environmentally responsible manner is a major objective of this CCT by-product research. Information is needed to determine which by-product types are appropriate for treating metal-laden hazardous

wastes. This information includes chemical, mineralogical and physical properties for correlation with leaching effects. It also includes determination of solid-phase hydration reactions responsible for desired engineering properties.

It is well known that fly ash is an inherently variable material due to differences in the inorganic chemical composition of the source coal, the preparation received by the coal, the combustion conditions, and ash collection and handling methods at individual facilities. The variable nature of coal, combined with conversion process variables and ash collection options, result in materials exhibiting a wide range of chemical, mineralogical, physical, and reactive characteristics. Although the by-product characteristics are unique, they are predictable, within a range, for any given CCT process. [Pflughoeft-Hassett, 1991] The chemical, mineralogical, and physical properties are characterized below. Determination of the leaching characteristics is also provided to demonstrate that these materials are not inherently hazardous in their own right.

Chemical Properties

Chemical analysis reveals information about the bulk chemical composition of a material through the application of accepted methods of analysis, such as atomic absorption (AA) and inductively coupled plasma (ICP).

The combustion of coal and the subsequent dry pollution control equipment generate a material called "fly ash". The chemical composition of coal fly ash may vary widely because of variation in coal composition, combustion conditions, and ash collection systems. Most fly ashes, however, contain a substantial amount of SiO_2 and Al_2O_3 . The University of North Dakota's Energy & Environmental Research Center's Coal Ash Properties Database (CAPD) shows bituminous coal ashes ranging from 24-65 % SiO_2 and from 12-35 % Al_2O_3 . These types of ashes (designated Class F) also generally have low levels of CaO, but are reactive with calcium hydroxide and are termed "pozzolans." The lime-pozzolan reaction forms a low-strength cement. Ashes from low-rank coals, subbituminous and lignite (designated Class C), generally have a higher CaO content with enough CaO free to react with silica, forming a cement. These types of ashes are generally considered cementitious. The CAPD shows a range of 17-65% SiO_2 , 10-25 % Al_2O_3 , and 1-31% CaO for these coal ashes. Other constituents such as alkalis or iron may alter the cementitious or pozzolanic reactions. The bulk chemistry of the coal ash and the wastes to be stabilized and solidified must be compatible for the beneficial reactions to occur. [Eylands, 1994]

The American Society for Testing and Materials (ASTM) has created specifications for useful coal ashes. An "F Ash" is an ash with a total quantity of pozzolans, i.e., silicon, aluminum and iron oxides equaling or exceeding 70 % by weight of the total ash mass. Some typical examples of "F Ash" are given in Table 3.1 and the range of oxide

compounds specific to typical fly ash is given in Table 3.2. [Baldwin, 1993 and ACAA, 1993, respectively]

TABLE 3.1: Typical Percent Specifications For Examples of "F Ash"

Example #	CaO	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	K ₂ O	Fe ₂ O ₃	SO ₃	LOI
1	6.69	55.1	12.1	1.61	1.73	1.24	5.16	0.52	0.62
2	2.2	48.3	19.4	0.73	2.12	-	11.8	0.56	2.33
3	1.53	44.1	19.6	0.7	0.33	2.39	21.5	0.77	4.93
4	7.48	48.9	22.8	1.54	2.86	0.67	6.09	0.30	0.54

LOI = Lost On Ignition (organic matter volatilized during test)

TABLE 3.2: Total Oxide Compound Analysis of Typical Fly Ash

Oxide Compound	Range % Composition of Fly Ash
Silicon Dioxide (SiO ₂)	30-60
Aluminum Oxide (Al ₂ O ₃)	18-32
Iron Oxide (Fe ₂ O ₃)	3-11
Calcium Oxide (CaO)	1-28
Magnesium Oxide (MgO)	0.5-7.0
Sulfur Trioxide (SO ₃)	0-3

The exact composition of sulfur sorption by-products is dependent upon the specific process, coal and sorbent compositions, and plant operating conditions. However, in general these by-products consist of a mixture of conventional ash, unspent sorbent (usually lime or dolomite), and the primary reaction product which is anhydrite (CaSO₄) or calcium sulfite (CaSO₃·1/2H₂O). Due to their lime contents, dry sulfur sorption by-products are highly alkaline with calcium carbonate equivalents (CCE) in the range of 40-60% and free or available lime contents of up to 25% CaO. The anhydrite can be rendered unreactive ("dead-burned") if the combustion temperature is high. These properties may reflect more or less desirable characteristics for use in waste stabilization/solidification. [Beeghly, Brigham and Dick, 1993]

Mineralogical Properties

Of equal importance to the bulk chemistry of the coal ash is the mineralogy. Chemical analysis alone reveals only composition, not the structural arrangement (mineralogy). While the bulk chemistry of the coal ash indicates which elements are present and in what quantities, the mineralogy will indicate how those elements have arranged themselves into crystalline structures or minerals. Thus, mineralogical characterization provides information on the structure and assemblage of atoms (crystallinity) in material. Mineralogical characterization is typically carried out using x-ray diffraction (XRD) and/or computer-controlled scanning electron microscopy (CCSEM) with electron microprobe analysis (EMPA). [Pflughoeft-Hassett, 1991]

Bituminous coal ashes tend to have relatively few minerals forming in them; quartz (SiO_2) and mullite ($\text{Al}_6\text{Si}_2\text{O}_{13}$) are the dominant ones. Other minerals found in the bituminous coal ashes are hematite (FeO_3) and spinels (MgAl_2O_4). The mineralogy found in low-rank coals often include quartz, mullite, anhydrite (CaSO_4), melilite ($\text{NaCaAlSi}_2\text{O}_7$), hematite, merwinite ($\text{Ca}_3\text{Mg}[\text{SiO}_4]_2$), lime (CaO) and periclase (MgO). These minerals often only constitute 10-40% of the coal ash and are generally non-reactive.

The remainder of the coal ash is usually a glassy or amorphous phase of variable composition. It is the glass-phase that accounts for the pozzolanic and cementitious properties of these ashes. The lime (CaO) found in some of the ashes is the exception, where it can be free to react with the silica, forming a cement when it comes into contact with water. CaO can also be incorporated into the glassy phases where it can be detected by several different analytical techniques.

The mineral content of the coal fly ashes should be considered as part of the overall material properties when a coal fly ash is considered for hazardous waste stabilization/solidification, because most properties of dry sulfur sorption by-products are directly related to their mineralogical composition. [Eylands, 1994] The exact composition is an outcome of the injection technology, the coal burned and the type of sorbent; but, in general, the minerals in ash include reaction by-products (calcium sulfate, calcium sulfite, calcium carbonate, magnesium oxide, etc.), unreacted sorbent (lime, hydrated lime, dolomite, etc.) and fly ash.

Tables 3.3 and 3.4 give the typical operating parameters of a 20 MW FBC plant and an example of the mineralogical composition of the FBC ash from the Tennessee Valley Authority's Shawnee Pilot Plant in Kentucky, respectively. [Harness, 1987] Table 3.5 gives the mineralogical composition of typical spray dryer and PFBC by-products. [Beeghly, Bigham and Dick, 1993]

TABLE 3.3: Typical Operating Parameters of a 20-MW FBC Pilot Plant

Calcium-to-Sulfur Ratio	2.4
Sulfur Retention	90%
Recycle Ratio	2.0-2.5
Combustion Efficiency	98%
Bed Depth	4 ft.
Bed Temperature	1530°F
Superficial Velocity	8 ft/sec

TABLE 3.4: Typical Analysis of the Waste Streams from TVA's 20-MW FBC Pilot Plant

Waste Stream	CaSO ₄	CaO	CaCO ₃	Carbon	Non-Carbonate	Other Ash	Total
Spent Bed %	57.2	28.2	-	-	85.5	14.2	100
Char %	36.5	26.2	4.4	11.3	78.4	21.6	100
FBC Fly Ash	24.6	13.3	4.6	7.6	50.1	49.9	100

TABLE 3.5: Mineralogical Composition of Typical Dry CCT By-Products (wt %)

Sample	CaSO ₄	CaMg (CO ₃) ₂	CaO	Ca (OH) ₂	CaCO ₃	CaSO ₃ 1/2H ₂ O	MgO	Fly Ash	Total
Spry Dryer	ND	ND	ND	30	17	30	ND	21	98
PFBC Bed Ash	36	ND	3	ND	27	ND	27	10	103
PFBC Cyclone Ash	22	23	ND	ND	11	ND	13	32	101

ND = Not Detected

These typical mineralogical results show that FBC residues consist primarily of CaO (lime) and CaSO₄ (anhydrite), while scrubber residues from a spray dryer consist primarily of Ca(OH)₂ (portlandite) and CaSO₃·1/2H₂O (calcium sulfite hemihydrate). The phases in scrubber residues are indicative of low flue gas reaction temperatures in the range of 150-200°C. Bed ash from the PFBC facility is enriched with CaSO₄, CaCO₃ and MgO (periclase), which is derived from calcination of the dolomite [CaMg(CO₃)₂] sorbent; whereas cyclone material contains mostly CaMg(CO₃)₂ and CaSO₄, and contains less MgO. The dry sulfur sorption material described here contained 10-50% fly ash arising from coal combustion. Chemical analyses of coal fly ash residues from the by-products are dominated by Al, Fe and Si. This chemistry is consistent with fly ash mineralogy.

Physical Properties

Physical characterization reveals information relevant to the utilization of ash as an engineering material. The methods used for the tests applied to materials are rigidly uniform and have been carefully detailed in the protocols of the American Society for Testing and Materials (ASTM).

The bulk density of coal ash is important when a fly ash is considered for a stabilization/solidification application. Bulk density, specific gravity, and moisture content are properties used in the stabilization and solidification process to calculate porosity, which is of prime importance for the entrapment of contaminated particles. Fineness of a coal ash is an important physical property, with the finer ashes being more desirable because they tend to decrease the porosity of the solidified wastes. Fineness is a difficult property to measure directly, however, therefore specific surface area measurements are used instead, with higher surface areas indicating finer particles. The fineness of the coal ash affects the development of the cured product in that the finer the pozzolanic particles are, the stronger the end product is. [Eylands, 1994]

Some typical physical properties of representative dry sulfur sorption by-products are given in Table 3.6. [Behr-Andres, 1994 and OSU, 1993]

TABLE 3.6: Physical Properties of Selected Dry Sulfur Sorption By-Products

Sample	No. Samples	pH	CCE CaCO ₃ %	Surface Area m ² /g	Particle Density g/cm ³	Bulk Density g/cm ³	Temperature Reactivity °C/20min
FBC Bed Ash	1	12.39	39.5	--	--	--	--
FBC Cyclone Ash	1	12.48	39.2	--	--	--	--
Spray Dryer	5	12.3	65.2	13.5	2.39	.59	1
PFBC Bed Ash	7	11.9	66.0	0.9	2.92	1.29	<1
PFBC Cyclone Ash	7	9.8	61.9	2.8	2.76	1.29	<1

Table 3.6 shows that the sulfur sorption by-products have calcium carbonate equivalents (CCE) ranging from 39.2-66.0 % as percent CaCO₃. It should be noted that the pH of the FBC ashes is quite higher because of the lime content. The dry sulfur sorption by-product from the spray dryer has a relatively high surface area (13.5 m²/g) and is found to pass a 100 mesh sieve (similar to fly ash). [Behr-Andres, 1994]

Leaching Properties

Leaching behavior, not always thought of as a component of chemical characterization, provides information on what materials may be liberated when a solid comes in contact with a liquid. Mineralogical characterization of the leached solids can also provide scientific insights concerning secondary phase formations and interactions within the material affecting the final leachate. [Pflughoeft-Hassett, 1991]

When a waste is exposed to water, a rate of dissolution can be measured; this process is called leaching. The contaminated water that passes through the waste is the leachate and the capacity of the waste material to leach is called its leachability. Leaching is a rate phenomenon and is of interest, environmentally, as the rate at which hazardous or other undesirable constituents are removed from the waste and passed into the environment via the leachate. This rate is usually measured and expressed, however, in terms of concentration of the constituents in the leachate. [Conner, 1990] Leaching tests are often used to evaluate the availability and/or mobility of various constituents in wastes, including coal ash, which is frequently considered a waste for regulatory purposes. [Eylands, 1994]

The Toxicity Characteristic Leaching Procedure (TCLP) is the federally mandated EPA regulatory procedure for determination of hazardousness. The TCLP leachate must be analyzed for an extensive list of organic constituents and trace elements to determine the hazardousness of a particular material or waste. [Eylands, 1994] Table 3.7 gives a comparison of water and acid TCLP leachate from a Pyporpower, 300,000 lb per hour CFBC rated at 28 MW and operated by General Motors in Pontiac Michigan; a Babcock & Wilcox designed PFBC called the Tidd Plant in Brilliant Ohio, which has a gross electrical output of 74 MW and produces both cyclone and bed ash; and a Joy Environmental spray dryer designed for a gas flow of 82,000 standard cubic feet per minute operated by the Ohio State University Power Plant at Columbus, Ohio. [Beeghly, Bigham and Wolfe, 1993]

TABLE 3.7: Comparison of Water and Acid TCLP Leachates
From Representative Dry Sulfur Sorption By-Products

All results given in mg/L

Sample		CFBC	PFBC cyclone	PFBC bed	Spray Dryer
Ag (Silver)	TCLP	<0.024	<0.024	<0.024	<0.024
	Water	0.007	<0.005	<0.005	0.007
As (Arsenic)	TCLP	<0.005	<0.005	<0.005	<0.005
	Water	<0.005	<0.005	<0.005	<0.005
Ba (Barium)	TCLP	0.693	0.141	0.141	0.348
	Water	0.310	0.166	0.202	0.292
Cd (Cadmium)	TCLP	<0.003	<0.003	<0.003	<0.003
	Water	<0.001	<0.001	<0.001	<0.001
Cr (Chromium)	TCLP	<0.005	0.011	<0.005	0.009
	Water	<0.011	<0.011	<0.011	<0.011
Cu (Copper)	TCLP	<0.013	<0.013	<0.013	<0.013
	Water	<0.007	<0.007	<0.007	<0.007
Hg (Mercury)	TCLP	<0.0002	<0.0002	<0.0002	<0.0002
	Water	<0.0002	<0.0002	<0.0002	<0.0002
Ni (Nickel)	TCLP	<0.011	<0.011	<0.011	<0.011
	Water	<0.10	<0.10	<0.10	<0.10
Pb (Lead)	TCLP	0.002	<0.001	<0.001	0.017
	Water	<0.001	<0.001	<0.001	0.012
Se (Selenium)	TCLP	0.005	<0.001	0.001	0.004
	Water	<0.005	<0.005	<0.005	<0.005
Zn (Zinc)	TCLP	<0.006	<0.006	<0.006	<0.006
	Water	<0.006	<0.006	<0.006	0.007
pH	TCLP	12.12	9.58	9.61	11.98
	Water	12.01	11.42	11.77	12.26

The RCRA list of trace elements includes As, Ba, Cd, Cr, Pb, Hg, Se and Ag, some of which are likely to be present in coal fly ash. Very low concentrations of these trace elements are present in the leachates generated from coal fly ash. Thus, wastes stabilized with coal fly ash may leach low concentrations of these trace elements. [Eylands, 1994]

As with hazardousness, the effectiveness of remediation is also often measured using a leaching test. Stabilization/solidification is performed to reduce the leachability or mobility of potentially hazardous constituents to below the point of hazardousness. [Eylands, 1994] To find out the likely environmental consequences of utilizing residues, an understanding of the leaching characteristics is required. Knowledge of the morphology and composition of residues may aid prediction of leaching behavior. [Clarke, 1994]

When Portland cement is compared to quality "F Coal Fly Ash" in the matter of toxic metals that can be acid leached, it is worth noting that the ASTM "F Ash" does as well or better than many commercial Portland cements, a material many consider the premier pozzolanic material. Examples of acetic acid (H_2CO_3) extraction testing produced the data given below in Table 3.8. [Baldwin, 1993]

TABLE 3.8: Leaching of Toxic Metals in Portland Cement and "F Fly Ash"

Reagent Name	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel
Portland Cement Type I	<0.010	1.010	<0.010	0.260	0.180	0.260	<0.001	0.020
Portland Cement Type II	<0.010	1.770	<0.010	0.240	0.210	0.340	<0.001	0.020
F Fly Ash	0.030	0.053	<0.005	0.310	0.240	<0.025	<0.0002	0.160

The leaching characteristics of the coal fly ash should be considered before the fly ash is used in stabilization/solidification applications. Trace element mobility (leachability) in coal fly ashes can be characterized for individual materials, but not for generalized categories of coal by-products. Each individual coal ash should be assessed for leachability before it is used in a stabilization/solidification process, as a coal fly ash with highly mobile constituents may not be suitable material for hazardous waste stabilization. [Eylands, 1994]

Hydration Reactions

When coal fly ash is added to cement, it tends to initially retard the cement hydration reactions, but then accelerate them during most of the reaction. The major reaction between the cement and fly ash is the formation of calcium silicate hydrate caused by the calcium hydroxide in the cement reacting with the glassy silica in the fly ash. The aluminum contained in the glassy portion of the coal fly ash also forms calcium aluminum hydride, or if sulfate is also present, ettringite ($\text{Ca}_6\text{Al}_2[\text{SO}_4]_3[\text{OH}]_{12}\cdot 26\text{H}_2\text{O}$) can also form.

The formation of the mineral ettringite is an important hydration product for many coal fly ashes and other types of coal combustion by-products. It forms when there are sufficient amounts of calcium, aluminum, and sulfate available from the glassy portions of the ash and pH conditions are greater than 11.5.

When coal fly ash is used as a pozzolanic admixture in concrete, it helps remove the calcium hydroxide in the cement that is subject to chemical attack. It is theorized that the calcium silicate levels in the hydrated mixture are higher than in that of plain Portland cement, increasing the protective action of the calcium silicate hydrate. [Eylands, 1994]

High calcium fly ashes have hydration reactions that result in the formation of ettringite ($\text{Ca}_6\text{Al}_2[\text{SO}_4]_3[\text{OH}]_{12}\cdot 26\text{H}_2\text{O}$); monosulfate ($\text{Ca}_4\text{Al}_2\text{SO}_4[\text{OH}]_{12}\cdot 6-7\text{H}_2\text{O}$); and stratlingite ($\text{Ca}_2\text{Al}_2\text{SiO}_7\cdot 8\text{H}_2\text{O}$). It has been found that ettringite formation is beneficial and reduces the amount of leachable selenium and boron in contaminated samples of coal fly ash and advanced combustion residues. [Eylands, 1994] Both of these metals exist in an oxide form, different from the other metals, such as Cd, Pb and Cr.

Summary Of By-Product Characterization

Mineralogical characterization of crystalline phases provides a means of identification and quantification. This must be included as a part of a complete characterization scheme for CCT by-products in addition to the nominal bulk chemical analyses and physical tests. In addition to these tests, a determination of the leaching characteristics should also be included. Chemical interactions between mineralogical phases within the coal by-product or other materials it may contact during utilization are key to understanding the engineering and chemical behavior of the products of these contacts. [Pflughoeft-Hassett, 1991] Such a complete characterization of CCT by-products is needed if they are to be developed into commercial hazardous waste treatment chemicals.

CONCLUSION

Today there are a variety of by-products produced from coal combustion. Besides fly ash and bottom ash from pulverized coal combustion, which comprise the bulk of commercially utilized residues, there are novel residues emerging from many new technologies being developed to control the emission of gaseous air pollutants. As electricity production increases and additional flue gas desulfurization treatment plants are fitted to power stations, the quantities of new, novel residues will increase and produce additional challenges for by-product management. [Conner, 1990]

The exact composition of a dry sulfur sorption by-product is dependent upon the specific process, coal and sorbent compositions, and plant operating conditions. However, upon completing a literature review on CCT by-products, it was found that, in general, these by-products consist of a mixture of conventional fly ash, unspent sorbent (usually lime or dolomite), and the primary reaction product which is anhydrite (CaSO_4) or calcium sulfite ($\text{CaSO}_3 \cdot 1/2\text{H}_2\text{O}$). Because of their lime contents, dry sulfur sorption by-products are highly alkaline with calcium carbonate equivalents (CCE) in the range of 40-60% and free or available lime contents of up to 25% CaO . These properties may reflect desirable fixation and cementitious characteristics for use in metal-laden hazardous waste stabilization and solidification. [Beeghly, Bigham and Dick, 1993]

3.2 HAZARDOUS WASTE TREATMENT INDUSTRY

METALS IN THE ENVIRONMENT

Metals are natural constituents in the environment. However, since society has industrialized, huge changes in the global budget of critical chemicals at the earth's surface have occurred. [Allen, 1995] Various human activities have allowed metals to be concentrated in amounts that can prove harmful to many types of life. Metal contamination can disrupt the balance of physical, chemical and biological processes in the environment. Pollution of soils by heavy metal compounds may inhibit microbial enzyme activity and reduce the diversity of populations of soil flora and fauna. Metals may be transferred to humans by consumption of contaminated plants or animals that have consumed contaminated plants or soils. Land disposed contaminated materials may also allow metal transport to soils or waterways, which can compromise public drinking water supplies.

Because of the above adverse effects, reasonable metal control in the environment is a necessity. Prior to the passage of the Resource Conservation and Recovery Act (RCRA) of 1976, there was little regulation limiting the release of metals, or for that matter any hazardous constituents, to the environment. With the passage of RCRA, provisions were established for determining which wastes are hazardous, establishing standards for siting, design and operation of disposal facilities and encouraging states to develop their

own regulatory programs. These early regulations and subsequent regulations such as the 1984 Hazardous and Solid Waste Amendments (HSWA) lead to the development of the hazardous waste treatment industry.

HAZARDOUS WASTE TREATMENT FACILITIES

Although hazardous waste treatment facilities existed prior to RCRA, most were specialized units operated by generators who saw a need for treatment of their waste prior to discharge. Many generators constructed and operated on-site facilities to handle their wastes. Other generators that did not have a suitable site or that did not generate significant quantities of waste to justify an on-site facility transported their waste to specialized off-site commercial facilities for management. The commercial hazardous waste management industry began developing off-site facilities in the late 1960s. [LaGrega, 1994] The post RCRA age ushered in the development of a large number of hazardous waste treatment, storage and disposal (TSD) facilities. The predominant types of facilities include:

Recovery/recycling facilities: facilities that recover material as a salable product or recover energy values in waste.

Land disposal facilities: facilities that provide permanent emplacement of waste on or below land surface.

Treatment facilities: facilities that change the physical or chemical characteristics of a waste, or degrade or destroy waste constituents, using any of a wide variety of physical, chemical, thermal or biological methods.

A more detailed description of each of these three types of facilities is given below.

Recovery/Recycling Facilities

Metal recovery technologies can be grouped as pyrometallurgical or hydrometallurgical. Pyrometallurgy uses the differences in the melting and boiling properties to separate metals at high temperatures. The heat is typically provided by roasting or smelting. The hydrometallurgy technology extracts and concentrates metals from liquid waste using any of a variety of processes such as leaching, ion exchange, electrodialysis, reverse osmosis, membrane filtration, adsorption, electrowinning, solvent stripping and precipitation. These technologies are most applicable to liquid wastes, as non-liquid wastes first require dissolution.

Land Disposal Facilities

Land disposal facilities include deep well injection, surface impoundments and landfills. Deep well injection involves injection of liquid wastes into a deep, porous subsurface geological formation. The receiving formation is well below potable water sources, and should have an impermeable layer above it. Surface impoundments are used for the retention of liquid wastes and sludges. They require liners and other protective elements to ensure contaminants are not released to the environment. Landfills are the most popular types of disposal facilities. Landfilling involves the permanent emplacement of wastes. A landfill facility has several protective elements such as liners, leak detection systems and leachate collection systems. In most cases, wastes will be treated at a treatment facility prior to being placed in a landfill.

Treatment Facilities

The operations at hazardous waste TSD facilities generally consists of five subsystems: 1) pre-shipment waste analysis, 2) waste receiving, 3) waste storage and preparation, 4) waste treatment and 5) residuals management. A detailed description of each of these subsystems is given below.

Pre-Shipment Waste Analysis. A waste analysis plan is an important part of facility operations. This plan specifies the sampling and analytical procedures and types and frequency of analysis that must be performed on all materials proposed for management at the facility. Before a facility can accept a waste, it must perform a detailed physical and chemical analysis of the waste material. Many facilities require pre-shipment samples be provided by the generators of the wastes. Upon arrival at the facility, a sample of the shipment is obtained for verification of the physical and chemical characteristics of the waste. If a discrepancy is identified between the waste shipment and the comparison information, the shipment is retained on the transport vehicle until the discrepancy is resolved. If the discrepancy cannot be resolved, the waste shipment may be returned to the generator.

Waste Receiving. Wastes are generally received in bulk shipments. Liquid wastes are transported in tank trucks and solid wastes in roll-off or dump vehicles. Both liquid and solid wastes may also be received in drums. Assuming that the waste shipment conforms to the standards established for receipt, the manifest is signed by the receiver, a copy is retained and a copy is sent to the generator. The transporter is directed to the unloading area of the facility appropriate to the type of waste. The waste is then unloaded into the proper storage or treatment unit.

Waste Storage and Preparation. There are four objectives of storage and preparation: 1) store the waste safely before being introduced into the treatment or disposal processes, 2) provide adequate accumulation time during periods when treatment and disposal units are out of service, 3) facilitate mixing, blending and repackaging of the waste and 4) allow staged input of various wastes with reagents to the treatment unit processes. Prior to storing a waste, the issue of compatibility, both with the material used to construct the storage unit being used and with other wastes stored together, must be addressed.

Waste Treatment. Wastes managed at hazardous waste TSD facilities may be contaminated with a number of contaminants that are both organic and inorganic. Prior to disposal, most wastes must first be treated. There are a wide range of treatment technologies commonly used. This discussion will only address those technologies that are commonly used to treat wastes contaminated with inorganic materials. The treatment process employed is a function of the waste type, the contaminants present and the ultimate disposal method selected. Treatment processes commonly used by central waste treaters to treat inorganic contaminated wastes include physical/chemical processes, thermal methods and stabilization/solidification. A detailed discussion of each of the technologies used at TSD facilities is presented below under "TREATMENT PROCESSES."

Residuals Management. Most waste treatment processes produce residuals, such as gaseous emissions, wastewater effluents, and solid by-products which require subsequent management. A full-service facility usually has the capacity to provide all the necessary management of residuals, however, smaller facilities may have to collect the residuals and transport them to another facility for management.

TREATMENT PROCESSES

Physical/Chemical Processes

Physical/chemical processes are processes that reduce the toxicity or mobility of wastes by changing their physical or chemical properties. This can be accomplished by phase changes, adsorption or chemical reactions. Physical/chemical processes commonly employed for treating inorganic contaminated hazardous wastes include neutralization/precipitation, membrane processes, chemical reduction and chemical oxidation.

Neutralization/Precipitation

Waste materials requiring neutralization, such as spent pickle liquors and other highly acidic wastes, are batch neutralized in a reactor. A lime slurry or other neutralizing agent is prepared in a separate mixing unit. A portion of the lime slurry

is then introduced into the reactor and the waste added at a controlled rate. The lime slurry is added first in order to maintain the reactor in an alkaline condition throughout the neutralization process. The pH of the resultant mixture is monitored and additional lime slurry or waste introduced as required to achieve an endpoint pH in the range of 9.0-12.5.

Less acidic materials, such as wastewater treatment plant sludges which generally only require minor pH adjustments, are treated in a similar manner. However, in this case the waste is generally added to the reactor followed by sufficient neutralizing agent to achieve the desired endpoint pH.

Neutralization/precipitation treatment for solid/semi-solid wastes which contain toxicity characteristic metals is usually performed in batch reactors. The wastes are slurried with water and treated with one or more commercial chemical products such as lime, sodium phosphate, sodium sulfate, ferrous sulfate, Portland Cement and sulfuric acid. Cement kiln dust and other chemical agents may also occasionally be used. The end product of the neutralization/precipitation process is a slurry consisting of a solid component (metal hydroxides) and a dissolved component [salt (calcium chloride, calcium sulfate, etc.)] in water. This slurry can be managed in a number of ways, including addition of a solidifying agent or water content reduction by filtering. Most residues are landfilled after undergoing neutralization/precipitation treatment.

Membrane Processes

The application of membranes to separate water from contaminants is a well-established technology in industry. The term membrane refers to a barrier to flow which allows only the passage of water and small particles or molecules. In most cases, the solution flow is parallel to the membrane and the transfer of solute or solvent occurs through application of direct electrical current (electrodialysis) or high pressures (reverse osmosis or ultrafiltration) to the solution. Membrane processes are limited in many applications due to the presence of materials that may foul or degrade the membrane. It is usually reserved for instances where extremely toxic materials cannot be removed by a more cost-effective technology.

Chemical Reduction

In certain heavy metal-containing wastes, the metals present are in a form whereby they remain in solution even after pH adjustment. In order to effect a change in the form of the metal to enable the neutralization/precipitation process described above to effectively remove the constituent, a chemical reduction process may be utilized. One process commonly used is reduction using ferrous iron. In this process, the wastes are mixed with a reducing agent (ferrous iron) in a reducing environment (low pH) causing the oxidation of the iron to the ferric state and the corresponding reduction of the metal species. Waste sulfuric and hydrochloric acids from steel finishing operations may be utilized for this purpose, in lieu of virgin chemical products, due to the abundance of ferrous iron in these wastes. Mixing

is generally accomplished in a reactor by introducing the waste first, then adding the treatment chemicals to the mixer. The chemical conversion is confirmed through sampling and testing of the treated waste for the presence of the metal species of concern. The waste is then neutralized as described above and tested prior to disposal to confirm the process efficiency. One particular use of this technology is the reduction of chromium from the hexavalent state to the less soluble (and less toxic) trivalent state.

Chemical Oxidation

Chemical oxidation is a well-established technology that can be used to destroy a wide range of organic molecules and inorganics such as cyanide. The oxidizing agents most commonly used for hazardous waste treatment are ozone, hydrogen peroxide and chlorine. In chemical oxidation for hazardous waste treatment, an oxidizing agent is added to oxidize the waste components of concern, which serves as the reducing agents. Oxidizing agents are nonspecific and will react with any reducing agents present in the waste stream. Therefore, these processes are most economical when organics other than the ones of concern are in low concentrations.

Certain wastes may contain concentrations of either reactive cyanide or reactive sulfide which must be treated prior to disposal. Two chemical oxidation processes are generally employed depending on the type of contaminant present in the waste. For wastes containing free cyanides, an alkaline chlorination process is used while sulfide-containing wastes are treated with hydrogen peroxide. Due to the incompatibility of reactive cyanide and reactive sulfide with other materials, these wastes are generally not stored at the site and are treated as soon as possible upon receipt. In the alkaline chlorination process, the pH of the waste is raised to 10 or above with lime. Calcium hypochlorite or sodium hypochlorite is then added to the waste. Oxidation/reduction potential measurements are made to monitor the process and the endpoint confirmed by testing for the presence of any detectable amount of cyanide remaining. Following confirmation of the complete oxidation of the cyanide, the pH of the mixture is lowered to 8 and additional hypochlorite is added to convert the end product of the initial oxidation reaction (cyanate) to nitrogen and carbon dioxide. Lime is then added if necessary to complete the treatment of the acidic materials used and ensure compliance with other disposal restrictions. Sulfide wastes are oxidized using hydrogen peroxide by introducing the wastes in liquid form into a reactor and adjusting the pH, if necessary, to 8 or above. Hydrogen peroxide is then added until the sulfide concentration meets the disposal criteria. The end products of this reaction are sulfates and water.

Thermal Methods

The most widely used thermal method is incineration. Incineration is particularly applicable to wastes contaminated with organics. By destroying the organic fraction and converting it to carbon dioxide and water vapor, incineration effectively reduces the volume of the waste. Inorganic components of wastes fed to an incinerator cannot be destroyed, only oxidized. However, by reducing the volume of the waste through incineration, the inorganics can sometimes be more easily managed.

Hazardous waste incinerators typically operate in the temperature range of 1,600 to 2,200°F (870 - 1,200°C). Incineration at these temperatures breaks the chemical bonds of organic compounds and other substances. Incineration technology is most economically useful when the organic content of the waste is high because of the energy content of such wastes. Incineration of wastes with low organic contents often necessitates the addition of costly amounts of fuel.

Although incineration effectively reduces the volume of a waste and may destroy a target toxic chemical, other toxic chemicals are sometimes formed during the incineration process. Therefore, incineration systems require complex control to ensure that toxic chemicals are not being released to the atmosphere. These complex controls often make incineration systems very expensive, and public resistance often makes the permitting process very difficult.

The hazardous waste feed to incinerators can be in a number of forms, including solids, liquids, sludges and gases. Incineration destroys the compounds to varying degrees, usually at a destruction and removal efficiency (DRE) level greater than 99.9%.

In addition to incineration, another thermal method that has seen some use is vitrification. Vitrification involves melting and fusion of materials at very high temperatures (1600 - 2000°C) followed by rapid cooling into a non-crystalline solid form. Vitrification results in a structurally stable mass with a reduced potential for contaminant migration. Vitrification, while considered a thermal technology by some because of the high temperatures involved, can also be considered a stabilization/solidification process since the end product is a solid mass that limits release of contaminants to the environment.

Stabilization/Solidification

Introduction

Stabilization/Solidification (S/S) is one of the most widely used technologies for treating inorganic contaminated hazardous wastes. In order to understand the S/S field, it is important to understand the terminology commonly used. The words

stabilization and solidification are sometimes used interchangeably, but they do have specific meanings. Stabilization refers to processes that convert the contaminants into a less soluble, less mobile or less toxic form. The physical nature and handling characteristics of the waste are not necessarily altered by stabilization reactions. Solidification refers to processes that encapsulate the waste in a monolithic solid of high structural integrity. The encapsulation may be that of fine waste particles (microencapsulation) or of a large block or container of wastes (macroencapsulation). Solidification does not necessarily involve a chemical interaction between the wastes and the solidifying reagents, but may mechanically bind the waste into the monolith. Contaminant migration is restricted by decreasing the surface area exposed to leaching and/or by isolating the wastes within an impervious capsule. [Conner, 1990]

History

The first use of S/S technology was in the 1950s for radioactive waste solidification. The nuclear industry had an interest in solidifying radioactive wastes before shipping them to disposal sites. Radioactive liquid wastes were solidified by mixing them with various mineral sorbents or by making a cementitious mixture with large quantities of Portland cement. These processes were not very volume efficient nor well controlled, and constituents were sometimes present which retarded the setting of the Portland cement. Because of these problems, the use of urea-formaldehyde and asphalt systems came into use to provide more consistency, lower weight and better space efficiency. [Conner, 1990] The late 1950s saw the addition of sodium silicate to Portland cement to provide a better means of solidification. The nuclear waste industry also experimented with the use of organic polymers and cement/flyash/clay compositions.

The mining industry also developed the use of S/S technology to produce hydraulic mine backfills. Portland cement in combination with flyash and solid mine waste was pumped into mines to eliminate the need for structural pillars and walls. Portland cement also saw undocumented use by various waste generators and operators at disposal sites to reduce the water content of wastes prior to disposal in landfills. Lime first came into use for stabilizing wastes formed by processes such as steel pickling. Lime was used to neutralize the acid content of the wastes and flyash. Portland cement was frequently added to produce a material that could easily be landfilled.

Prior to the passage of RCRA, the main use of S/S technology was only to change the physical form of the waste and to neutralize strong acids so that landfills would accept the waste. In the mid 1970s, S/S systems began to receive more attention in anticipation of the passage of RCRA. The EPA's Office of Solid Waste

Management (OSW) began to develop a series of projects to evaluate existing S/S processes and to investigate other possible systems. They also started to develop the necessary testing and evaluation criteria for S/S technology. This culminated in the May 19, 1980 promulgation of regulations for a federal hazardous waste management system under Subtitle C of RCRA. After the passage of RCRA, hazardous waste generators and disposal companies began to show interest in S/S technology.

Principles of Stabilization/Solidification

A number of factors or mechanisms affect the degree of S/S displayed by a particular system. Among these are: 1) pH control, 2) redox potential control, 3) chemical reaction, 4) passivation and 5) encapsulation. A discussion of each of these mechanisms is given below.

pH Control. Cement and pozzolan-based waste forms rely heavily on pH control for metal containment. Normally, high pH is desired because most metal hydroxides have a minimum solubility in the range of pH 7.5-11. However, waste mixtures are complex assemblages, so leachability cannot be predicted on pH alone. Waste mixtures contain many species that may change the solubility of any metal due to effects such as common ion, complexation, total ionic strength and redox potential. Certain metals exhibit completely different solubilities in their various valence states and may exist in cationic and/or anionic form in the same waste.

Redox Potential Control. The presence of strong oxidants or reductants can change the valence states of a number of metals, affecting their chemical speciation and their mobilities. There are seven metals commonly found in S/S systems that have more than one valence state. These metals are arsenic, chromium, iron, mercury, manganese, nickel and selenium.

Chemical Reaction. In addition to hydroxide precipitation from pH control, there are a number of other chemical reactions important for metal fixation. Metals can be precipitated as carbonates, sulfides, silicates, sulfates and other simple species, as well as complexes. Many nonmetal inorganic species (such as cyanides or sulfides) can also be precipitated in various forms or destroyed chemically.

Passivation. Passivation is very important in S/S treatment. Metal ions dissolving from a solid surface may precipitate on the surface after contacting an anion in solution that forms a less soluble species. If the precipitate forms a tight, impermeable layer, it may block or inhibit further

reaction at the surface. One such system is the formation of silica gel on the surface of metal salts exposed to a soluble silicate solution. The gel layer prevents the passage of further metal ions into solution, thus slowing dissolution for a time.

Encapsulation. Encapsulation is the physical isolation of waste particles from the environment. There are two levels of encapsulation: microencapsulation and macroencapsulation. Microencapsulation is the most common encapsulation mechanism present in S/S systems treating sludges and other suspended solids containing wastes. Small waste particles or agglomerates are isolated within the solidified matrix. This occurs on a microscopic scale as particles are incorporated into the crystal matrix of the solidifying agents. Macroencapsulation is the containment of large waste particles within a larger solidified matrix. The degree of protection afforded to this mechanism is solely a function of the stability of the solidified matrix. Any breakdown of the matrix will allow contaminant release to the environment.

Types of Systems

There are a number of different types of S/S processes commonly used in industry. Those that are of the most interest for this investigation are systems that utilize Portland cement, lime and flyash.

Portland Cement Based Systems

Portland cement based processes were first used in the nuclear waste field in the 1950s. Since then, Portland cement has been the most widely applied ingredient in S/S systems. [Conner, 1990] The popularity of these processes is based on a number of reasons including its consistent composition from source to source, the large amount of data concerning Portland cement setting and hardening reactions and good data on leaching of cement based systems from the nuclear waste field.

Portland cement is produced by pulverizing clinker consisting essentially of hydraulic calcium silicates along with some calcium aluminates and calcium aluminoferrites, usually containing one or more forms of calcium sulfate as an interground aggregate. Selected raw materials are crushed, milled and proportioned in such a way that the resulting mixture has the desired chemical composition. The raw materials are generally a mixture of calcareous material, such as limestone, chalk or shells, and an argillaceous (silica and alumina) material such as clay, shale or blast-furnace slag. Either a dry or a wet process is used. In the dry process, grinding and blending are done with dry materials. In the wet process, the grinding and

blending operations are done with the materials in slurry form. After blending, the ground raw material is fed into the upper end of a kiln. The raw mix passes through the kiln at a rate controlled by the slope and rotational speed of the kiln. Burning fuel is forced into the lower end of the kiln where temperatures of 2600-3000°F change the raw material chemically into cement clinker. The clinker is then cooled and pulverized. A small amount of gypsum may be added to regulate the setting time of the cement. The clinker is ground to pass a No. 200 mesh sieve. The resulting fine gray powder is portland cement. [Kosmatka, 1988]

Portland cement is basically a calcium silicate mixture containing predominantly tricalcium and dicalcium silicates (C_3S and C_2S , respectively¹⁰), with smaller amounts of tricalcium aluminate and calcium aluminoferrite (C_3A and C_4AF , respectively). Typical weight proportions in an ordinary cement are 50% C_3S , 25% C_2S , 10% C_3A , 10% C_4AF and 5% other oxides.

In the presence of water, each of the major crystalline compounds hydrates. Tricalcium aluminate and sulfates react almost immediately to form crystalline hydrates. If sufficient sulfate is present, the reaction product is hydrated calcium aluminate sulfate (ettringite) which coats the surfaces of the particles, preventing further rapid hydration of the C_3A . This is why gypsum retards setting. If no gypsum is present, calcium aluminum hydrates form immediately and the system sets. The overall contribution of aluminate and ferrite hydrates to the strength of the system is thought to be minor. [Conner, 1990] Strength development after setting is primarily due to C_3S and C_2S , both of which give the reaction products and $Ca(OH)_2$ and calcium silicate hydrate, or tobermorite gel (CSH).

Portland cement based S/S systems typically provide compressive strengths in the range from 15-1000 psi. The final form of the treated waste depends greatly on the physical form of the waste, the water content of the mixture¹¹ and any waste characteristics that inhibit setting.

Chemical properties of Portland cement based processes, like other processes, are described in terms of leachability. Studies have shown that heavy metal compounds such as oxides and hydroxides, chlorides, sulfates and nitrates interact in the hydration reactions of cement both during setting and later during the hardening process. In addition to affecting the setting and hardening rate, these interactions also may function to fix the metals chemically or physically into the microstructure.

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¹⁰ This notation system represents calcium, silicon, aluminum, iron oxides and water by C, S, A, F and H, respectively. The subscripts denote the relative mole ratios of each component, for example, $2CaO \cdot SiO_2$ is C_2S .

¹¹ An increase in water content separates the crystals and formation of the crystalline network that leads to setting and high compressive strengths.

Lime/Flyash Based Systems

Lime is the most common used alkali in S/S technology. Lime is used by literally thousands of waste generators in the U.S. and elsewhere. Originally used for neutralization of acidic wastewaters and to precipitate metals before discharge, many generators found that they could meet leaching test standards simply by using excess lime.

Lime (CaO or Ca(OH)_2) and lime products may be either high calcium or dolomitic. The latter contains substantial amounts of MgO or Mg(OH)_2 in place of the calcium. Both quicklime (anhydrous) and hydrated lime are used in S/S work, but the hydrated form is more common because it is easier and safer to store and handle.

Most TSD facilities use lime as a stabilizing agent, along with other additives as required. Lime is commonly used to stabilize ferric chloride etching waste, steel pickle liquor, incinerator ash and phosphoric acid residue. Lime operates by controlling the pH of the waste form so that the metals are kept in a range where they are least soluble. When several metals are present in significant quantities, pH control must be a compromise. Also, the pH of interest is not that of the waste form, but of the leaching test solution after the test is complete. For these reasons, adjustment and control of pH with lime alone is difficult, and is a primary reason for the addition of other reagents, such as cement, flyash and carbonate ion.

Lime contains no pozzolanic properties¹², therefore waste stabilized with lime will exhibit little or no solidification potential. For this reason, lime is often combined with flyash to form a cementitious material. Compositions including lime and flyash comprise the largest volume of waste treated in the U.S. This is largely due to the use of this technology in the electric power industry to solidify flue gas cleaning sludges from fossil fuel burning power plants.

Cementitious reaction products are typically mixtures of gel, semicrystalline and crystalline structures. Many of the reactions of lime/flyash mixtures are analogous to those of portland cement. In general, however, these reactions are slower than those of cement and do not produce exactly the same products in terms of chemical and physical properties. Unconfined compressive strengths typically fall in the range of 20-1000 psi.

Because of the nature of flyash, other differences from cement chemistry are introduced. For example, unburned organics reduce the

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¹² A pozzolan is a material that produces cementitious hydrates when mixed with lime and moisture, it does not do so when mixed only with water. A hydraulic cement is a material, such as Portland cement, that produces cementitious hydrates when mixed simply with water.

cementing action by covering reactive surfaces and preventing contact of the cementitious materials. Some flyashes (Type C) have self-hardening characteristics (contain large quantities of calcium oxide), so that the addition of water alone will produce a cementing reaction without the addition of lime. Typically, these are produced when low-rank western coals are combusted.

Lime processes, in general, are not as effective in reducing leachability of metals as the cement based systems. One reason for this is the very high pH that usually results from these systems. High pH can redissolve amphoteric metal oxides. Also, the pozzolanic processes that result in these systems do not bring metals such as lead and chromium into the silica matrix as effectively as does cement.

Portland Cement/Flyash Based Systems

Flyash in a Portland cement/flyash process acts as both a bulking agent and as a pozzolan. Flyash is composed primarily of silica, alumina, iron oxide and calcium oxide. Physically, flyash consists of finely divided spheroids of siliceous glass, about 1-50 microns in diameter, plus minor fractions or larger, irregularly shaped particles.

While most flyashes do not harden significantly by themselves, in the presence of a sufficiently large amount of Portland cement they will exhibit cementing activity. This is believed to be caused by the release of calcium hydroxide by the Portland cement as it crystallizes, which then reacts with the flyash to form calcium aluminum silicates that harden much as does the Portland cement itself. The resulting cement paste may have higher strength than Portland cement alone. The flyash helps to bind additional water, decreases the pore pH and acts as an adsorbent for metal ions.

CONCLUSIONS

The presence of hazardous materials in the environment is a subject of great concern to today's environmentally aware society. Consequently, these materials must be properly managed in order to limit adverse environmental and health effects. Society continues to frown upon the simple relocation of hazardous materials to more "secure" locations. Therefore, the hazardous waste management community must continue to develop new methods of management. One such method, stabilization and solidification, has the potential to effectively limit the toxicity of certain materials. Continued research is needed in this field to understand the underlying principles and develop a working knowledge of the mechanisms at work and how best to apply them in industry.

4.0 PROCEDURES

4.1 OVERVIEW

This project is divided into two one-year phases. In Phase 1, samples of four clean coal technology by-products were collected by Dravo Lime Company (DLC) and characterized. Samples of characteristic metal-laden hazardous wastes were collected by Mill Service, Inc. (MSI) and characterized. MSI tested eleven waste samples to see if they failed the TCLP test, of which six waste samples did and were thus identified as being suitable for use in this project. As soon as the six wastes were so identified, laboratory treatments were conducted with three of the four by-products (**NOT** including the AES Thames by-product). Laboratory-scale treatments of each of the six wastes with each of three by-products were performed at the Yukon Plant of MSI in a manner identical to the commercial treatability tests used at that site. The resulting treated waste samples were then analyzed for stabilization and solidification.

The laboratory results were built in a layered fashion. The first layer was the total metals analyses of the four by-products and the six hazardous wastes. These analyses first determined which metals were to be sought in the extracts from the treated waste samples. The purpose of the metals analyses performed on the digested CCT solid by-product samples was also to determine which of the regulated metals might be added to the treated waste matrix through the material. In like manner, the purpose of the metals analyses performed on the digested waste samples was to identify which constituents are present at high concentrations and, therefore, may be of concern in the treated waste.

The second layer was analyses of the TCLP extracts of these by-products and wastes. These analyses were used to: 1) demonstrate that the by-products were non-hazardous and the wastes were hazardous and 2) to determine what metals were contributed by the by-products. Thus, the purpose of the extract analyses performed on the CCT solid by-product samples was to verify that these materials do not inherently exhibit any hazardous waste characteristics. The purpose of the extract analyses performed on the waste samples was to verify that the samples actually exhibit the expected toxicity characteristics and determine which metals are present in the extract at concentrations that exceed anticipated future treatment standards.

The third layer was the analysis of extracts of 54 treated waste samples, obtained by treating each of the six wastes with each of three by-products at ratios of 10/100, 30/100 and 50/100 by-product/waste. Analyses of the TCLP extracts of these samples determined which level of treatment was optimal.

The fourth layer was the evaluation of the 18 optimal waste/by-product pairs for leachability under the ASTM protocol and for compressive strength.

4.2 CCT BY-PRODUCTS

IDENTIFICATION OF BY-PRODUCT SOURCES

Four by-products were identified for potential use in laboratory studies, of which three were actually used in studies of the stabilization/solidification of metal-laden solid hazardous wastes. The producers of the coal-fired circulating fluid bed combustor residue (the AES Thames River by-product) expressed hesitation in supplying this material as the fourth treatment chemical for this project due to the publication of results. Also of concern to the producer was the potential for the by-product supplier to become liable for the future cleanup of a site to which the treated hazardous waste was disposed. As a result, this by-product was characterized in Phase 1 but not used in the treatability studies.

The sources of the four by-products are identified below:

Dry Scrubber Residue supplied by CONSOL Inc. from a Joy Niro Spray Dryer. This material is produced by the cogeneration project of Chambers Cogeneration Limited Partnership, operated by U. S. Operating Services Company at the Carneys Point Cogeneration Plant on the grounds of DuPont's Chambers Works in New Jersey. The spray drier at Carneys Point is the first one on a pulverized coal boiler burning high-sulfur eastern coal. CONSOL Inc. supplies the coal used in the plant and backhauls the residue in special pneumatic rail tankers to its mines in western Pennsylvania and West Virginia. Some or all of the approximately 100,000 tons/year of this by-product could be easily diverted to hazardous waste treatment plants along the general rail route from New Jersey to western Pennsylvania and West Virginia. At Carneys Point flue gas enters the bottom of the spray drier and all of the sulfur-capture residue rises through the upper port with the fly ash. The combined solids are captured in the baghouse and the baghouse residue is combined with the bottom ash from the boiler in a single silo. The boiler operates at a very stable load. If there is any problem with the system, the plant shifts to oil firing. The unit never operates with coal as a feed when the scrubber is not in operation. Thus, the combined by-product should be very consistent in its composition. The residue is designed to contain 45% fly ash, 36% $\text{CaSO}_3/\text{CaSO}_4$, 10% $\text{Ca}(\text{OH})_2$, 2% CaCO_3 and 7% other inert material. The moisture specification is 2% or less.

Residue from a Coal-Fired Pressurized Fluid Bed Combustor (PFBC) at the Tidd Station of Ohio Power Company, a subsidiary of American Electric Power Corporation, at Brilliant, OH. This demonstration facility was constructed and operated in cooperation with the U.S. Department of Energy in Round I of the Clean Coal Technology Program. The sorbent fed to the plant, rather than lime or limestone, was dolomite. Dolomite was used at the Tidd Station because its sulfated product was both more porous (and thus more reactive) and easier to handle than that from limestone. This was due to its magnesium content. It did not deposit around the tuyeres, nor did it bridge in the piping system

through which it had to be transferred out of the unit. By operating at high pressure, little of the dolomite in the residue is in the oxide form but is mostly present as carbonate. The residue could be obtained as bottom ash, fly ash, or a mixture. The dolomitic character of the sorbent yielded a residue that is lower in pH than that produced from lime-based sorbents. This characteristic is particularly advantageous in stabilizing arsenic-laden waste solids. As this by-product contains magnesium, it will buffer the stronger lime alkalinity. The chemical composition of the residue is 50-60% equivalent CaCO_3 and 1-2% available (free or uncombined) CaO .

Residue from a Coal-Waste-Fired Circulating Fluid Bed Combustor (CFBC) operated by the Ebensburg Power Company. Approximately 200,000 tons/year of this material is produced in an operating unit at Ebensburg, Pennsylvania. Currently it is being trucked back to the mines from which the coal wastes are derived. Some or all of this by-product could be diverted to nearby sites for beneficial use if they could be identified. The coal waste fed to the boiler has a sulfur content between 1.4 and 2.0 %. The limestone is 83% CaCO_3 . It is sized at 12 mesh x 0 and contains between 5-10% through 140 mesh. The fly ash is removed in a ten-segment baghouse and conveyed to the silo. Approximately 70% of the by-product in the silo is baghouse ash, 30% is bottom ash. It is a relatively coarse material, as it contains both bottom and fly ash from the boiler. The bottom ash is at about 350°F when it exits the ash cooler below the boiler. The residue is designed to contain 82% ash, 12.5% limestone equivalent and 5.5% $\text{CaSO}_3/\text{CaSO}_4$.

Residue from a Coal-Fired CFBC supplied by Anker Energy Corporation. This material is produced by the cogeneration project of Applied Energy Service at its Thames River Plant near Uncasville, Connecticut. Anker Energy Corporation supplies the coal used in the plant and through early 1995 backhauled the residue in open gondola railcars to its mines in West Virginia. Some or all of the approximately 100,000 tons/year of this by-product could have been easily diverted to hazardous waste treatment plants along the general rail route from Connecticut to West Virginia. The AES Thames River Plant is base-loaded, operating at 95-96% of capacity constantly. It generally has two scheduled outages each year and experiences only one or two unplanned outages per year. It has a very high availability, thus ash from this source has a very high probability of coming from a steady-state period. The residue is a relatively coarse material, as it contains both bottom and fly ash from the boiler, and is designed to contain 45% limestone equivalent, 28% ash and 27% $\text{CaSO}_3/\text{CaSO}_4$.

COLLECTION OF BY-PRODUCTS

Dravo Lime Company (DLC) collected ten samples from each of the four by-product sources. In addition, just prior to the permanent shutdown of the Tidd unit, DLC collected a fifty-ton sample of the Tidd by-product for use in Phase 2 of the project. The sampling protocol followed by DLC is described in detail below.

General Sampling Program

The by-product sampling program was managed by DLC. A sampling protocol for each of the four sources of by-products was developed during a visit with either the by-product generator or back-hauler. Obtaining samples which were representative of the matrix being sampled was the first step to producing data of high quality. After defining the specific by-product to be utilized in this project from each plant, the project team discussed how to assure representativeness of the samples. In general, samples came from a homogeneous by-product matrix produced under stable, well-defined plant operating conditions. The sampling procedures followed ASTM-C-311 - Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete.

Sample Point Determination

As one of the objectives of the project is to determine the cementitious solidification properties of dry FGD by-products, recently-produced samples were collected in the dry form before any ash conditioning, i.e., before mixing with water to control fugitive dust during the current land disposal operation. Collection of the sample at the production facility, followed by careful, special transportation, was the best way to achieve this. However, two of the by-products are currently transported considerable distances for land disposal. It was decided to sample these by-products at the terminus of their bulk transportation, as this represents a realistic delivery mode. The addition of moisture or water to the top surface of bulk material at the production plant or during transportation or storage has the distinct potential to reduce the effectiveness of this upper material. To this end, DLC coordinated sampling activities for the two by-products collected at the plant with plant personnel to insure that all by-products at the sampling point (i.e., ash silo) were produced and shipped under the desired conditions. For those by-products collected after transportation, coordination was carried out with the recipient of the material following its long-distance open conveyance to insure that dry material was gathered well below the upper crust.

Amount Of Sample

According to ASTM-C-311, grab samples should weigh at least 8 lb. In addition to the by-product required by DLC for their characterization study, it was determined that Pitt would require one 5-gallon bucket for the ASTM and TCLP leaching procedures and that MSI would require three 5-gallon buckets or about 100 pounds for their treatability study. Thus, ten 5-gallon buckets of each by-product sample were collected, which were distributed among DLC, MSI and Pitt for their respective analyses.

Collection Of Sample

Given the relatively small amounts needed, samples for Phase 1 were collected in 5 gallon plastic buckets with lids. All containers were filled as full as possible and tightly sealed to minimize sample contact with air and moisture. At the time of sampling, sample information was written on adhesive labels which were affixed to the sample container and lid. All information regarding the samples (sample identification, date of collection, sampler, sample volume and sample distribution) were entered into a sample log.

A brief description of the collection of each by-product sample is given below:

CONSOL Inc. On October 13, 1994 details of collection of the residue produced at the Carneys Point Cogeneration Plant were worked out on a visit to the research laboratories of CONSOL Inc. CONSOL required that its operating personnel perform the sampling from the pneumatic cars at the Waynesburg, PA receiving terminal. Car numbers and dates loaded were recorded for each of the ten samples collected.

Tidd Station. Ten samples were collected from the Tidd plant cyclone ash silo. The silo at Tidd had a one-day capacity when the unit was operating at its full rating. The ash from the silo includes the electrostatic precipitator ash. Verbal communication with plant engineers determined that boiler operations were stable and producing power at the time of collection.

In addition to the ten samples collected for Phase 1, a large amount of Tidd by-product was collected for use in Phase 2. The PFBC at the Tidd Station was permanently shutdown in the early spring of 1995. Therefore, in late February the project team collected a 50-ton sample of this by-product, which will be needed for Phase 2. The initial thought was to install a new fill nozzle on the silo at Tidd to connect to super-sacks. However, the material in the silo is kept at 300-400°F to assure that no moisture will condense on the ash, which could lead to plugging. The super-sacks cannot tolerate temperatures this high. Therefore, it was decided to use the existing elephant trunk to transfer the hot ash to pneumatic tanker trucks provided by Bulk Transit Company. This approach involved travel of the tanker trucks to a commercial bagger, Aimcor in Aurora, Indiana, which has the capability of removing the ash from the tanker trucks, cooling it, filling the super-sacks and placing them on pallets for transport back to the Pittsburgh area for storage. Super-sacks were coated so that they could be stacked on pallets outdoors under a tarp. As MSI does not have a permit to allow storage of the super-sacks at its Yukon Plant, DLC agreed to clear a portion of a building at their Research Center to house the super-sacks until they can all be shipped to MSI during Phase 2.

Ebensburg Power Company. On October 20, 1994 details of collection of the residue from this plant were worked out on a visit to the facility. Ten dry samples were collected from the storage silo for the characterization program. The silo samples are a

blend of bed ash and cyclone ash. Separate samples of each were obtained for comparison. No significant problems in sampling occurred to prevent obtaining grab samples of dry ash from the silo that are representative of good operating conditions. An operating report representing boiler and gas cleanup conditions for the sample period was obtained and the operating conditions were sent on to Pitt along with each sample.

AES Thames River Plant. On September 29, 1994 details of collection of the residue from the AES Thames River Plant were worked out on a visit to the Albright Mine of the Patriot Mining Company, a subsidiary of Anker Energy Corporation (AEC), where the residue was being disposed. Ten samples of dry cyclone ash were taken from under the crust on top of hopper cars at Anker Energy's Albright (WV) receiving station. Sampling was accomplished from the car before it was moved into the unloading building. To obtain the samples, the crust was punched with a backhoe and a mass of by-product was taken from six inches below the crust. Car numbers and car loading dates were recorded. As the project team did not receive approval from CSX to use this by-product in the treatability studies, it was only characterized in Phase 1 and NOT used to treat metal-laden hazardous waste.

As the various by-product materials are very fine, they have been considered homogeneous and samples could then be drawn from any part of the buckets for laboratory analyses.

Storage of Samples

All samples were collected and received in a dry powder form which will be the expected form for bulk handling and shipment on a commercial basis, i.e., pneumatic transport trucks or railcars. Because the samples contain free lime, it was important to maintain the samples in air tight containers with a minimum of head space.

Sample Distribution

Samples were split so that a representative portion could be retained by DLC for their characterization study and representative portions also given to MSI and Pitt for their respective programs.

ANALYSIS OF BY-PRODUCTS

The by-products were analyzed by all three of the principal participants in the project (Dravo Lime Company, Mill Service, Inc. and the University of Pittsburgh). It should be noted that much of the analytical work provided by MSI was performed by its regular analytical service contractor, Antech Ltd. The tests conducted in Phase 1 of this project were generally standard bench-scale laboratory analyses defined by EPA and ASTM protocols. As such, the equipment utilized is that which has been installed in the laboratories of DLC, MSI, Antech Ltd. and Pitt. A listing of the standard procedures that are available for application by the participants in this project will be given below.

Dravo Lime Company

A description of the analyses conducted by DLC of the chemical and physical properties of the samples obtained from the by-product producers is given below.

Sampling Frequency and Schedule. A complete physical and chemical analysis data base was built on three samples for each source while operating a normal power load. A partial analysis, also called a routine QA/QC analysis (defined in Section 5 under Quality Assurance/Quality Control), was performed on ten samples.

Elemental Chemical Analysis was determined in the Dravo Lime Company Research Center laboratory. Major elemental components were reported in the geochemical oxide format: CaO, MgO, Fe₂O₃, Al₂O₃, CO₂, SiO₂, sulfate sulfur as SO₃, sulfite sulfur as SO₂ and Loss on Ignition @ 600°C and 1100°C. Standard wet analysis procedures of ASTM-C-114 and ASTM-C-25 were followed. The amount of calcium sulfate and/or calcium sulfite present was calculated. Unreacted sorbent in the form of free CaO and CaCO₃ was determined by ASTM-C-25 Available Lime Index.

Alkalinity and Acid Neutralization parameters were reported by DLC. They are pH, free or available lime and total neutralizing power, which is also called calcium carbonate equivalent (CCE). Available lime was tested according to ASTM-C-25 and CCE according to ASTM-C-602. Paste pH was determined by placing equal volumes of by-product and distilled water in a 70 ml cup as per ASTM-D-1293.

Physical Properties. In addition to determining moisture by ASTM-C-25, three analyses were made by DLC for physical properties of the particles in the samples obtained from the by-product producers. These three include density, fineness and surface area:

- Density
  - Particle specific gravity - gas pycnometer
  - Bulk density, loose, dry - ASTM-C-33
  - Bulk density, compact, dry - ASTM-C-33
  - Bulk density, as received - ASTM-C-33
- Fineness
  - Particle Size Distribution (minus 8 mesh)
  - % passing 200 and 325 sieve - ASTM-C-430 (wet sieving)
- Surface Area
  - BET Specific Surface Area - ASTM-D-4567
  - Blaine Fineness (air permeability method) - ASTM-C-204

Reactivity. DLC analyzed the by-product samples for stabilization/solidification and thermal reactivity. The thermal reactivity or temperature rise from hydration of quicklime and anhydrite was measured by ASTM-C-110. The heat generated is important for some stabilization objectives and to determine if available lime is quicklime or hydrated lime $[Ca(OH)_2]$. The stabilization or fixation capacity of the by-product with water was determined by a Chemical Waste Management procedure called the Mixed Ratio. The Mixed Ratio is defined as the amount of material (in this case, the amount of by-product) required to set up one gallon of water. This value, along with the temperature rise, was recorded.

Mill Service, Inc. and the University of Pittsburgh

By-product samples were digested for total metals analyses and extracted by the TCLP and ASTM methods for leachable metals analyses.

Total Metals Analysis. Total metals were determined by MSI and Pitt using standard techniques given below. MSI sent one sample of each by-product (CONSOL #1, Tidd #2, Ebensburg #3 and AES Thames River #4) to Antech, Ltd. to be analyzed for the total concentrations of certain of the eight RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver) and three other metals of concern (copper, nickel and zinc) and to Pitt to be analyzed for the metals antimony, beryllium, thallium and vanadium.

TCLP Analysis. Extracts of the four by-product samples (CONSOL #1, Tidd #2, Ebensburg #3 and AES Thames River #4) prepared at MSI were analyzed for leachable (TCLP) concentrations of the eight RCRA metals (Ag, As, Ba, Cd, Cr, Pb, Hg and Se) and three other metals of concern (Cu, Ni and Zn) by Antech, Ltd. The analysis of these samples for the metals Sb, Be, Tl and V was conducted at Pitt. In addition to these four by-product samples, Pitt analyzed nine additional samples (CONSOL #5 and 7, Tidd #8 and 10, Ebensburg #2, 4 and 5 and AES Thames River #2 and 7) for leachable (TCLP) concentrations of all fifteen metals.

ASTM Analysis. The four by-product samples (CONSOL #1, Tidd #2, Ebensburg #3 and AES Thames River #4) were analyzed for leachability of all fifteen metals by the ASTM method at Pitt to provide useful information in case of any tougher future regulatory actions. In addition to these four by-product samples, Pitt analyzed eight additional samples (CONSOL #5 and 7, Tidd # 8 and 10, Ebensburg #2, 4 and 5 and AES Thames River #2) for leachability of all fifteen metals by the ASTM method.

Extractions, digestions and metals analyses of all by-product samples were performed using the methods specified by the USEPA in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (SW-846). The specific methods used were:

Extraction	SW-846 Reference
Toxicity Characteristic	
Leaching Procedure (TCLP)	Method 1311
Sample Digestions	SW-846 Reference
TCLP	Method 3010A or 3020A
Total	Method 3050A
Metals Analysis	SW-846 Methods ¹³
Arsenic (As)	Method 6010 or 7061A
Barium (Ba)	Method 6010 or 7080
Cadmium (Cd)	Method 6010 or 7130
Chromium (Cr)	Method 6010 or 7190
Copper (Cu)	Method 6010 or 7210
Lead (Pb)	Method 6010 or 7420
Mercury (Hg)	Method 7470 or 7471
Nickel (Ni)	Method 6010 or 7520
Selenium (Se)	Method 6010 or 7741
Silver (Ag)	Method 6010 or 7760A
Zinc (Zn)	Method 6010 or 7950

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¹³ Method 6010 is the analytical method involving Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP). All other methods referenced are Atomic Absorption Spectroscopy methods.

Mill Service collected representative aliquots from the following by-product samples provided by DLC for use in the Phase 1 waste treatment studies:

- CONSOL # 1
- Tidd # 2
- EPC # 3
- AES Thames # 4

A 100-gram portion of each aliquot was extracted according to the TCLP protocol (SW846, Method 1311). The extract generated for each by-product was then distributed into two 1-liter sample bottles and preserved with nitric acid for subsequent analysis. Antech, Ltd. and Pitt were each provided with one of the 1-liter extract samples of each by-product. In addition, each laboratory was provided with a 250-gram sample of each by-product (part of the representative aliquot originally collected) for analysis. Analytical request forms accompanied the samples to the laboratories. The forms identified the parameters to be analyzed, the analytical methods to be used and the detection levels to be achieved.

Antech, Ltd. digested the total metals and TCLP samples provided by MSI and performed ICP analyses for eleven metals on the digestates (Ag, As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn). Pitt also digested these by-products to obtain both total metals and TCLP digestates for analysis of the four additional metals (Be, Sb, Tl and V) by graphite furnace AA.

All ASTM analyses of the by-products and TCLP analyses of the additional samples of each by-product (Consol #5 and 7, Tidd #8 and 10, EPC #2, 4 and 5, and AES Thames River #2 and 7) were conducted at Pitt. Eight metals were analyzed by flame AA (Ag, Ba, Cd, Cr, Cu, Ni, Pb and Zn) and four by graphite furnace AA (Be, Sb, Tl and V). In addition, there are three more metals (As, Hg and Se) which had yet to be analyzed by the end of Phase 1, but which will be analyzed in the first quarter of Phase 2, by flame AA. The extract metals were measured at Pitt by atomic absorption spectrometry using the methodology presented above. Direct aspiration analyses were performed on metals using a Perkin-Elmer Model 1100B AA spectrophotometer. Commercially available certified standards were used to determine the purity of the working standards. Arsenic and selenium will also be analyzed by flame AA procedures found in the Perkin Elmer AA instruction manual. Because the detection limits for these two metals is close to the regulatory maximum concentrations for toxicity characteristic, the hydride method will be substituted. The method described in a Varian application note, "Some studies with a Varian-76 Hydride Generator," will be followed. Finally, mercury will be analyzed by the cold vapor method.

Detection Levels for Metals Analyses

The concentration of eight metals from the toxicity characteristic list (As, Ba, Cd, Cr, Pb, Hg, Se and Ag), plus two of the new BDAT constituents (Ni and Zn) and Cu as it is a regulated parameter in some states (MI), were determined in the solid received by-product samples (as well as in the metal toxicity characteristic wastes received by MSI, which will be discussed in the next section). Typically, any of the eleven that do not appear in solid received samples are not sought by MSI in the leachate. Silver (Ag) is almost always excluded on this basis. This metal may in fact be eliminated from the toxicity characteristics list in new RCRA regulations. Therefore, it was agreed that in leachates from the solid received samples and in the leachates from the products of treatment, the concentration of only those metals whose total solution would cause the leachates to exceed regulated levels were to be measured.

The regulations that set the new BDAT standards, in addition to adding the constituents Ni and Zn, have also added a new uniform treatment standard for wastes other than the metal toxicity characteristic wastes. This new standard reduces the allowable concentrations of seven of the eight metals (all but arsenic - As) significantly. It was determined that the tests used in this project should have detectability levels below the new uniform treatment standards.

As a result, particular attention was paid to detection limits. In order of increasing sensitivity are ICP, flame AA and graphite furnace AA. There are two detection limits: 1) the absolute one based upon the lowest observable signal from the instrument and 2) the instrumental one based upon the lowest calibration value. For this project, it was determined that ICP was sufficient for most metal analyses, but that the four additional metals (Be, Sb, Tl and V) would have to be measured by graphite furnace AA and certain by-product metals would be measured by flame AA, which is the standard method at Pitt. It should be noted that the detection limit can vary for a given metal as a function of interferences ("chemical noise") from other components in the sample.

The following table provides information about regulatory and detection levels for fourteen trace metals in leachates. All values are in mg/L.

<u>Metal</u>	<u>Current</u> <u>TCLP</u>	<u>BDAT</u>	<u>Detection Limits in Extract</u>		
	<u>Maximum</u>	<u>Maximum</u>	<u>ICP</u>	<u>Flame AA</u>	<u>Graphite Furnace AA</u>
As	5.0	5.0	0.1	1.0	0.004
Ba	100.0	7.6	10.0	10.0	0.001
Cd	1.0	0.19	0.1	0.01	0.0001
Cr	5.0	0.86	0.1	0.04	0.0002
Pb	5.0	0.37	0.1	0.1	0.0005
Se	1.0	0.16	0.1	1.0	0.005
Ag	5.0	0.30	0.1	0.1	0.00005
Cu			1.0	0.02	0.0002
Ni		5.1	0.1	0.1	0.001
Zn		5.3	1.0	0.02	0.00001
Sb		2.1	10.0	0.1	0.002
Be		0.014	0.1		
Tl		0.078	10.0	0.1	0.001
V		0.23	1.0	0.1	

This tabular comparison was used to select that analytical method which was used for each of the leachate metals. For nine of the metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb and Zn) flame AA was sufficient. However, seven of the metals (Ag, Ba, Be, Sb, Se, Tl and V) required analysis by graphite furnace AA. From the table it is clear that the detection levels for As, Cd, Cr, Pb, Ag, Ni and Zn using both ICP and flame AA are below current and potential future regulatory levels. The barium ICP detection level shown can be improved with good QC samples to the range of 5.0-7.0, however, a graphite furnace method was needed using AA. The selenium ICP detection level is below regulatory levels, thus a graphite furnace method was again needed using AA. The detection levels for antimony and vanadium using flame AA are below regulatory levels, but the ICP detection levels are not. Neither ICP nor flame AA detection levels are below regulatory levels for thallium and the graphite furnace method using AA was required.

4.3 METAL-LADEN HAZARDOUS WASTES

IDENTIFICATION OF SUITABLE HAZARDOUS WASTES

MSI evaluated eleven commercial solid wastes from those accepted for treatment at its plant at Yukon, PA for use in the one-year laboratory studies of Phase 1 of this project. Included were two industrial wastewater treatment plant (WWTP) residues, six contaminated soils, two air pollution control dusts and one sandblast waste. A brief general description of these four different types of wastes is given below.

Wastewater Treatment Plant Residues. Industries that generate wastewaters as part of their manufacturing processes frequently treat that wastewater on-site and, in the process, generate a sludge that requires subsequent disposal. Such residues generated from the treatment of metal-laden wastewaters often exhibit the toxicity characteristic for one or more metals. MSI routinely receives WWTP residues from customers that include a residue containing cadmium and lead generated from the treatment of acidic wastewaters produced during lead acid battery manufacture and secondary lead smelting and a residue containing lead from the wet scrubbing of emissions from a basic oxygen steel manufacturing facility.¹⁴

Contaminated Soil. As a result of releases of materials, soil often becomes contaminated with constituents present in or leached from those materials. Occasionally, the contamination is sufficient to require remediation of the soil. MSI frequently receives soils from remediation projects where the constituents of concern are metals, generally cadmium, chromium or lead.

Air Pollution Control System Dusts. Manufacturing processes often release particulates that must be captured in order to comply with air quality regulations. Depending on the process, the captured particulates may contain metals (most often lead) at sufficient concentrations that the resultant waste is considered hazardous. Among the dusts routinely managed by MSI are dust from a baghouse used to control particulate emissions from a basic oxygen steel manufacturing facility, which exhibits the lead toxicity characteristic,¹⁵ and dust from an electrostatic precipitator used to control emissions from a municipal waste incinerator that typically exhibits the cadmium, lead and selenium toxicity characteristics.

Sandblast Wastes. Scale (rust) and paint is removed from the surface of steel structures by propelling a solid media (steel shot, walnut shells, plastic, sand, etc.) against the surface. The media and removed material are collected for disposal.¹⁶ Sandblast wastes are frequently considered hazardous due to the presence of metals (primarily lead) in the paints removed in the process. MSI routinely receives sandblast wastes from customers that include a sandblast waste generated from the refurbishing of mobile equipment that typically contains cadmium, chromium and lead and a sandblast waste generated from a bridge repainting project that typically contains lead.

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¹⁴ Air pollution control sludge collected from basic oxygen furnace carbon steel production is currently excluded from regulation as a hazardous waste in accordance with 40 CFR 261.4(b)(7)(xvii). However, the waste leaches sufficient lead to be considered hazardous were it not for the exclusion and is appropriate for inclusion in this project.

¹⁵ Air pollution control dust collected from basic oxygen furnace carbon steel production is currently excluded from regulation as a hazardous waste in accordance with 40 CFR 261.4(b)(7)(xvii). However, the waste leaches sufficient lead to be considered hazardous were it not for the exclusion and is appropriate for inclusion in this project.

¹⁶ Some effort may be made by the generator to recover the blast media prior to disposal.

For each of the eleven wastes, 250-pound samples were obtained from the generators of the waste or collected from shipments of the waste received at the MSI Yukon TSD facility. A representative aliquot of each waste was then removed for analysis. A 100-gram portion of each aliquot was extracted according to the TCLP protocol and the extract generated for each waste was then distributed into two 1-liter sample bottles and preserved with nitric acid for subsequent analysis. One of the extract samples was then delivered to Antech, Ltd. for analysis to determine if the waste exhibited the expected hazardous waste characteristic(s).

Five of the eleven wastes sampled were disqualified from use in the project on the basis that analysis of their TCLP extracts did not verify that the wastes exhibited the expected hazardous waste characteristic(s). On this basis, six of the wastes qualified for use in this project. The wastes that qualified, and the hazardous characteristics exhibited by each, were:

<u>Waste</u>	<u>Characteristic(s)</u>
Industrial Wastewater Treatment Residue from a Battery Manufacturing Plant	Lead
Contaminated Soil from a Remediation Project Conducted at a Munitions Depot	Lead
Contaminated Soil from a Remediation Project Conducted at an Abandoned Industrial Site	Lead
Contaminated Soil from a Remediation Project Conducted at a Former Sewage Treatment Plant	Lead
Air Pollution Control Dust from Basic Oxygen Furnace Steel Production	Lead
Air Pollution Control Ash from Municipal Waste Incineration	Lead

SOURCES OF SUITABLE HAZARDOUS WASTES

A review of these six selected hazardous wastes that qualified for use in this project was provided from the files of MSI and is given below.

Multi-Use Industrial Site Soil

Source: This waste is a contaminated soil from a multi-use city industrial site. The site is underlain by artificial fill material consisting of sandy and silty clays and gravelly and clayey sands. The fill debris material consists of bricks, furnace slag, plastic, cloth, decomposed paper and coal fragments. Due to the artificial nature of the fill material, it appears that the contaminated soil material was mixed with debris from plant operations in the area and placed on the site between 1975 and 1978. No known process within the industrial area generates lead, therefore, an off-site source is suspected. Imported fill material was placed on the site and this material is the suspected contaminant source.

Characteristics: The waste is a solid, brown in color and has no odor. The pH range is 7-8. The waste exhibits toxicity characteristics for cadmium and lead, as well as high levels of total petroleum hydrocarbons (TPH).

Current Treatment: The waste is stabilized with lime. If additional metals control is necessary, other chemicals, such as phosphates and ferrous sulfate, are also used. Upon receipt, the waste is unloaded into a tank and treated. Following treatment, the waste is stored for approximately 24 hours while the efficiency of the treatment process is confirmed. The treated waste is then disposed off-site.

Battery Manufacturing Sludge

Source: This waste is a wastewater treatment plant sludge. The waste sludge is generated as a result of treating sulfuric acid wastewater from the production of lead-acid storage batteries and from the operation of a secondary lead smelter. The wastewater is pH adjusted using lime and/or sodium hydroxide. The sludge is collected from a conventional circular clarifier and an iron co-precipitation clarifier. Ferrous sulfate is added to the waste stream prior to the iron co-precipitation process. The sludge is then dewatered with a vacuum drum filter.

Characteristics: The waste is a solid, off-white to brown in color and has no odor. The pH range is 6.0-9.0. The waste exhibits toxicity characteristics for lead and cadmium.

Current Treatment: The waste is slurried with water and lime stabilized to a pH between 9.0-12.5 prior to disposal in a surface impoundment which is to be closed as a landfill. If additional metal control is required, soluble phosphate is added to the waste.

Basic Oxygen Furnace Air Pollution Control Dust

Source: This waste is basic oxygen shop baghouse dust. The facility is a basic oxygen steel manufacturing facility in which molten iron and scrap, along with specific ores, are mixed to produce a specific grade of steel. During this operation, the transfer of raw materials and product generate secondary particulate emissions which require capture and disposal. Secondary emissions from a desulfurizer, a slag skimming system and two production vessels are captured in a baghouse and transferred via screw conveyors to storage in an 80 ton dust silo prior to disposal.

Characteristics: The waste is a solid, brownish grey in color and has a slight metallic odor. The pH range is 9.0-12.4. The waste exhibits the toxicity characteristic for lead.

Current Treatment: The waste is slurried with water and stabilized prior to disposal. Metal control is accomplished with soluble phosphate, ferrous sulfate, lime and/or silicate. Sulfuric acid may also be required for pH control. The treated waste is then disposed of in a surface impoundment which is to be closed as a landfill.

Municipal Waste Incineration Air Pollution Control Ash

Source: This waste is fly ash from a municipal waste incinerator. The plant is a 3-step multiple hearth, two-stage incinerator with fire heat recovery boilers. The ash is collected using a United-McGill electrostatic precipitator. A detailed process schematic was not available.

Characteristics: The waste is a solid, powdery and grey in color. The pH range is 5.3-9.8. The waste exhibits toxicity characteristics for cadmium and lead.

Current Treatment: Current treatment information was not available.

Sewage Treatment Plant Soil

Source: This waste is a contaminated soil from a former state hospital wastewater treatment plant site. The site was formerly occupied by sewage-drying beds from

the plant. It is believed that the contamination resulted from leaching of lead pipes of the former hospital's water and sewage distribution system.

Characteristics: The waste is a solid, black in color and has no noticeable odor. The pH range is 5.5-9. The waste exhibits toxicity characteristics for lead.

Current Treatment: The waste is stabilized with lime. If additional metals control is necessary, other chemicals, such as phosphates and ferrous sulfate, are also used. Upon receipt, the waste is unloaded into a tank and treated. Following treatment, the waste is stored for approximately 24 hours while the efficiency of the treatment process is confirmed. The treated waste is then disposed off-site.

Munitions Depot Soil

Source: This site is contaminated soil from a former munitions depot. The contamination resulted from storing lead-containing munitions on the site.

Characteristics: The waste is a solid, brown in color and has a soil odor. The pH range is 5-9. The waste exhibits toxicity characteristics for lead.

Current Treatment: The waste is stabilized with lime. If additional metals control is necessary, other chemicals, such as phosphates and ferrous sulfate, are also used. Upon receipt, the waste is unloaded into a tank and treated. Following treatment, the waste is stored for approximately 24 hours while the efficiency of the treatment process is confirmed. The treated waste is then disposed off-site.

COLLECTION AND SAMPLING OF HAZARDOUS WASTES

Collection Method

MSI collected the samples of metal-laden hazardous wastes from among the waste sources mentioned above which were available to it at the time Phase 1 of this project was performed. MSI collected these samples of the various waste sources from waste shipments routinely received at their Yukon facility for management or from waste samples provided by the generator (as was the case for the Municipal Waste Incinerator Ash). MSI has maintained the sources of the individual wastes used in Phase 1 confidential.

Amount and Frequency of Collection

Approximately 250 lbs of waste were collected from each source. The samples

were provided with identification labels and weighed. A tracking sheet was started for each waste to monitor distributions from the sample container. The samples were retained at the MSI Yukon Laboratory in an area devoted to treatability study samples to minimize the potential for tampering.

Sampling Methodology

As indicated above, MSI obtained most of the samples for use in this project from shipments of waste that arrived for management at the Yukon TSD facility. Typically, such wastes are delivered in tarped bulk containers (roll-offs or dump trailers) varying in size from 20 to 60 cubic yards. Samples were obtained from the containers by removing the tarps and collecting samples at a minimum of three locations distributed evenly along the length of the container. Additional sampling locations were utilized if insufficient sample was collected from the initial three locations for the purposes of this project. 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. This device and sampling method generates a "core" sample that reasonably represents the vertical distribution of the waste contained in the shipment. 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. Since these devices only permit sampling near the surface, multiple samples were collected from different depths at each location to ensure that the sample was representative. The individual samples of each waste were composited into a clean sample container for subsequent use in the project. The sampling equipment was cleaned with laboratory detergent and potable water prior to and following each sampling event to minimize the potential for contamination of the sample with foreign material.

Samples of the wastes (and, as previously mentioned, the CCT solid by-products) were obtained for analysis and for use in the extraction procedure by the quartering method detailed in "Standard Practice for Reducing Field Samples of Aggregate to Testing Size" (ASTM C702-87). In short, this sampling methodology involves the placement of the material on a hard, clean, level surface, thorough mixing of the material by turning the sample over three times, conical piling of the material after mixing and quartering of the pile. The opposite quarters are then retained and the procedure repeated until the desired sample size is obtained.¹⁷ The equipment needed to perform sample reduction included a straight-edged scoop, shovel or trowel, a broom or brush and a plastic sheet. All of the equipment was cleaned between uses or discarded to minimize the potential for accidental addition of foreign material.

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¹⁷ In the final reduction, the sample was divided so that MSI retained a minimum of one pound for TCLP extraction, Pitt received a minimum of one pound for metals analysis of the digested solids and Antech, Ltd. received a minimum of one pound for metals analysis of the digested solids.

ANALYSIS OF HAZARDOUS WASTES

The hazardous waste samples collected by MSI were characterized to determine the total concentration of each of the 15 metals mentioned in the previous section (Section 4.2 describing the metals analysis of the CCT by-products), as well as the concentrations present in an extract of each waste.

The metals concentrations of the hazardous waste samples were similarly characterized as the CCT solid by-products as noted above in Section 4.2. The extractions, digestions and analyses were performed using the methods specified by the USEPA in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (SW-846). These methods are commonly employed for waste evaluations throughout the industry and mandated in certain situations. The specific methods used were:

Extraction	SW-846 Reference
Toxicity Characteristic Leaching Procedure (TCLP)	Method 1311
Sample Digestions	SW-846 Reference
TCLP	Method 3010A or 3020A
Total	Method 3050A
Metals Analysis	SW-846 Methods ¹⁸
Arsenic (As)	Method 6010 or 7061A
Barium (Ba)	Method 6010 or 7080
Cadmium (Cd)	Method 6010 or 7130
Chromium (Cr)	Method 6010 or 7190
Copper (Cu)	Method 6010 or 7210
Lead (Pb)	Method 6010 or 7420
Mercury (Hg)	Method 7470 or 7471
Nickel (Ni)	Method 6010 or 7520
Selenium (Se)	Method 6010 or 7741
Silver (Ag)	Method 6010 or 7760A
Zinc (Zn)	Method 6010 or 7950

Total Metals Analysis

MSI provided Antech, Ltd., of Export, PA, with a 250-gram sample of each of the six selected hazardous wastes (part of the representative aliquot originally collected) for full

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¹⁸ Method 6010 is the analytical method involving Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP). All other methods referenced are Atomic Absorption Spectroscopy methods.

digestion and extraction for determination of total metals content. In addition, a portion of the extract (a 100-gram sample) was provided to Pitt for analysis of the four special metals (Be, Sb, Tl and V) by graphite furnace AA.

TCLP Metals Analysis

MSI performed all of the TCLP extractions at its Yukon Laboratory. The extracts generated by the procedure were then distributed to Antech, Ltd. and Pitt for analysis of all the metals. The TCLP extracts were properly preserved¹⁹, then transferred to a sample container for delivery for analysis. Sample holding times were carefully adhered to in order to ensure the acceptability of the results. Approximately 1-liter of TCLP extract generated from each of the six qualified wastes was provided to Antech, Ltd. for metals analysis. Pitt was also provided with a 1-liter extract sample of each of the six hazardous wastes for analysis of the four metals (Be, Sb, Tl and V) by graphite furnace AA. Analytical request forms accompanied all samples to the laboratories. The forms identified the parameters to be analyzed, the analytical methods to be used and the detection levels to be achieved. Any extra extract was retained by MSI.

4.4 TREATED WASTES

OVERVIEW

As soon as the total metals were known for the six selected hazardous wastes, treatments at the 1/10, 3/10 and 5/10 ratios of by-product/waste were conducted using the six wastes and three of the four by-products (excluding the AES Thames River material). TCLP extracts were made of the fresh and day-old treatment products. Analyses of leachates of the products of 54 of these treatments were performed to determine the results of the metals stabilization. The best recipe (acceptable recipes must stabilize all metals) was then repeated to produce cylinders for compressive strength testing and an extra mass was sent to Pitt for ASTM testing.

TREATMENT OF SUITABLE HAZARDOUS WASTES AT MSI

The six characteristic metal-laden hazardous wastes determined to be suitable for use in this project were each treated by MSI during the third quarter of Phase 1 with the three approved by-products at weight ratios of 1:10, 3:10 and 5:10 (by-product:waste). All treatments were performed at the Yukon Laboratory of MSI. Equal 200-gram aliquots of each waste source were thoroughly blended with each CCT solid by-product at dosages

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¹⁹ Per SW-846, TCLP extracts were placed into plastic bottles and preserved with nitric acid to pH<2.

of 10%, 30% and 50% by weight of waste. The aliquots of the wastes and CCT solid by-products used for analysis were obtained from the treatment residues using the ASTM C702-87 procedure mentioned above. A small quantity of potable water²⁰ was then added to activate the reagents. Water addition was controlled to ensure that no free liquids were present in the treated residue.²¹ The mixing of the wastes and CCT solid by-products was performed in plastic buckets using a clean trowel. The buckets and mixing equipment were thoroughly cleaned using laboratory detergents and potable water before and after each use. In addition, the buckets and mixing equipment were visually inspected before each use and verified as being free of deposits. In general, each waste was treated within one or two weeks of collection to establish an orderly, uniform sequence of analyses of the treated wastes by MSI and Pitt.

DETERMINATION OF MOST EFFECTIVE BY-PRODUCT DOSAGE FOR STABILIZATION

Immediately following treatment, a 100-gram aliquot of each by-product/waste mixture was removed and extracted at MSI according to the TCLP protocol described previously for metals analysis of CCT by-products and wastes. (Only TCLP extracts were analyzed to determine the immediate effectiveness of the various CCT solid by-product dosages.) The extract generated was then distributed into two 1-liter sample bottles and preserved with nitric acid for subsequent analysis. This procedure was repeated for each of the by-product/waste mixtures 24 hours after the completion of the treatment batch. One of each of the TCLP extract samples was then delivered to Antech, Ltd. for analysis 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 characteristics 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. For this third determination, the residues were analyzed for the parameters in Table C.1 shown in Appendix C. The review leading to this table compared the results of waste and by-product analyses against projected future LDR treatment standards. As a safety factor, 80% of the LDR level was assumed as the cutoff for testing. One of each of the extract samples was also delivered to Pitt for analysis of the four metals (Be, Sb, Tl and V) by graphite furnace AA. Analytical request forms accompanied the samples to Antech, Ltd. and Pitt. The forms identified the parameters to be analyzed, the analytical methods to be used and the detection levels to be achieved.

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²⁰ The water used in the project was collected from a tap at the Yukon Plant and stored in a carboy. The water was analyzed to determine the concentration of each of the metals analyzed in the wastes and by-products.

²¹ The presence of free liquids would prohibit the disposal of the treated waste into landfills anywhere in the United States.

The analytical data generated from the stabilized waste testing was reviewed jointly by MSI and Pitt to determine which of the CCT solid 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. (See background discussion under "CHARACTERISTIC METAL-LADEN HAZARDOUS WASTES" in Section 2.3.) In the event multiple dosages achieved comparable results, the most economical dosage was judged to be the best.

DETERMINATION OF SOLIDIFICATION

Overview

Solidification tests were conducted for successful by-product/waste combinations. For those combinations immediately successful, a water-containing blend having a 1½" to 2" slump was placed in 3" x 6" cylinders, cured and tested for compressive strength. The solidification test using the best CCT solid by-product/waste dosage used a 60-lb aliquot of the by-product/waste combination and sufficient water to obtain the appropriate consistency needed for filling and rodding the molds.²² The treated waste was then loaded into twenty-five 3" diameter by 6" long test cylinders and delivered to Pitt for curing and compressive strength testing. The cylinders were transported by ground vehicle to Benedum Hall, University of Pittsburgh after sitting for 24 hours to set up. A separate aliquot of approximately 500-grams of the by-product/waste combination was also delivered to Pitt for ASTM extract analysis.

For those combinations which were not immediately successful, a moist blend having a maximum density as a compacted soil by the Proctor Test was examined for compressive strength.

Immediately Successful Stabilization

For each of the treated waste samples which demonstrated immediate stabilization, a set of small-scale samples was prepared at MSI and tested at Pitt for leachable (ASTM) concentrations to collect information of value for possible future permitting requirements. A set of 3" x 6" cylinders was also prepared at MSI and then cured and tested at Pitt for compressive strength to determine the extent of solidification effected by the treatments.

Before preparing the first cylinders for the recipes that were immediately successful in meeting both current and possible future regulations, it was estimated that 50 lbs of dry

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²² The solidification tests for a particular CCT solid by-product/waste dosage was not conducted if none of the dosages achieved the criteria for disposal of the treatment residues.

mixture was required to fill 25 3" x 6" cylinders. For example, if a 1:10 by-product:waste recipe (10% dosage of by-product into the waste) was desired, 4.5 lbs of by-product would be blended with 45 pounds of the waste. [Because of confusion in interpretation, the first solidification test using the Ebensburg by-product with the Munitions Soil was prepared with the ratio of 10:10 (25 lbs of by-product with 25 lbs of waste) instead of the desired ratio of 5:10 (25 lbs of by-product with 50 lbs of waste).]

For each of the recipes that were immediately successful in meeting both current and possible future regulations, a water-containing blend having a 1"-2" slump was prepared. This mixture was prepared by placing a measured weight of by-product into a 32" x 21" x 9" plastic mortar box. Large particles such as rocks and glass were removed from the waste by passing the material through a 3/4" sieve [ASTM C 192-90a - "Practice for Making and Curing Concrete Test Specimens in the Laboratory" states that the diameter of cylindrical specimens shall be at least three times the nominal maximum size of the coarse aggregate in the concrete]. A measured weight of sieved waste was then added to the mortar box and the mixture blended with a cement hoe until well mixed in consistency and color. A measured volume of water was then added to the mixture and blended until well mixed. This step was repeated if the mix was too dry. The slump of the mixture was tested as per the requirements of ASTM C 143-90a - "Test Method for Slump of Hydraulic Cement Concrete." In this test, a sample of the freshly mixed grout is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the mixture allowed to subside. The distance between the original and displaced position of the center of the top surface of the mixture is measured and reported as the slump. If the slump was not in the desired range of 1 - 2", the mixture was adjusted by adding more water if the mixture was too dry, or adding proportional amounts of waste and by-product if the mixture was too wet. In cases where the waste contained a very high water content (such as the Battery Manufacturing Sludge) and the desired slump could not be obtained at the optimum percentage mixture, additional by-product was added to the mixture in order to obtain the desired 1-2" slump. Once the desired slump was obtained, the mixture was compacted into 3" x 6" cylinders as per ASTM C 192-90a. This procedure involved placing the material into the molds in three equal layers and consolidating each layer by rodding 25 strokes with a 5/8" diameter tamping rod. After consolidation the surface was struck off with a trowel to produce a flat surface level with the edge of the mold. After finishing, the specimens were covered with plastic in order to prevent moisture loss and stored for 48 hours. Additionally, a sample of approximately 500 grams was returned to Pitt in order to undergo ASTM extraction for heavy metals leachability according to ASTM D 3987-85 - "Test Method for Shake Extraction of Solid Waste With Water". Following the 48 hour setup period, the samples were transported to Pitt, the molds were stripped and the specimens placed in a moist room to cure.

A summary of the solidification tests prepared to date using this methodology is given below in Table 4.1.

TABLE 4.1: Summary of Solidification Tests Performed For Immediate Stabilization

Test # and Date Prepared	Mixture Type	Weight By- Product (lbs)	Weight Waste (lbs)	Mixture Ratio	Water Added (liters)	Slump (inches)
#1 6/27/95	CONSOL/ Battery Sludge	15	45	3.3:10	0	2.0
#2 6/27/95	Ebensburg Munitions Soil	30	30	10:10	6.8	1.5
#3 7/11/95	Tidd/ Industrial Soil	22	44	5:10	4.0	1.25
#4 7/17/95	CONSOL/ Munitions Soil	25	50	5:10	7.5	1.5
#5 7/17/95	Tidd/ Battery Sludge	32.5	45	7.2:10	0	2.0
#6 8/15/95	Tidd/ Munitions Soil	22.5	45	5:10	4.0	1.5

Sample holding times were carefully adhered to in order to ensure the acceptability of the results. The solidification tests proceeded over a three-month period. Cylinders were stored during this period in the environmentally controlled room inside Room SB86 of Benedum Hall. Following specified curing times of 3, 7, 14, 28 and 90-days the compressive strength of the above solidification mixtures was evaluated according to ASTM C 39-86 - "Test Method for Compressive Strength of Cylindrical Concrete Specimens". Breaks of four cylinders each were made at 3, 7, 14, 28 and 90 days, using the test machine in Room SB82 of Benedum Hall. When possible, samples were capped with sulfur mortar prior to testing according to ASTM C 617-87 - "Practice for Capping Cylindrical Concrete Specimens" in order to provide plane surfaces on the ends of the cylinders. Samples that did not undergo significant solidification were not able to be capped.

Slow Stabilization

For each unsuccessful combination of waste and by-products (the remaining combinations of the 18 combinations in all) a set of small-scale samples was prepared at MSI and tested at Pitt for leachable (TCLP) concentrations to determine the rate of slow stabilization and the possibility of full stabilization within a reasonable "curing" time. For each successful slow stabilization, a set of 4" diameter cylinders was also prepared at Pitt and, after curing, tested for compressive strength.

For the recipes that were immediately successful in meeting current regulations but were not immediately successful in meeting possible future regulations, that were to be prepared by the Proctor method, it was estimated that 90 lbs of dry mixture was required in order to prepare 20 4" x 4.6" cylinders [5 for moisture-density determinations and approximately 15 for compressive strength testing]. Therefore, 30 lbs of by-product was blended with 60 lbs of waste to obtain a 50% dosage. [Again, because of confusion in interpretation, Test #7 and 8 in Table 4.2 were prepared at a ratio of 10:10 instead of 5:10].

For those recipes that were immediately successful in meeting current regulations but were not immediately successful in meeting possible future regulations,²³ a dry mixture consisting of 50% by-product to waste was prepared, placed in 5-gallon buckets and transported to Pitt for evaluation by the so-called Proctor method [ASTM D 698-91 - "Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³))"]. In this test, a material at a selected water content is placed in three layers into a mold with dimensions of 4.0" diameter and 4.584" height, with each layer compacted by 25 blows of a 5.5-lbf rammer dropped from a height of 12" producing a compactive effort of 12,400 ft-lbf/ft³. The resulting dry unit weight is determined. The procedure is repeated for a sufficient number of water contents to establish a relationship between the dry unit weight and the water content for the soil. This data, when plotted, represents a curvilinear relationship known as the compaction curve. The values of optimum water content and standard maximum dry unit weight were then determined from the compaction curve.

Following determination of the optimum water content, 12 specimens were prepared at the optimum water content so unconfined compression testing could be performed on laboratory cured specimens of 14, 28 and 90 day ages according to ASTM D 5102 - "Test Method for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures". These samples were prepared using the same equipment and procedure as specified above for construction of the compaction curve. Following curing periods of 28 and 90 days, a TCLP

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²³ It should be noted that for several recipes that were immediately successful in meeting both present and possible future regulations dry mixes for evaluation by the so-called Proctor method were also prepared. This was done to provide a comparison of the two solidification methods.

was prepared in order to evaluate the success of long-term stabilization .

A summary of the solidification tests prepared to date using this methodology is given in Table 4.2 below.

TABLE 4.2: Summary of Solidification Tests Performed
For Slow Stabilization by the Proctor Method

Test # and Date Prepared	Mixture Type	Weight By-Product (lbs)	Weight Waste (lbs)	Mixture Ratio	Optimum Moisture Content (%)
#7 6/27/95	CONSOL/ Industrial Soil	50	50	10:10	31
#8 6/27/95	Tidd/ Industrial Soil	50	50	10:10	Insufficient Sample to Determine
#9 7/11/95	CONSOL/ BOF Dust	40	80	5:10	*
#10 7/11/95	Tidd/ Munitions Soil	40	80	5:10	23
#11 8/15/95	Ebensburg/ Industrial Soil	30	60	5:10	18

* Analysis was not performed on this mixture due to the inability of the CONSOL material to stabilize.

Specific methods for solidification testing of the immediately unsuccessful recipes include production of 4" x 6" cylinders by ASTM Test Method D 698-91 (the so-called Proctor Test) as mentioned previously, curing the cylinders and testing their compressive strength by ASTM Test Method C 311-87a.

SUMMARY OF TREATED WASTE EVALUATIONS

In summary, a review of the laboratory analysis procedures followed by MSI and Pitt is given below.

Mill Service, Inc.

- Digestions according to EPA SW-846, Methods 3010A, 3020A or 3050A;
- TCLP (Toxicity Characteristic Leaching Procedure) Extractions by EPA SW-846, Method 1311;
- Metals Analysis by EPA SW-846, Method 6010 or by the series of EPA Methods 7061A, 7080, 7130, 7190, 7210, 7420, 7470, 7471, 7520, 7741, 7760A and 7950²⁴;
- Production of 3"x6" cylinders by ASTM-C311-87a.
- Production of 4" or 6" diameter cylinders by ASTM-D698-91 or ASTM-D1557-91

University of Pittsburgh

- Digestions according to EPA SW-846, Methods 3010A, 3020A or 3050A;
- Treated Waste TCLP by EPA Method 1310;
- Treated Waste Extraction and Extract Analysis according to EPA SW-846;
- Treated Waste Extraction by ASTM-D-3987;
- Metal Analysis by EPA SW-846 Methods 7041, 7080, 7091, 7131, 7190, 7210, 7420, 7471, 7520, 7760A, 7841, 7911 and 7950 and by direct aspiration (Perkin-Elmer Model 1100B AA Spectrophotometer method), hydride formation (Varian-76 Hydride Generator and method), and, for mercury, the cold vapor method²⁵;

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²⁴ Should a hazardous metal be present in the waste in a quantity small enough that its entire dissolution would produce a concentration below the regulated level, the concentration of that metal will not be sought in the extract. In the event of interferences or the appearance of other metals of concern, other recognized procedures may be required. Should such an event occur, modifications will be recommended to the COR.

²⁵ See Footnote 1.

- Curing of 3"x6" cylinders and 4" diameter cylinders by ASTM-C311-87a;
- Compressive strength testing by ASTM-C311-87a.

5.0 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

5.1 OVERVIEW

There are two basic elements of the project's QA/QC Program - the maintenance of chain of custody documentation for all samples and the use of blank, duplicate, and spiked samples.

CHAIN OF CUSTODY

Samples of both by-products and hazardous wastes were drawn, labeled, shipped and received under a strict logging system to assure that each sample was properly identified, analyzed and utilized throughout the project. Digestates and extracts were similarly produced, labeled, shipped and received to make certain that analytical results were accurately attributed to the proper material.

BLANK, DUPLICATE, AND SPIKED SAMPLES

Quality Assurance/Quality Control (QA/QC) was practiced during all laboratory analysis by the use of blank samples, spiked blank samples, spiked samples and duplicate samples. As an example, at Pitt blank samples were carried through both the TCLP and ASTM extraction procedures. The blank samples for the TCLP extractions were simply the acetic acid extraction fluid, and the blank samples for the ASTM extractions consisted of deionized water. Blank samples were prepared in order to indicate any contamination of the sample batches that may have occurred during the laboratory procedures. Spiked blank samples were prepared by spiking the appropriate extraction fluid with 10 ml of a spiking solution that contained the metals of interest at known concentrations. The purpose of the spiked blanks was to ensure that no losses of the metals of interest occurred either by physical or chemical means during the laboratory procedures. Likewise, spiked samples were prepared by spiking the samples with 10 ml of a spiking solution that contained the metals of interest. Duplicate samples were prepared in the same manner as the original sample for the purpose of measuring the reproducibility of the laboratory data.

A brief description of the QA/QC protocol followed by each of the individual participants in this project is given below.

5.2 DRAVO LIME COMPANY

DLC defines routine QA/QA analyses as those needed to determine variation in properties affecting treatment reactivity and stabilization performance. These are:

- Alkalinity: Free Lime as CaO
Total Alkalinity as CaCO₃
- Reactivity: Stabilization (mixed ratio)
Thermal (1:1 with water)
- Fineness: Blaine Fineness
Percent passing 200 and 325 sieves

DLC's Analytical Services Department has extensive quality control operating procedures and policies. Their QA/QC program is sufficient in scope and content to produce data of known quality in the characterization testing of CCT by-products. For each sample, an entry was made in the sample analysis log, recording the date, analyst, identification and location of resulting data. For each test procedure, an internal quality control procedure was followed to assure adequate precision and accuracy. Some tests, i.e., available lime, were analyzed within a few days of receipt of the sample because of possible relatively rapid changes with time. The oxides and ignition loss were totaled to see how close to 100% by weight the major constituents were. The determinations made on the dry FGD by-product material were made in accordance with ASTM-C-25 and ASTM-C-114. The test method for chemical analysis of fly ash (ASTM-C-311) refers to ASTM-C-114. For the most part, these methods were used to determine the total concentration of a given analyte, although they were calculated on an oxide basis as required by the method. Examples of this are total calcium calculated as CaO and total iron calculated as Fe₂O₃. In a few cases, direct determinations were made of compounds as in the case of carbon dioxide or of functional groups as in the case of sulfite. This convention, often used so that the analyst may add the calculated oxides to the ignition loss to determine if a major error has occurred in the analysis, is particularly useful in process control applications when dealing with relatively simple, highly homogeneous materials of well known characteristics. This calculation is sometimes useful as a check on the internal consistency of the data. It is not intended to imply or suggest that anything has been measured except the total elemental concentrations of the analytes. Neither ASTM-C-25 or ASTM-C-114 suggests that the sum of calculated compounds should equal 100% or any other predetermined value. The interpretation of totals so derived are subject to the limitations of the methods of analysis and should be restricted by the definitions of the test and the validity of the underlying assumptions. In other words, the elemental analysis may not necessarily add up 100%±2%.

The precision statement for ASTM-C-25 (Standard Test Methods for the Chemical

Analysis of Limestone, Quicklime and Hydrated Lime) states that the precision of the method is unknown. ASTM-C-114 (Standard test Methods for Chemical Analysis of Hydraulic Cement) does specify the maximum permissible variation in duplicate analysis for most of the analytes covered by the method. These are specific to the analysis of cement, however.

All testing was carried out in accordance with the methods specified by highly trained and skilled analysts. No better analytical procedures are known to DLC for the analysis of this material. Typical quality control strategies used by DLC's laboratory were replicate analyses, analysis of spiked samples and analysis of standard reference materials.

The DLC QA/QC coordinator was responsible for tracking all samples and keeping an up-to-date database listing of all samples. The database contained all the information included on sample labels and sample logs, information on coal and sorbent analysis and plant operating conditions (for Ebensburg Power Company only), and a record indicating division of the sample material among the various cooperating laboratories as well as any others who were issued sample material. Individual cooperating laboratories could only release sample material after notification of the QA/QC coordinator.

5.3 MILL SERVICE, INC.

All hazardous waste samples provided to Antech, Ltd. and Pitt for the performance of analyses were accompanied by Chain of Custody documentation containing the following:

- Description of sample
- Date of shipment
- Quantity of sample
- Sample collector's name
- Laboratory's name

Other sample distributions were similarly documented.

The quality of the laboratory data was assured through the performance of data validation checks such as the analysis of method blanks, spikes and duplicates. The frequencies varied based on the practices of the laboratory. The Laboratory Procedure Manual developed for MSI's Yukon Laboratory and the Quality Assurance Plan followed

by Antech, which indicate the frequencies of data validation checks, describe the major equipment used and practices followed by the laboratories, are available upon request.

5.4 UNIVERSITY OF PITTSBURGH

The objectives of Pitt's internal quality assurance program are accuracy, precision, completeness, representativeness and comparability. Elements of this program include sampling, shipping, calibrating, preventive maintenance, use of known standards, data reduction, reporting and auditing. The various requirements governing the collection, transportation, sample size, storage, disposal and record keeping, which are presented in the **Pennsylvania Bulletin**, Vol. 23, No. 3., January 16, 1993, pages 381-383, are followed. Quality control procedures for metals analysis are consistent with methodology presented in EPA SW-846.

All QA/QC data obtained to date indicate that there has been no problem with the analysis so far. Metal concentrations of blank samples were low as to be expected, spiked samples had metal concentrations close to those concentrations of the initial spike and duplicate samples had metal concentrations close to the original sample concentrations.

Pitt also assumed responsibility for coordinating a program to integrate cross-laboratory samples. As part of this program, Pitt was responsible for assuring that the data collected by each laboratory was compatible with that collected by all of the other laboratories participating in this project.

6.0 RESULTS AND DISCUSSION

6.1 BY-PRODUCT EVALUATIONS

CHARACTERIZATION OF BY-PRODUCTS

Dravo Lime Company's results of the geochemical analysis, reactivity testing and testing of the physical properties of the four different by-products are given in Tables A.1-A.4 of Appendix A. A brief summary of these results is given below for each by-product source.

CONSOL Spray Dryer Ash. As shown in Table A.1 of Appendix A, the three geochemical analyses add up to percent totals of 100.3%, 100.2% and 97.9%. The ratio of calcium to sulfur (Ca/S) is the lowest at 2.05. The samples have a high fineness characteristic in terms of their high surface area as measured by the Blaine fineness and percent passing the 325 mesh sieve. It has the lowest average mean particle size of 17.74 micron. Like the AES Thames River FBC material, the bulk densities are very low. A unique characteristic of this by-product which is different from the others is that the sulfur is mostly in the form of calcium sulfite, CaSO_3 . This is mostly due to collection/absorption at lower temperatures. The CONSOL by-product has good waste stabilization activity and a high CCE in contrast to the AES Thames River FBC ash. However, it has a low free lime content at 2-4% CaO. Because of the use of lime slurry, the free lime is in the hydrated form. The small temperature rise confirms that the free lime is already hydrated.

Tidd Pressurized Fluid Bed Combustion (PFBC) Cyclone Ash. As shown in Table A.2 of Appendix A, the geochemical analyses total 98.0%, 98.0% and 98.1% for the three samples of Tidd cyclone ash. The bed or bottom ash was not sampled because of its coarse, sand-like size distribution and particle morphology. The chemical composition of this by-product is unique due to its magnesium content as a result of the use of dolomite as the sorbent. Even though it has the lowest free lime content and lowest pH, it has the highest CCE content. Based on ten samples, the average CCE was 52.6% CaCO_3 ranging from 43-61%. The Tidd cyclone ash has the heaviest bulk density. Although the mixed ratio stabilization of 20 is the least impressive, this material is known to be highly cementitious and able to attain high strength when mixed with the optimum amount of water. The ratio of $(\text{Ca} + \text{Mg})/\text{S}$ is 5.05.

Ebensburg Power Co. Fluid Bed Combustion Ash. This material differs from the others in that it contains bottom ash due to being stored in a common silo with the fly ash. The silo ash is not homogenous. There is large variation in bulk

density and fineness parameters. As shown in Table A.3 of Appendix A, the total chemistries are slightly low at 97.3%, 96.1% and 97.3%. Due to burning low grade, high ash fuel, the alumina and silica contents are high. Correspondingly, the calcium content is low. Although this proportion does not seem to hinder the waste stabilization potential of this by-product, the CCE is decreased.

AES Thames River FBC Cyclone Ash. The geochemical analyses for the three samples, as shown in Table A.4 of Appendix A, have totals of 96.1%, 96.4% and 99.7%. Significant variation is only seen in the total CaO and CO₂ determinations. This variation is also seen in the range of data for the available (free) lime index (i.e., 4.9-10.5%) and the calcium carbonate equivalent (CCE as % CaCO₃) ranging from 14.0-25.1%. The CCE is lower than expected. This low level can partly be attributed to the efficient use of the limestone sorbent. The ratio of Ca/S is 3.72. The amount of alkalinity is mostly the uncombined lime, also called available or free lime, reported as CaO. From the low amount of CO₂, there is very little unused limestone in this by-product in contrast to the Tidd PFBC data. The bulk densities are low or otherwise lightweight. The waste stabilization potential is good at 13 lbs per gallon based the take up of water via the mixed ratio test which determines the pounds of ash to solidify one gallon of water.

For each by-product source, the three samples for geochemical analysis and ten samples testing reactivity and physical properties are statistically analyzed in Tables A.5-A.8 of Appendix A. The data spread within each source does not show a significant degree of variation as seen by the range and coefficient of variation shown in Tables A.5-A.8 for each individual parameter within the ten-sample set of each by-product. Although one of the initial objectives of this project was to determine how specific operating conditions within the various processes affect the measured properties of the by-products, the project team was only able to obtain the operating conditions for the first five samples from the Ebensburgh Power Company (EPC). These operating conditions are given in Table A.9 of Appendix A. The operating data and the analytical results from EPC were examined and it was found that the variability within the by-product properties is relatively small. Therefore, the lack of detailed operational data for all four by-product sources has been deemed of no significance to the project.

The arithmetic mean of the characterization data of the four dry FGD by-products is listed in Table A.10 of Appendix A. There is significant variance among the four different by-product sources. For example, the average, total CaO content varies as follows: 10.61% for Ebensburg, 18.64% for AES Thames River, 20.94% for Tidd and 28.91% for CONSOL. The spread of calcium carbonate equivalency (or total neutralizing capacity) is from 11.6% CaCO₃ for Ebensburg to 52.6% for Tidd PFBC cyclone ash. An important observation put forward at this time is the relative concentration of sulfides, sulfites and sulfates in the four by-products. In particular, the by-product from the Tidd Station (pressurized fluid-bed combustion) has higher levels of sulfides and sulfites when

compared to those in the by-products from the Ebensburg Power Company (coal waste-fired atmospheric fluid-bed combustion) or from the AES Thames River Plant (coal-fired atmospheric fluid-bed combustion), both of which contain high levels of sulfates. The different sulfur-containing anions exhibit different performances in the stabilization of metal cations. In particular, in conjunction with calcium and silicate ions, sulfates can form ettringite which is known to incorporate certain cations in the structure over an extended period of time. This is being studied in particular by Dr. David Hassett at the University of North Dakota Energy and Environmental Research Center.

The differences in characteristics among the four by-products are due to the different processes from which they are generated and the different compositions of the sorbent and coal utilized. The CONSOL material is unique in the fact that there is little oxidation and the sulfur is mostly in the form of CaSO_3 , in contrast to the EPC and AES Thames River materials which experience oxidation to CaSO_4 . This is mostly due to the collection/absorption of the CONSOL material at lower temperatures than the FBC materials. When anhydrite (CaSO_4) is heated above 300-400°C (as is the case for the FBC materials) it is converted to an insoluble form. During this conversion, the CaSO_4 crystal lattice collapses, becomes tightly packed and does not readily hydrate upon contact with water vapor, thus becoming insoluble. This process, by which anhydrite in the FBC ash does not readily hydrate to hemihydrate ($\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$) or further to gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) as a result of exposure to high temperatures from a boiler, is referred to as "dead burning." Thus, one explanation for the differences among the by-products is that the CONSOL material comes from a low temperature process and does not experience dead burning, whereas the other three by-products are exposed to high temperatures and experience dead burning. In addition to the type of process, the composition of the sorbent also effects the characteristics of the by-product material. The CONSOL material is finer than the FBC materials because of the use of lime instead of limestone as the sorbent. This finer cyclone ash is more reactive, a good characteristic for waste stabilization/solidification. On the other hand, the AES Thames River material uses limestone, which is not as fine as lime, as the sorbent and the EPC material contains bottom ash due to being stored in a common silo with the fly ash, which is more coarse than fly ash alone. As a result, this effects the particle size analysis of the ash. The Tidd material is unique due to its magnesium content as a result of the use of dolomite as the sorbent. The Tidd material also has a high amount of CO_2 in contrast to the AES Thames River material which contains very little CO_2 and unused limestone. A final source of variance among the by-products is the composition of the coal burned. For example, the EPC by-product is characterized by high silica and alumina contents as a result of burning low grade, high ash, coal waste as fuel. Correspondingly, the calcium content of the EPC by-product is low compared to the other three by-product materials.

In summary, the following general observations were made of the by-product characterization:

1. By visual observation, all samples from each source appear to have the same physical appearances, i.e., color and texture.
2. No large variation can be seen within each source in physical properties, such as specific gravity (g/cc) or bulk density (lb/ft³).
3. No large variation can be seen within each source in the "reactivity" and neutralization parameters, such as available lime, calcium carbonate equivalency (CCE) and mixed ratio (solidification of water). The amount of CCE (as % CaCO₃) appears to correlate with the available lime index. The amount of total CaO due to unspent calcium carbonate sorbent can be judged from the amount of CO₂ reported.
4. The totals for the geochemical analysis of major elements calculated to the oxide bases are close enough to 100%, ranging from 96.13-100.33%. (The total is arrived at by adding CaO, MgO, SiO₂, Fe₂O₃, Al₂O₃, SO₃, SO₂ and loss on ignition [LOI at 1100°C].) Minor elements, such as Na, K, Ti, Mn, P and unburned carbon, were not analyzed.
5. Some pH's of EPC and AES Thames River Plant by-products exceeded the upper limit of 12.50 for residual (non-hazardous) landfills, which will cause concern. The pH of lime solutions can exceed 12.50 as the temperature cools below 25°C.
6. Based on the mixed ratio test, all the samples of the four sources show solidification potential, and due to the free or available lime and silica, they all have potential to stabilize heavy metals.

METALS ANALYSIS OF BY-PRODUCTS

None of the four by-products exhibited any of the metal toxicity characteristics based on TCLP extractions of one sample from each source by MSI. The results of the by-product analyses performed by Antech, Ltd. and Pitt are presented in Table A.11 of Appendix A.²⁶ However, the level of three to five TCLP metal concentrations exceeded Land Disposal Restriction treatment standards for all four of the samples. Each of the by-products did contain some metals at concentrations greater than or equal to 20 times the

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²⁶ All of the TCLP results were reported below the analytical detection level except for As in the EPC#3 material and V in all four materials.

toxicity characteristic limits or greater than or equal to 20 times the Land Disposal Restriction (LDR) treatment standards.²⁷ Metal concentrations at these levels were of concern due to the potential that they would contribute to the extractable metals concentrations in the treated waste samples generated during the waste treatment portion of this project. The parameters of concern in each of the by-products were:

- CONSOL #1 (Cd, Cr and Hg)
- Tidd #2 (As, Ba, Cd and Cr)
- EPC #3 (As, Ba, Cd, Cr and Hg)
- AES Thames River #4 (Ba, Cr, Hg and Ni)

In addition, the leachates from the EPC #3 and AES Thames River #4 by-products exceeded the potential future treatment standard for vanadium as seen in Table A.11 of Appendix A.

The results of ASTM and TCLP analyses of additional samples of each of the four by-products performed by Pitt are presented in Table A.12 of Appendix A. The metals concentrations of these additional samples of each of the four by-products were consistent with those of the original four by-product samples (CONSOL #1, Tidd #2, EPC #3 and AES Thames River #4). Since there were no significant variance within each of the by-product sources, all ten samples of each by-product could be used in the treatment of the metal-laden hazardous wastes.

6.2 WASTE EVALUATIONS

Six of the initial eleven wastes received and analyzed at the MSI Yukon plant qualified for use in the Phase 1 treatability studies as analysis of their TCLP extracts verified that these wastes exhibited the expected hazardous waste characteristics. The wastes that qualified and the hazardous characteristics exhibited by each were:

<u>Waste</u>	<u>Characteristic(s)</u>
Industrial Wastewater Treatment Residue from a Battery Manufacturing Plant	Lead
Contaminated Soil from a Remediation Project Conducted at a Munitions Depot	Lead

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²⁷ A safety factor of 0.8 was used to evaluate the data.

Contaminated Soil from a Remediation Project Conducted at an Abandoned Industrial Site	Lead
Contaminated Soil from a Remediation Project Conducted at a Former Sewage Treatment Plant	Lead
Air Pollution Control Dust from Basic Oxygen Furnace Steel Production	Lead
Air Pollution Control Ash from Municipal Waste Incineration	Lead

For each of these six wastes that qualified, a full metals analysis was conducted consisting of total and TCLP concentrations of all 15 metals. These results obtained by Antech, Ltd. (and Pitt for the four graphite furnace AA metals: Sb, Be, Th and V) are presented in Table B.1 of Appendix B.

None of the wastes exhibited any other toxicity characteristics than are identified above (all in fact being principally lead-leaden). However, each of the wastes did contain some metals at concentrations greater than or equal to 20 times the toxicity characteristic limits or greater than or equal to 20 times the LDR treatment standards. Metal concentrations at these levels in the wastes were of concern due to the potential that they would leach under the altered conditions present in the treated waste samples generated during the waste treatment portion of this project. The parameters of concern in each of the wastes were:

Industrial Wastewater Treatment Residue a from Battery Manufacturing Plant: Cd, Pb and Sb

Contaminated Soil from a Remediation Project Conducted at a Munitions Depot: Ba, Be, Cd, Cr, Pb, V and Zn

Contaminated Soil from a Remediation Project Conducted at an Abandoned Industrial Site: Ba, Be, Cd, Cr, Pb, Hg, V and Zn

Contaminated Soil from a Remediation Project Conducted at a Former Sewage Treatment Plant: Be, Pb, V and Zn

Air Pollution Control Dust from Basic Oxygen Furnace Steel Production: Cd, Cr, Pb, Ni, V and Zn

Air Pollution Control Ash from Municipal Waste Incineration: As, Ba, Be, Cd, Cr, Pb, Hg, Ni, Sb, Se, Ag, V and Zn

6.3 TREATED WASTE EVALUATIONS

For each of the 54 treatment combinations conducted at small scale, a determination was first made of its effectiveness for stabilization. The most effective dosage for stabilization was chosen for each of the 18 by-product/waste combinations for intermediate scale testing. For each of the 18 treatment combinations conducted at intermediate scale, the following determinations were made: 1) its effectiveness for stabilization to compare with the test at small scale and 2) its effectiveness for solidification.

STABILIZATION

The results of the metals analyses of the 54 treated waste extracts are given in Tables C.2-C.4 of Appendix C for both immediate and 24-hour TCLP concentrations. These results were evaluated by MSI. The following comments from MSI are based on the use of the by-products as a stabilization (not solidification) agent under conditions that are similar to those employed at MSI's TSD facility on a daily basis. In evaluating the data, the treatment residue TCLP results were compared against the current disposal criteria (TC limits) as well as the anticipated future limits (LDR UTS). The potential that the treatment achieved could be attributed to dilution was also evaluated.

- The EPC #3 by-product is not an effective waste stabilization agent. The use of this by-product generated a treatment residue that could be land disposed under today's standards in only 2 of the 18 treatability tests attempted.²⁸ The successful treatments occurred in the Munitions Depot Soil at the highest by-product dosage tested after the material was allowed to "age" for 24 hours and in the WWTP Soil at the highest by-product dosage. The use of this by-product generated a treatment residue that could be land disposed under the projected future standards in only 1 of the 18 treatability tests attempted (WWTP Soil at the highest by-product dosage).
- The Tidd #2 by-product was generally more effective than the EPC #3 by-product but MSI's overall evaluation is that it is not an effective waste stabilization agent either. The use of this by-product generated a treatment residue that could be land disposed under today's standards in only 3 of the

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²⁸ A second test also appeared to be successful (Multi-Use Industrial Site Soil at the highest by-product dosage); however, the extraction performed after the treatment residue aged for 24 hours failed to confirm the initial result.

18 treatability tests attempted.²⁹ The successful treatments occurred in the Munitions Depot Soil, the Multi-Use Industrial Site Soil and the WWTP Soil at the highest by-product dosage tested in all 3 cases. The results of the fresh and aged materials were comparable. Both meet today's land disposal standards. The use of this by-product generated a treatment residue that could be land disposed under the projected future standards in only 1 of the 18 treatability tests attempted (Munitions Depot Soil at the highest by-product dosage).

- The CONSOL #1 by-product was the most effective of the three by-products tested and MSI would consider it to be an effective waste stabilization agent when used in combination with certain types of wastes. The use of this by-product generated a treatment residue that could be land disposed under today's standards in 13 of the 18 treatability tests attempted.³⁰ The successful treatments occurred in the Battery Manufacturing Sludge, Munitions Depot Soil, Multi-Use Industrial Site Soil and WWTP Soil at all of the by-product dosages tested and in the BOF Dust at the highest by-product dosage tested (after aging). The results of the fresh and aged materials were comparable. Both meet today's land disposal standards. The use of this by-product was less successful in generating a treatment residue that could be land disposed under the projected future standards. Only 4 of the 18 treatability tests attempted (Battery Manufacturing Sludge/all by-product dosages, Munitions Depot Soil/highest by-product dosage) achieved the future standards. The success of the CONSOL by-product is such that MSI has calculated the value that MSI would place upon the CONSOL by-product as a commercial treatment product, FOB the Yukon Plant, if it were used in the best recipe found to date (see Section 6.5 for the economic evaluation).
- None of the by-products were particularly successful in stabilizing the wastes generated by high temperature processes (BOF Dust and Municipal Incinerator Ash). MSI assumes this may be due to the form of the metals present in these wastes (likely present as oxides that leach but do not readily chemically combine with the constituents available in the by-products).

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²⁹ As with the EPC #3 by-product, the Tidd #2 by-product produced a treatment residue when combined with a third waste (Battery Manufacturer Sludge at the highest by-product dosage) that also appeared to be successful based on the initial analysis; however, the extraction performed after the treatment residue aged for 24 hours failed to confirm the initial result.

³⁰ As with the other by-products, the CONSOL #1 by-product produced one treatment residue (BOF Dust at the lowest by-product dosage) that also appeared to be successful based on the initial analysis; however, the extraction performed after the treatment residue aged for 24 hours failed to confirm the initial result.

- Overall, there was little difference in the results achieved in the treatment residues analyzed immediately after treatment and in the residues analyzed after a 24-hour aging period.
- The EPC #3 by-product does not appear to offer much buffering capacity based on the fact that Extraction Fluid #1 was used in most of the TCLP extractions.
- The lower pH values of the treated materials are not a problem as they are well above the lower limit for residual (non-hazardous) landfills. As mentioned previously, some samples of the original by-products do, however, exceed the upper limit of 12.5.
- None of the successful treatments achieved could be attributed solely to dilution. Thus, the success of the treatments may be directly attributed to encapsulation/stabilization or reduction in permeability caused by the by-products as treatment chemicals.

Metal Stabilization

Evaluation of the treatability data of the 54 treatment combinations conducted at small scale indicates that lead and zinc were the principal metals governing the success of the treatments. In the treatability tests performed on the three contaminated soils, lead was the only metal that exceeded current regulatory levels in any of the treatments. This was also the case with the Battery Manufacturing Sludge. Treatments of the BOF Dust and the Municipal Waste Incinerator Dust proved more challenging. Both of these wastes exhibited high amounts of lead and zinc in the TCLP extracts of the treatment combinations. The Municipal Waste Incinerator Dust also proved hazardous for cadmium leachability after treatment, even though the raw waste did not exhibit toxic levels of cadmium leachability. Based on these observations, detailed discussions of lead, zinc and cadmium stabilization in the treated wastes is presented below.

Lead Stabilization

Based on the results of the treatability tests performed during Phase 1, the CONSOL by-product appears to be more effective in immediately stabilizing lead than either the Tidd or Ebensburg by-products. The CONSOL by-product was generally successful in stabilizing lead at the lowest dosage (10%), while the Tidd and Ebensburg by-products usually required a higher dose (50%). The CONSOL by-product effectively reduced the TCLP lead concentrations of all six wastes to a level below the current

regulatory limit of 5.0 mg/L. With the exception of the BOF Dust, the dosage required for treatment was 10%. The BOF Dust required a dosage of 50%, and also required 24 hours to stabilize (the immediate TCLP lead concentration for the 5:10 CONSOL:BOF Dust mixture was 6.9 mg/L). The by-product from CONSOL immediately stabilized the lead in the more acidic wastes (containing hydroxides, sulfates, etc.) surprisingly well, even without the phosphate-containing additive usually used by MSI. In fact, it exceeded current regulations far enough to even meet the proposed future land disposal regulations. However, it did not perform well with the more highly oxidized materials. Graphs illustrating lead stabilization with the CONSOL by-product (both immediate and after 24-hours) are shown in Figures 6.1 and 6.2.

The Tidd by-product is generally more effective than the Ebensburg by-product in stabilizing lead. At a dosage of 50%, the Tidd by-product effectively reduced the TCLP lead concentration of three wastes (Munitions Soil, Industrial Soil and Wastewater Treatment Plant Soil) below the current regulatory limit of 5.0 mg/L. Treatment of the Battery Manufacturing Sludge with the Tidd by-product at a dosage of 50% met the regulatory limit for lead with the immediate TCLP, but failed to meet the regulatory limit with the 24-hour TCLP. The 24-hour TCLP lead concentration of this mixture was 5.1 mg/L. Graphs illustrating lead stabilization with the Tidd by-product (both immediate and after 24-hours) are shown in Figures 6.3 and 6.4.

The Ebensburg by-product was effective in stabilizing lead in only two of the six wastes evaluated. Treatment of the Munitions Soil and the Wastewater Treatment Plant Soil with the Ebensburg by-product at a dosage of 50% resulted in treatment residues with TCLP lead concentrations below the regulatory limit of 5.0 mg/L. Graphs illustrating lead stabilization with the Ebensburg by-product (both immediate and after 24-hours) are shown in Figures 6.5 and 6.6.

None of the by-products were particularly successful in stabilizing the lead present in wastes generated by high-temperature processes (BOF Dust and Municipal Waste Incinerator Dust). The lead present in contaminated soils and sludges was stabilized much more readily.

Based on data collected to date, there appears to be little difference in stabilization between the immediate TCLP and the 24-hour TCLP. In some instances, lead concentrations decreased slightly after 24 hours, while in other instances lead concentrations increased slightly after 24 hours.

**Fig. 6.1: Lead Concentration in Wastes
Treated With CONSOL By-Product**
Immediate TCLP

**Fig. 6.2: Lead Concentration in Wastes
Treated With CONSOL By-Product
24-Hour TCLP**

**Fig. 6.3: Lead Concentration in Wastes
Treated With Tidd PFBC By-Product**
Immediate TCLP

**Fig. 6.4: Lead Concentration in Wastes
Treated With Tidd PFBC By-Product
24-Hour TCLP**

**Fig. 6.5: Lead Concentration in Wastes
Treated With Ebensburg By-Product**
Immediate TCLP

**Fig. 6.6: Lead Concentration in Wastes
Treated With Ebensburg By-Product
24-Hour TCLP**

Zinc Stabilization

The CONSOL by-product was not particularly successful in stabilizing zinc. The CONSOL by-product failed to reduce zinc levels of the Munitions Soil and the Industrial Soil below the projected future level of 5.3 mg/L at any dosage. In the case of the Municipal Waste Incinerator Dust, the zinc concentration of the untreated waste was below the 5.3 mg/L level, however, treated residues exhibited TCLP levels of zinc several hundred times greater than the untreated waste TCLP, which greatly exceeded the 5.3 mg/L level.

The Tidd by-product effectively controlled zinc levels in at least one dosage with every waste except the Municipal Waste Incinerator Dust. Like the CONSOL by-product, zinc levels in the Tidd/Municipal Waste Incinerator Dust mixture were several hundred times greater than the raw waste leachable zinc concentration and greatly exceeded the 5.3 mg/L level.

The Ebensburg by-product provided zinc stabilization results similar to the Tidd by-product. The Ebensburg by-product controlled zinc levels to acceptable amounts in at least one dosage of each of the waste combinations, with the exception of the Municipal Waste Incinerator Dust.

None of the by-products evaluated were particularly successful in stabilizing zinc in the case of the Municipal Waste Incinerator Dust. As just noted, the TCLP zinc concentrations of the treated waste combinations were several orders of magnitude higher than the TCLP zinc concentrations of the untreated waste. This indicates that zinc is being released from this waste with the addition of the by-products, possibly due to the pH change that occurs.

Cadmium Stabilization

Even though none of the raw wastes exhibited toxic levels of cadmium leachability, all of the treated Municipal Waste Incinerator Dust combinations had TCLP concentrations significantly higher than the TCLP concentrations of the untreated waste and exceeded the current cadmium BDAT standard of 1.0 mg/L, both immediately or after 24 hours. Like zinc mentioned above, this indicates that cadmium is being released from this waste with the addition of the by-products, possibly due to the pH change that occurs.

Factors Affecting Stabilization

It is difficult to determine what specific parameters account for the differences in effectiveness of metal stabilization. The Ebensburg by-product has a percent free lime (%)

CaO) less than half that of the CONSOL and Tidd by-products, which may account for its inability to stabilize the lead present in the wastes as effectively as the Tidd or CONSOL by-products. The CONSOL by-product has a Blaine fineness about twice as high as the Tidd and Ebensburg by-products. This may indicate that the increased surface area of the CONSOL by-product is responsible for its effectiveness as a stabilizing agent. The means by which metals are incorporated into the final crystal structure of the stabilized waste will be examined in Phase 2 by evaluation of mineralogical and chemical transformations using x-ray diffraction and scanning electron microscopy.

Stabilization of By-Product/Waste Mixtures Prepared for Solidification Testing

At the time of this report, the analyses of the by-product/waste mixtures prepared for solidification testing for all 15 metals were incomplete. Analysis of 9 metals (Ag, Be, Cd, Cr, Cu, Pb, Ni, Sb and Zn) has been completed for all treated waste samples prepared for solidification, however, not all samples have been analyzed for the remaining 6 metals (As, Ba, Hg, Se, Tl and V). The results to date of the metals analyses of the 24-hour ASTM and 90-day TCLP extracts of the by-product/waste mixtures prepared at MSI for compressive strength testing are given in Table C.5 of Appendix C. The results to date of the metals analysis of the 28 and 90-day TCLP extracts of the cylinders prepared for Proctor testing are given in Table C.6 of Appendix C. A detailed discussion of these results will be reported during Phase 2 when analyses of all 15 metals are complete.

SOLIDIFICATION

Cylinders Prepared for Compressive Strength Testing

Evaluation of the compressive strength data for the by-product/waste mixtures obtained during Phase I indicates that significant solidification takes place over time with both the Tidd PFBC residue and the Ebensburg CFBC residue. However, the CONSOL spray dryer residue does not indicate the development of significant solidification over time. A summary of the compressive strength of the eight by-product/waste mixtures evaluated during Phase 1 is presented in Table C.7 of Appendix C. This table presents the values of unconfined compressive strength of the eight mixtures after curing times of 3, 7, 14, 28 and 90 days. Blank entries in the table indicate that solidification sufficient to evaluate the compressive strength for that particular mixture, at that particular curing time, had not yet occurred.

The Ebensburg by-product produced mixtures with the highest unconfined compressive strength of the three by-products evaluated. A mixture of the Ebensburg by-product and the Wastewater Treatment Plant Soil produced the highest compressive strength of all by-product/waste combinations evaluated for solidification properties. This

mixture produced an average unconfined compressive strength of 652 pounds per square inch (psi) after a curing time of 28 days. The 90-day unconfined compressive strength of this mixture was 539 psi, a reduction in strength of 17%. A mixture of the Ebensburg by-product with the Munitions Depot Soil produced the second highest unconfined compressive strength of all combinations evaluated. This mixture produced an average unconfined compressive strength of 494 psi after 28 days. The 90-day unconfined compressive strength of this mixture was 341 psi, a reduction in strength of 31%. As of the completion of this portion of the evaluation, the reason for the decrease in unconfined compressive strength during the curing period between 28 days and 90 days is not known. One explanation for the reduction in strength may be related to the high sulfate content of the by-product. The presence of high amounts of sulfate can cause sulfate attack, whereby the formation of expansive solids can result in cracking, deterioration and an associated decrease in strength. SEM/XRD analysis during Phase 2 may provide information showing whether or not expansive solids are being formed.

The Tidd by-product was not as effective as the Ebensburg by-product in solidifying the wastes evaluated, but still produced very good solidification properties. Four by-product/waste combinations were evaluated for unconfined compressive strength using the Tidd by-product. Figure 6.7 illustrates the strength development over time of the four mixtures prepared with the Tidd by-product. A mixture of the Tidd by-product with the Multi-Use Industrial Site Soil produced the highest strength of these four mixtures. This mixture produced an unconfined compressive strength of 378 psi after 90 days of curing. The three other mixtures prepared with the Tidd by-product produced 90-day compressive strengths between 188-364 psi. All four of the mixtures prepared with the Tidd by-product produced increasing compressive strength over the entire curing time, in contrast to the decrease in strength exhibited by the EPC by-product/waste mixtures between 28 and 90 days of curing.

The CONSOL by-product/waste mixtures did not indicate the development of significant solidification. Two mixtures were prepared using the CONSOL by-product as the solidification agent. In both cases, the 90-day compressive strength of the mixtures was less than 50 psi. The end product of the CONSOL mixtures after 90 days of curing was a weak and brittle solid, as opposed to the hard and solid monoliths produced with both the Ebensburg and Tidd by-products. The difference in solidification properties of the three by-products is illustrated in Figure 6.8, which shows the compressive strength development of the Munitions Depot Soil when solidified with the three different by-products. The lack of significant strength development with the CONSOL by-product indicates that there is little crystal growth when this residue is used as a solidification agent. This lack of crystal growth may be attributable to a high amount of unburned carbon in this residue, which may form carbonates instead of strength-forming compounds such as calcium silicate hydrate (tobermorite gel). SEM/XRD analysis during Phase 2 may give insight into the types of crystalline species being formed with each of the by-products and their effects on strength development.

FIG. 6.7: Solidification of Hazardous Wastes With Tidd PFBC By-Product

FIG. 6.8: Solidification of Munitions Depot Soil With CCT By-Products

Cylinders Prepared for Proctor Testing

Three mixtures were evaluated completely for stabilization/solidification by the Proctor compaction method. Tables C.8-C.13 of Appendix C illustrate the construction of the compaction curve and determination of the optimum moisture content for three mixtures. Compressive strength samples of these three mixtures were prepared and tested for unconfined compressive strength at periods of 14, 28 and 90 days. The results are summarized Table C.14 of Appendix C. The results show that significant solidification did not occur in these samples in the 90-day period they were stored. However, these samples still possess strengths similar to comparable soils. Additional time may be needed for the pozzolanic materials in these samples to activate. Long-term evaluations of these samples will continue into Phase 2 of this project.

6.4 SUMMARY OF NEPA REPORT

The Center for Hazardous Materials Research (CHMR) prepared an environmental information report to fulfill requirements for environmental review of a U.S. DOE proposed action pursuant to DOE's Implementing Procedures (10 CFR 1021, Subpart B) under the National Environmental Policy Act (NEPA). This report is supplemented by a completed DOE Morgantown Energy Technology Center (METC) Environmental Questionnaire to determine the level of NEPA required. In order to determine the potential environmental impacts of the proposed demonstration project, current environmental characteristics of the Yukon Plant site as well as potential impacts resulting from the project were evaluated. The project information included in this report consists of a description of the proposed action, project and report objectives, estimated project schedule, proposed action location and facilities, and a summary of the permits obtained by the MSI Yukon Plant facility and any other permits required to conduct the Phase 2 demonstration project.

A copy of CHMR's environmental information report can be found in Appendix D. The findings of the environmental review, which indicate that no significant direct, indirect or cumulative impacts are anticipated, can be summarized as follows:

- There will be no new impacts on land use or aesthetic views of the region as a result of the proposed action.
- There will be negligible air quality impacts on the Yukon Plant site and surrounding area as a result of the proposed action.
- The proposed project activities will not impact a floodplain or wetland, require diversion of a flowing body of water or alter a drainage pattern, cause an increase or decrease in the surface area of an existing body of water, or cause soil erosion or adversely affect the quality or movement of

groundwater.

- The proposed action will not significantly affect plant or animal species or their habitats, endangered or threatened plant or animal species, or migratory condors.
- There will be no affect on any archaeological or historic resources as a result of the proposed action.
- There will be no effects on local population, the transportation system, public services, property values or energy resources as a result of the proposed action.
- There will be no new worker health and safety issues as a result of the proposed action.

6.5 ECONOMIC EVALUATIONS

An important element of Phase 2 of this project will be a comprehensive economic analysis of the technical approach. Several of the key parameters that will affect the economic success of this work may be indentified by considering the already available specific financial computations that can be made for the application of the by-products to be used in this project to treat wastes at the MSI Yukon plant. Transportation and disposal costs, waste tipping fees and prices for by-products will be developed. A base case will be developed for each commercially useful waste/by-product combination, assuming a specific transportation distance, mode of transportation, ash conditioning, tipping fee and other factors influencing the cost for disposal or treatment of the by-product and metal-laden hazardous waste. A sensitivity analysis for each factor will then be performed. Comparisons will then be made with the cost of current commercial practices. Preliminary examples, based on a classssical, external viewpoint are presented and discussed below.

For the CFBC residue from Ebensburg Power Company, \$320 is required for transport of 50 tons of by-product, containing 12.5% limestone equivalent (6.2 tons), to MSI's Yukon Plant from the cogeneration plant in Ebensburg. From this, however, may be subtracted an \$80 tipping fee for the elimination of the cost of hauling the waste back to the mines. Thus, transportation costs for this by-product are $(\$320 - \$80) / 6.2 \text{ tons} = \$38.71/\text{ton}$ limestone equivalent. The inert in the CFBC residue requires \$10/ton less than the \$25 charge to MSI because of a tipping fee generated by eliminating the disposal cost at the mines. Thus, $(\$15/\text{ton} \times 43.8 \text{ tons inert}) / 6.2 \text{ tons limestone equivalent} = \$657 / 6.2 = \$105.97$ is needed for disposal of the inert in this residue. As a result, the total cost of limestone equivalent from this by-product at MSI is $\$38.71 + \$105.97 = \$144.68/\text{ton}$ of limestone equivalent.

For the dry scrubber residue from CONSOL, Inc., \$150 is required for transport of 50 tons of by-product, containing 12% limestone equivalent (6 tons) to the Yukon Plant from the cogeneration plant in New Jersey. Transportation costs for this by-product are $\$250/6 \text{ tons} = \$41.67/\text{ton}$ limestone equivalent. The inert in the dry scrubber residue requires $(\$25/\text{ton} \times 44 \text{ tons inert})/6 \text{ tons limestone equivalent} = \$1,100/6 = \$183.33/\text{ton}$ limestone equivalent for disposal. Thus, the total cost of limestone equivalent from this by-product at MSI is $\$41.67 + \$183.33 = \$225.00/\text{ton}$ of limestone equivalent.

In these two examples, it is assumed that the lime or limestone equivalent remaining in each by-product is fully available as a treatment chemical. This is likely not to be true in practice. To balance this, however, no economic benefit has been attributed to the stabilization characteristics of the "inert", which includes both fly ash and calcium sulfite and sulfate, both of which are accepted as treatment materials in their own right.

These examples also clearly show that transportation and disposal costs for the "inerts" in the by-products are serious considerations. Certainly, the foregone transportation and disposal costs to the utility must be applied to the total cost, resulting in a tipping fee to the hazardous waste treater, which can eliminate a portion of those new costs. However, in neither of the two cases does the cost of lime or limestone equivalent fall below that of spent lime.

One thing that is needed in these economic calculations are reduced transportation costs, obtained by decreasing the distance or the mileage per ton-mile between the by-product generator and the waste treater. Also needed are reduced disposal costs, which can only be brought about by the delisting of the non-hazardous product of treatment of hazardous waste with by-product.

Examining the economics from MSI's viewpoint, the results of the treatability tests using the three by-products reflect that only the CONSOL by-product could be substituted for chemicals currently used by MSI in the treatment of certain wastes. Actual field operations at the MSI Yukon treatment facility reflect a use of 15% of treatment chemicals to successfully treat a ton of similar waste as treated with the CONSOL by-product. The cost of chemicals to treat and the cost of disposal of treatment residue of one ton of waste is as follows:

Historical Costs

Chemicals 15%	\$ 12.85
Cost to dispose of treated residue	\$ 27.60
Total	<u>\$ 40.45</u>

The above analysis takes into account only direct costs and not the costs associated with the labor for treatment, lab analysis or the cost for storage. MSI, however, has estimated

incremental costs for the additional by-product needed for treatment. They estimate that the incremental cost per ton would be approximately \$7. (The incremental costs cover additional storage and handling costs as the additional by-product will change the treatment scheme. For instance instead of treating 3 ½ loads per batch, they would be limited to 3 loads per batch with the additional by-product. Every 6 loads of waste would require an extra storage container and land space for storage.)

Adding these estimated costs to the transportation and disposal costs of the treated residue, MSI would need to charge CONSOL \$2.55 per ton to break even. This price would be a delivered price to the MSI's Yukon facility.

Projected Costs:

CONSOL by-product 50% Charge	\$ 2.55
Cost to dispose of treated residue	\$ 36.00
Estimated incremental costs	\$ 7.00
Total	\$ 40.45

An analysis would be needed to study the feasibility and impact that using the by-product would have on the limited space available for the treated residue and the additional time required to use the by-product. In addition, it appears that the by-product can be used but the question is how will it actually work in the field. Lab treatabilities do not always imitate exactly the field operations. The actual use of the by-product in the field may provide different results. This all is to be examined in Phase 2.

It should be noted that Phase 1 is based upon the chemicals that MSI currently utilizes now in its actual operations which does not adequately compare with the typical hazardous treatment industry today. Most other facilities make use of kiln dust in addition to other materials that MSI is not yet permitted to use in the treatment of like wastes. Therefore the results of this study will not be directly applicable to other hazardous treatment facilities.

A final aspect of a commercial project using by-product to treat hazardous waste is the need for proper indemnification and insurance for the by-product generator and the operator of the treatment plant against any future liability arising from the disposal of the stabilized waste. The cost of this type of insurance and the present value of any litigation that might arise in the future will need to be estimated and factored into the economic analysis. The experience that similar projects have had with these problems will be examined in the Final Report of this project.

7.0 CONCLUSIONS

Four measures of success may be applied to this project. The first is a specific measurement, while the others are increasingly more general in the order listed below.

The specific measurement is simply the discovery for each by-product/waste combination of that amount of by-product which is just sufficient to render the hazardous waste either non-hazardous and acceptable for land disposal under current RCRA regulations or slowly but eventually non-hazardous and potentially acceptable for structural fill. Further success is achieved if an economic advantage is observed by the use of a hypothetical "nearby" by-product to treat the waste. The third measure of success is the agreement in principle that proper indemnification is achieved for the nearest available by-product to a commercial waste treatment plant. Finally, the project will be a total success if one or more by-product producers find continuing markets for their materials as waste treatment agents.

It was observed that by-products from advanced Clean Coal Technologies contain large amounts of two components that waste lime products, currently used by Mill Service, Inc., lack:

- Pozzolanic precursors which slowly build cementitious structures into the composite product of hazardous waste treatment
- Sulfates which combine with pozzolans to slowly build ettringite crystals into the composite product of hazardous waste treatment.

By-products from four different advanced Clean Coal Technologies were collected and analyzed, of which three were used in treatability studies to determine their ability to stabilize and solidify characteristic metal-laden hazardous wastes.

The hazardous waste treatment business that MSI operates must use treatment chemicals that immediately stabilize metals. The company can ship (with a tipping fee to a permitted, non-hazardous, industrial landfill) only treated wastes whose characteristic hazard has been eliminated. A treatment chemical which requires some days to remove the characteristic hazard is not economically useful to MSI. Thus, only immediate stabilization has been examined so far in the tests conducted by the project team. On this basis, the CONSOL by-product has been found to be a very effective treatment chemical. The EPC by-product was the least effective, while the Tidd by-product was more effective than that from EPC, but still not sufficient to be considered of commercial interest to MSI. None of the by-products were particularly successful in stabilizing the wastes generated by high temperature processes (BOF Dust and Municipal Incinerator Dust).

The project team sees the possibility that an economically successful hazardous waste treatment business might be devised, however, in which treatment of hazardous waste is obtained using a slow stabilization chemical. The economics would be obtained if the treated waste, after proof of its having become characteristically non-hazardous by the end of a "curing" time, would be sold as a structural fill to a nearby construction project. For a use such as this, a "successful" treatment chemical will stabilize the metals within a reasonable curing time. This slower rate of stabilization is one area for further research in Phase 2.

In the Final Report of this project, the amount of by-product required for stabilization and the compressive strength developed during solidification will be compared across by-products and wastes, using characteristic physical and chemical properties of by-products and concentrations of individual metal contaminants of wastes for developing correlations and for seeking underlying principles. The background on variability of properties, developed from METC contractors, coal and sorbent providers, by-product providers and analyses performed in this project to date plus future analyses (such as characterization of metal uptake in stabilized wastes by SEM/XRD), will be used for comprehensive interpretation of the stabilization results.

8.0 SUGGESTIONS FOR FURTHER RESEARCH

OVERVIEW OF WORK PLANNED FOR PHASE 2

The principal work of Phase 2 centers on field studies. For up to ten of the by-product/waste combinations giving immediate successful stabilization as evaluated during the laboratory studies of Phase 1, one commercial batch of waste will be treated with by-product by MSI and analyzed there for leachable (TCLP) concentrations to determine whether the waste has been stabilized. If additional space is permitted (application is being considered at the present time), several product/waste combinations giving slow successful stabilization as evaluated during the laboratory studies of Phase 1 will be substituted. For combinations giving immediate stabilization, 3" x 6" cylinders for measuring compressive strength will be cast from the large-scale batch at the time of treatment (the addition of water will likely be necessary in order for the full-scale treatment batches to solidify), taken to Pitt and tested there. For any combinations giving slow stabilization, material for use in measuring compressive strength and stress behavior will be collected from large-scale batches as received by MSI, taken to Pitt and tested there. Small-scale samples will then be prepared at Pitt with dosages bracketing that used at MSI and tested for leachable (TCLP) concentrations to verify the range of dosages leading to stabilization.

The field studies will be conducted at the Yukon Plant of MSI. They will consist of up to ten full-scale treatments using the same by-product and waste matrices as evaluated in the laboratory treatability studies. To the extent possible, the treatments will be performed using the same wastes evaluated in the laboratory treatability studies. However, MSI is unable to guarantee that those same wastes will be available at the time the full-scale treatments are to be conducted. Only wastes authorized for management at the Yukon Plant will be used in the full-scale tests.

The up to ten waste/by-product combinations selected will be mixed at the optimum of the three dosages as determined by the laboratory treatability studies. In the event the laboratory testing of a particular waste/by-product combination does not indicate that the levels of the metals of concern in each of the wastes can be reduced to below the hazardous level, no full-scale testing of that waste/by-product combination will be conducted. All mixing of wastes and by-products will be performed in the Solid Waste Stabilization/Solidification Unit at MSI's Yukon Plant. As in the laboratory, water will be added to activate the reaction between the waste and by-products.

The full-scale treatments will be performed on batches consisting of up to 20 tons of treated waste. Following treatment, the waste will be loaded into containers for storage pending the results of TCLP analysis. As in the laboratory tests, TCLP testing and metals (11) analyses will be conducted immediately following treatment and after a 24 hour

holding period. For slow stabilization (if permitted) a third TCLP test will be conducted at the end of the curing period. An aliquot of the treated waste will also be provided to Pitt for compressive strength (3-day, 7-day, 14-day and 28-day) and stress analyses (as appropriate).

Following a successful demonstration, the ten treatment residues will be disposed at an authorized facility.

Also following a successful demonstration, Pitt will identify a higher and a lower dosage as compared to that used by MSI and will conduct a laboratory-scale treatment, similar to those conducted at MSI during the laboratory studies. These samples will be analyzed for leachable (TCLP) concentrations of the eight RCRA metals and up to three other metals of concern to provide a data base for correlation with the results of the laboratory studies.

The field studies at MSI's Yukon Plant also match precisely with its normal activities as a RCRA hazardous waste treatment facility under Pennsylvania Department of Environmental Protection permits with one possible exception. A particular new problem that may be encountered during the field studies there is that of fugitive dust. The by-products being examined in this project all are residues from systems that operate with sorbents having no bulk moisture associated with them, except in some cases during their injection into the combustor, ductwork or scrubber. Thus as product materials they have a significant potential for dust emissions. This potential will have to be carefully evaluated and dust suppression methods employed properly when they are being used by MSI as treatment materials.

A question might naturally arise at this point concerning the possibility of one or more field test batches of treated hazardous waste not being rendered non-hazardous, because of the ineffectiveness of by-product at large scale. Provision for such an occurrence is standard at the Yukon Plant. Any batch that MSI fails to render non-hazardous is transferred to a hazardous waste disposal site by MSI. The same will be done with any batches from this project that fail to be rendered non-hazardous by treatment with by-product, or - more likely - the waste will be retreated with conventional reagents employed by MSI.

A second major element of the work of Phase 2 will be fundamental laboratory work conducted at Pitt. A number of fundamental questions have been developed in Phase 1, relating to immediate vs. slow stabilization, solidification leading to concrete for grouting vs. compacted materials (soil-like) for structural filling. In addition to the normal evaluations of materials and extracts flowing from the field studies, the project team members from Pitt will conduct fundamental examinations of the microscopic properties and rates of both stabilization and solidification of different waste/by-product combinations of interest as suggested by the work of Phase 1 and the field studies of Phase 2. Details

of the various aspects of this second major element of the work of Phase 2 are provided in the following sections.

CHARACTERIZATION OF METAL UPTAKE IN STABILIZED WASTES

Two principal areas require considerable new work: 1) mineralogical studies of fresh by-product and stabilized waste products and 2) experiments directed toward understanding if and by what means metals are incorporated into the final crystal structure of the stabilized/solidified waste. Professor Jean Blachere of the Materials Science and Engineering Department of the University of Pittsburgh can provide much assistance in both of these areas.

Several evaluations of aged treated wastes (aged either naturally or with acceleration) for mineralogical and chemical transformations, such as x-ray diffraction (XRD) and scanning electron microscopy (SEM), will be performed with particularly attractive waste/by-product combinations at Pitt. The following is a brief description of the XRD and SEM methodologies available in the Materials Science and Engineering Department.

X-ray Diffraction. The X-ray diffraction laboratory contains two state-of-the-art Phillips "X-pert" X-ray diffractometers. These instruments are PC based and built around the Phillips optical goniometer which offers a tenfold increase in sensitivity when compared with more standard diffractor goniometers with stepping motor systems. One diffractometer is dedicated to powders and thin film diffraction. It can be fitted with a curved monochromator for diffraction under focussing symmetrical conditions used for powder diffraction. This instrument is also equipped with parallel beam optics with a flat monochromator for asymmetric grazing incidence diffraction and X-ray reflectivity measurements on thin film. In grazing angle diffraction, the low value of the angle of incidence of the X-rays on the surface of the sample controls their depth of penetration into the sample. X-ray diffraction and phase identification can be performed, therefore, as a function of depth nominally from 20 nm to 50,000 nm. A hot stage is also available for these experiments (up to 1,200°C). Extensive software is available for spectrum processing, phase identification, quantitative analysis, etc. The second diffractometer is fitted with a eulerian cradle and dedicated to the study of textures of materials and other special experiments using an X-ray point source. It is used to generate quantitative pole figures and orientation distribution functions.

Scanning Electron Microscopy. The microanalysis laboratory is built around JEOL JSM-35CF research SEM which is fitted with two X-ray crystal spectrometers and an energy dispersive X-ray spectrometer (EDS) for microanalysis. The microscope has a resolution of 6 nm in the secondary electron imaging mode. It has a back scattered electron detector capable of imaging with atomic number contrast on flat specimens. The

X-ray microanalysis can be performed on a volume as small as $1\text{ }\mu\text{m}^3$. The crystal spectrometers are equipped with six different crystals and can analyze all elements of the periodic table down to boron. The EDS system analyzes all elements with atomic numbers greater than ten. The computer based EDS system is currently being upgraded with a MacIntosh Quadra 650 and new DST software from NIST. The new computer system will store the X-ray characteristic spectra and have available various modes of quantitative X-ray microanalysis based on the ZAF, $\phi(\rho z)$ methods. The computer system, currently under installation, will also acquire and archive digital SEM micrographs on hard discs and will have extensive image processing capability using NIH image. The image or analytical outputs will be printed with the Polaroid digital palette.

LONG TERM STABILIZATION

Pitt is also exploring the possibility of examining the long-term stabilization performance of the Tidd and Ebensburg by-products with the suggestion to consider their beneficial use in structural fills, mortars and grouts. Portland cement-based stabilizers (and by inference pozzolanic stabilizers) tie up lead much more slowly than the lime-based stabilizers. Thus, it is not surprising that the EPC and Tidd materials were immediately unsuccessful. Stabilization over a longer time should be explored with these materials. The slow stabilization of those wastes with by-products which do not provide immediate stabilization will be examined by conducting a TCLP extraction on the treated waste cured for the usual period of time before placement in a structural fill.

Unfortunately, commercial treaters such as MSI cannot economically utilize such slow stabilizers under their existing temporary storage permits, which limit the amount of space in which treated wastes may be held while awaiting clearance from TCLP tests for transfer to landfill. MSI cannot afford to store the treated material more than the one day required to run a TCLP on the immediate product of stabilization, as the TCLP extraction requires 18 hours and the metals analysis requires 6 hours. However, a different commercial scenario is conceivable in which a slowly (but surely) stabilized waste is placed in a monitored structural fill. Such a placement would likely be made using a treated product having soil-like properties (lower water content), rather than slurry properties (higher water content) such as are used to pour (trowel) as mortar (with or without coarse aggregate) into concrete forms or to pump as grout into cavities. Under this new scenario, the solidification characteristics of the soil-like material become important. Because these characteristics are best determined through the Proctor Test, rather than the typical mortar test, the project team prepared a request (which was approved) to modify the test plan to evaluate long-term stabilization and to shift to Proctor Testing for those waste/by-product mixtures which were stabilized only in the long-term. The project team will expand its examination in Phase 2 to include the determination of successful slow stabilization recipes and the compaction (as a soil-like material) of treated wastes obtained by these slow successful recipes. Such materials would be useful in structural fills,

pavement bases and subbases, and stabilized subgrades.

USE OF ADDITIVES TO IMPROVE STABILIZATION

It was agreed that the by-products from the Ebensburg Power Company and the Tidd Station did not immediately stabilize lead in any of the hazardous wastes tested. The project team is discussing the possible use of additives to improve the performance of the EPC and Tidd by-products for use commercially by MSI for rapid stabilization and landfilling of the product. The principal type of additive used by MSI and other waste treaters to stabilize lead-containing wastes is one containing the phosphate ion. The phosphate ion is reported as the usual second ingredient in a lime-based hazardous waste treatment. [Conner, 1990] Many commercial sources of the phosphate ion contain silicates which are also known to participate significantly in metal stabilization.

FREEZE-THAW TESTS

Several modified freeze-thaw tests may be performed with particularly attractive waste/by-product combinations at Pitt, either using existing funds if they can be included in the test plan for Phase 2 with no additional cost, or using funds provided by the U.S. DOE which expand the present budget, all as approved by the COR.

PERMEABILITY TESTING

Another idea for further research might be to acquire and use a flexible-wall, high-pressure permeameter to evaluate the diffusion of water through the concrete cylinders prepared during the solidification testing portion of the project.

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APPENDIX A: RESULTS OF BY-PRODUCT EVALUATIONS

TABLE A.1: ANALYSIS OF THE CONSOL BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Consol#1	Consol#2	Consol#3	Consol#4	Consol#5	Consol#6	Consol#7	Consol#8	Consol#9	Consol#10
CaO	25.41				28.91		29.2			
MgO	0.7				0.7		0.61			
SiO2	22.33				20.18		20.09			
Fe2O3	6.23				6.39		6.32			
Al2O3	11.4				10.24		9.98			
CO2	3.58				3.94		3.55			
Total Sulfur as S	9.62				10.03		9.62			
SO3	1.79				3.11		1.94			
SO2	17.79				17.55		17.67			
LOI@ 600 oC	3.17									
LOI @ 1100 oC	14.68				13.13		12.09			
Total of Elements Determined	100.33				100.21		97.9			

Reactivity:	1	2	2	1	4	3	3	4	2	1
Temperature Rise of	42.5	42.1	42.2	42.8	46.4	47.2	48	44	47	39
Calc. Carb. Equiv., %CaCO3	3.2	2.3	3	2.2	4.89	4.65	6.6	4.6	6.3	2
Available Lime Index, %CaO	12.36@26	12.30@23	12.25@23	12.29@24	12.51@18C	12.56	12.3	12.3@24C	12.3@24C	12.3@24C
pH (soil)	13	13	13	13	13	13	12	12	14	13
Mixed Ratio (lbs/gal)										

Physical Properties:	2.4	2.4	2.42	2.42	2.4	2.4	2.4	2.42	2.4	2.45
Specific Gravity, g/cc	35	36	37	35	36	36	37	36	37	32
Bulk Density (Loose), lb/ft3	42	42	42	43	42	42	44	42	44	40
Bulk Density (Tamped), lb/ft3	13190	12680	11510	11120	9320	8940	10510	10800	10300	10930
Blaine Fineness, cm2/g	96	99	98	92	91	92	91	87	93	90
Passing 200 Mesh, %	83	90	81	76	86	88	91	87	86	74
Passing 325 Mesh, %	6.57				6.71			7.03		
Specific Surface Area, m2/g										
Particle Size Distribution:										
Passing 80 Mesh, %	99.6				98.7			99		
10% passing, micron	1.66				2.18			1.72		
50% passing, micron	4.61				18.49			5.26		
90% passing, micron	32.9				55.5			28.84		
Ave. Particle Size(MV), micron	11.59				24.33			11.14		

APPENDIX A: RESULTS OF BY-PRODUCT EVALUATIONS

TABLE A.1: ANALYSIS OF THE CONSOL BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Consol#1	Consol#2	Consol#3	Consol#4	Consol#5	Consol#6	Consol#7	Consol#8	Consol#9	Consol#10
CaO	25.41				28.91		29.2			
MgO	0.7				0.7		0.61			
SiO2	22.33				20.18		20.09			
Fe2O3	6.23				6.39		6.32			
Al2O3	11.4				10.24		9.98			
CO2	3.58				3.94		3.55			
Total Sulfur as S	9.62				10.03		9.62			
SO3	1.79				3.11		1.94			
SO2	17.79				17.55		17.67			
LOI@ 600 oC	3.17									
LOI @ 1100 oC	14.68				13.13		12.09			
Total of Elements Determined	100.33				100.21		97.9			

Reactivity:										
Temperature Rise of F	1	2	2	1	4	3	3	4	2	1
Calc. Carb. Equiv., %CaCO3	42.5	42.1	42.2	42.8	46.4	47.2	48	44	47	39
Available Lime Index, %CaO	3.2	2.3	3	2.2	4.89	4.65	6.6	4.6	6.3	2
pH (soil)	12.36@26	12.30@23	12.25@23	12.29@24	12.51@18C	12.56	12.3	12.3@24C	12.3@24C	12.3@24C
Mixed Ratio (lbs/gal)	13	13	13	13	13	13	12	12	14	13

Physical Properties:										
Specific Gravity, g/cc	2.4	2.4	2.42	2.42	2.4	2.4	2.4	2.42	2.4	2.45
Bulk Density (Loose), lb/ft3	35	36	37	35	36	36	37	36	37	32
Bulk Density (Tamped), lb/ft3	42	42	42	43	42	42	44	42	44	40
Blaine Fineness, cm2/g	13190	12680	11510	11120	9320	8940	10510	10800	10300	10930
Passing 200 Mesh, %	96	99	98	92	91	92	91	87	93	90
Passing 325 Mesh, %	83	90	81	76	86	88	91	87	86	74
Specific Surface Area, m2/g	6.57				6.71			7.03		
Particle Size Distribution:										
Passing 80 Mesh, %	99.6				98.7			99		
10% passing, micron	1.66				2.18			1.72		
50% passing, micron	4.61				18.49			5.26		
90% passing, micron	32.9				55.5			28.84		
Ave. Particle Size(MV), micron	11.59				24.33			11.14		

TABLE A.2: ANALYSIS OF THE TIDD BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Tidd #1	Tidd #2	Tidd #3	Tidd #4	Tidd #5	Tidd #6	Tidd #7	Tidd #8	Tidd #9	Tidd #10
CaO		22.13						21.3		19.4
MgO		14.38						13.68		10.61
SiO2		19.93						21.55		23.76
Fe2O3		9.02						10.04		13.28
Al2O3		7.75						8.82		11.6
CO2		12.57						8.6		8.77
Total Sulfur as S		4.59						5.13		3.7
SO3		10.6						12.46		8.69
SO2		0.69						0.28		0.44
LOI@ 600 oC										
LOI @ 1100 oC		13.54						9.85		10.3
Total of Elements Determined		98.04						97.98		98.08

Reactivity:										
Temperature Rise of	2	2	11	5	2	4	9	11	5	2
Calc. Carb. Equiv., %CaCO3	53.8	53.4	45.9	52.0	58.8	52.8	61.2	51.2	54	43.3
Available Lime Index, %CaO	0.5	1.0	1.1	1.0	0.98	0.72	1.06	0.64	1.2	0.9
pH (soil)	10.02@23C	11.92@25C	11.03@22C	11.91@22C	11.70@22C	10.53@22C	12.0@22C	11.9	12	11.72
Mixed Ratio (lbs/gal)	25	25	20	20	20	20	18	18	18	20

Physical Properties:										
Specific Gravity, g/cc	2.85	2.88	2.87	2.88	2.83	2.79	2.79	2.8	2.81	2.8
Bulk Density (Loose), lb/ft3	58	64	60	60	58	55	60	62	60	54
Bulk Density (Tamped), lb/ft3	67	70	72	70	69	65	73	74	74	63
Blaine Fineness, cm2/g	6150	5610	5580	5480	5270	6120	5370	5410	5310	5580
Passing 200 Mesh, %	91	92	81	89	86	83	90	87	90	86
Passing 325 Mesh, %	85	85	73	83	82	77	81	79	81	79
Specific Surface Area, m2/g		2.65						2.66		3.47
Particle Size Distribution:										
Passing 80 Mesh, %		94						93.7		94.9
10% passing, micron		2.87						2.28		2.6
50% passing, micron		13.39						9.09		10.36
90% passing, micron		58.33						53.35		54.78
Ave. Particle Size(MV), micron		23.6						20.08		20.49

TABLE A.3: ANALYSIS OF THE EBENSBURG POWER COMPANY BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	EPC#1	EPC#1A	EPC#1B	EPC#2	EPC#3	EPC#4	EPC#5	EPC#6	EPC#7	EPC#8	EPC#9	EPC#10
CaO				10.15	11.06		9.6					
MgO				1.15	1.36		1.08					
SiO ₂				48.47	46.64		42.89					
Fe ₂ O ₃				6.76	7.08		8.09					
Al ₂ O ₃				18.94	17.95		17.69					
CO ₂				0.68			0.97					
Total Sulfur as S				2.22	2.37		2.53					
SO ₃				4.99	5.46		4.175					
SO ₂				0.44	0.37		1.72					
LOI@ 600 oC												
LOI @ 1100 oC				6.4	4.16		12.09					
Total of Elements Determined				97.3	96.08		97.34					

Reactivity:												
Temperature Rise of	17			17	5	6	2	2	6	6	9	5
Calc. Carb. Equiv., %CaCO ₃	13			11.3	12.9	11.4	12.4	13.4	10.6	12	10.7	12.4
Available Lime Index, %CaO	3.4	2.1	2.1	3.4	4.4	3.7	3.9	3.33	4.91	4.58	5.07	3.45
pH (soil)	12.42@25			12.42@25	12.52	12.59@24C	12.66	12.51@22	12.60@23	12.60@23	12.60@23	12.60@23
Mixed Ratio (lbs/gal)	18			17	17	18	18	18	14	16	14	14

Physical Properties:												
Specific Gravity, g/cc	2.68			2.68	2.68	2.74	2.64	2.65	2.72	2.7	2.68	2.7
Bulk Density (Loose), lb/ft ³	63			56	58	49	42	58	48	48	47	43
Bulk Density (Tamped), lb/ft ³	70			63	66	57	50	66	57	57	55	54
Blaine Fineness, cm ² /g	7860			7270	7410	9080	9540	9900	9150	9620	8560	8450
Passing 200 Mesh, %	42			49	46	61	88	84	61	66	53	65
Passing 325 Mesh, %	36			39	37	55	73	73	51	54	46	55
Specific Surface Area, m ² /g				11.86	9.41		15.88					
Particle Size Distribution:												
Passing 80 Mesh, %				50.7	48.9		91					
10% passing, micron				3.23	3.5		3.4					
50% passing, micron				23.75	29.42		20.14					
90% passing, micron				96.66	124.3		92.74					
Ave. Particle Size(MV), micron				37.29	48.04		34.04					

TABLE A.4: ANALYSIS OF THE AES THAMES RIVER BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Thames#1	Thames#2	Thames#3	Thames#4	Thames#5	Thames#6	Thames#7	Thames#8	Thames#10	Thames#11
CaO	18.41			15.11			22.4			
MgO	0.6			0.62			0.61			
SiO2	25.28			30.6			27.34			
Fe2O3	6.41			5.11			6.38			
Al2O3	14.41			17.43			15.71			
CO2	1.64			1.32			2.9			
Total Sulfur as S	3.85			3.03			3.85			
SO3	8.61			6.87			8.85			
SO2	0.8			0.56			0.61			
LOI@ 600 oC										
LOI @ 1100 oC	21.61			20.06			17.82			
Total of Elements Determined	96.13			96.36			99.72			

Reactivity:										
Temperature Rise of	13	13	13	4	4	6	7	2	2	2
Calc. Carb. Equiv., %CaCO3	17.2	20.3	20.4	15.4	24.6	18.3	25.1	16.6	15.3	14
Available Lime Index, %CaO	6.1	6.9	7	5.8	10.5	9.5	9	4.92	5.12	4.91
pH (soil)	12.34@25	12.10@26C	12.06@26C	12.60@24	12.59@24C	12.57@24C	12.55@25C	12.67@22C	12.64@22C	12.68@23C
Mixed Ratio (lbs/gal)	12	12	12	12	12	12	18	12	12	12

Physical Properties:										
Specific Gravity, g/cc	2.52	2.52	2.52	2.5	2.66	2.6	2.72	2.6	2.54	2.6
Bulk Density (Loose), lb/ft3	37	35	41	38	38	38	38	35	35	35
Bulk Density (Tamped), lb/ft3	44	40	46	46	47	46	45	42	44	42
Blaine Fineness, cm2/g	5920	6390	6240	6620	6520	6390	7450	7430	7120	7380
Passing 200 Mesh, %	85	92	94	94	97	90	96	94.5	96.5	93.5
Passing 325 Mesh, %	75	78	82	88	82	75	83	80.5	81.5	77.5
Specific Surface Area, m2/g		11.95		11.48			12.79			
Particle Size Distribution:										
Passing 80 Mesh, %		99.6		98.2			99.6			
10% passing, micron		4.06		3.56			3.45			
50% passing, micron		25.23		23.89			18.29			
90% passing, micron		73.08		74.82			61.64			
Ave. Particle Size(MV), micron		32.32		31.78			26.64			

TABLE A.5: STATISTICAL ANALYSIS OF THE CONSOL BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Mean	Range	Minimum	Maximum	Average Deviation	Standard Deviation	Coefficient Variation
CaO	27.84	3.79	25.41	29.20	1.62	2.11	0.06
MgO	0.67	0.09	0.61	0.70	0.04	0.05	0.06
SiO ₂	20.87	2.24	20.09	22.33	0.98	1.27	0.05
Fe ₂ O ₃	6.31	0.16	6.23	6.39	0.06	0.08	0.01
Al ₂ O ₃	10.54	1.42	9.98	11.40	0.57	0.76	0.05
CO ₂	3.69	0.39	3.55	3.94	0.17	0.22	0.05
Total Sulfur as S	9.76	0.41	9.62	10.03	0.18	0.24	0.02
SO ₃	2.28	1.32	1.79	3.11	0.55	0.72	0.24
SO ₂	17.67	0.24	17.55	17.79	0.08	0.12	0.00
LOI@ 600 oC							
LOI @ 1100 oC	13.30	2.59	12.09	14.68	0.92	1.30	0.07
Total of Elements Determined	99.48						

Reactivity:							
Temperature Rise of F	2	3	1	4	1	1	0
Calc. Carb. Equiv., %CaCO ₃	44.1	9.0	39.0	48.0	2.4	2.9	0.1
Available Lime Index, %CaO	4.0	4.6	2.0	6.6	1.4	1.7	0.4
pH (soil)		0.31	12.25	12.56			
Mixed Ratio (lbs/gal)	13	2	12	14	0	1	0

Physical Properties:							
Specific Gravity, g/cc	2.41	0.05	2.40	2.45	0.01	0.02	0.01
Bulk Density (Loose), lb/ft ³	36	5	32	37	1	1	0
Bulk Density (Tamped), lb/ft ³	42	4	40	44	1	1	0
Blaine Fineness, cm ² /g	10930	4250	8940	13190	956	1320	0
Passing 200 Mesh, %	93	12	87	99	3	4	0
Passing 325 Mesh, %	84	17	74	91	5	6	0
Specific Surface Area, m ² /g	6.77	0.46	6.57	7.03	0.17	0.24	0.3
Particle Size Distribution:							
Passing 80 Mesh, %	99.1	0.9	98.7	99.6	0.3	0.5	0.0
10% passing, micron	1.9	0.5	1.7	2.2	0.2	0.3	0.1
50% passing, micron	9.45	13.88	4.61	18.49	6.02	7.83	0.64
90% passing, micron	39.08	26.66	28.84	55.50	10.95	14.36	0.28
Ave. Particle Size(MV), micro	15.69	13.19	11.14	24.33	5.76	7.49	0.37

TABLE A.6: STATISTICAL ANALYSIS OF THE TIDD BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Mean	Range	Minimum	Maximum	Average Deviation	Standard Deviation	Coefficient Variation
CaO	20.94	2.73	19.40	22.13	1.40	1.03	0.07
MgO	12.89	3.77	10.61	14.38	2.01	1.52	0.16
SiO ₂	21.75	3.83	19.93	23.76	1.92	1.34	0.09
Fe ₂ O ₃	10.78	4.26	9.02	13.28	2.22	1.67	0.21
Al ₂ O ₃	9.39	3.85	7.75	11.60	1.99	1.47	0.21
CO ₂	9.98	3.97	8.60	12.57	2.24	1.73	0.22
Total Sulfur as S	4.47	1.43	3.70	5.13	0.72	0.52	0.16
SO ₃	10.58	3.77	8.69	12.46	1.89	1.26	0.18
SO ₂	0.47	0.41	0.28	0.69	0.21	0.15	0.44
LOI@ 600 oC							
LOI @ 1100 oC	11.23	3.69	9.85	13.54	2.01	1.54	0.18
Total of Elements Determined	98.03						

Reactivity:							
Temperature Rise of	5	9	2	11	4	3	1
Calc. Carb. Equiv., %CaCO ₃	52.6	17.9	43.3	61.2	5.3	3.6	0.1
Available Lime Index, %CaO	0.9	0.7	0.5	1.2	0.2	0.2	0.2
pH (soil)		1.98	10.02	12.00			
Mixed Ratio (lbs/gal)	20	7	18	25	3	2	0

Physical Properties:							
Specific Gravity, g/cc	2.83	0.09	2.79	2.88	0.04	0.03	0.01
Bulk Density (Loose), lb/ft ³	59	10	54	64	3	2	0
Bulk Density (Tamped), lb/ft ³	70	11	63	74	4	3	0
Blaine Fineness, cm ² /g	5588	880	5270	6150	311	223	0
Passing 200 Mesh, %	88	11	81	92	4	3	0
Passing 325 Mesh, %	80.50	12.00	73.00	85.00	3.69	2.80	0.05
Specific Surface Area, m ² /g	2.93	0.82	2.65	3.47	0.47	0.36	0.16
Particle Size Distribution:							
Passing 80 Mesh, %	94.2	1.2	93.7	94.9	0.6	0.5	0.0
10% passing, micron	2.6	0.6	2.3	2.9	0.3	0.2	0.1
50% passing, micron	10.95	4.30	9.09	13.39	2.21	1.63	0.20
90% passing, micron	55.49	4.98	53.35	58.60	2.56	1.90	0.05
Ave. Particle Size(MV), micron	21.39	3.52	20.08	23.60	1.92	1.47	0.09

TABLE A.7: STATISTICAL ANALYSIS OF THE EBENSBURG BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Mean	Range	Minimum	Maximum	Average Deviation	Standard Deviation	Coefficient Variation
CaO	10.27	1.46	9.60	11.06	0.53	0.74	0.05
MgO	1.20	0.28	1.08	1.36	0.11	0.15	0.09
SiO ₂	46.67	5.75	42.89	48.64	2.52	3.27	0.05
Fe ₂ O ₃	7.31	1.33	6.76	8.09	0.52	0.69	0.07
Al ₂ O ₃	18.19	1.25	17.69	18.94	0.50	0.66	0.03
CO ₂	0.83	0.29	0.68	0.97	0.15	0.21	0.18
Total Sulfur as S	2.37	0.31	2.22	2.53	0.10	0.16	0.04
SO ₃	4.88	1.29	4.18	5.46	0.47	0.65	0.10
SO ₂	0.84	1.35	0.37	1.72	0.58	0.76	0.69
LOI@ 600 oC							
LOI @ 1100 oC	7.55	7.93	4.16	12.09	3.03	4.09	0.40
Total of Elements Determined	96.91						

Reactivity:							
Temperature Rise of	8	15	2	17	5	6	1
Calc. Carb. Equiv., %CaCO ₃	12.0	2.8	10.6	13.4	0.8	1.0	0.1
Available Lime Index, %CaO	3.7	3.0	2.1	5.1	0.7	1.0	0.2
pH (soil)		0.24	12.42	12.66			
Mixed Ratio (lbs/gal)	17	4	14	18	1	1	0

Physical Properties:							
Specific Gravity, g/cc	2.69	0.10	2.64	2.74	0.03	0.03	0.01
Bulk Density (Loose), lb/ft ³	53	21	42	63	6	7	0
Bulk Density (Tamped), lb/ft ³	61	20	50	70	6	7	0
Blaine Fineness, cm ² /g	8729	2630	7270	9900	912	1052	0
Passing 200 Mesh, %	62	46	42	88	11	15	0
Passing 325 Mesh, %	52	37	36	73	10	13	0
Specific Surface Area, m ² /g	12.38	6.47	9.41	15.88	2.33	3.27	0.19
Particle Size Distribution:							
Passing 80 Mesh, %	63.5	42.1	48.9	91.0	18.3	23.8	0.3
10% passing, micron	3.4	0.3	3.2	3.5	0.1	0.1	0.0
50% passing, micron	24.44	9.28	20.14	29.42	3.32	4.68	0.14
90% passing, micron	104.57	31.57	92.74	124.31	13.16	17.21	0.13
Ave. Particle Size(MV), micron	39.79	14.00	34.04	48.04	5.50	7.33	0.14

TABLE A.8: STATISTICAL ANALYSIS OF THE AES THAMES RIVER BY-PRODUCT BY DRAVO LIME COMPANY

Geo Chemical, %:	Mean	Range	Minimum	Maximum	Average Deviation	Standard Deviation	Coefficient Variation
CaO	18.64	7.29	15.11	22.40	2.51	3.65	0.13
MgO	0.61	0.02	0.60	0.62	0.01	0.01	0.01
SiO ₂	27.74	5.32	25.28	30.60	1.91	2.68	0.07
Fe ₂ O ₃	5.97	1.30	5.11	6.41	0.57	0.74	0.10
Al ₂ O ₃	15.85	3.02	14.41	17.43	1.05	1.51	0.07
CO ₂	1.95	1.58	1.32	2.90	0.63	0.84	0.32
Total Sulfur as S	3.58	0.82	3.03	3.58	0.36	0.47	0.10
SO ₃	8.11	1.98	6.87	8.85	0.83	1.08	0.10
SO ₂	0.66	0.24	0.56	0.80	0.10	0.13	0.15
LOI@ 600 oC							
LOI @ 1100 oC	19.83	3.79	17.82	21.61	1.34	1.91	0.07
Total of Elements Determined	97.40						

Reactivity:							
Temperature Rise of	6	11	2	13	3	4	1
Calc. Carb. Equiv., %CaCO ₃	18.7	11.1	14.0	25.1	3.1	3.8	0.2
Available Lime Index, %CaO	7.0	5.6	4.9	10.5	1.6	2.0	0.2
pH (soil)		0.62	12.06	12.68			
Mixed Ratio (lbs/gal)	13	6	12	18	1	2	0

Physical Properties:							
Specific Gravity, g/cc	2.58	0.22	2.50	2.72	0.06	0.07	0.02
Bulk Density (Loose), lb/ft ³	37	6	35	41	2	2	0
Bulk Density (Tamped), lb/ft ³	44	7	40	47	2	2	0
Blaine Fineness, cm ² /g	6746	1530	5920	7450	479	554	0
Passing 200 Mesh, %	93	12	85	97	3	4	0
Passing 325 Mesh, %	80	13	75	88	3	4	0
Specific Surface Area, m ² /g	12.07	1.31	11.48	12.79	0.48	0.66	0.04
Particle Size Distribution:							
Passing 80 Mesh, %	99.1	1.4	98.2	99.6	0.6	0.8	0.0
10% passing, micron	3.7	0.6	3.5	4.1	0.2	0.3	0.1
50% passing, micron	22.47	6.94	18.29	25.23	2.79	3.68	0.12
90% passing, micron	69.85	13.18	61.64	74.82	5.47	7.16	0.08
Ave. Particle Size(MV), micron	30.25	5.68	26.64	32.32	2.40	3.14	0.08

TABLE A.9: OPERATING CONDITIONS FOR THE EBENSBURG POWER COMPANY

Condition:	Ebensburg #1	Ebensburg #2	Ebensburg #3	Ebensburg #4	Ebensburg #5
Date	10/25/94	10/28/94	11/18/94	11/25/94	12/27/94
Time	11:38:24	9:33:13	8:52:18	8:23:16	9:24:18
Megawatt Rating	52.1	54.4	54.5	51.7	54.6
Total Air Flow, klb/hr	583	573	582	563	590
Total Fuel Flow, klb/hr	105.8	100.2	102.4	103	101.5
Total Limestone Flow, klb/hr	12.79	10.16	14.02	11.72	11.28
Average Bed Temperature, oF	1608	1642	1623	1630	1638
Average Bed Level, " H2O	28.1	29.6	32.7	29.8	31.2
Air Heater Pressure, "H2O	68.4	68.2	67.6	71	68.8
Air Flow, CMPT 1&2, klb/hr	176.9	182.9	170.6	182.4	173.9
Air Flow, CMPT 3&4, klb/hr	178.7	176.1	175.3	177.2	177.3
Temperature CMPT 1&2, oF	375	372	376	378	382
Temperature CMPT 3&4, oF	387	386	394	389	389
Upper Shaft Pressure, "H2O	14.61	13.45	14.84	16.78	15.79
Upper Furnace Pressure, "H2O	-0.78	-1.6	-0.31	-0.3	-0.22
Baghouse Temperature, oF	311.9	30.9	320.7	313.3	314.8
Baghouse Pressure, "H2O	-20.23	-20.01	-20.04	-17.66	-19.06
SO2 Removed, ppm	202.5	235.4	208.9	270	251
Opacity, %	3.8	4.7	7.3	10.3	6.7
O2, %	1.68	2.03	1.79	1.69	1.3

TABLE A.10: MEAN COMPARISON OF BY-PRODUCT PROPERTIES BY DRAVO LIME COMPANY

Geo Chemical, %:	CONSOL Carney's Point Spray Dryer Fly Ash Mean	Tidd AEP PFBC Cyclone Ash Mean	Ebensburgh Power Co. CFBC Ash Mean	AES Thames River CFBC Ash Mean
CaO	28.91	20.94	10.61	18.64
MgO	0.7	12.89	1.26	0.61
SiO ₂	20.18	21.75	48.56	27.74
Fe ₂ O ₃	6.39	10.78	6.92	5.97
Al ₂ O ₃	10.24	9.39	18.45	15.85
CO ₂	3.94	9.98	0.68	1.95
Total Sulfur as S	10.03	4.47	2.3	3.58
SO ₃	3.11	10.58	5.23	8.11
SO ₂	17.55	0.47	0.41	0.66
LOI@ 600 oC				
LOI @ 1100 oC	13.13	11.23	5.28	19.83
Total of Elements Determined	100.21	98.03	96.69	97.4

Reactivity:				
Temperature Rise of	2	5	8	6
Calc. Carb. Equiv., %CaCO ₃	43.8	52.6	11.6	18.7
Available Lime Index, %CaO	3.7	0.9	4.0	7.0
pH (soil)				
Mixed Ratio (lbs/gal)	13	20	16	13

Physical Properties:				
Specific Gravity, g/cc	2.41	2.83	2.7	2.58
Bulk Density (Loose), lb/ft ³	36	59	52	37
Bulk Density (Tamped), lb/ft ³	42	70	60	44
Blaine Fineness, cm ² /g	10700	55888	8506	6746
Passing 200 Mesh, %	93	88	57	93
Passing 325 Mesh, %	84	81	48	80
Specific Surface Area, m ² /g	6.87	2.93	10.64	12.07
Particle Size Distribution:				
Passing 80 Mesh, %	98.9	94.2	49.8	99.1
10% passing, micron	2	2.6	3.4	3.7
50% passing, micron	11.88	10.95	26.59	22.47
90% passing, micron	42.17	55.49	110.49	69.85
Ave. Particle Size(MV), micron	17.74	21.39	42.67	30.25

TABLE A.11: METALS ANALYSIS OF THE 4 BY-PRODUCTS USED

	Property	Units	BDAT Standard		Consol #1	Tidd #2	Ebensburg #3	AES Thames River #4
			Current	Future				
Total Metals	Antimony (Sb)	mg/kg			<4	<4	<4	<4
	Arsenic (As)	mg/kg			41	140	95	21
	Barium (Ba)	mg/kg			97	150	160	170
	Beryllium (Be)	mg/kg			2.22	2.60	2.00	8.84
	Cadmium (Cd)	mg/kg			6.6	4.8	10	2.2
	Chromium (Cr)	mg/kg			29	15	50	52
	Copper (Cu)	mg/kg			20	17	35	30
	Lead (Pb)	mg/kg			3	4.6	3.6	4.9
	Mercury (Hg)	mg/kg			0.55	<0.10	1.1	0.66
	Nickel (Ni)	mg/kg			23	12	21	280
	Selenium (Se)	mg/kg			<0.2	<0.2	<0.2	1.4
	Silver (Ag)	mg/kg			<2.0	<2.0	<2.0	<2.0
	Thallium (Th)	mg/kg			<0.5	<4	<4	<4
	Vanadium (V)	mg/kg			54.15	26.10	55.25	97.60
	Zinc (Zn)	mg/kg			34	78	52	37
TCLP Metals	Antimony (Sb)	mg/L	---	2.1	<0.020	0.022	0.024	<0.020
	Arsenic (As)	mg/L	5.0	5.0	<0.1	<0.1	0.89	<0.1
	Barium (Ba)	mg/L	100.0	7.6	<5.0	<5.0	<5.0	<5.0
	Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L	1.0	0.19	<0.1	<0.1	<0.1	<0.1
	Chromium (Cr)	mg/L	5.0	0.86	<0.1	<0.1	<0.1	<0.1
	Copper (Cu)	mg/L	---	---	<1.0	<1.0	<1.0	<1.0
	Lead (Pb)	mg/L	5.0	0.37	<0.1	<0.1	<0.1	<0.1
	Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01
	Nickel (Ni)	mg/L	---	5.1	<0.1	<0.1	<0.1	<0.1
	Selenium (Se)	mg/L	1.0	0.16	<0.1	<0.1	<0.1	<0.1
	Silver (Ag)	mg/L	5.0	0.3	<0.1	<0.1	<0.1	<0.1
	Thallium (Th)	mg/L	---	0.078	<0.005	<0.005	<0.005	<0.005
	Vanadium (V)	mg/L	---	0.23	0.074	0.013	0.316	0.412
	Zinc (Zn)	mg/L	---	5.3	<1.0	<1.0	<1.0	<1.0
ASTM Metals	Antimony (Sb)	mg/L			<0.020	<0.020	<0.020	<0.020
	Arsenic (As)	mg/L						
	Barium (Ba)	mg/L			1.69	0.65	0.83	1.29
	Beryllium (Be)	mg/L			<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L			<0.05	<0.05	<0.05	<0.05
	Chromium (Cr)	mg/L			<0.50	<0.50	<0.50	<0.50
	Copper (Cu)	mg/L			<0.20	<0.20	<0.20	<0.20
	Lead (Pb)	mg/L			<1.00	<1.00	<1.00	<1.00
	Mercury (Hg)	mg/L						
	Nickel (Ni)	mg/L			<0.30	<0.30	<0.30	<0.30
	Selenium (Se)	mg/L						
	Silver (Ag)	mg/L			<0.05	<0.05	<0.05	<0.05
	Thallium (Th)	mg/L			<0.005	<0.005	<0.005	<0.005
	Vanadium (V)	mg/L			<0.010	<0.010	<0.010	<0.010
	Zinc (Zn)	mg/L			<0.05	<0.05	<0.05	<0.05

* BDAT Standards do not apply to shaded areas.

* Blank spaces indicate samples which have yet to be analyzed.

TABLE A.12: METALS ANALYSIS OF ALL THE BY-PRODUCTS RECEIVED AT PITT

	Property	Units	BDAT Standard		Consol #1	Consol #5	Consol #7	Tidd #2	Tidd #8	Tidd #10	EPC #2	EPC #3
			Current	Future								
TCLP Metals	Antimony (Sb)	mg/L	---	2.1	<0.020	<0.020	<0.020	0.022	<0.020	<0.020	<0.020	0.024
	Arsenic (As)	mg/L	5.0	5.0	<0.1			<0.1				0.89
	Barium (Ba)	mg/L	100.0	7.6	<5.0	1.07	1.89	<5.0	0.50	0.50		<5.0
	Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L	1.0	0.19	<0.1	<0.05	<0.05	<0.1	<0.05	<0.05	<0.05	<0.1
	Chromium (Cr)	mg/L	5.0	0.86	<0.1	<0.05	<0.05	<0.1	<0.05	<0.05	<0.50	<0.1
	Copper (Cu)	mg/L	---	---	<1.0	<0.20	<0.20	<1.0	<0.20	<0.20	<0.20	<1.0
	Lead (Pb)	mg/L	5.0	0.37	<0.1	<0.5	<0.5	<0.1	<0.5	<0.5	<1.00	<0.1
	Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01			<0.01				<0.01
	Nickel (Ni)	mg/L	---	5.1	<0.1	<0.3	<0.3	<0.1	<0.3	<0.3	<0.3	<0.1
	Selenium (Se)	mg/L	1.0	0.16	<0.1			<0.1				<0.1
	Silver (Ag)	mg/L	5.0	0.3	<0.1	<0.05	<0.05	<0.1	<0.05	<0.05	<0.05	<0.1
	Thallium (Th)	mg/L	---	0.078	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Vanadium (V)	mg/L	---	0.23	0.074	0.065	<0.010	0.013	0.028	0.030	0.316	0.316
	Zinc (Zn)	mg/L	---	5.3	<1.0	0.05	0.06	<1.0	<0.05	0.06	<0.05	<1.0

ASTM Metals	Antimony (Sb)	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
	Arsenic (As)	mg/L										
	Barium (Ba)	mg/L	1.69		1.11	1.39	0.65	0.40	0.46			0.83
	Beryllium (Be)	mg/L	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Chromium (Cr)	mg/L	<0.50		<0.05	<0.05	<0.50	<0.05	<0.05	<0.05	<0.50	<0.50
	Copper (Cu)	mg/L	<0.20		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Lead (Pb)	mg/L	<1.00		<0.5	<0.5	<1.00	<0.5	<0.5	<0.5	<1.00	<1.00
	Mercury (Hg)	mg/L										
	Nickel (Ni)	mg/L	<0.3		<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
	Selenium (Se)	mg/L										
	Silver (Ag)	mg/L	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Thallium (Th)	mg/L	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Vanadium (V)	mg/L	<0.010		<0.010	<0.010	<0.010	0.018	0.019	0.019	<0.010	<0.010
	Zinc (Zn)	mg/L	<0.05		0.05	0.06	<0.05	0.05	0.05	0.05	<0.05	<0.05

* BDAT Standards do not apply to shaded areas.

* Blank spaces indicate samples which have yet to be analyzed.

**TABLE A.12: METALS ANALYSIS OF ALL THE BY-PRODUCTS RECEIVED AT PITT
(CONTINUED)**

TCLP Metals	Property	Units	BDAT Standard		EPC #4	EPC #5	AES Thames River #2	AES Thames River #4	AES Thames River #7
			Current	Future					
	Antimony (Sb)	mg/L	---	2.1	<0.020	<0.020	<0.020	<0.020	<0.020
	Arsenic (As)	mg/L	5.0	5.0				<0.1	
	Barium (Ba)	mg/L	100.0	7.6				<5.0	1.18
	Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L	1.0	0.19	<0.05	<0.05	<0.05	<0.1	<0.05
	Chromium (Cr)	mg/L	5.0	0.86	<0.50	<0.50	<0.50	<0.1	<0.50
	Copper (Cu)	mg/L	---	---	<0.20	<0.20	<0.20	<1.0	<0.20
	Lead (Pb)	mg/L	5.0	0.37	<1.00	<1.00	<1.00	<0.1	<1.00
	Mercury (Hg)	mg/L	0.2	0.20/0.025				<0.01	
	Nickel (Ni)	mg/L	---	5.1	<0.3	<0.3	<0.3	<0.1	<0.30
	Selenium (Se)	mg/L	1.0	0.16				<0.1	
	Silver (Ag)	mg/L	5.0	0.3	<0.05	<0.05	<0.05	<0.1	<0.05
	Thallium (Th)	mg/L	---	0.078	<0.005	<0.005	<0.005	<0.005	<0.005
	Vanadium (V)	mg/L	---	0.23	0.326	0.414	0.035	0.412	<0.010
	Zinc (Zn)	mg/L	---	5.3	0.127	0.099	<0.05	<1.0	<0.05

	Antimony (Sb)	mg/L			<0.020	<0.020	<0.020	<0.020	
	Arsenic (As)	mg/L							
	Barium (Ba)	mg/L			0.71	0.65		1.29	
	Beryllium (Be)	mg/L			<0.001	<0.001	<0.001	<0.001	
	Cadmium (Cd)	mg/L			<0.05	<0.05	<0.05	<0.05	
	Chromium (Cr)	mg/L			<0.05	0.05	<0.50	<0.50	
	Copper (Cu)	mg/L			<0.20	<0.20	<0.20	<0.20	
	Lead (Pb)	mg/L			<0.5	<0.5	<1.00	<1.00	
	Mercury (Hg)	mg/L							
	Nickel (Ni)	mg/L			<0.3	<0.3	<0.3	<0.3	
	Selenium (Se)	mg/L							
	Silver (Ag)	mg/L			<0.05	<0.05	<0.05	<0.05	
	Thallium (Th)	mg/L			<0.005	<0.005	<0.005	<0.005	
	Vanadium (V)	mg/L			0.015	0.021	<0.010	<0.010	
	Zinc (Zn)	mg/L			0.05	0.07	<0.05	<0.05	

* BDAT Standards do not apply to shaded areas.

* Blank spaces indicate samples which have yet to be analyzed.

APPENDIX B: RESULTS OF WASTE EVALUATIONS

TABLE B.1: METALS ANALYSIS OF THE WASTES

	Property	Units	BDAT Standard		Battery Sludge	Munitions Soil	Industrial Soil	WWTP Soil	Furnace Dust	Municipal Waste Dust
			Current	Future						
Total Metals	Antimony (Sb)	mg/kg			35.3	18.6	>60	<1.90	<4	54.1
	Arsenic (As)	mg/kg			<20	<20	<20	4.4	<20	84
	Barium (Ba)	mg/kg			13	130	130	84	34	550
	Beryllium (Be)	mg/kg			<0.2	0.3	0.46	0.10	<0.2	0.78
	Cadmium (Cd)	mg/kg			3.0	4.8	5.4	<2.0	55	630
	Chromium (Cr)	mg/kg			12	59	22	8.7	260	130
	Copper (Cu)	mg/kg			30	210	260	64	57	1300
	Lead (Pb)	mg/kg			3000	1200	5000	750	1400	5700
	Mercury (Hg)	mg/kg			0.14	0.20	3.2	0.36	0.30	4.7
	Nickel (Ni)	mg/kg			15	19	26	<10	130	96
	Selenium (Se)	mg/kg			<0.2	<0.2	<0.2	0.36	<0.2	85
	Silver (Ag)	mg/kg			<2.0	3.6	<2.0	<2.0	<2.0	6.9
	Thallium (Th)	mg/kg			<0.5	<0.5	<0.5	<0.48	<0.5	<0.5
	Vanadium (V)	mg/kg			1.8	26.28	18.76	12.63	75.74	39.4
	Zinc (Zn)	mg/kg			30	580	660	150	41000	23000
TCLP Metals	Antimony (Sb)	mg/L	---	2.1	0.328	0.121	0.201	<0.020	0.035	0.404
	Arsenic (As)	mg/L	5.0	5.0	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
	Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5
	Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L	1.0	0.19	0.19	<0.1	<0.1	<0.1	<0.1	<0.1
	Chromium (Cr)	mg/L	5.0	0.86	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Copper (Cu)	mg/L	---	---	1.3	1.6	<1	<1	<1	<1
	Lead (Pb)	mg/L	5.0	0.37	20	26	80	7.8	14	20
	Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Nickel (Ni)	mg/L	---	5.1	0.78	0.041	0.23	<0.1	<0.1	<0.1
	Selenium (Se)	mg/L	1.0	0.16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Silver (Ag)	mg/L	5.0	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Thallium (Th)	mg/L	---	0.078	<0.005	<0.005	<0.005	0.0084	<0.005	0.0266
	Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	<0.010	<0.010	0.012	<0.010
	Zinc (Zn)	mg/L	---	5.3	2.9	8.2	17	3.9	4.4	2.1

* BDAT standards do not apply to shaded areas.

APPENDIX C: RESULTS OF TREATED WASTE EVALUATIONS

TABLE C.1

PARAMETERS TO DETERMINE ACHIEVEMENT OF LDR TREATMENT STANDARDS

PARAMETER	WASTE					
	Battery Sludge	Furnace Dust	Industrial Soil	Munitions Soil	Mun. Waste Dust	Sewage Plant Soil
Antimony	X (2)				X (2)	Pending
Arsenic	X (1)	X (1)	X (1)	X (1)	X (1,2)	X (1)
Barium	X (1)	X (1)	X (1,2)	X (1,2)	X (1,2)	X (1)
Beryllium	X (1)	X (1)	X (1,2)	X (1,2)	X (1,2)	Pending
Cadmium	X (1,2)	X (1,2)	X (1,2)	X (1,2)	X (1,2)	X (1)
Chromium	X (1)	X (1,2)	X (1,2)	X (1,2)	X (1,2)	X (1)
Copper						
Lead	X (2)	X (2)	X (2)	X (2)	X (2)	X (2)
Mercury	X (1)	X (1)	X (1,2)	X (1)	X (1,2)	X (1)
Nickel	X (1)	X (1,2)	X (1)	X (1)	X (1,2)	X (1)
Selenium					X (2)	
Silver					X (2)	
Thallium						Pending
Vanadium	X (1)	X (1,2)	X (1,2)	X (1,2)	X (1,2)	Pending
Zinc		X (2)	X (2)	X (2)	X (2)	X (2)

Notes: (1) Based on concentration in one or more byproduct samples.
 (2) Based on concentration in waste sample.

TABLE C.2: METALS ANALYSIS OF WASTES TREATED WITH THE CONSOL BY-PRODUCT

Heavy Metals Concentrations of Wastes Treated With CONSOL By-Product																
Immediate TCLP Concentrations																
BDAT Standard			Battery Sludge				Munitions Soil				Industrial Soil					
Property	Units	Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%	
Antimony (Sb)	mg/L	---	2.1	0.328	0.407	0.398	0.303	0.121	N/A	N/A	N/A	0.201	N/A	N/A	N/A	
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	<0.10	<0.10	<0.10	0.12	<0.10	
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Beryllium (Be)	mg/L	---	0.014	<0.001	<.001	0.0025	0.0027	<0.001	<0.001	0.0023	0.0020	<0.001	<0.001	0.0019	0.0023	
Cadmium (Cd)	mg/L	1.0	0.19	0.19	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	0.23	0.15	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Copper (Cu)	mg/L	---	---	1.3	N/A	N/A	N/A	1.6	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	
Lead (Pb)	mg/L	5.0	0.37	20.00	0.14	0.28	0.19	26.00	0.37	0.41	0.28	80.00	0.54	0.54	0.37	
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nickel (Ni)	mg/L	---	5.1	0.78	0.71	0.69	0.58	0.04	0.10	0.15	0.15	0.23	0.18	0.28	0.25	
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	
Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	0.060	0.053	<0.010	<0.010	0.033	0.039	<0.010	<0.010	0.016	0.019	
Zinc (Zn)	mg/L	---	5.3	2.9	N/A	N/A	N/A	8.2	4.3	8.0	5.3	17.0	5.2	8.3	8.4	

Heavy Metals Concentrations of Wastes Treated With CONSOL By-Product																
24-Hour TCLP Concentrations																
BDAT Standard			Battery Sludge				Munitions Soil				Industrial Soil					
Property	Units	Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%	
Antimony (Sb)	mg/L	---	2.1	0.328	0.381	0.389	0.234	0.121	N/A	N/A	N/A	0.201	N/A	N/A	N/A	
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Beryllium (Be)	mg/L	---	0.014	<0.001	0.0027	0.0027	0.0029	<0.001	<0.001	0.0021	0.0021	<0.001	<0.001	0.0027	0.0024	
Cadmium (Cd)	mg/L	1.0	0.19	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	0.25	0.17	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Copper (Cu)	mg/L	---	---	1.3	N/A	N/A	N/A	1.6	N/A	N/A	N/A	<1	N/A	N/A	N/A	
Lead (Pb)	mg/L	5.0	0.37	20.00	0.15	0.21	0.21	26	0.41	0.35	0.28	80.00	0.15	0.26	0.21	
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nickel (Ni)	mg/L	---	5.1	0.78	0.49	0.68	0.56	0.04	<0.10	0.11	0.12	0.23	0.14	0.27	0.22	
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	
Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	0.034	0.057	<0.010	<0.010	0.046	0.027	<0.010	<0.010	0.020	0.029	
Zinc (Zn)	mg/L	---	5.3	2.9	N/A	N/A	N/A	8.2	9.9	6.7	5.1	17.0	8.2	9.4	13.0	

TABLE C.2 (CONTINUED)

Heavy Metals Concentrations of Wastes Treated With CONSOL By-Product																		
Immediate TCLP Concentrations																		
BDAT Standard			BOF Dust				Municipal Waste Dust				Sewage Treatment Plant Soil							
Property	Units	Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%			
Antimony (Sb)	mg/L	---	2.1	0.035	N/A	N/A	N/A	0.404	0.847	0.398	0.446	<0.020	N/A	N/A	N/A			
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	0.20	<0.10	<0.10	<0.10	<0.10	<0.10	0.20	0.21			
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5			
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0012	0.0014			
Cadmium (Cd)	mg/L	1.0	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	13.00	8.00	<0.10	<0.10	<0.10	<0.10			
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10			
Copper (Cu)	mg/L	---	---	<1	N/A	N/A	N/A	<1	N/A	N/A	N/A	<1	N/A	N/A	N/A			
Lead (Pb)	mg/L	5.0	0.37	14.00	1.50	5.10	6.90	20.00	1.30	0.46	0.26	7.80	0.39	0.57	0.46			
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
Nickel (Ni)	mg/L	---	5.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.63	0.46	0.40	<0.10	<0.10	<0.10	<0.10			
Selenium (Se)	mg/L	1.0	0.16	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A			
Silver (Ag)	mg/L	5.0	0.3	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A			
Thallium (Tl)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	0.0266	N/A	N/A	N/A	0.0084	N/A	N/A	N/A			
Vanadium (V)	mg/L	---	0.23	0.012	<0.010	<0.010	<0.010	<0.010	0.171	0.282	0.641	<0.010	0.014	0.049	0.047			
Zinc (Zn)	mg/L	---	5.3	4.4	4.1	3.9	3.1	2.1	740.0	410.0	310.0	3.9	2.1	4.7	1.7			

Heavy Metals Concentrations of Wastes Treated With CONSOL By-Product 24-Hour TCLP Concentrations																		
BDAT Standard			BOF Dust				Municipal Waste Dust				Sewage Treatment Plant Soil							
Property	Units	Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%			
Antimony (Sb)	mg/L	---	2.1	0.035	N/A	N/A	N/A	0.404	0.347	0.141	0.206	<0.020	N/A	N/A	N/A			
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	0.20	<0.10	<0.10	<0.10	<0.10	<0.10	0.17	0.19			
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5			
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0016	0.0015			
Cadmium (Cd)	mg/L	1.0	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	24.00	14.00	9.00	<0.10	<0.10	<0.10	<0.10			
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10			
Copper (Cu)	mg/L	---	---	<1	N/A	N/A	N/A	<1	N/A	N/A	N/A	<1	N/A	N/A	N/A			
Lead (Pb)	mg/L	5.0	0.37	14.00	17.00	9.60	4.30	20.00	1.60	0.45	0.27	7.80	0.47	0.56	0.55			
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
Nickel (Ni)	mg/L	---	5.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.68	0.55	0.36	<0.10	<0.10	<0.10	<0.10			
Selenium (Se)	mg/L	1.0	0.16	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A			
Silver (Ag)	mg/L	5.0	0.3	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A			
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	0.0266	N/A	N/A	N/A	0.0084	N/A	N/A	N/A			
Vanadium (V)	mg/L	---	0.23	0.012	<0.010	<0.010	<0.010	<0.010	0.019	0.017	0.052	<0.010	<0.010	0.051	0.047			
Zinc (Zn)	mg/L	---	5.3	4.4	3.9	3.3	2.6	2.1	650.0	330.0	280.0	3.9	2.3	2.9	1.9			

TABLE C.3: METALS ANALYSIS OF WASTES TREATED WITH THE TIDD BY-PRODUCT

Heavy Metals Concentrations of Wastes Treated With Tidd By-Product															
Immediate TCLP Concentrations															
Property	Units	BDAT Standard		Battery Sludge			Munitions Soil			Industrial Soil					
		Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%
Antimony (Sb)	mg/L	---	2.1	0.328	0.231	0.180	0.115	0.121	N/A	N/A	N/A	0.201	N/A	N/A	N/A
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Beryllium (Be)	mg/L	---	0.014	<0.001	0.0028	0.0012	<0.001	<0.001	0.0010	0.0011	<0.001	<0.001	0.0023	<0.001	<0.001
Cadmium (Cd)	mg/L	1.0	0.19	0.19	0.19	0.15	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Chromium (Cr)	mg/L	5.0	0.86	<0.10	0.31	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Copper (Cu)	mg/L	---	---	1.3	N/A	N/A	N/A	1.6	N/A	N/A	N/A	<1.0	N/A	N/A	N/A
Lead (Pb)	mg/L	5.0	0.37	20.00	6.50	10.00	4.10	26	10.00	13.00	1.20	80	13.00	7.00	1.70
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (Ni)	mg/L	---	5.1	0.78	0.92	0.63	0.44	0.04	<0.10	0.32	<0.10	0.23	0.25	0.12	1.80
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A
Thallium (Tl)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A
Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc (Zn)	mg/L	---	5.3	2.9	N/A	N/A	N/A	8.2	7.1	5.2	1.0	17.0	15.0	7.0	2.9

Heavy Metals Concentrations of Wastes Treated With Tidd By-Product														
24-Hour TCLP Concentrations														
Property	Units	BDAT Standard		Battery Sludge			Munitions Soil			Industrial Soil				
		Current	Future	0%	10%	30%	0%	10%	30%	0%	10%	30%		
Antimony (Sb)	mg/L	---	2.1	0.328	0.330	0.132	0.136	0.121	N/A	0.201	N/A	N/A	50%	
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<0.10	
Beryllium (Be)	mg/L	---	0.014	<0.001	0.0016	<0.001	<0.001	<0.001	0.0020	0.0011	<0.001	<0.001	<0.001	
Cadmium (Cd)	mg/L	1.0	0.19	0.19	0.18	0.14	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Chromium (Cr)	mg/L	5.0	0.86	<0.10	0.27	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Copper (Cu)	mg/L	---	---	1.3	N/A	N/A	N/A	1.6	N/A	N/A	N/A	N/A	N/A	
Lead (Pb)	mg/L	5.0	0.37	20.00	6.80	6.60	5.10	26.00	16.00	80.00	17.00	22.00	1.60	
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nickel (Ni)	mg/L	---	5.1	0.78	0.78	0.60	0.44	0.04	<0.10	0.23	0.29	0.15	<0.10	
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	N/A	<0.1	N/A	N/A	N/A	
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	N/A	<0.1	N/A	N/A	N/A	
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	<0.005	N/A	<0.005	N/A	N/A	N/A	
Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Zinc (Zn)	mg/L	---	5.3	2.9	N/A	N/A	N/A	8.2	7.7	17.0	14.0	7.6	2.4	

TABLE C.3 (CONTINUED)

Heavy Metals Concentrations of Wastes Treated With Tidd By-Product																
Immediate TCLP Concentrations																
BDAT Standard			BOF Dust				Municipal Waste Dust				Sewage Treatment Plant Soil					
Property	Units	Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%	
Antimony (Sb)	mg/L	---	2.1	0.035	N/A	N/A	N/A	0.404	0.546	0.542	0.398	<0.020	N/A	N/A	N/A	
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	0.2	<0.10	<0.10	<0.10	<0.10	<0.10	0.12	0.15	
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0017	<0.001	<0.001	
Cadmium (Cd)	mg/L	1.0	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	25.00	18.00	14.00	<0.10	<0.10	<0.10	<0.10	
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.14	0.17	
Copper (Cu)	mg/L	---	---	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	
Lead (Pb)	mg/L	5.0	0.37	14.00	20.00	14.00	13.00	20.00	16.00	17.00	9.10	7.80	21.00	9.40	2.30	
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nickel (Ni)	mg/L	---	5.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.64	0.45	0.35	<0.10	<0.10	<0.10	<0.10	
Selenium (Se)	mg/L	1.0	0.16	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A	
Silver (Ag)	mg/L	5.0	0.3	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A	
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	0.0266	N/A	N/A	N/A	0.0084	N/A	N/A	N/A	
Vanadium (V)	mg/L	---	0.23	0.012	<0.010	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Zinc (Zn)	mg/L	---	5.3	4.4	4.2	4.3	4.3	2.1	550.0	400.0	280.0	3.9	4.3	2.1	<1.0	

Heavy Metals Concentrations of Wastes Treated With Tidd By-Product																			
24-Hour TCLP Concentrations																			
BDAT Standard			BOF Dust				Municipal Waste Dust				Sewage Treatment Plant Soil								
			Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%			
Property	Units																		
Antimony (Sb)	mg/L	---	2.1	0.035	N/A	N/A	N/A	0.404	0.336	0.331	0.258	<0.020	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.12	<0.16	<0.16	<0.16	<0.16
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0015	0.0011	<0.001	<0.001	<0.001	<0.001
Cadmium (Cd)	mg/L	1.0	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	30.00	17.00	13.00	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.14	0.16	0.16	0.16	0.16
Copper (Cu)	mg/L	---	---	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead (Pb)	mg/L	5.0	0.37	14.00	19.00	15.00	9.60	20.00	13.00	16.00	12.00	7.80	23.00	11.00	2.10	2.10	2.10	2.10	2.10
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (Ni)	mg/L	---	5.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.70	0.46	0.35	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Selenium (Se)	mg/L	1.0	0.16	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A	N/A	N/A
Silver (Ag)	mg/L	5.0	0.3	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A	N/A	N/A	N/A
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	0.0266	N/A	N/A	N/A	0.0084	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vanadium (V)	mg/L	---	0.23	0.012	<0.010	<0.010	<0.010	<0.010	N/A	N/A	N/A	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Zinc (Zn)	mg/L	---	5.3	4.4	3.9	3.7	3.3	2.1	700.0	370.0	270.0	3.9	7.8	2.9	1.0	1.0	1.0	1.0	1.0

TABLE C.4: METALS ANALYSIS OF WASTES TREATED WITH THE EBENSBURG BY-PRODUCT

Heavy Metals Concentrations of Wastes Treated With Ebensburg By-Product																
Immediate TCLP Concentrations																
Property	Units	BDAT Standard		Battery Sludge				Munitions Soil				Industrial Soil				
		Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%	
Antimony (Sb)	mg/L	---	2.1	0.328	0.202	0.109	0.068	0.121	N/A	N/A	N/A	0.201	N/A	N/A	N/A	
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Cadmium (Cd)	mg/L	1.0	0.19	0.19	0.15	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Copper (Cu)	mg/L	---	---	1.3	N/A	N/A	N/A	1.6	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	
Lead (Pb)	mg/L	5.0	0.37	20.00	7.80	46.00	13.00	26.00	34.00	17.00	5.60	80.00	17.00	17.00	0.85	
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nickel (Ni)	mg/L	---	5.1	0.78	0.58	0.46	0.31	0.04	<0.10	<0.10	<0.10	0.23	0.18	0.13	<0.10	
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	
Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.0120	<0.010	<0.010	<0.010	<0.010	
Zinc (Zn)	mg/L	---	5.3	2.9	N/A	N/A	N/A	8.2	6.1	2.6	1.8	17.0	10.0	5.4	<1.0	

Heavy Metals Concentrations of Wastes Treated With Ebensburg By-Product 24-Hour TCLP Concentrations																
Property	Units	BDAT Standard		Battery Sludge				Munitions Soil				Industrial Soil				
		Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%	
Antimony (Sb)	mg/L	---	2.1	0.328	0.154	0.124	0.114	0.121	N/A	N/A	N/A	0.201	N/A	N/A	N/A	
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Cadmium (Cd)	mg/L	1.0	0.19	0.19	0.15	0.12	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Copper (Cu)	mg/L	---	---	1.3	N/A	N/A	N/A	1.6	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	
Lead (Pb)	mg/L	5.0	0.37	20.00	15.00	11.00	26.00	26.00	20.00	9.10	4.30	80.00	29.00	7.40	5.40	
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.10	<0.10	<0.10	<0.01	<0.10	<0.10	<0.10	<0.01	<0.10	<0.10	<0.10	
Nickel (Ni)	mg/L	---	5.1	0.78	<0.10	<0.10	<0.10	0.041	<0.10	<0.10	<0.10	0.23	0.20	0.10	<0.10	
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	<0.1	N/A	N/A	N/A	
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	<0.005	N/A	N/A	N/A	
Vanadium (V)	mg/L	---	0.23	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.0101	<0.010	<0.010	<0.010	<0.010	
Zinc (Zn)	mg/L	---	5.3	2.9	N/A	N/A	N/A	8.2	6.7	3.3	1.8	17.0	12.0	6.2	3.1	

TABLE C.4 (CONTINUED)

Heavy Metals Concentrations of Wastes Treated With Ebensburg By-Product Immediate TCLP Concentrations																			
Property	Units	BDAT Standard		BOF Dust					Municipal Waste Dust					Sewage Treatment Plant Soil					
		Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%				
Antimony (Sb)	mg/L	---	2.1	0.035	N/A	N/A	N/A	0.404	0.443	0.343	0.312	<0.020	N/A	N/A	N/A				
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.39				
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5				
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0011	0.0017	<0.001	<0.001	<0.001	<0.001				
Cadmium (Cd)	mg/L	1.0	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	22.00	18.00	15.00	<0.10	<0.10	<0.10	<0.10				
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10				
Copper (Cu)	mg/L	---	---	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A				
Lead (Pb)	mg/L	5.0	0.37	14.00	22.00	16.00	13.00	20.00	12.00	20.00	13.00	7.80	4.90	4.60	0.31				
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01				
Nickel (Ni)	mg/L	---	5.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.65	0.57	0.44	<0.10	<0.10	<0.10	<0.10				
Selenium (Se)	mg/L	1.0	0.16	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A				
Silver (Ag)	mg/L	5.0	0.3	<0.10	N/A	N/A	N/A	<0.10	<0.10	<0.10	<0.10	<0.10	N/A	N/A	N/A				
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	0.0266	N/A	N/A	N/A	0.0084	N/A	N/A	N/A				
Vanadium (V)	mg/L	---	0.23	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.013	0.057				
Zinc (Zn)	mg/L	---	5.3	4.4	4.6	4.9	4.7	2.1	530.0	500.0	370.0	3.9	2.3	<1.0	<1.0				

Heavy Metals Concentrations of Wastes Treated With Ebensburg By-Product 24-Hour TCLP Concentrations																			
Property	Units	BDAT Standard		BOF Dust					Municipal Waste Dust					Sewage Treatment Plant Soil					
		Current	Future	0%	10%	30%	50%	0%	10%	30%	50%	0%	10%	30%	50%				
Antimony (Sb)	mg/L	---	2.1	0.035	N/A	N/A	N/A	0.404	0.232	0.124	0.234	<0.020	N/A	N/A	N/A				
Arsenic (As)	mg/L	5.0	5.0	<0.10	<0.10	<0.10	<0.10	0.20	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10				
Barium (Ba)	mg/L	100.0	7.6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5				
Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
Cadmium (Cd)	mg/L	1.0	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	20.00	17.00	14.00	<0.10	<0.10	<0.10	<0.10				
Chromium (Cr)	mg/L	5.0	0.86	<0.10	<0.10	<0.10	<0.10	<0.10	0.14	0.13	0.14	<0.10	<0.10	<0.10	<0.10				
Copper (Cu)	mg/L	---	---	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A	<1.0	N/A	N/A	N/A				
Lead (Pb)	mg/L	5.0	0.37	14.00	20.00	14.00	8.10	20.00	22.00	22.00	24.00	7.80	11.00	<0.10	0.18				
Mercury (Hg)	mg/L	0.2	0.20/0.025	<0.01	<0.10	<0.10	<0.10	<0.01	<0.10	<0.10	<0.10	<0.01	<0.01	<0.01	<0.01				
Nickel (Ni)	mg/L	---	5.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.60	0.54	0.40	<0.10	<0.10	<0.10	<0.10				
Selenium (Se)	mg/L	1.0	0.16	<0.1	N/A	N/A	N/A	<0.1	<0.10	<0.10	<0.10	<0.1	N/A	N/A	N/A				
Silver (Ag)	mg/L	5.0	0.3	<0.1	N/A	N/A	N/A	<0.1	<0.10	<0.10	<0.10	<0.1	N/A	N/A	N/A				
Thallium (Th)	mg/L	---	0.078	<0.005	N/A	N/A	N/A	0.0266	N/A	N/A	N/A	0.0084	N/A	N/A	N/A				
Vanadium (V)	mg/L	---	0.23	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.101				
Zinc (Zn)	mg/L	---	5.3	4.4	4.1	3.9	3.5	2.1	500.0	420.0	300.0	3.9	2.0	<1.0	<1.0				

TABLE C.5: METALS ANALYSIS OF THE BY-PRODUCT/WASTE MIXTURES PREPARED AT MSI FOR COMPRESSIVE STRENGTH TESTING

ASTM Metals	Property	Units	BDAT Standard		Battery Sludge w/ 33.3% Consol	Battery Sludge w/ 72.2% Tidd	Munitions Soil w/ 50% Consol	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 100% EPC	Industrial Soil w/ 50% Tidd	WWTP w/ 50% Tidd	WWTP w/ 50% EPC
			Current	Future								
24 hours	Antimony (Sb)	mg/L			<0.020	0.101	<0.020			0.056	<0.020	<0.020
	Arsenic (As)	mg/L										
	Barium (Ba)	mg/L			0.15	0.27	0.09	0.17	0.19	0.17	0.16	0.10
	Beryllium (Be)	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Cadmium (Cd)	mg/L			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Chromium (Cr)	mg/L			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Copper (Cu)	mg/L			<0.05	<0.05	0.06	0.06	<0.05	<0.05	<0.05	<0.05
	Lead (Pb)	mg/L			3.6	1.3	<0.5	<0.5	0.6	0.5	<0.5	<0.9
	Mercury (Hg)	mg/L										
	Nickel (Ni)	mg/L			<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
	Selenium (Se)	mg/L										
	Silver (Ag)	mg/L			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Thallium (Th)	mg/L			<0.005	<0.005	<0.005		<0.005	<0.005		
	Vanadium (V)	mg/L			<0.010	<0.010	<0.010		0.016	<0.010		
	Zinc (Zn)	mg/L			0.14	0.08	0.10	<0.05	0.07	<0.05	<0.05	<0.05

TCLP Metals 90 day	Property	Units	BDAT Standard		Battery Sludge w/ 33.3% Consol	Battery Sludge w/ 72.2% Tidd	Munitions Soil w/ 50% Consol	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 100% EPC	Industrial Soil w/ 50% Tidd	WWTP w/ 50% Tidd	WWTP w/ 50% EPC
			Current	Future								
	Antimony (Sb)	mg/L	---	2.1	0.242	0.107	0.024	0.026	<0.020	0.238	<0.020	<0.020
	Arsenic (As)	mg/L	5.0	5.0								
	Barium (Ba)	mg/L	100.0	7.6								
	Beryllium (Be)	mg/L	---	0.014	<0.001	<0.001	0.0040	<0.001	0.0025	<0.001	<0.001	0.0027
	Cadmium (Cd)	mg/L	1.0	0.19	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Chromium (Cr)	mg/L	5.0	0.86	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Copper (Cu)	mg/L	---	---	0.08	<0.05	0.97	0.09	0.82	0.13	<0.05	0.09
	Lead (Pb)	mg/L	5.0	0.37	<0.50	0.7	0.9	1.2	9.0	14.0	0.6	6.0
	Mercury (Hg)	mg/L	0.2	0.20/0.025								
	Nickel (Ni)	mg/L	---	5.1	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
	Selenium (Se)	mg/L	5.7	0.16								
	Silver (Ag)	mg/L	5.0	0.30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
	Thallium (Th)	mg/L	---	0.078								
	Vanadium (V)	mg/L	---	0.23								
	Zinc (Zn)	mg/L	---	5.3	0.40	0.20	5.60	0.23	3.20	1.10	0.08	2.56

* BDAT standards do not apply to shaded areas.

* Blank spaces indicate samples which have yet to be analyzed.

TABLE C.6: METALS ANALYSIS OF THE CYLINDERS PREPARED FOR PROCTOR TESTING

	Property	Units	BDAT Standard		Munitions Soil w/ 50% Tidd	Industrial Soil w/ 100% Consol	WWTP Soil w/ 50% EPC
			Current	Future			
TCLP Metals	Antimony (Sb)	mg/L	---	2.1	0.102	<0.020	<0.020
28 day	Arsenic (As)	mg/L	5.0	5.0			
Proctors	Barium (Ba)	mg/L	100.0	7.6		2.18	
	Beryllium (Be)	mg/L	---	0.014	<0.001	0.0114	0.0029
	Cadmium (Cd)	mg/L	1.0	0.19	<0.05	<0.05	<0.05
	Chromium (Cr)	mg/L	5.0	0.86	<0.50	0.05	<0.50
	Copper (Cu)	mg/L	---	---	0.14	0.52	0.20
	Lead (Pb)	mg/L	5.0	0.37	1.6	0.7	7.8
	Mercury (Hg)	mg/L	0.2	0.20/0.025			
	Nickel (Ni)	mg/L	---	5.1	<0.3	<0.3	<0.3
	Selenium (Se)	mg/L	5.7	0.16			
	Silver (Ag)	mg/L	5.0	0.30	<0.05	<0.05	<0.05
	Thallium (Th)	mg/L	---	0.078			
	Vanadium (V)	mg/L	---	0.23		0.097	
	Zinc (Zn)	mg/L	---	5.3	0.4	7.4	1.8

	Property	Units	BDAT Standard		Munitions Soil w/ 50% Tidd	Industrial Soil w/ 100% Consol	WWTP Soil w/ 50% EPC
			Current	Future			
TCLP Metals	Antimony (Sb)	mg/L	---	2.1	<0.020	0.101	<0.020
90 day	Arsenic (As)	mg/L	5.0	5.0			
Proctors	Barium (Ba)	mg/L	100.0	7.6			
	Beryllium (Be)	mg/L	---	0.014	<0.001	0.0072	<0.001
	Cadmium (Cd)	mg/L	1.0	0.19	<0.05	<0.05	<0.05
	Chromium (Cr)	mg/L	5.0	0.86	<0.50	<0.50	<0.50
	Copper (Cu)	mg/L	---	---	0.07	4.32	0.06
	Lead (Pb)	mg/L	5.0	0.37	1.3	0.8	0.5
	Mercury (Hg)	mg/L	0.2	0.20/0.025			
	Nickel (Ni)	mg/L	---	5.1	<0.3	<0.3	<0.3
	Selenium (Se)	mg/L	5.7	0.16			
	Silver (Ag)	mg/L	5.0	0.30	<0.05	<0.05	<0.05
	Thallium (Th)	mg/L	---	0.078			
	Vanadium (V)	mg/L	---	0.23			
	Zinc (Zn)	mg/L	---	5.3	0.5	8.6	0.6

* Blank spaces indicate samples which have yet to be analyzed.

TABLE C.7: COMPRESSIVE STRENGTH OF BY-PRODUCT/WASTE MIXTURES AFTER SPECIFIED CURING TIMES

All Strengths Reported in Pounds Per Square Inch (psi)

Curing Time	Mixture Type							
	CONSOL/ Battery Sludge	CONSOL/ Munitions Soil	Tidd/ Battery Sludge	Tidd/ Munitions Soil	Tidd/ Industrial Soil	Tidd/ WWTP Soil	Ebensburg/ Munitions Soil	Ebensburg/ WWTP Soil
3-Days	---	---	35	21	39	---	29	---
7-Days	---	---	61	40	82	32	295	71
14-Days	---	---	138	55	153	71	433	519
28-Days	---	27	178	143	217	134	494	652
90-Days	46	31	270	188	378	364	341	539

TABLE C.8: MOISTURE DENSITY DATA FOR CONSOL/INDUSTRIAL SOIL MIXTURE

UNIVERSITY OF PITTSBURGH

SOILS MECHANICS LABORATORY

COMPACTION TEST

Soil Sample Description CONSOL / Industrial Soil Sample 5:5

Location _____

Boring No. _____ Sample Depth _____

Sample No. _____ Test No. _____

Field Water Content 7.1 % Specific Gravity _____Date 6/29/95 Tested By J. Pitts

DENSITY

Determination No.	1	2	3	4	5
Wt. of mold + Comp. Soil (gm)	12.44	13.01	12.84	12.96	
Weight of Mold (gm)	9.55	9.49	9.35	9.57	
Weight of Compacted Soil (gm)	2.89	3.52	3.49	3.39	
Wet Density, γ (pcf)	86.8	105.7	104.8	101.8	
Dry Density, γ_d (pcf)	72.3	81.0	76.7	72.3	
Void Ratio, e					
Porosity, n					

WATER CONTENT

Determination No.	1	2	3	4	5
Container No.	1	2	3	4	
Weight of Container (gm)	75.42	71.22	86.21	72.18	
Weight of Container + Wet Soil	160.36	175.70	203.11	204.38	
Weight of Container + Dry Soil	146.21	151.29	171.82	166.08	
Weight of Water, W_w (gm)	14.15	24.41	31.29	93.90	
Weight of Dry Soil, W_s (gms)	70.79	80.07	85.61	38.30	
Water Content, $w\%$	19.99	30.49	36.55	40.78	

TABLE C.9: COMPACTION CURVE FOR CONSOL/INDUSTRIAL SOIL MIXTURE

JOB: CONSOL/Industrial SoilDATE TESTED: 6/29/95

HOLE NO.	SAMPLE NO.	w_n %	w_{opt} %	γ_d (max) pcf	METHOD OF TESTING
	1	20.0		72.3	
	2	30.5		81.0	
	3	36.6		76.7	
	4	40.8		72.3	

TABLE C.10: MOISTURE DENSITY DATA FOR TIDD/MUNITIONS SOIL MIXTURE

UNIVERSITY OF PITTSBURGH

SOILS MECHANICS LABORATORY

COMPACTION TEST

Soil Sample Description Tidd/ Munitions Soil Sample 5070

Location _____

Boring No. _____ Sample Depth _____

Sample No. _____ Test No. _____

Field Water Content 7.9% Specific Gravity _____Date 8/2/95 Tested By J. Pitts

DENSITY

Determination No.	1	2	3	4	5
Wt. of mold + Comp. Soil (gm) ^{lbs}	13.19	13.40	13.57	13.52	
Weight of Mold (gm) ^{lbs}	9.55	9.55	9.55	9.55	
Weight of Compacted Soil (gm) ^{lbs}	3.64	3.85	4.02	3.97	
Wet Density, γ (pcf)	109.3	115.6	120.7	119.2	
Dry Density, γ_d (pcf)	97.0	99.4	100.1	94.7	
Void Ratio, e					
Porosity, n					

WATER CONTENT

Determination No.	1	2	3	4	5
Container No.	16	8	10	18	
Weight of Container (gm)	69.89	70.60	73.67	2.605	
Weight of Container + Wet Soil	151.11	149.48	146.72	64.013	
Weight of Container + Dry Soil	142.00	138.42	134.27	53.449	
Weight of Water, W_w (gm)	9.11	11.06	12.45	13.169	
Weight of Dry Soil, W_s (gms)	72.11	67.82	60.60	50.844	
Water Content, w%	12.63	16.31	20.54	25.9	

TABLE C.11: COMPACTION CURVE FOR TIDD/MUNITIONS SOIL MIXTURE

JOB: Tidd/Munitions SoilDATE TESTED: 8/2/95

HOLE NO.	SAMPLE NO.	$w_n\%$	$w_{opt.}\%$	γ_d (max)pct	METHOD OF TESTING
	1	12.6		97.0	
	2	16.3		99.4	
	3	20.5		100.1	
	4	25.9		94.7	

TABLE C.12: MOISTURE DENSITY DATA FOR EBENSBURG/WWTP SOIL MIXTURE

UNIVERSITY OF PITTSBURGH

SOILS MECHANICS LABORATORY

COMPACTION TEST

Soil Sample Description Ebensburg / WWTP Soil Sample 5090

Location _____

Boring No. _____ Sample Depth _____

Sample No. _____ Test No. _____

Field Water Content 7.6 % Specific Gravity _____Date 9/25/95 Tested By J. Priddy

DENSITY

Determination No.	1	2	3	4	5
Wt. of mold + Comp. Soil (gm)	—	—	—	—	—
Weight of Mold (gm)	—	—	—	—	—
Weight of Compacted Soil (gm)	1626	1697	1802	1780	
Wet Density, γ (pcf)	100.9	112.2	119.2	117.7	
Dry Density, γ_d (pcf)	93.8	99.5	101.7	97.3	
Void Ratio, e					
Porosity, n					

WATER CONTENT

Determination No.	1	2	3	4	5
Container No.	4	30	24	26	
Weight of Container (gm)	2.6221	2.6071	2.6142	2.6052	
Weight of Container + Wet Soil	59.8560	54.2843	56.6351	56.7303	
Weight of Container + Dry Soil	55.7899	48.4176	48.7019	47.3197	
Weight of Water, W_w (gm)	4.0661	5.8667	7.9332	9.4106	
Weight of Dry Soil, W_s (gms)	53.1678	45.8105	46.0877	44.7145	
Water Content, $w\%$	7.6	12.8	17.2	21.0	

TABLE C.13: COMPACTION CURVE FOR EBENSBURG/WWTP SOIL MIXTURE

JOB: Ebensburg/WWTP Soil

DATE TESTED: 9/25/95

HOLE NO.	SAMPLE NO.	$\omega_n\%$	$\omega_{opt.}\%$	γ_d (max)pcf	METHOD OF TESTING
	1	7.6		93.8	
	2	12.8		99.5	
	3	17.2		101.7	
	4	21.0		97.3	

**TABLE C.14: COMPRESSIVE STRENGTH OF BY/PRODUCT WASTE MIXTURES PREPARED BY THE PROCTOR
COMPACTION METHOD AFTER SPECIFIED CURING TIME**

All Strengths Reported in Pounds Per Square Inch (psi)

Curing Time	Mixture Type		
	CONSOL/Industrial Soil	Tidd/Munitions Soil	Ebensburg/WWTP Soil
14-Days	101	59	166
28-Days	106	60	110
90-Days	109	98	88

APPENDIX D: NEPA REPORT

Center for

Hazardous

Materials

Research

300-5354-002

**ENVIRONMENTAL
INFORMATION REPORT FOR
PHASE TWO: TREATMENT OF
METAL-LADEN HAZARDOUS
WASTES WITH ADVANCED
CLEAN COAL TECHNOLOGY
BY-PRODUCTS**

Prepared for:

UNIVERSITY OF PITTSBURGH
Energy Resources Program

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ENVIRONMENTAL INFORMATION REPORT FOR PHASE TWO: TREATMENT OF METAL-LADEN HAZARDOUS WASTES WITH ADVANCED CLEAN COAL TECHNOLOGY BY-PRODUCTS

OCTOBER 1995

Prepared For:

UNIVERSITY OF PITTSBURGH
Energy Resources Program

U.S. DEPARTMENT OF ENERGY
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EXECUTIVE SUMMARY

The University of Pittsburgh Energy Resources Program has been awarded a contract from the U.S. Department of Energy (DOE) to evaluate the effectiveness of using by-products from advanced sulfur removal systems to treat metal-laden characteristic hazardous wastes. The Center for Hazardous Materials Research (CHMR) has been subcontracted by the University of Pittsburgh to provide the environmental information needed for DOE to make an environmental review determination pursuant to DOE's Implementing Procedures (10 CFR 1021, Subpart B) under the National Environmental Policy Act (NEPA).

This environmental information report is supplemented by the completed DOE Morgantown Energy Technology Center (METC) Environmental Questionnaire included in Appendix A. The DOE METC Environmental Questionnaire is used by DOE to determine the level of NEPA review required. This environmental information report extends the scope of the questionnaire, which is often used as a basis for a Categorical Exclusion determination, to include topics typically addressed in an Environmental Assessment.

This report includes project information, including a description of the proposed action, project and report objectives, estimated project schedule, and proposed action location and facilities. Potential environmental impacts and environmental compliance issues are discussed. A summary of the permits obtained by the Mill Service, Inc. (MSI) Yukon Plant facility, the location of the proposed demonstration, and any other permits required to conduct the Phase Two demonstration project are provided. Finally, a summary of the existing characteristics of the proposed action site and potential environmental impacts is included.

Major findings of CHMR's review include the following:

- There will be no new land use impacts to the region. Similarly, existing aesthetic views at the Yukon Plant site will not be affected by the proposed action.
- The proposed action would have negligible air quality impacts on the Yukon Plant site and surrounding area.
- The Yukon Plant site currently meets air quality permit requirements for commercial operations at the site. A permit determination form will be

filed by MSI to notify the Pennsylvania Department of Environmental Protection (PADEP) that a new material will be used to treat hazardous waste.

- The proposed project activities will not impact a floodplain or wetland.
- Any wastewater generated from the proposed project would be reused and/or discharged under MSI's current National Pollutant Discharge Elimination System (NPDES) permit. No additional permits are required.
- The Yukon Plant currently follows and would continue to follow during the proposed demonstration solid and hazardous waste management procedures as required under the Resource Conservation and Recovery Act (RCRA). A permit modification to allow MSI to treat metal-laden hazardous waste using stabilization and solidification has been filed with PADEP.
- The proposed action does not have the potential to significantly affect plant or animal species or their habitats, endangered (or threatened) plant or animal species, or migratory condors.
- The proposed action would not affect any archaeological or historic resources.
- No effects on local population, the transportation system, public services, property values, or energy resources are expected.
- There are no impacts anticipated on public services, property values, or energy resources as a result of the proposed action.
- The MSI Yukon Plant's Health and Safety Plan (overall site and operations) and Chemical Hygiene Plan (laboratory) requirements address the Occupational Safety and Health Administration and Environmental Protection Agency requirements for the site's current commercial operations. No new worker health and safety issues are anticipated to result from conducting the proposed action.

1.0 INTRODUCTION

The Center for Hazardous Materials Research (CHMR) has prepared this environmental information report to fulfill requirements for environmental review of a U.S. Department of Energy (DOE) proposed action pursuant to DOE's Implementing Procedures (10 CFR 1021, Subpart B) under the National Environmental Policy Act (NEPA). Information concerning effects on environmental resources in the proposed project area is necessary for DOE to determine the level of NEPA review required for a proposed action.

The proposed action is an evaluation of the use of by-products from advanced sulfur removal systems in the treatment of metal-laden characteristic hazardous wastes. The University of Pittsburgh Energy Resources Program has been awarded a contract from DOE to evaluate the effectiveness of this type of treatment.

Included in Appendix A is a completed DOE Morgantown Energy Technology Center (METC) Environmental Questionnaire for the proposed project. The DOE METC Environmental Questionnaire is necessary for DOE to determine the level of NEPA review required, i.e., whether it can be covered under a Categorical Exclusion (CX) or would require an Environmental Assessment (EA).

It is the intent of CHMR in the development of this report to go beyond the scope of the Environmental Questionnaire, covering topics included on the questionnaire and additional environmental resource topics typically addressed in an EA. This additional environmental review has been provided to address any and all potential environmental concerns with the proposed action in order to facilitate DOE's NEPA determination process.

Section 2.0 of this environmental information report includes a proposed action description, project and report objectives, estimated project schedule, and a description of proposed action location and facilities. Potential environmental impacts from the proposed action and environmental compliance issues are detailed in Section 3.0. Section 4.0 includes information on the specific permits currently held by MSI for the Yukon Plant commercial operations and any additional permits needed to conduct the project. A summary of the potential impacts is presented in Section 5.0.

Finally, addresses and telephone numbers of federal and state officials who were asked to review the proposed action, copies of the letters submitted to those officials (and mail receipts), and copies of response letters are included in Appendices B, C, and D, respectively.

2.0 PROJECT DESCRIPTION

Phase Two of the project includes conducting up to 10 commercial-scale treatments of characteristic metal-laden hazardous wastes at the Mill Service, Inc. (MSI) Yukon Plant, using solid by-products generated through Clean Coal Technologies (CCT). The waste streams would contain appropriate ratios of waste and by-product as researched during the Phase One treatability study. The waste batches would total between 22 and 40 tons each (waste and by-product).

Following are descriptions of the project and report objectives, project schedule, the location of the proposed action area, and the project plan.

2.1 PROPOSED ACTION OBJECTIVES

The general objective for the Phase Two field study is to provide information on the ability of new sources of chemical treatment materials to be used by the hazardous waste management industry. In particular, the proposed action will provide data on the potential for by-products from advanced clean coal technologies to be used effectively to treat metal-laden characteristic hazardous wastes. Ultimately, this generation of data on the ability of by-products from advanced CCT to be used to stabilize and solidify hazardous wastes would:

- Provide new sources of treatment material for hazardous waste management facilities
- Provide new uses for by-products of advanced coal combustors and desulfurizers
- Lessen the need to landfill significant amounts of by-products with limited commercial value.

The specific objective of the project as noted in the "Statement of Cooperative Agreement Objectives" of the contract document between DOE and the University of Pittsburgh Energy Resource Program is the following:

"The objective of this project is to evaluate treatment of [characteristic] metal-laden hazardous wastes using solid by-products generated by Clean Coal Technologies (CCT). The project is divided into two phases...In Phase Two, the participant will evaluate treatment of the [characteristic] metal-laden hazardous waste using CCT solid by-products in 20-ton batches. Complete physical and

chemical characterization of the CCT solid by-products, and treated and untreated [characteristic] metal-laden hazardous waste will be performed in both phases. An economic analysis is included in both phases to assess the commercial viability of treating metal-laden hazardous waste with CCT solid by-products."

2.2 REPORT OBJECTIVES

Pursuant to DOE NEPA Implementing Procedures (10 CFR 1021, Subpart B), DOE is required to consider the potential environmental consequences of all proposed actions during the early planning stages. This environmental review report and the DOE METC Environmental Questionnaire (included in Appendix A) will enable DOE to determine the level of NEPA review required for this proposed action. In addition, this supplemental report is intended to provide the additional information that may be needed beyond the Environmental Questionnaire in order for DOE to make the required NEPA determination.

2.3 PROJECT SCHEDULE

The proposed demonstration project would be a temporary action, to last no longer than 12 months. Funding for the demonstration is in effect from September 30, 1995 to September 30, 1996. However, it is anticipated that the project would not begin until December 1995 or January 1996 and end in September 1996.

2.4 LOCATION

The proposed Phase Two demonstration project is planned to occur at the MSI Yukon Plant located in South Huntingdon Township, Westmoreland County, Pennsylvania. The address is: R.D. #1, Box 135A, Yukon, Pennsylvania 15698. Figure 2-1 shows the location of the MSI Yukon Plant site and the proposed action area.

2.5 FACILITIES AND PROJECT PLAN

The MSI Yukon Plant is a Resource Conservation and Recovery Act (RCRA) permitted treatment, storage, and disposal (TSD) facility, authorized to treat and store certain hazardous wastes and to treat, store, and dispose of certain nonhazardous wastes. Treated hazardous wastes are evaluated at an on-site laboratory to determine whether they meet applicable RCRA treatment standards. This same process would be

FIGURE 2-1
LOCATION OF MSI YUKON PLANT SITE AND PROPOSED ACTION AREA

practiced for the incoming metal-laden hazardous wastes to be treated under the proposed action.

Under the proposed action, samples of the treated wastes would also be sent to the University of Pittsburgh Energy Resources Program for further characterization. All unused waste residues would be returned to the Yukon Plant for disposal.

Nonhazardous materials that MSI does not dispose in its permitted on-site solid waste impoundment would be packaged and sent to an off-site permitted disposal facility, most likely the Greenridge Reclamation facility in Scottdale, Pennsylvania (see Section 3.4 of this document for a list of other available facilities). Wastes and treatment residues that demonstrate hazardous waste characteristics (e.g., lead) would be treated again using routine methods or disposed at a permitted hazardous waste disposal facility.

3.0 POTENTIAL ENVIRONMENTAL IMPACTS FROM PROJECT

This section includes information concerning current environmental characteristics of the Yukon Plant site and any potential environmental impacts that may be anticipated from the proposed action. Included are discussions on the potential impacts on land use and aesthetics, air quality, water quality, ecology, cultural resources, socioeconomics, and noise levels. Also described are the current status and potential impacts from Phase Two activities on the solid and hazardous waste management practices and on worker health and safety at the site. General compliance issues are discussed. However, a more detailed review of permits currently held at the Yukon Plant and any additional permits required for the Phase Two demonstration is provided in Section 4.0.

In addition, as stated previously, a completed DOE METC Environmental Questionnaire is included in Appendix A of this document. The information provided below supplements the information provided in that questionnaire.

3.1 LAND USE AND AESTHETIC QUALITY

The MSI Yukon Plant site in South Huntingdon Township, Westmoreland County, is a RCRA-permitted commercial hazardous waste TSD facility located on approximately 160 acres (of which 50 to 75 acres are undeveloped). The proposed action area would encompass approximately 2 acres of that existing site. Locations of the Yukon Plant and proposed action area are shown on Figure 2-1. There will be no new construction as a result of the project.

South Huntingdon Township has no zoning requirements within the township. The proposed action is consistent with the Yukon Plant's industrial land use at the site. Residences are located within 200 feet of the perimeter of MSI's property boundary. Trucks hauling materials/wastes for the proposed action would access the site through the same roads and access points currently used by trucks hauling wastes and treatment chemicals to the Yukon Plant for commercial operations (see Section 3.7 of this report). The project would not introduce any new land use impacts to the region.

Views of the Yukon Plant are partially blocked through natural barriers (e.g., tree lines and hills) and constructed barriers (e.g., impoundment dikes). These barriers aesthetically separate industrial and residential uses of the land.

Scenic views would not be changed by the proposed action. There would be no physical changes to the Yukon Plant site due to the proposed action. Since the action would take place at the existing facility, the project is not expected to have any effects on existing or future recreational opportunities in the area. The site is not located in or near a national park or wilderness area. Thus, there are no anticipated impacts to visual and aesthetic values resulting from the proposed action at the Yukon Plant site.

3.2 AIR QUALITY

CHMR has toured the currently operating Yukon Plant site and has reviewed MSI's air quality permits. Based on this review, it is CHMR's understanding that the site meets PADEP's air quality compliance rules for current operations. MSI's Yukon Plant has obtained the following air quality permits for their current operations: fabric filter for material unloading system, venturi scrubber for acid waste reactor, acid tank covers, and fabric filter for lime handling system. CHMR believes, based on a cursory review of air quality information obtained from MSI, that current commercial operations at the site do not fall into the major source¹ category of air emissions.

It is anticipated that the proposed project would also not require a Plan Approval or Operating Permit, since the activities would not be expected to be a major source of air emissions. In addition, no major changes to the existing facility's air quality control permits are necessary to meet compliance for the proposed action. However, since MSI will be bringing in a new material to treat the metal-laden hazardous waste (i.e., coal by-product), MSI has indicated that it intends to submit a PADEP "Request for Determination of Requirement for Plan Approval/Operating Permit Application" form.

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¹PADEP defines major sources as those with the potential to emit to the outside air ≥ 100 tons per year (tpy) of any criteria pollutant, ≥ 50 tpy of volatile organic compounds (VOCs), ≥ 10 tpy of any single hazardous air pollutant (HAP), or ≥ 25 tpy of any combination of HAPs. This definition is the same as the federal definition.

The proposed project would not be classified as construction of a new source or a major modification to an existing source. Therefore, the project would not be subject to new source performance standards (NSPSs) or prevention of significant deterioration (PSD). The proposed project is in compliance with the national emission standards for hazardous air pollutants (NESHAPs). The area in which MSI's Yukon Plant site is located, however, is not in compliance with all of the National Ambient Air Quality Standards (NAAQS); the area is in noncompliance for ozone, as is the rest of Pennsylvania. New hazardous air pollutants (HAPs) may result from the proposed action, including: beryllium, chromium, nickel, arsenic, selenium, cadmium, antimony, mercury, and lead. The potential emissions of these HAPs, however, are extremely small and thus, are anticipated to have a negligible impact on the area.

CHMR's evaluation of potential air quality impacts at the site indicates that the proposed action will not adversely affect human health or the environment as a result of air emissions.

As a result of local resident concern of the MSI Yukon Plant's air quality impacts under current operations (e.g., complaints of visible emissions and odors, concerns over past operation violations by the local citizen's group--Concerned Residents of the Yough), PADEP has initiated a year-long on-site/off-site air sampling program to quantify air quality impacts of current operations at the MSI Yukon Plant site. The list of chemicals being analyzed using PADEP high-volume samplers include: chromium, arsenic, selenium, silver, cadmium, barium, lead, and total suspended particulate. The air samplers operate for a 24-hour period every 3 days. PADEP is also collecting on-site meteorological data, including temperature, wind direction and speed, radiation, and precipitation. The map included in Figure 3-1 indicates the approximate locations of the air samplers and meteorological tower.

Since the proposed action is planned to occur as a part of regular commercial operations, no additional impacts relative to the mass emissions are expected. Nearly all emissions resulting from the proposed action are expected to be from fugitive rather than point sources. According to MSI representatives, should fugitive emissions become a problem, a cover would be used along with a water spray containing a dust suppressant. It is expected that this would capture in excess of 95 percent of the emissions. The contents of the potential fugitive emissions, due to by-product and waste stream constituents, may include some or all of the following:

FIGURE 3-1
APPROXIMATE LOCATIONS OF HIGH-VOLUME SAMPLERS
AND METEOROLOGICAL TOWER

beryllium, vanadium, chromium, lead, nickel, zinc, arsenic, selenium, silver, cadmium, antimony, barium, and mercury.

In summary: (1) current operations at the Yukon Plant are in compliance with current PADEP air quality rules² and the proposed action would also be in compliance, and (2) the proposed action would have negligible air quality impacts at the Yukon Plant site and the surrounding area.

3.3 WATER RESOURCES

The MSI Yukon Plant routinely collects, treats, and disposes of wastewater generated on site as part of its normal operations. The National Pollutant Discharge Elimination System (NPDES) permitted treatment system, as shown in the accompanying flow diagram, Figure 3-2, has the flexibility to treat both hazardous wastewaters (from an old RCRA cell and mine drainage) and nonhazardous wastewaters from the active disposal unit.

Treated wastewaters are discharged to the Sewickley Creek in accordance with MSI's NPDES and Water Management permits. The Commonwealth of Pennsylvania, PADEP, Bureau of Water Quality Management regulates water quality in the area and monitors compliance with the facility NPDES discharge permit. No additional local requirements apply to this discharge.

Several thousand gallons of wastewater could possibly be generated during the proposed Phase Two project if decontamination of the treatment unit is needed between the full-scale waste treatment tests. Decontamination would only be necessary if a batch of materials with a different ultimate disposal site is treated. In this case, wastewater from decontamination would be collected and blended into a subsequent similar batch as a wetting agent to activate the reaction between waste and by-products. If necessary, wastewater could also be diverted to the current wastewater treatment system for treatment and discharge under the existing NPDES permit. This small amount of wastewater would not significantly impact the

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²This is based on the understanding that MSI will submit a "Request for Determination of Requirement for Plan Approval/Operating Permit Application" form to PADEP and that fugitive emissions will be monitored and actions will be taken accordingly.

FIGURE 3-2
MSI YUKON PLANT NPDES TREATMENT SYSTEM FLOW DIAGRAM

treatment system that currently processes approximately 80,000 gallons of wastewater each day.

Water for decontamination activities would be supplied as necessary from the Municipal Authority of Westmoreland County Beaver Run water treatment plant. No groundwater sources would be used as a water supply.

The proposed project activities, which would utilize MSI's existing facility and equipment, would not:

- Require the diversion of a flowing body of water or alter a drainage pattern
- Cause an increase or decrease in the surface area of an existing body of water
- Cause soil erosion or adversely affect the quality or movement of groundwater.

Finally, the proposed action would not impact a floodplain or wetland. A letter requesting review of potential impacts of the proposed project on U.S. Corps of Engineers projects, wetlands, or 100-year floodplains was submitted to James A. Purdy, Chief, Environmental Studies Branch of the U.S. Department of the Army, Pittsburgh District, Corps of Engineers in Pittsburgh, Pennsylvania (see copy of letter in Appendix C). The Pittsburgh District of the Corps of Engineers reviewed the project information and location and determined that no wetlands, Corps projects, or 100-year floodplains would be impacted as a result of the project (see response letter in Appendix D).

3.4 SOLID AND HAZARDOUS WASTE MANAGEMENT

Details on the waste management practices currently followed at the Yukon Plant and any changes required to conduct the Phase Two demonstration project are provided below. This description includes information on waste characteristics, quantities, storage, transportation, and disposal practices. It also includes a brief discussion concerning compliance with environmental regulations; see Section 4.0 of this document for further details on the status of required permits.

Waste Identification

All hazardous waste streams received for treatment at the Yukon Plant must be pre-approved for acceptance and treatment. The pre-approval process includes chemical and physical characterization through laboratory analyses. The proposed Phase Two study would include up to ten full-scale batch treatments using the same types of treatment chemical (by-product) and waste streams evaluated in the laboratory treatability studies conducted during Phase One of the study.

Under RCRA, hazardous waste TSD facilities are required to conduct compatibility testing on all process materials (wastes and treatment materials) prior to acceptance of any wastes for processing. This pre-approval testing must be completed, and the treatment facility must provide formal written acceptance of the waste stream to the generator prior to either transporting or treating the waste.

MSI's program incorporates these requirements into their routine procedures. Random, on-site fingerprint analyses in accordance with internal quality control procedures are performed on waste materials received at the facility prior to processing. This testing ensures that each waste batch received is consistent with both physical and chemical composition of the approved waste streams. Waste streams are only accepted for treatment after analysis confirms consistency. Any waste streams not conforming to the pre-approved characteristics (e.g., excessive dust and fines, uncharacteristic pH, excessive odor) are returned to the generator. Sampling of the incoming waste shipments is performed in accordance with MSI's waste shipment sampling protocol. Treatability studies, waste characterization, and analyses of all waste streams proposed for treatment are performed in MSI's on-site laboratory.

Treatment Process

Once wastes have met identification criteria, they are transported to a designated treatment unit and transferred from the transport container directly into the unit. The unit to be used for Phase Two are the Mixing Pits, a system of three tanks that are used to treat solid (form) hazardous wastes. Each tank has the following characteristics:

Treatment capacity:	20-80 tons
Tank dimensions:	30 ft. X 12 ft. X 12 ft.
Capacity:	Total 160 cu. yds. @ freeboard operation 133 cu. yds.
Type of construction:	18 inch reinforced concrete (outer shell) 3/4-inch steel inner shell

During off-loading, the transport vehicle is parked on an impervious (concrete) pad that slopes towards the mixing pits. A primary concern during unloading is the dispersal of particulate (fugitive emissions) into the ambient air. MSI has means to deal with fugitive emissions at the Mixing Pits but attempts not to manage wastes with this potential in these units. If excessive particulate emissions occur during the proposed action, MSI will use a fine water spray for particulate control as necessary during waste unloading. (See Section 3.2 of this document, *Air Quality*, for further discussion.)

Following off-loading, the waste stream is thoroughly mixed with treatment chemicals by mechanical means (e.g., excavator, earth moving equipment). The amount of treatment chemicals needed for each waste stream is pre-determined during treatability testing as part of the waste acceptance process.

Two to four hours of mixing is required to provide adequate waste/treatment chemical contact time and thorough blending of materials. As with the unloading, MSI would use a fine water spray to control particulate emissions as necessary. This phase of treatment poses minimal operator exposure to the treatment materials.

For the proposed Phase Two demonstration, CCT by-products would be used as the treatment chemicals for metal-laden hazardous wastes. In Phase One, CCT by-products from three companies were tested to identify which by-product was best suited to the Phase Two demonstration. Based on Phase One treatability testing, the CCT by-product from Consol, Inc. was identified as the most effective waste stabilization agent with a variety of heavy metal-contaminated wastes. During Phase Two, by-products either from one of the three facilities participating in the Phase One study, or a similar by-product from another facility would be used as a stabilizing agent. For Phase Two activities, stabilization materials would be stored adjacent to the mixing pits in one or more shipping containers for ready access.

Once the treated waste is rendered nonhazardous, it would be disposed either in a permitted on-site solid waste impoundment or sent off-site to a permitted residual waste disposal facility. If a treatment batch from the Phase Two demonstration fails the Toxicity Characteristic Leaching Procedure (TCLP), MSI would follow its current procedures and either: (1) add other stabilization chemicals to complete successful treatment, or (2) ship the waste off site to an authorized hazardous waste disposal facility. Additional treatment chemicals and stabilizing agents would be added using mechanical means, such as excavator buckets, bags, or scoops.

Treatment Validation

After the mixing process is completed, the mixed material is sampled and analyzed at the on-site MSI or off-site laboratory. The primary parameters analyzed are TCLP and any specific waste-related parameters required by MSI or the disposal vendor.

MSI's sampling protocol follows guidelines in Section 5.3, Sampling Methods, of Hazardous Waste Permit No. PAD004835146 Permit Modification Request, dated January 15, 1993. These protocol include the collection of four samples with an excavator shovel at even distances along the length of the mixing pit. An aliquot of each excavator shovel is removed using a clean scoop and composited into a sample container. The composite sample is thoroughly mixed and sent to MSI's laboratory for analysis and characterization. If the sampling occurs after the treated waste has been loaded into shipping containers, the protocol used for sampling solid waste shipments is used. This protocol requires the collection of three equally distributed samples, using a trier/core sampling device, along the length of the container to obtain a composite sample.

Under the proposed Phase Two demonstration, the mixed waste would be stored on site in a transport container. Sampling will follow MSI's sampling protocol for treated wastes in storage containers. Additional samples may be taken for further research purposes as designated by University of Pittsburgh project team.

Quality Assurance/Quality Control

In all hazardous waste treatment applications, laboratory testing verifies the success or failure of the treatment process. Thus, the generator must be assured that all

laboratory analyses are properly conducted in accordance with applicable standards. The primary reference used by MSI to verify acceptable performance standards of its on-site laboratory is MSI's *Laboratory Quality Assurance Program*, April 5, 1993; Revised September 21, 1994. The purpose of the *Laboratory Quality Assurance Program* is to ensure that the MSI Yukon Plant Laboratory produces accurate and precise analytical data by establishing standards for the performance of all laboratory work. The quality assurance program is applicable to all analyses performed by the laboratory, including treatment verification tests, waste characterization samples, treatability study samples (related to the waste stabilization process), and surface and groundwater samples.

The primary references utilized by the on-site laboratory are:

- EPA-600/4-79-019 "Handbook for Water Quality Control in Water and Wastewater Laboratory"
- EPA-600/4-79-020 "Methods for Chemical Analysis of Water and Wastes".
- EPA-SW-846 "Test Methods for Evaluating Solid Waste, Physical/-Chemical Methods"
- "Standard Methods for the Examination of Water and Wastewater."

On-site Storage

After the mixing/stabilization process is completed, the treated wastes are transferred to a storage container (e.g. a 30-yd³ roll-off box lined with plastic and covered with a tarp). Loading into the container takes place on an impervious sloped pad. Any spillage during the loading operation would be redirected back into the mixing pit.

Once loaded, the storage containers are moved to a designated area near the mixing pit area. Waste containers in this area are managed using the following practices:

- Roll-off boxes are lined to contain the entire volume of material.
- Roll-off boxes are covered to prevent precipitation infiltration.
- Liners and covers are compatible with treated wastes.
- Each roll-off is labelled according to contents.

- The storage container areas are inspected daily for signs of spillage or leakage.
- Roll-off boxes are sufficiently segregated to allow easy inspection.

Treated Waste Disposal

MSI expects to send the treated waste from the Phase Two demonstration project to Greenridge Reclamation located in Scottdale, Pennsylvania, a residual waste disposal facility. All incoming and outgoing transportation would occur over established routes. In addition to Greenridge Reclamation, MSI contracts the following facilities for off-site disposal of treated wastes:

BFI Waste Systems
Carbon Limestone Landfill
Poland, OH
(High pH and residual wastes)

M.C. Arnoni Company
South Hills Disposal
Pittsburgh, PA
(Residual wastes)

Westmoreland County Municipal Authority
Monessen, PA
(Residual wastes)

Certain wastes treated as part of the Phase Two demonstration may also be disposed in MSI's Impoundment No. 6 Residual Waste Disposal Facility at the Yukon Plant, permitted in August 1986.

Substances Involved in Stabilization Process

METAL-LADEN WASTE STREAMS

These waste streams are typically RCRA "characteristic" wastes in solid and sludge forms. The primary pollutant in Phase One was lead. In Phase One activities, the following waste streams were treated:

- Battery manufacturing sludge with the following parameters of concern: cadmium, lead, and antimony

- Munitions depot soil with the following parameters of concern: barium, cadmium, chromium, lead, zinc, beryllium, vanadium
- Multi-use industrial site soil with the following parameters of concern: barium, cadmium, chromium, lead, mercury, zinc, beryllium, vanadium.

Under Phase Two, the wastes to be treated would be similar to the Phase One waste streams and would be selected from wastes received at MSI's Yukon Plant for treatment during the project period.

STABILIZATION AGENTS

These are nonhazardous materials used to stabilize and treat hazardous wastes in accordance with regulatory requirements. Under Phase One activities, the following by-products were tested:

- Dry scrubber residue supplied by Consol, Inc. from a Joy Niro Spray Drier in New Jersey
- Residue from a Coal-Waste-Fired CFBC operated by the Ebensburg Power Company in Ebensburg, Pennsylvania
- Residue from a Coal-Fired Pressurized Fluid Bed Combustor (PFBC) at the Tidd Station of Ohio Power Company, a subsidiary of American Electric Power Corporation, at Brilliant, Ohio.

The primary treatment material to be used in the Phase Two project would be one of the above materials, or possibly a similar by-product from a different facility that would be made available to the project. Other solidification/stabilization agents and chemicals may be used in the mixing process including: (1) lime, cements, cement kiln dust, flyash, bentonite/clays, silicates, aluminates, and (2) proprietary chemicals, and other treatment chemicals including ferrous sulfate, sodium sulfate, and phosphates.

3.5 ECOLOGY

No significant impacts on wildlife or vegetation are anticipated as a result of the proposed action. The proposed action does not include planned construction or any increase in the amount of waste treatment operations currently taking place at the Yukon Plant. Therefore, the action does not have the potential to significantly affect

plant or animal species or their habitats, endangered (or threatened) plant or animal species, or migratory corridors.

A letter of notification was submitted to the U.S. Fish and Wildlife Service regional office (see copy of letter sent in Appendix C). A response letter from the Supervisor of the U.S. Fish and Wildlife Service regional office in State College, Pennsylvania (see copy of letter in Appendix D) indicates that, pursuant to the Endangered Species Act of 1973, there are no federally listed or proposed threatened or endangered species known to exist in the project impact area. Therefore, no Biological Assessment or further consultation under the Endangered Species Act with the Fish and Wildlife Service was recommended.

The response letter noted that information concerning state-listed endangered or threatened species can be obtained from the Pennsylvania Game Commission (birds and mammals), the Pennsylvania Fish and Boat Commission (fish, reptiles, and amphibians), and the Pennsylvania Department of Conservation and Natural Resources (plants). However, discussion with staff at the U.S. Fish and Wildlife Service regional office indicated that such actions were not deemed necessary for this type of action, a short-term demonstration at an existing RCRA-permitted industrial facility.

3.6 ARCHAEOLOGICAL, CULTURAL, AND HISTORICAL RESOURCES

The Yukon Plant site does not contain any buildings over 50 years of age. There would be no new construction and no ground disturbance as a result of this proposed action. Thus, the proposed action would not significantly affect any structures listed in the National Register of Historic Places or other structures 50 years old or older.

A letter of notification was submitted to the State Historic Preservation Officer (see Appendix C). The Chief, Division of Archaeology & Protection, Bureau for Historic Preservation, Pennsylvania Historical and Museum Commission, reviewed the proposed project's potential impact on historic and archaeological resources in accordance with Section 106 of the National Historic Preservation Act of 1966. A letter from the Chief, included in Appendix D of this document, indicates that this proposed project would have no effect on archaeological or historic resources.

3.7 SOCIOECONOMICS

Labor Force

Presently at the Yukon Plant, there are two shifts in operation (8 a.m. to 4 p.m. and 4 p.m. to 12 a.m.). Between 10 and 15 employees are on site during the daylight shift--a director of operations, an assistant manager, 1 or 2 laboratory technicians, 6 to 7 management staff, and 2 to 5 laborers.

During the proposed Phase Two demonstration project, current staff would conduct the treatment process and laboratory analysis. No additional employees will be needed. Therefore, no effects on the local population are expected as a result of the proposed action.

Transportation

The current transportation system at the site is not expected to be impacted by the proposed action. Currently, transport vehicles that haul wastes to and from the Yukon Plant access Interstate 70 at the Mt. Pleasant/West Newton exit (Exit 24) and travel SR 3061 and SR 3059 to and from the facility entrance. It is a total of less than three miles from Interstate 70 to the facility entrance gate. It is estimated that as many as 70 loads of waste per day have been received at the Yukon Plant, although the current number is approximately half of that amount. MSI estimates that as many as 20 vehicles (including roll-offs and dump trailers) travel to and from the Yukon Plant each day for the purpose of disposing treated wastes off-site.

Since MSI plans to conduct the treatment tests during typical commercial operation times, it is anticipated that there will be no additional vehicles on nearby roads due to the project. The same roads and access points are expected to be used during the proposed demonstration project as are currently used during commercial operations.

Public Services

There are no impacts anticipated on public services as a result of the proposed action. Since there are no additional employee requirements due to the demonstration project, no change in the local population is expected that would result in a greater demand

for local services such as schools, fire protection, and police protection. Further, property values are not expected to be affected since the proposed action would occur at an already permitted hazardous waste TSD facility.

Energy Requirements

MSI's current operations, with respect to the Phase Two demonstration, primarily involve mechanical mixing and transporting of wastes; they do not require high-volume electrical or natural gas usage. Electricity and/or natural gas are used strictly for heating and lighting purposes. Mechanical equipment and vehicles used in the operations are fueled with diesel fuel.

Because the proposed Phase Two demonstration would be incorporated in MSI's existing, non-energy intensive operations, no increase in energy usage in or energy efficiency of the municipality would occur. There would not be a need for additional transmission lines, nor would there be any significant impact on the local community's energy supply.

3.8 NOISE

The Health and Safety Plan (HASP) for current operations at the Yukon Plant site indicates that no one on site is currently exposed to noise levels that equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of 50 percent (level set in OSHA 29 CFR 1910.95). Although residents in the area have reportedly complained about alarm bells coming from the pump station during the night, actual noise levels within site boundaries have not been monitored in excess of the 85 decibel level. No additional noise sources would be present under the proposed action.

In order to avoid potential overexposure, the HASP indicates that MSI monitors ambient noise levels twice per year. If the critical noise threshold is reached, staff would be required to implement hearing protection measures. This would include having employees wear hearing protection and conducting an audiometric testing program to document any hearing loss.

3.9 OCCUPATIONAL SAFETY AND HEALTH

CHMR has reviewed MSI's HASP in order to determine whether it currently addresses the requirements of OSHA 29 CFR 1910.120 and EPA 40 CFR 311 and whether any changes would be necessary to conduct the proposed action. The HASP covers all areas, operations, and personnel on site except for the laboratory. MSI has developed a specific Chemical Hygiene Plan for this operation. In addition, MSI has developed and maintains a hazard communication program.

Health and Safety Plan

MSI's HASP indicates that employees are being trained and records are being maintained in accordance with OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) regulations. This level of training is sufficient for the proposed Phase Two demonstration.

Based on required workplace hazard assessments, MSI selects and determines the appropriate personal protective equipment (PPE) to be used by employees to protect them from hazards relating to each operation implemented. For each operation, employees are informed of the potential hazards and if PPE must be used to protect them from a hazardous condition. Each employee is properly fitted with necessary PPE for hazardous operations. All employees required to wear PPE are trained to know: when PPE is necessary; what type of PPE is necessary; how to properly don, doff, and wear PPE; and the limitation, care and maintenance, useful life, and disposal of PPE. An assessment of new hazards under the proposed action and any necessary subsequent PPE fitting and training (e.g., respiratory protection) would be conducted by MSI prior to the start-up of the Phase Two demonstration project.

Finally, MSI has a medical surveillance program in place for employees involved in hazardous waste operations. This program addresses any concerns for workers who may need to wear respirators under the Phase Two demonstration (due to the potential increased dispersal of particulate). Under the program, employees are evaluated annually.

Chemical Hygiene Plan

To protect workers in the laboratory, MSI has a chemical hygiene plan for the on-site laboratory. The chemical hygiene plan addresses health and safety concerns for the laboratory setting, including but not limited to: employee protection from health hazards associated with chemicals in the laboratory, standard operating procedures related to safety and health considerations when hazardous chemicals are being used, provisions for employee information and training, performance of PPE, and measures to reduce employee exposure to hazardous chemicals. General provisions under the plan address the requirements for operations at the laboratory under the proposed action.

Hazard Communication Program

MSI has a written hazard communication program and specific chemical information (i.e., Material Safety Data Sheets, or MSDSs) available on site to all employees. Employees are required to be trained in the detection of the presence or release of hazardous chemicals in the work area, physical and health hazards of chemicals in the work area, measures that they can use to protect themselves from hazards, the labeling system, MSDSs, how they can use appropriate hazard information, and specific practices implemented to enhance the hazard communication program. This hazard communication program would not need to be expanded for the proposed action.

In sum, no new provisions under the site's health and safety program are required to be implemented under the proposed action. A respiratory protection program would be incorporated if necessary. Similarly, the proposed action would not have any detrimental impacts on worker health and safety at the site.

4.0 PERMITS REQUIRED FOR THE PROJECT

MSI currently holds a number of permits for current commercial hazardous waste treatment operations and nonhazardous waste disposal at its Yukon Plant. CHMR staff has reviewed these permits and MSI's plans to obtain the additional permits required to meet environmental compliance for conducting the proposed action. These environmental compliance issues are briefly described below. Permits currently held by MSI for current operations and permit modifications submitted for the proposed activities are summarized in Table 4-1.

4.1 HAZARDOUS WASTE TREATMENT AND STORAGE

MSI currently holds a permit for hazardous waste treatment, storage, and disposal using the following methods: neutralization and precipitation, chemical reduction and oxidation, oil separation, leachate treatment and sludge dewatering using storage and treatment tanks, storage containers, storage waste piles, and filter press units.

MSI has filed an application for modification of its permit to add stabilization and solidification agents to its approved treatment chemical list. This permit modification is necessary in order for the proposed action to occur at the MSI Yukon Plant. Although MSI has submitted a modification to include an additional container storage area, this proposed container area is not needed to conduct the Phase Two demonstration project. The application has been submitted to accommodate long-range commercial operation plans for the Yukon Plant.

4.2 SOLID WASTE DISPOSAL

MSI has one active solid waste impoundment on site--No. 6. Treated nonhazardous wastes are either disposed at this impoundment or shipped to an off-site permitted residual waste management facility. Treated nonhazardous wastes from the Phase Two demonstration project would follow the same disposal practices as described above. These treated nonhazardous wastes from the Phase Two project would most likely be sent to the Greenridge Reclamation facility in Scottdale, Pennsylvania. Other available waste management facilities are listed in Section 3.4 of this report.

**TABLE 4-1
PERMITS ISSUED FOR THE MSI YUKON PLANT**

AGENCY/PERMIT #	PERMIT COVERAGE	DATE ISSUED	DATE EXPIRED
HAZARDOUS WASTE STORAGE AND TREATMENT			
PADEP/ PAD004835146	Hazardous waste TSD-- neutralization/ precipitation, chemical reduction/oxidation, oil separation, leachate treatment/sludge dewatering using storage/treatment tanks, storage containers, storage waste pile, and filter press units	6/12/92	6/12/02
PADEP/ PAD004835146	Application for modification to permit for stabilization and solidification of hazardous waste	1/15/93 application	
PADEP/ PAD004835146	Application for major permit modification to expand treated hazardous waste storage container capacity	3/14/95 application	
PADEP/ PAD004835146	Revision to 3/14/95 application for major permit modification to expand the treated hazardous waste storage container capacity	6/28/95 revision to application	
SOLID WASTE DISPOSAL			
301071	Permit for solid waste disposal and/or processing facility-- impoundment no. 6	8/6/86	

**TABLE 4-1
(Continued)**

AGENCY/PERMIT #	PERMIT COVERAGE	DATE ISSUED	DATE EXPIRED
<i>AIR QUALITY CONTROL</i>			
65-313-005	Venturi scrubber for acid waste reactor	7/20/93	6/30/98
65-313-005A	Venturi scrubber for acid waste reactor--acid tank covers	6/16/94	5/31/99
65-309-040	Operating permit renewal--fabric filter for lime handling system	7/20/93	6/30/98
65-309-041	Operating permit renewal--fabric filter for material unloading system	7/19/93	6/30/98
<i>WATER DISCHARGE</i>			
PA0027715 ¹	NPDES Permit	5/18/93	5/18/98
6576203	Industrial waste treatment facility construction	2/18/77	
6576203-A1	Caustic feed system and pH adjustment tank	5/5/89	
6576203-A2	Water Management Permit--upgrade to treatment facility	5/18/93	

¹The osmotic pressure limit was amended on August 25, 1995 to include allowable variations from the 1,000 mo/kg limit specified in the May 18, 1993 NPDES permit. Specifically, when monthly average effluent concentration exceeds 1,000 mo/kg but does not exceed 1,500 mo/kg, the maximum daily discharge flow rate must not exceed 50 gpm. If there are higher osmotic pressure levels, the maximum daily discharge flow rate must not exceed 40 gpm during this period and the monthly average must not exceed 2,000 mo/kg. Other permit conditions are specified in the NPDES permit amendment.

4.3 AIR QUALITY CONTROL

The MSI Yukon Plant operates under air quality control permit renewals for the venturi scrubber for the acid waste reactor, the fabric filter for the lime handling system, and the fabric filter for the material unloading system. No major modification to existing permits or new plan approval or operating permit is anticipated to be required for the proposed action. MSI will file a "Request for Determination of Requirement for Plan Approval/Operating Permit Application" form with PADEP in order to ensure compliance with air quality control regulations for the proposed action.

4.4 WATER DISCHARGE

The MSI Yukon Plant is authorized to discharge treated wastewaters to the Sewickley Creek in accordance with effluent limitations, monitoring requirements, and other conditions set forth in its NPDES and Water Management permits. The permit and authorization to discharge expire at midnight on May 18, 1998. Any discharges resulting from the proposed action, although not anticipated, would be subject to the MSI Yukon Plant's current NPDES discharge limitations and monitoring requirements. A summary of the discharge limitations is shown in Table 4-2.

Proposed Phase Two activities would not require a new NPDES permit or a modification to the existing NPDES permit.

4.5 WETLANDS AND FLOODPLAINS

The proposed action will not require any modification to wetlands or floodplains. Therefore, there are no required permits or notices for dredging or filling of wetlands or floodplains.

TABLE 4-2
MSI YUKON PLANT NPDES DISCHARGE LIMITATIONS

DISCHARGE PARAMETER	DISCHARGE LIMITATIONS--CONCENTRATIONS ¹ (mg/l unless otherwise indicated)		
	AVERAGE MONTHLY	MAXIMUM DAILY	INSTANT. MAXIMUM
FOR OUTFALL 001 WHICH RECEIVES WASTE FROM: Outfall 101 and the treatment plant handling chemical landfill leachate and stormwater from impoundment No. 6, inactive impoundments, mine discharge, miscellaneous leachate, and recycled sludge dewatering filtrate			
Suspended Solids	30	60	
Oil and Grease	15		30
Ammonia-nitrogen	45	90	
Total Residual Chlorine	Monitor/report		
Barium	4.0	8.0	
Iron	3.5	7.0	
Cadmium	0.025	0.05	
Chromium	0.5	1.0	
Hexavalent Chromium	0.05	0.1	
Copper	0.1	0.2	
Lead	0.12	0.24	
Nickel	1.0	2.0	
Zinc	0.35	0.7	
Free Cyanide	0.1	0.2	
Phenols (4AAP)	0.1	0.2	
Osmotic pressure (mo/kg)	1,000	2,000	
Aluminum	1.0	2.0	
Silver	0.005	0.01	
Tin	Monitor/report		
Molybdenum	Monitor/report		
Antimony	Monitor/report		
pH	Not less than 6.0 nor greater than 9.0 standard units		

TABLE 4-2
(Continued)

DISCHARGE PARAMETER	DISCHARGE LIMITATIONS--CONCENTRATIONS ¹ (mg/l unless otherwise indicated)		
	AVERAGE MONTHLY	MAXIMUM DAILY	INSTANT. MAXIMUM
FOR OUTFALL 101 WHICH RECEIVES WASTE FROM: Organic waste treatment system²			
BOD 5-day	25	50	
Suspended Solids	30	60	
Ammonia Nitrogen	10	20, 50 ³	
Oil and Grease	15		30
Phenol	0.05	0.1	
Cyanide (Free)	0.05	0.1	
pH	Not less than 6.0 nor greater than 9.0 standard units		

¹Monitoring requirements, including measuring frequency and sample type required, as well as other permit conditions, are not included in this table.

²To date, the organic waste treatment system has not been constructed, and Outfall 101 does not exist. MSI has no immediate plans to construct or operate this unit in the near future.

³From May 1 to October 31, 20 mg/l; from November 1 to April 30, 50 mg/l.

5.0 SUMMARY OF POTENTIAL ENVIRONMENTAL IMPACTS

In order to determine the potential environmental impacts of the proposed demonstration project, current environmental characteristics of the Yukon Plant site as well as potential impacts resulting from the project were evaluated. Environmental compliance issues were also considered, including current permits obtained by MSI for current commercial operations and any additional permits necessary to conduct the proposed action.

The findings of this environmental review, which indicate that no significant direct, indirect, or cumulative impacts are anticipated from the proposed action, are summarized below.

Land Use and Aesthetics

Since there would be no physical changes to the existing Yukon Plant site, an already permitted RCRA TSD facility, there will be no new land use impacts to the region. Similarly, existing aesthetic views at the Yukon Plant site would not be affected by the proposed action.

Air Quality

The Yukon Plant site currently meets air quality permit requirements for commercial operations at the site. A "Request for Determination of Requirement for Plan Approval/Operating Permit Application" form would be filed by MSI to document that new material would be brought to the site to treat metal-laden hazardous waste under the proposed action.

The proposed action would have negligible air quality impacts at the Yukon Plant site and surrounding area.

Water Resources

Wastewater is not expected to be generated from the proposed project. Should wastewater be generated from decontamination of the mixing pit, it would be reused and/or discharged under its NPDES permit. No additional permits are required.

The proposed project activities would not: (1) impact a floodplain or wetland, (2) require diversion of a flowing body of water or alter a drainage pattern, (3) cause an increase or decrease in the surface area of an existing body of water, or (4) cause soil erosion or adversely affect the quality or movement of groundwater.

Solid and Hazardous Waste Management

The Yukon Plant currently follows solid and hazardous waste management procedures as required under RCRA. A permit modification to allow MSI to treat metal-laden hazardous waste using stabilization and solidification with CCT by-products has been filed with PADEP. Treated waste from the proposed demonstration project rendered nonhazardous would be disposed at an on-site permitted solid waste impoundment or shipped to a permitted residual waste disposal facility. Hazardous waste would be treated again at the Yukon Plant using conventional methods or shipped to an authorized hazardous waste disposal facility.

Ecology

The proposed action does not have the potential to significantly affect plant or animal species or their habitats, endangered (or threatened) plant or animal species, or migratory condors.

Archaeological, Cultural, and Historic Resources

The proposed action would not affect any structures listed in the National Register of Historic Places or other structures 50 years old or older. No archaeological or historic resources would be impacted by the project.

Socioeconomics

Since current staff at the Yukon Plant would conduct the proposed demonstration testing, no effects on local population are expected.

The current transportation system would not be impacted since no additional vehicles are expected to be necessary than are already traveling to the site with commercial

waste. The same roads and access points used during commercial operations would be used for hauling materials to the site for the proposed demonstration project.

There are no impacts anticipated on public services, property values, or energy resources as a result of the proposed action.

Worker Health and Safety

The Yukon Plant's current HASP (overall site and operations) and Chemical Hygiene Plan (laboratory) address the OSHA and EPA requirements for the site's current commercial operations. No new health and safety provisions are anticipated to be necessary to conduct the proposed action.

APPENDIX A

**U.S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
ENVIRONMENTAL QUESTIONNAIRE**

U.S DEPARTMENT OF ENERGY (DOE)
MORGANTOWN ENERGY TECHNOLOGY CENTER (METC)

ENVIRONMENTAL QUESTIONNAIRE

Pursuant to Section (A) of the DOE NEPA Implementing Procedures (10 CFR 1021, Subpart B), the DOE is to incorporate careful consideration of the potential environmental consequences of all proposed actions during the early planning stages. To this end, the DOE is to determine at the earliest possible time, whether such actions require either an Environmental Assessment (EA), an Environmental Impact Statement (EIS), or can be covered under a Categorical Exclusion. To comply with these procedures, it will be necessary to complete an Environmental Questionnaire for all proposed projects. This information will be used by the DOE to determine the level of NEPA review required for each specific project. The final decision will be subject to concurrence by the METC Environmental staff.

Please complete as thoroughly as possible.

I. PROJECT DESCRIPTION

---

1. Solicitation No. DE-FC21-94MC31175
2. Program Area _____
3. Proposer (Company, University, etc.) University of Pittsburgh
4. Principal Investigator of Proposer Professor James T. Cobb, Jr.
5. Project Title Treatment of Metal-laden Hazardous Wastes with Advanced Clean Coal Technology By-Products, Phase Two.
6. Project Duration 12 months
7. Type of Project: (check all that apply)

GROUP A	GROUP B
a. ☐ Computer Modeling	e. ☐ Bench-Scale Research
b. ☐ Workshop/Conference	f. ☐ Laboratory-Scale Research
c. ☐ Library/Literature Search	g. ☐ Small-Scale pilot Plant
d. ☐ Paper Study	h. ☐ Pilot Plant Construction/Operation
	i. ☒ Full-Scale Demonstration Project
	j. ☐ Other (please describe) _____
8. Project Scale (e.g., 200 tons per hour):

a. ☐ tons per hour	b. ☐ MMBtu/hr	c. ☐ scfm	d. ☐ MW

e. ☒ other (i.e. building size, cost data), please explain: Approximately 400 tons of material (10 batches of up to 40 tons each) would be used during the Phase Two demonstration project.
9. Summary of Proposed Action:
The Phase Two demonstration project includes up to 10 commercial-scale treatments of metal-laden hazardous wastes using solid by-products generated through advanced clean coal technologies.
10. The project would be located at a(n): (check all that apply)

a. ☐ Existing Building	b. ☒ Developed Site	c. ☐ Undeveloped Site

If any item from Group B was selected for Question 7, all items in Sections II and III must be answered. Otherwise, if no item from Group B was selected for Question 7, proceed to Section III.

II. ENVIRONMENTAL IMPACTS

This section is designed to objectively assess the environmental impacts of each project. NEPA procedures require that all possible effects (including: land use plans, energy requirements, natural or depletable resources, historic and cultural resources, and source pollutants) to the environment resulting from the proposed action must be evaluated. Please answer the questions as completely as possible. Also, for "yes" or "no" answers, please answer "yes" if there will be any effect, or if there may be an effect. (Failure to answer the questions completely will result in delays in project awards.)

1. LAND USE

- a. Location(s) of the proposed project including city, county, state. For each location, a separate questionnaire must be filled out. The Mill Service, Inc. (MSI) Yukon Plant is located approximately 0.5 miles west of the Village of Yukon in South Huntingdon Township, Westmoreland County, Pennsylvania.
- b. What would be the total size of the project site? The total size of the Yukon Plant site is approximately 160 acres. The proposed action area (laboratory, mixing pits, and container area) is less than 2 acres of the site.
- c. What is the present use of the land where the project would be located?
☐ Urban	☒ Industrial	☐ Agriculture	☐ University Campus
☐ Suburban	☐ Residential	☐ Forest	☐ Research Facility
☐ Rural	☐ Commercial	☐ Other, Please describe. _____	
- d. Would the project require construction, earthmoving, or excavation? (Please describe.)
No
- e. Is the purpose of this project to retrofit or repower an already existing source/plant?
- ☐ Yes ☒ No
- f. If this is a new source/plant, are there plans to reclaim and/or revegetate the area following the project? Not Applicable
- ☐ Yes ☐ No
- g. Would changes to the site resulting from the project be expected to affect the way the site and surrounding area could be used in the future?
- ☐ Yes, please explain: _____
- ☒ No
- h. Would the project affect any unique or unusual landforms (e.g. cliffs, waterfalls, etc.)?
- ☐ Yes ☒ No

2. AIR QUALITY

- a. What type of fuel would be used (e.g. coal, natural gas)? No fuel is expected to be used directly for this project. Indirect usage is expected, such as fuel for vehicles and equipment to haul and process material.

b. What types of emissions, including fugitives, are anticipated and what are the estimated quantities of these emissions? Negligible amounts of beryllium, vanadium, chromium, nickel, zinc, arsenic, selenium, silver, cadmium, antimony, barium, mercury, thallium, lead, and sulfur dioxide may occur.

c. What would be the maximum emission rate (i.e., in tons/year) of the following, as a result of the project (answer as applicable)?

☒ sulfur dioxide	☒ aluminum	☐ carbon monoxide
☒ mercury	☐ hydrogen chloride	☒ arsenic
☒ cadmium	☐ volatile organic carbons	☒ selenium
☐ ozone	☒ particulates (<10 μ m)	☐ hydrogen sulfide
☐ nitrogen dioxide	☒ lead	

* = Negligible mass emission rates expected (i.e., <1 tpy)

d. Estimate the percentage of the emissions that would result from point sources. 0¹

e. Estimate the percentage of the emissions that would result from fugitive sources. 100¹

f. What types of emission control or particulate collection devices would be used? If necessary, MSI would provide portable covers over tanks and water sprays with dust suppressant.

g. What percentage of emissions would they collect? 95% (estimated)

h. If no control devices are used, how would the emissions be vented? Fugitive

i. What would be the frequency and duration of the tests being conducted? Laboratory evaluation would be intermittent throughout the project period.

j. List any new hazardous emissions that would be introduced to the area: Negligible quantities of beryllium, chromium, nickel, arsenic, selenium, cadmium, antimony, mercury, and lead are possible.

k. Would the proposed project be capable of reducing the amount of emissions in the area?

☐ Yes, please explain: _____

☒ No

l. Is the site presently in compliance with the National Ambient Air Quality Standards?

☐ Yes ☒ No

If not, please identify the pollutants for which the area is in non-compliance (e.g., carbon monoxide, sulfur dioxide, etc.). Ozone, as is all of Pennsylvania

m. Would the project be classified as either a New Source or a major modification to an existing source?

☐ Yes ☒ No

n. If the project involves a New Source, would it be in compliance with the New Source Performance Standards?

☐ Yes ☐ No ☒ Not Applicable

¹ If a containment structure is constructed, 95% of the emissions would result from point sources and 5% would result from fugitive sources. However, a structure is not likely to be installed before the project is complete.

- o. If the project is a major modification, would it be subject to prevention of significant determination review?
- ☐ Yes ☐ No ☒ Not Applicable
- p. Would the project be in compliance with the National Emissions Standards for Hazardous Air Pollutants?
- ☒ Yes ☐ No, why not? _____
- q. What authority regulates the emissions in the project area (i.e., Federal, state, and/or local regulators)? (Please identify.) Commonwealth of Pennsylvania, Department of Environmental Protection
- r. How does the regulator define a major source of air emissions (e.g., thermal input of 250 MMBtu/hr)? Ambient air emissions $\geq$ 100 tpy for any criteria pollutant, $\geq$ 50 tpy for VOCs, $\geq$ 10 tpy for a single HAP, or $\geq$ 25 tpy for any combination of HAPs (same as federal definition)

3. WATER RESOURCES/WATER QUALITY

- a. What authority regulates the water quality in the area (i.e., Federal, state, and/or local regulators)? (Please identify.) Commonwealth of Pennsylvania, Department of Environmental Protection
- b. Where would the water used during the project come from? Municipal Authority of Westmoreland County, Beaver Run Water Treatment Plant
- What quantity of water would be used and for what purpose? Several thousand gallons may be used for decontamination of the mixing pit and dust suppression/reagent activation.
- c. Would the project generate any wastewater?
- ☒ Yes ☐ No
- If so, what amount of wastewater would be generated during a single test? Not applicable
- During the entire test period? Up to several thousand gallons
- d. Describe the wastewater that would be generated. Wastewater could be generated during Phase Two if decontamination of the mixing pit is needed during full-scale treatment tests.
- e. How would the wastewater be collected and treated? Wastewater from decontamination would be collected and blended into a subsequent similar batch of materials as a wetting agent to activate the reaction between the waste and by-products. If necessary, the wastewater would be diverted to the current wastewater treatment system for treatment and discharge.
- f. Where would the wastewater effluent be discharged? If necessary, wastewater effluent would be discharged under the existing NPDES permit to the receiving water named Sewickley Creek (Outfall 001).
- g. Would the project be permitted to discharge effluents into an existing body of water?
- ☒ Yes ☐ No

If so, is this body of water used for household purposes by the local community, and would the effluents alter compliance with National Drinking Water Standards?

☐ Yes ☒ No ☐ Not Applicable

- h. Would either a new or a modification to an existing National Pollutant Discharge Elimination System (NPDES) permit be required?

☐ Yes ☒ No

- i. Would the project impact a floodplain or wetland?

☐ Yes, please explain: _____

☒ No

- j. Would the project require the diversion of a flowing body of water or alter drainage patterns?

☐ Yes ☒ No

- k. Would the project cause an increase or decrease in the surface area of an existing body of water?

☐ Increase ☐ Decrease ☒ Not Applicable

- l. Would the project possibly cause soil erosion?

☐ Yes ☒ No

- m. Would the project adversely affect the quality or movement of groundwater?

☐ Yes ☒ No

4. SOLID WASTE AND HAZARDOUS MATERIALS

- a. Would the project generate, use, or store hazardous or toxic substances?

☒ Yes, please describe the substances and quantities: Metal-laden hazardous wastes may be temporarily stored prior to treatment. Nonhazardous coal by-products would be used to treat the hazardous waste streams and render them nonhazardous. [See Section 3.4 of the Environmental Information Report for more detail.]

☐ No

- b. How would the hazardous or toxic products be collected and stored? Metal-laden hazardous wastes to be treated under this action would be analyzed and "screened" for approval prior to transport to the facility. Once on site, the wastes would be analyzed for approval and temporarily stored in the designated and RCRA-permitted storage area pending treatment. Treated materials would be subsequently stored pending analytical verification that the hazardous characteristics have been removed. [See Section 3.4 of the Environmental Information Report for more detail.]

- c. Would the project produce a hazardous waste as defined by RCRA?

☐ Yes, please describe the substances and quantities: _____

☒ No [See Section 3.4 of the Environmental Information Report for detail on the treatment effectiveness verification procedures.]

- d. How would the hazardous waste(s) be transported? Hazardous waste to be treated would be transported to the site by licensed contractors.
- e. How would the hazardous waste(s) be treated, stored, and/or disposed? Under the Phase Two demonstration, metal-laden hazardous wastes would be treated using clean coal technologies by-products in mixing pits at the MSI Yukon Plant site. The by-products would be stored adjacent to the mixing pits in one or more shipping containers for ready access. Nonhazardous waste would be disposed either in a permitted on-site solid waste impoundment or sent off site to a permitted residual waste disposal facility. Any hazardous wastes resulting from treatment (treated wastes that fail TCLP) would either be treated again with other stabilization chemicals or shipped off site to an authorized hazardous waste disposal facility. [For more detailed information on hazardous waste management, see Section 3.4 of the Environmental Information Report.]

Is the treatment/storage/disposal facility licensed under RCRA? Yes

- f. If the hazardous waste would be disposed of off site, have arrangements been made with a certified treatment/storage/disposal facility?

   Yes, please give name and type of facility: _____

  x   No No hazardous waste is expected to result from the Phase Two demonstration. Any treated waste that fails TCLP would most likely be treated again with other stabilization chemicals in order to be rendered nonhazardous.

- g. Identify each type of nonhazardous solid waste (e.g., fly ash, scrubber waste, etc.) that would be produced and estimate the production volumes. The treatment demonstration would result in 220-400 tons of nonhazardous waste.
- h. How would the nonhazardous solid waste be disposed of and how would it be transported to the disposal area? The resulting treated nonhazardous waste would be disposed of at the Greenridge Reclamation facility in Scottdale, Pennsylvania. [See Section 3.4 of the Environmental Information Report for contingency disposal facilities.]
- i. Who is the regulating authority for solid and hazardous wastes? Commonwealth of Pennsylvania, Department of Environmental Protection, Pittsburgh Regional Office

5. IMPACT ON VEGETATION AND ANIMALS

- a. Would any plant or animal species be affected by the project, i.e., would their habitat be destroyed or altered?

   Yes   x   No

- b. Are there any endangered (proposed or threatened) plant or animal species in the proposed project area?

   Yes   x   No

- c. Would any migratory corridors be disrupted?

   Yes   x   No

- d. Would any species or subspecies, not indigenous to the area, be introduced as a result of the project (e.g., introducing a new bacterial strain, as in microbial desulfurization projects)?

   Yes   x   No

- e. Who is the regulating authority? U.S. Fish and Wildlife, Pennsylvania Game Commission, Pennsylvania Fish and Boat Commission, Pennsylvania Department of Conservation and Natural Resources

6. AESTHETICS

- a. Would construction related to the project contrast with the present landscape?
☐ Yes ☒ No
- b. Would the project eliminate or alter major scenic views important to the area?
☐ Yes ☒ No
- c. Would the project have an effect on existing or future recreational opportunities in the area?
☐ Yes, please describe: _____
☒ No
- d. Would the project be located in or near a national park or wilderness area?
☐ Yes, please describe: _____
☒ No

7. HISTORICAL/CULTURAL RESOURCES

- a. Are there any historical or cultural resources in or near the proposed project area? Note if they are listed on the National Register of Historic Places (NRHP).
☐ Yes ☐ Listed on NRHP
☒ No
If yes, would construction, excavation, or earthmoving resulting from this project impact these resources? Not Applicable
☐ Yes ☐ No
- b. Would project operations impact any of these historical or cultural resources? Not Applicable
☐ Yes ☐ No
- c. Has the State Historic and Preservation Office been contacted with regard to this project?
☒ Yes ☐ No

8. TRANSPORTATION

- a. Would the project alter present traffic patterns?
☐ Yes, the effect would be: ☐ Small to moderate
☐ Potentially large
☒ No

b. Would new transportation access (roads, rail, etc.) be required?

☐ Yes ☒ No

9. ENERGY REQUIREMENTS

a. Would the project cause an increase in energy usage in the municipality where it will be located?

☐ Yes ☒ No

b. Would the project increase the energy efficiency of the municipality?

☐ Yes ☒ No

c. Would the project significantly impact the community's fuel or energy supply?

☐ Yes, the effect would be: ☐ Small to moderate
☐ Potentially large

☒ No

d. Would any new transmission lines be required?

☐ Yes, please describe voltage and length of line: _____

☒ No

10. NOISE LEVEL

a. Would the construction phase of the project cause an increase in ambient noise levels?

☐ Yes, increase by how much? ☐ %

☒ No

b. Would the operation phase of the project cause an increase in ambient noise levels?

☐ Yes, increase by how much? ☐ %

☒ No

c. Would project construction result in the removal of natural barriers that act as noise screens for the adjacent community?

☐ Yes ☒ No

d. What would be the expected highest decibel level at closest point of public access? The level is unknown, but it would not be changed as a result of the proposed action.

e. What would be the highest decibel level expected in the work area? The level would be less than 85 decibels (TWA), and it would not be changed as a result of the proposed action.

f. Would hearing protection be required for workers? No, this is not anticipated to be required. However, should periodic monitoring indicate that the 85 decibel (TWA) threshold is exceeded, a suitable hearing conservation program would be implemented.

11. ENVIRONMENTAL RESTORATION AND/OR WASTE MANAGEMENT

Can the proposed action be considered an environmental restoration and/or waste management activity under any of the following categories?

- a. CERCLA removals/similar actions under RCRA or other authorities, meeting CERCLA cost/time limits or exemptions. ☐ Yes ☒ No
- b. Siting/construction/operation of pilot-scale waste collection/treatment/stabilization/containment facilities. ☒ Yes ☐ No
- c. Improvements to environmental control systems to an existing structure/building. ☐ Yes ☒ No
- d. Siting/construction/operation/decommissioning of facility for storing packaged hazardous waste for 90 days or less. ☐ Yes ☒ No

12. WORKER HEALTH AND SAFETY

- a. Would there be any potential for workers to be exposed to toxic/hazardous chemicals or wastes?

☒ Yes, please describe: The Phase Two demonstration would not present any additional exposure risks than are typically associated with commercial operations at the Yukon Plant. Under Phase Two, workers would be potentially exposed to metal-laden hazardous wastes, stabilizing agents, and chemicals in the laboratory.

☐ No

- b. Would there be any potential for exposure to extreme temperatures?

☐ Yes, please describe: _____

☒ No

- c. Would there be any special physical hazards associated with the project?

☐ Yes, please describe: _____

☒ No The Phase Two demonstration would not present any special physical hazards other than those typically associated with heavy equipment machinery and vehicles used in commercial operations at the site.

- d. Would personal protective equipment or clothing be required?

☒ Yes, please describe: MSI's Health and Safety Plan for the site currently addresses activities requiring the use of personal protective equipment and clothing. These guidelines would be strictly adhered to during the Phase Two demonstration. [See Section 3.9 of the Environmental Information Report for further detail.]

☐ No

- e. Does the project proponent have a worker safety program in place?

☒ Yes, please describe: The MSI Yukon Plant currently has in place a Health and Safety Plan for the site and a Chemical Hygiene Plan for the laboratory.

☐ No

- f. Is safety training necessary for any laboratory or equipment and processes involved with the project?

x Yes, please describe: Training requirements for workers using equipment working in the laboratory or involved in the treatment process with the project are detailed in the site's Health and Safety Plan. [See Section 3.9 of the Environmental Information Report for further detail.]

— No

13. Are there any issues that may generate public controversy regarding the project?

— Yes, please list the issues: _____

x No

14. List the alternatives to this action which have been considered.

Not Applicable

15. Identify how other environmental laws, related to NEPA (Endangered Species Act, Fish and Wildlife Coordination Act, etc.) will be addressed. What permits (e.g., NPDES) are necessary for the project?

MSI has submitted a modification to its RCRA TSD permit to allow the use of new stabilizing agents such as the advanced clean coal technology material as a treatment chemical. Approval would be obtained prior to beginning Phase Two demonstration.

MSI has indicated that it would file a "Request for Determination of Requirement for Plan Approval/Operating Permit Application" form with the Pennsylvania Department of Environmental Protection to ensure compliance with current air quality control regulations.

Currently, the MSI Yukon Plant is authorized to discharge treated wastewaters to the Sewickley Creek under its NPDES and Water Management permits. No new NPDES or modification to existing permit is required for Phase Two activities.

No permits or notices for dredging or filling of wetlands or floodplains are required, since no modifications to wetlands or floodplains are anticipated.

The U.S. Fish and Wildlife Service regional office in State College, Pennsylvania has determined that there are no federally listed or proposed threatened or endangered species, pursuant to the Endangered Species Act of 1973, known to exist in the project area.

[For more detailed information on other environmental laws related to NEPA, and on environmental permits required for the project, see Sections 3.0 and 4.0, respectively, of the Environmental Information Report.]

16. Would there be a high probability that this project would lead to further development in the project area? If so, please elaborate on the projected development.

Yes. A successful full-scale demonstration would provide information and data on the ability of by-products from advanced clean coal technologies to effectively stabilize and solidify metal-laden hazardous wastes. Ultimately, this project would: (1) enable the hazardous waste management community to use new sources of treatment material, (2) provide new uses for clean coal technology by-products, and (3) lessen the need to landfill these by-products.

III. CERTIFICATION

I hereby certify that the information provided herein is current, accurate and complete as of the date shown immediately below.

DATE: ____ / ____ / ____
month day year

SIGNATURE: _____

TYPED NAME: Dr. James T. Cobb, Jr., P.E.

TITLE: Associate Professor of Chemical Engineering

ORGANIZATION: University of Pittsburgh

APPENDIX B

**ADDRESSES AND TELEPHONE NUMBERS
OF FEDERAL AND STATE OFFICIALS
WHO RECEIVED NOTICES CONCERNING THE PROPOSED ACTION**

**ADDRESSES AND TELEPHONE NUMBERS OF
FEDERAL AND STATE OFFICIALS
WHO RECEIVED NOTICES CONCERNING THE PROPOSED ACTION**

Mr. James Purdy
Chief
Environmental Studies Section
U.S. Army Corps of Engineers
Pittsburgh District Office
1000 Liberty Ave.
Pittsburgh, PA 15222
(412) 644-6800

Mr. Charles Kulp
Supervisor
U.S. Fish and Wildlife Service
315 South Allen St.
Suite 322
State College, PA 16801
(814) 234-4090

Dr. Kurt Carr
Chief
Division of Archaeology and Protection
Bureau for Historic Preservation
P.O. Box 1026
Harrisburg, PA 17108-1026
(717) 787-4363

APPENDIX C

COPIES OF LETTERS SUBMITTED AND MAIL RECEIPTS

Center for Hazardous Materials Research

University of Pittsburgh Applied Research Center
320 William Pitt Way - Pittsburgh, PA 15238
(412) 826-5320 - Fax (412) 826-5552

August 25, 1995

Mr. James Purdy
Chief
Environmental Studies Section
U.S. Army Corps of Engineers
Pittsburgh District Office
1000 Liberty Avenue
Pittsburgh, PA 15222

Notification
U.S. Department of Energy Proposed Demonstration Action
Treatment of Metal-Laden Hazardous Wastes
with Advanced Clean Coal Technology By-Products, Phase Two
University of Pittsburgh and Mill Service, Inc.

Dear Mr. Purdy:

This letter invites comments from your agency regarding Phase Two of a proposed U.S. Department of Energy (DOE) research project, *Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology (CCT) By-Products*, to be located at an existing industrial facility in Westmoreland County, Pennsylvania. The purpose of this project is to evaluate the short- and long-term stabilization potential of CCT by-products in treating metal-laden hazardous wastes. DOE Implementing Procedures (10 CFR 1021, Subpart B) pursuant to the National Environmental Policy Act (NEPA) require that DOE consider the potential environmental consequences of all proposed actions during the early planning stages. Information concerning effects on U.S. Army Corps of Engineers projects/wetlands/100-year floodplains in the proposed project area is necessary for DOE to determine the level of NEPA review required for a proposed action.

PROJECT HISTORY

In Phase One of the project, the project team (DOE, University of Pittsburgh, Dravo Lime, and Mill Service, Inc.) treated six hazardous wastes at the laboratory scale with three CCT solid by-products.

For this phase of the project, a categorical exclusion determination was made under DOE NEPA Implementing Procedures, 10 CFR 1021, Subpart D, Appendix B.3.6, "Indoor bench-scale research projects or conventional laboratory operation within existing laboratory facilities," effective May 26, 1992.

PROPOSED PROJECT DESCRIPTION

Phase Two of the project is to include full-scale field testing on batches of up to 40 tons of typical metal-laden wastes received by Mill Service, Inc. at its Yukon Plant. Up to ten full-scale treatments using the same by-product and wastes as under Phase One will be performed in the Solids Mixing Unit at the Yukon Plant.

Toxicity characteristic leaching procedure (TCLP) analysis will follow immediately after treatment, after a 24-hour holding period, and possibly at the end of the curing period. Complete physical and chemical characterization of the CCT solid by-products and the treated and untreated (characteristic) metal-laden hazardous wastes will be conducted.

PROJECT LOCATION

The proposed action is to be located at the Mill Service, Inc. Yukon Plant approximately 0.5 miles west of the Village of Yukon in South Huntingdon Township, Westmoreland County, Pennsylvania.

In order to assist your agency's review, we have enclosed a topographical map showing the Yukon Plant and proposed Phase Two action area on the Smithton, PA U.S.G.S. quadrangle.

PROBABLE IMPACTS

The above-described DOE demonstration project is proposed to be located at an already existing RCRA-permitted commercial hazardous waste treatment facility (Mill Service, Inc. Yukon Plant) and will be a temporary action, to last no longer than 12 months. There will be no new construction. Therefore, there are no anticipated impacts on U.S. Army Corps of Engineers projects/wetlands/100-year floodplains in Pennsylvania as a result of this project.

Comments from your agency are encouraged and welcomed. Please send all comments within 30 days to:

Ms. Audrey G. Zelanko
Project Manager, NEPA Compliance
CHMR
320 William Pitt Way
Pittsburgh, PA 15238.

Thank you for your prompt attention to this matter.

Sincerely,

Audrey G. Zelanko
Project Manager

Attachment

TOPOGRAPHIC MAP

SCALE 1:24 000

2007
151 MILS
07511
15 MILS

Source: (7.5 minute series) U.S.G.S., Smithton, PA

PENNSYLVANIA

QUADRANGLE LOCATION

Is your RETURN ADDRESS completed on the reverse side?

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- Write "Return Receipt Requested" on the mailpiece below the article number.
- The Return Receipt will show to whom the article was delivered and the date delivered.

I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:

Mr. James Purdy
Chief
Environmental Studies Section
U.S. Army Corps of Engineers
Pittsburgh District Office
1000 Liberty Avenue
Pittsburgh, PA 15222

4a. Article Number

P 070 311 703

4b. Service Type

☒ Registered	☐ Insured
☐ Certified	☐ COD
☐ Express Mail	☐ Return Receipt for Merchandise

7. Date of Delivery

8/28

5. Signature (Addressee)

James Purdy

6. Signature (Agent)

[Signature]

8. Addressee's Address (Only if requested and fee is paid)

PS Form 3811, December 1991 * U.S.G.P.O. : 1992-307-530

DOMESTIC RETURN RECEIPT

Thank you for using Return Receipt Service.

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Receipt for Certified Mail

No Insurance Coverage Provided
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(See Reverse)

Sent to: <i>James Purdy</i>	
Street and No: <i>1500 Liberty Ave</i>	
P.O., State and Zip Code: <i>Pitt PA 15222</i>	
Postage:	\$
Certified Fee	
Special Delivery Fee	
Restricted Delivery Fee	
Return Receipt Showing to Whom & Date Delivered	
Return Receipt Showing to Whom Date and Addressee's Address	
TOTAL Postage & Fees	\$
Remarks or Data:	

PS Form 3800, June 1991

Center for Hazardous Materials Research

University of Pittsburgh Applied Research Center
320 William Pitt Way - Pittsburgh, PA 15238
(412) 826-5320 - Fax (412) 826-5552

300-5354-002

August 23, 1995

Mr. Charles Kulp
Supervisor
U.S. Fish and Wildlife Service
315 South Allen St.
Suite 322
State College, PA 16801

Notification
U.S. Department of Energy Proposed Demonstration Action
Treatment of Metal-Laden Hazardous Wastes
with Advanced Clean Coal Technology By-Products, Phase Two
University of Pittsburgh and Mill Service, Inc.

Dear Mr. Kulp:

This letter invites comments from your agency regarding Phase Two of a proposed U.S. Department of Energy (DOE) research project, *Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology (CCT) By-Products*, to be located at an existing industrial facility in Westmoreland County, Pennsylvania. The purpose of this project is to evaluate the short- and long-term stabilization potential of CCT by-products in treating metal-laden hazardous wastes. DOE Implementing Procedures (10 CFR 1021, Subpart B) pursuant to the National Environmental Policy Act (NEPA) require that DOE consider the potential environmental consequences of all proposed actions during the early planning stages. Information concerning effects on endangered (proposed or threatened) plant or animal species, plant or animal habitats, and migratory condors in the proposed project area is necessary for DOE to determine the level of NEPA review required for a proposed action.

PROJECT HISTORY

In Phase One of the project, the project team (DOE, University of Pittsburgh, Dravo Lime, and Mill Service, Inc.) treated six hazardous wastes at the laboratory scale with three CCT solid by-products.

For this phase of the project, a categorical exclusion determination was made under DOE NEPA Implementing Procedures, 10 CFR 1021, Subpart D, Appendix B.3.6, "Indoor bench-scale research projects or conventional laboratory operation within existing laboratory facilities," effective May 26, 1992.

PROPOSED PROJECT DESCRIPTION

Phase Two of the project is to include full-scale field testing on batches of up to 40 tons of typical metal-laden wastes received by Mill Service, Inc. at its Yukon Plant. Up to ten full-scale treatments using the same by-product and wastes as under Phase One will be performed in the Solids Mixing Unit at the Yukon Plant.

Toxicity characteristic leaching procedure (TCLP) analysis will follow immediately after treatment, after a 24-hour holding period, and possibly at the end of the curing period. Complete physical and chemical characterization of the CCT solid by-products and the treated and untreated (characteristic) metal-laden hazardous wastes will be conducted.

PROJECT LOCATION

The proposed action is to be located at the Mill Service, Inc. Yukon Plant approximately 0.5 miles west of the Village of Yukon in South Huntingdon Township, Westmoreland County, Pennsylvania.

In order to assist your agency's review, we have enclosed a topographical map showing the Yukon Plant and proposed Phase Two action area on the Smithton, PA U.S.G.S. quadrangle.

PROBABLE IMPACTS

The above-described DOE demonstration project is proposed to be located at an already existing RCRA-permitted commercial hazardous waste treatment facility (Mill Service, Inc. Yukon Plant) and will be a temporary action, to last no longer than 12 months. There will be no new construction. Therefore, there are no anticipated impacts on the fish and wildlife resources of Pennsylvania as a result of this project.

Comments from your agency are encouraged and welcomed. Please send all comments within 30 days to:

Ms. Audrey G. Zelanko
Project Manager, NEPA Compliance
CHMR
320 William Pitt Way
Pittsburgh, PA 15238.

Thank you for your prompt attention to this matter.

Sincerely,

Audrey G. Zelanko
Project Manager

Attachment

TOPOGRAPHIC MAP

SCALE 1:24 000

Source: (7.5 minute series) U.S.G.S., Smithton, PA

P 070 311 702

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(See Reverse)

PS Form 3800, June 1991

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U.S. Fish & Wildlife Serv	
315 South Allen St. #322	
State College, PA 16801	
Postage	\$
Delivery Fee	
Special Delivery Fee	
Restricted Delivery Fee	
Return Receipt Showing to Whom & Date Delivered	
Return Receipt Showing to Whom & Date Delivered and Addressee's Address	
TOTAL Postage & Fees	\$
Postmark or Date	
Sent 8/24/95	

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- Write "Return Receipt Requested" on the mailpiece below the article number.
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  - ☐ Restricted Delivery
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3. Article Addressed to:
U.S. FISH & WILDLIFE SERVICE
315 SOUTH ALLEN STREET
SUITE 322
STATE COLLEGE, PA 16801

4a. Article Number
P 070 311 702

4b. Service Type
☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail ☐ Return Receipt for Merchandise

7. Date of Delivery

8/28/95

8. Addressee's Address (Only if requested and fee is paid)

5. Signature (Addressee)

6. Signature (Agent)

Thank you for using Return Receipt Service.

Center for Hazardous Materials Research

University of Pittsburgh Applied Research Center
320 William Pitt Way - Pittsburgh, PA 15238
(412) 826-5320 - Fax (412) 826-5552

300-5354-002

August 23, 1995

Dr. Kurt Carr
Chief
Division of Archaeology and Protection
Bureau for Historic Preservation
P.O. Box 1026
Harrisburg, PA 17108-1026

Notification
U.S. Department of Energy Proposed Demonstration Action
Treatment of Metal-Laden Hazardous Wastes
with Advanced Clean Coal Technology By-Products, Phase Two
University of Pittsburgh and Mill Service, Inc.

Dear Dr. Carr:

This letter invites comments from your agency regarding Phase Two of a proposed U.S. Department of Energy (DOE) research project, *Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology (CCT) By-Products*, to be located at an existing industrial facility in Westmoreland County, Pennsylvania. The purpose of this project is to evaluate the short- and long-term stabilization potential of CCT by-products in treating metal-laden hazardous wastes. DOE Implementing Procedures (10 CFR 1021, Subpart B) pursuant to the National Environmental Policy Act (NEPA) require that DOE consider the potential environmental consequences of all proposed actions during the early planning stages. Information concerning historical or cultural resources in or near the proposed project area is necessary for DOE to determine the level of NEPA review required for a proposed action.

PROJECT HISTORY

In Phase One of the project, the project team (DOE, University of Pittsburgh, Dravo Lime, and Mill Service, Inc.) treated six hazardous wastes at the laboratory scale with three CCT solid by-products.

For this phase of the project, a categorical exclusion determination was made under DOE NEPA Implementing Procedures, 10 CFR 1021, Subpart D, Appendix B.3.6, "Indoor bench-scale research projects or conventional laboratory operation within existing laboratory facilities," effective May 26, 1992.

PROPOSED PROJECT DESCRIPTION

Phase Two of the project is to include full-scale field testing on batches of up to 40 tons of typical metal-laden wastes received by Mill Service, Inc. at its Yukon Plant. Up to ten full-scale treatments using the same by-product and wastes as under Phase One will be performed in the Solids Mixing Unit at the Yukon Plant.

Toxicity characteristic leaching procedure (TCLP) analysis will follow immediately after treatment, after a 24-hour holding period, and possibly at the end of the curing period. Complete physical and chemical characterization of the CCT solid by-products and treated and untreated (characteristic) metal-laden hazardous wastes will be conducted.

PROJECT LOCATION

The proposed action is to be located at the Mill Service, Inc. Yukon Plant approximately 0.5 miles west of the Village of Yukon in South Huntingdon Township, Westmoreland County, Pennsylvania.

In order to assist your agency's review, we have enclosed a topographical map showing the location of the Yukon Plant and proposed Phase Two action area on the Smithton, PA U.S.G.S. quadrangle.

PROBABLE IMPACTS

The above-described DOE demonstration project is proposed to be located at an already existing RCRA-permitted commercial hazardous waste treatment facility (Mill Service, Inc. Yukon Plant). The proposed demonstration project will not affect any buildings over 50 years of age. There will be no new construction and no ground disturbance as a result of this action. The DOE action is proposed to be a temporary full-scale demonstration, to last no longer than 12 months. Therefore, it is projected that there will be no impacts on historic preservation in Pennsylvania as a result of this project.

Comments from your agency are encouraged and welcomed. Please send all comments within 30 days to:

Ms. Audrey G. Zelanko
Project Manager, NEPA Compliance
CHMR
320 William Pitt Way
Pittsburgh, PA 15238.

Thank you for your prompt attention to this matter.

Sincerely,

Audrey G. Zelanko
Project Manager

Attachment

TOPOGRAPHIC MAP

SCALE 1:24,000

Source: (7.5 minute series) U.S.G.S., Smithton, PA

P 070 311 701

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See Reverse

Bur for Hist Preservation

P.O. Box 1026

Harrisburg, PA 17108-1026

\$

\$

Sent 8/24/95

PS Form 3800, June 1991

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SENDER:

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- Write "Return Receipt Requested" on the mailpiece below the article number.
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I also wish to receive the following services (for an extra fee):

1. ☐ Addressee's Address
2. ☐ Restricted Delivery

Consult postmaster for fee.

3. Article Addressed to:
DIV OF ARCHAEOLOGY & PROTECTION
BUREAU FOR HISTORIC PRESERVATION
P.O. BOX 1026
HARRISBURG, PA 17108-1026

4a. Article Number
P 070 311 701

4b. Service Type
☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail ☒ Return Receipt for Merchandise

7. Date of Delivery AUG 28 1995

5. Signature (Addressee)
[Signature]

8. Addressee's Address (Only if requested and fee is paid)

6. Signature (Sender)
[Signature]

PS Form 3811, December 1991 * U.S.G.P.O. 1992-307-530

DOMESTIC RETURN RECEIPT

Thank you for using Return Receipt Service.

APPENDIX D

**COPIES OF RESPONSE LETTERS
FROM FEDERAL AND STATE OFFICIALS**

DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS
WILLIAM S. MOORHEAD FEDERAL BUILDING
1000 LIBERTY AVENUE, PITTSBURGH, PA 15222

REPLY TO
ATTENTION OF

September 21, 1995

Environmental Studies Branch

Ms. Audrey G. Zelanko
Project Manager, NEPA Compliance
CHMR
320 William Pitt Way
Pittsburgh, Pennsylvania 15238

Dear Ms. Zelanko:

In response to your letter dated 25 August 1995 (enclosed), this letter will serve to formally transmit our District's comments as they relate to the U.S. Department of Energy's research project, *Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology (CCT) By-Products*, proposed for the Mill Service, Inc.'s Yukon Plant which is an existing industrial facility located in Westmoreland County, Pennsylvania.

A cursory review was conducted by in-house staff to determine the impacts that the said project may have upon Corps projects, wetlands or 100-year floodplains. Based upon the map which was provided showing the location of the Mill Services' Yukon Plant and the corresponding proposed Phase Two action area, and further based upon the premise that no new construction will be associated with the demonstration project, it is the District's belief that no wetlands, Corps projects or 100-year floodplains will be impacted as a result of the said project. If any aspect of the proposed project were to change, the Corps reserves the option to re-evaluate our initial determination.

If you have need any additional assistance, please feel free to call the undersigned or Ms. Eve Johnson at (412) 644-6942.

Sincerely,

James A. Purdy
Chief, Environmental Studies Branch

Enclosure

United States Department of the Interior

TAKE
PRIDE IN
AMERICA

FISH AND WILDLIFE SERVICE
Suite 322
315 South Allen Street
State College, Pennsylvania 16801

September 14, 1995

Ms. Audrey G. Zelanko
Center for Hazardous
Materials Research
University of Pittsburgh
Applied Research Center
320 William Pitt Way
Pittsburgh, PA 15238

Dear Ms. Zelanko:

This responds to your letter of August 23, 1995 requesting information about federally listed and proposed endangered and threatened species within the area affected by the proposed Demonstration Action Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology By-Products located in South Huntingdon Township, Westmoreland County, Pennsylvania. The following comments are provided pursuant to the Endangered Species Act of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.) to ensure the protection of endangered and threatened species.

Except for occasional transient species, no federally listed or proposed threatened or endangered species under our jurisdiction are known to exist in the project impact area. Therefore, no Biological Assessment or further Section 7 consultation under the Endangered Species Act is required with the Fish and Wildlife Service. Should project plans change, or if additional information on listed or proposed species becomes available, this determination may be reconsidered. A compilation of federally listed species in Pennsylvania is enclosed for your information.

This response relates only to endangered or threatened species under our jurisdiction based on an office review of the proposed project's location. No field inspection of the project area has been conducted by this office. Consequently, this letter is not to be construed as addressing other Service concerns under the Fish and Wildlife Coordination Act or other legislation.

Requests for information regarding State-listed endangered or threatened species should be directed to the Pennsylvania Game Commission (birds and mammals), the Pennsylvania Fish and Boat Commission (fish, reptiles, and amphibians), and the Pennsylvania Department of Conservation and Natural Resources (plants).

Please contact Carole Copeyon of my staff at 814-234-4090 if you have any questions or require further assistance regarding endangered, threatened, or candidate species.

Sincerely,

Charles J. Kulp
Supervisor

Enclosure

FEDERALLY LISTED SPECIES IN PENNSYLVANIA

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>STATUS*</u>	<u>DISTRIBUTION</u>
<u>FISHES</u>			
Shortnose sturgeon**	<i>Acipenser brevirostrum</i>	E	Delaware River and other Atlantic coastal waters
<u>REPTILES & AMPHIBIANS</u>			
None			
<u>BIRDS</u>			
Bald eagle	<i>Haliaeetus leucocephalus</i>	T	Entire state. Recent nesting in Butler, Crawford, Dauphin, Forest, Lancaster, Pike, Tioga, Warren and York Counties
Peregrine falcon (American)	<i>Falco peregrinus anatum</i>	E	Entire state. Recent nesting in and around Philadelphia and Pittsburgh (Allegheny, Delaware, Philadelphia and Bucks Counties)
Piping plover	<i>Charadrius melodus</i>	E	Presque Isle (Erie County). Migratory. No nesting in Pennsylvania since mid-1950s
<u>MAMMALS</u>			
Indiana bat	<i>Myotis sodalis</i>	E	Summer range: possibly state-wide in suitable habitat. Only one known winter hibernaculum (south-central Pennsylvania)
<u>MOLLUSKS</u>			
Clubshell mussel	<i>Pleurobema clava</i>	E	French Creek and Allegheny River watersheds; Clarion, Crawford, Erie, Forest, Mercer and Venango Counties
Northern riffleshell	<i>Epioblasma torulosa rangiana</i>	E	French Creek and Allegheny River watersheds; Crawford, Erie, Forest, Venango and Warren Counties
<u>PLANTS</u>			
Northeastern bulrush	<i>Scirpus ancistrochaetus</i>	E	Current - Blair, Centre, Clinton, Cumberland, Dauphin, Franklin, Huntingdon, Lackawanna, Lehigh, Monroe, Perry and Union Counties. Historic - Northampton County
Small-whorled pogonia	<i>Isotria medeoloides</i>	T	Current - Centre and Venango Counties. Historic - Berks, Chester, Greene, Monroe, Montgomery, Philadelphia Counties

* E = Endangered, T = Threatened

Revised 7/13/95

** Shortnose sturgeon is under the jurisdiction of the National Marine Fisheries Service

FEDERALLY LISTED SPECIES THAT NO LONGER OCCUR* IN PENNSYLVANIA

<u>COMMON NAME</u>	<u>SCIENTIFIC NAME</u>	<u>STATUS**</u>	<u>FORMER DISTRIBUTION</u>

MAMMALS

Delmarva Peninsula fox squirrel	<i>Sciurus niger cinereus</i>	E	mature forests of southeastern PA (Delaware and Chester Co.)
Eastern cougar	<i>Felis concolor cougar</i>	E	state-wide
Grey wolf	<i>Canis lupus</i>	E	state-wide

MOLLUSKS

Dwarf wedge mussel*	<i>Alasmidonta heterodon</i>	E	Delaware River drainage
Fanshell*	<i>Cyprogenia stegaria</i>	E	Ohio River drainage
Orange pimpleback*	<i>Plethobasus striatus</i>	E	Ohio River drainage
Pink mucket pearly mussel*	<i>Lampsilis abrupta</i>	E	Ohio River drainage
Ring pink mussel*	<i>Obovaria retusa</i>	E	Ohio River drainage
Rough pigtoe*	<i>Pleurobema plenum</i>	E	Ohio River drainage

INSECTS

American burying beetle	<i>Microphorus americanus</i>	E	state-wide
Karner blue butterfly	<i>Lycaeides melissa samuelis</i>	E	pine barrens, oak savannas (wild lupine habitat) (Wayne Co.)
Northeastern beach tiger beetle	<i>Cicindela dorsalis dorsalis</i>	T	along large rivers in southeastern PA

PLANTS

Eastern prairie fringed orchid	<i>Platanthera leucophaea</i>	T	wet prairies, bogs (Crawford Co.)
Sensitive joint-vetch	<i>Aeschynomene virginica</i>	T	freshwater tidal marshes of Delaware river (Delaware and Philadelphia Co.)
Virginia spiraea*	<i>Spiraea virginiana</i>	T	along Youghiogheny River (Fayette Co.)
Smooth coneflower	<i>Echinacea laevigata</i>	E	serpentine barrens (Lancaster Co.)

* It is possible that remnant populations of some of these species (indicated with an *) may still occur in Pennsylvania, however, there have been no confirmed sightings of these species for over 70 years.

** E = Endangered, T = Threatened

The following is a partial list of additional species that no longer occur in Pennsylvania: moose, bison, lynx, wolverine, passenger pigeon, Bachman's sparrow, common tern, lark sparrow, tiger salamander, mud sunfish, longjaw cisco, lake whitefish, butterfly mussel, precious underwing moth, American barberry, small white lady's-slipper, etc. etc.

Commonwealth of Pennsylvania
Pennsylvania Historical and Museum Commission
Bureau for Historic Preservation
Post Office Box 1026
Harrisburg, Pennsylvania 17108-1026

October 3, 1995

TO EXPEDITE REVIEW USE
BHP REFERENCE NUMBER

Audrey G. Zelanko
Project Manager
Center for Hazardous Materials Research
University of Pittsburgh Applied Research Center
320 William Pitt Way
Pittsburgh, PA 15238

Re: File No. ER 95-3522-129-A
DOE, Proposed Demonstration
Action, Treatment of Metal-
Laden Hazardous Wastes with
Advanced Clean Coal Technology
By-Products, Phase Two
University of Pittsburgh &
Mill Service, Inc., South
Huntingdon Twp., Westmoreland
Co.

Dear Ms. Zelanko:

The Bureau for Historic Preservation (the State Historic Preservation Office) has reviewed the above named project in accordance with Section 106 of the National Historic Preservation Act of 1966, as amended in 1980 and 1992, and the regulations (36 CFR Part 800) of the Advisory Council on Historic Preservation. These requirements include consideration of the project's potential effect upon both historic and archaeological resources.

In our opinion this project will have no effect on archaeological or historic resources. Should you have any further questions regarding this matter, please call the Bureau for Historic Preservation Office at (717) 783-8946.

Sincerely,

A handwritten signature in cursive script, appearing to read "Kurt W. Carr".

Kurt W. Carr, Chief
Division of Archaeology &
Protection

KC/tmw

APPENDIX B

**ARTICLE IN THE OCTOBER 1999 ISSUE OF
THE *JOURNAL OF THE AIR &
WASTE MANAGEMENT ASSOCIATION***

Stabilization of Heavy Metal Containing Hazardous Wastes with Byproducts from Advanced Clean Coal Technology Systems

Jesse W. Pritts

U.S. Environmental Protection Agency, Washington, D.C.

Ronald D. Neufeld and James T. Cobb

University of Pittsburgh, Pittsburgh, PA

ABSTRACT

The purpose of this investigation was to evaluate the success of residues from advanced Clean Coal Technology (CCT) systems as stabilization agents for heavy metal containing hazardous wastes. In the context examined here, stabilization refers to techniques that reduce the toxicity of a waste by converting the hazardous constituents to a less soluble, mobile, or toxic form.¹ Three advanced CCT byproducts were used: coal waste-fired circulating fluidized bed combustor residue, pressurized fluidized bed combustor residue, and spray drier residue. Seven metal-laden hazardous wastes were treated: three contaminated soils, two air pollution control dusts, wastewater treatment plant sludge, and sandblast waste. Each of the seven hazardous wastes was treated with each of the three CCT byproducts at dosages of 10, 30, and 50% by weight (byproduct:waste). The treatment effectiveness of each mixture was evaluated by the Toxicity Characteristic Leaching Procedure. Of the 63 mixtures evaluated, 21 produced non-hazardous residues. Treatment effectiveness can likely be attributed to mechanisms such as

precipitation and encapsulation due to the formation of hydrated calcium silicates and calcium sulfo-aluminates. Results indicate that these residues have potential beneficial uses to the hazardous waste treatment community, possibly substituting for costly treatment chemicals.

INTRODUCTION

The passage of the 1990 Clean Air Act Amendments prompted the development of a number of innovative technologies designed to reduce atmospheric sulfur dioxide emissions from coal-fired power plants. Fluidized-bed combustors and advanced scrubbers are two such technologies that have successfully progressed from the laboratory phase to commercial-scale facilities. These systems remove sulfur dioxide by reaction with a sorbent such as lime or limestone. Reactions can take place in the combustor as the coal burns, as with fluidized-bed combustors, or by reaction with the flue gases after the combustion process, either in the ductwork leading from the boiler or in advanced scrubbers. The residues obtained, while highly variable depending on the composition of the coal fed to the boiler and the type and operating conditions of the sulfur-removal technology used, are typically mixtures of fly ash, the primary reaction product (anhydrite— CaSO_4 , or calcium sulfite— $\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$), and unreacted sorbent. The high alkalinity of these residues, along with the high concentrations of free lime, make them potentially useful as treatment agents for heavy metal-contaminated hazardous wastes. Specifically, these residues have neutralization, sorption, and cementitious properties that make them highly useful as stabilization reagents.²

There has been extensive research into the stabilization reactions that occur in cement-based and fly ash-based treatment systems; however, little research has been conducted evaluating the stabilization effectiveness of advanced coal-combustion and clean coal technology

IMPLICATIONS

The 1990 Clean Air Act Amendments instituted a reduction in atmospheric sulfur dioxide emissions from coal-fired power plants. To meet these reductions, a new generation of advanced coal combustion systems was developed, designed to be environmentally cleaner and more efficient than conventional coal-burning processes. These systems effectively remove sulfur dioxide formed during coal combustion, preventing its release to the atmosphere. The disposal of residues produced by these systems is becoming increasingly problematic. The waste management community is actively searching for beneficial uses for these residues. One potential application is the use of these materials as treatment chemicals for hazardous wastes.

(CCT) byproducts. Stabilization reactions are a complex interaction of several competing mechanisms, each of which can help or hinder the overall stabilization effectiveness of the system. Cementitious- and pozzolanic-based treatment systems rely on a number of mechanisms to control contaminant release, including solubility changes due to pH control, formation of insoluble chemical species, and encapsulation.

Cementitious materials such as portland cement have been widely used as stabilization agents, and the chemistry of these systems is well documented. Such materials are basically a calcium silicate mixture containing predominantly tricalcium and dicalcium silicates, with smaller amounts of tricalcium aluminate and a calcium aluminoferrite. Typical weight proportions in an ordinary cement are 50% tricalcium silicate, 25% dicalcium silicate, 10% tricalcium aluminate, 10% tetracalcium aluminoferrite, and 5% other oxides. In the presence of water, the four major crystalline compounds hydrate. The calcium silicates hydrate to form the compounds calcium hydroxide and calcium silicate hydrate (tobermorite gel). Tricalcium aluminate reacts with water and calcium hydroxide to form tetracalcium aluminate hydrate. Tetracalcium aluminoferrite reacts with water to form calcium aluminoferrite hydrate. Tricalcium aluminate, gypsum, and water may combine to form calcium sulfoaluminate hydrate. The basic reactions are as follows:³

If sufficient sulfate is present, the reaction product of the last reaction is hydrated calcium aluminate sulfate (ettringite: $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 32\text{H}_2\text{O}$), which coats the surfaces of the particles, preventing further rapid hydration. This is why gypsum is often added to cement as a set retarder. If gypsum is not present in substantial amounts, calcium aluminum hydrates form almost immediately and the system sets.

Byproducts from advanced CCT systems typically exhibit cementitious properties. The fly ash content, along

with the unreacted lime present, allows these materials to enter into pozzolanic reactions upon the addition of water. The reactions that occur in dry CCT-based systems are analogous to those that occur with portland cement. In general, however, these reactions are slower than those of cement and do not produce the same products. Specifically, the lime reacts with SiO_2 from soluble silicates to form calcium silicate, which then hydrates in the same manner as portland cement. One exception is that tricalcium silicate is not formed during this process.⁴ The tricalcium silicate in portland cement is primarily responsible for the development of strength in portland cement mixtures.³ Consequently, the final properties of CCT residue systems frequently are not as good as portland cement mixtures. CCT byproducts can contain large amounts of gypsum. As a result, hydration of these residues is often accompanied by substantial formation of chemical species of the ettringite family.

MATERIALS

The materials required for this evaluation were of two types: CCT byproducts and hazardous wastes. There are no standard methods for sampling of CCT byproducts, so methods used for cement and fly ash were used. Byproduct samples were collected using sampling protocols conforming to ASTM C-311 (Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete). When possible, samples were collected directly from the ash storage silos at the generating facility. When this was not possible, samples were collected from the trucks or railcars used to transport the materials to disposal sites. Since coal feedstocks, production rates, and operating conditions of the combustors do not vary significantly on a day-to-day basis, the samples were expected to be fairly homogeneous. Waste samples were collected from bulk samples at the hazardous waste TSD facility. Prior to offloading the wastes from the trucks, samples were collected from a minimum of three locations along the length of the shipping container. Bulk samples of both wastes and byproducts were reduced to laboratory size in accordance with ASTM C700-87 (Standard Practice for Reducing Field Samples of Aggregate to Testing Size).

CCT Byproducts

In advanced CCT systems, sulfur is removed in the combustor as the coal burns or from the flue gases by reaction with a sorbent such as lime, limestone, or dolomite. Fluidized bed combustors typically use limestone or dolomite as sorbents, while spray driers use a lime slurry. In fluidized bed combustors, the sorbent is fed into the boiler along with the coal. As the sorbent is heated, the carbonate minerals in the limestone are calcined to act as a sorbent for sulfur dioxide released during coal combustion.

This mixture of fly ash, reaction products, and any unspent sorbent is then removed by particulate control systems. The reactions are:

In a spray drier, a lime slurry is prepared by mixing lime with water. This slurry is then sprayed into a tower through which the hot flue gases and fly ash pass. The lime combines with the sulfur dioxide, forming calcium sulfate or sulfite according to the latter two of the three reactions above. The excess water in the slurry evaporates in the tower, producing a dry residue.

Three advanced CCT byproducts were evaluated for their effectiveness as stabilization agents for metal-containing hazardous wastes. Two of the byproducts were obtained from fluidized bed combustors, and one was from a spray drier.

Circulating Fluidized Bed Combustor Residue. This material is a byproduct from a coal waste-fired circulating fluidized bed combustor (CFBC) operated by the Ebensburg Power Company at Ebensburg, PA. The coal waste fed to the boiler has a sulfur content between 1.4 and 2.0%. Sulfur released during coal waste combustion is removed in the boiler as the coal burns. In the combustor, crushed coal is mixed with limestone and suspended on jets of air. This bed of coal and limestone floats inside the boiler, tumbling much like a boiling liquid. As the coal burns, the released sulfur combines with the limestone before it can escape the boiler. More than 90% of the sulfur released from the coal can be captured in this manner. The sulfur-laden limestone forms a dry waste product that is removed with the coal ash. Approximately 30% of the residue is removed as bed ash through the bottom of the boiler, while the remaining 70% is carried out of the boiler with the fly ash and is removed in a baghouse. The bed ash and the fly ash are conveyed to a silo, where they are mixed for storage. The residue is designed to contain 82% ash, 12.5% limestone equivalent, and 5.5% $\text{CaSO}_3/\text{CaSO}_4$. Approximately 200,000 tons of this material is produced annually at the Ebensburg combustor.

Pressurized Fluidized Bed Combustor Residue. This byproduct is from a coal-fired pressurized fluidized bed combustor (PFBC) operating at the Tidd station of Ohio Power Company, a subsidiary of American Electric Power Corporation, at Brilliant, OH. A PFBC is operated at a pressure several times greater than atmospheric pressure, producing residue with different properties than typical CFBC residue. The sorbent fed to this plant was dolomite

($\text{CaMg}[\text{CO}_3]_2$), which was used at the Tidd station because its sulfated product was both more porous (and thus more reactive) and easier to handle than that from limestone. By operating at high pressure, little of the dolomite in the residue is in the oxide form but is mostly present as carbonate. The dolomitic character of the sorbent yields a lower-pH residue than that produced from lime-based sorbents. Byproduct from the combustor is removed both as bed ash and with the fly ash. The investigations performed here utilized only the residue removed with the fly ash. The Tidd station was a demonstration facility and is no longer in operating status. At the time of collection of the residues used in this investigation, the byproduct contained 50–60% equivalent CaCO_3 , 1–2% available CaO , and approximately 40–50% fly ash.

Dry Scrubber Residue. This byproduct is spray dry residue supplied by CONSOL, Inc., from a Joy Niro spray drier. The material is produced by the cogeneration project of Chambers Cogeneration Limited Partnership, operated by U.S. Operating Services Company at the Carney's Point Cogeneration Plant on the grounds of DuPont's Chambers Works in New Jersey. The spray drier at Carney's Point is the first one on a pulverized boiler burning high-sulfur eastern coal. At Carney's Point, the coal is burned in a conventional boiler. The SO_2 -laden flue gases are directed to a spray dry tower. In the tower, a lime slurry is sprayed through the hot flue gases as they rise through the tower. The lime combines with the sulfur dioxide, and the sulfur capture residue rises through the upper port of the tower with the fly ash. Because the flue gases are hot, the water from the lime slurry is vaporized, producing a dry residue. The combined solids are captured in a baghouse and directed to a silo for storage. The residue is designed to contain 45% fly ash, 36% $\text{CaSO}_3/\text{CaSO}_4$, 10% $\text{Ca}(\text{OH})_2$, 2% CaCO_3 , and 7% other inert material. Approximately 100,000 tons of residue is produced at Carney's Point each year.

Hazardous Wastes

Seven hazardous wastes were selected to be treated with the three CCT byproducts. Wastes evaluated were a wastewater treatment plant sludge, three contaminated soils, two air pollution control dusts, and a sandblast waste. A description of each of the wastes is presented in Table 1. Each of these wastes was characteristically hazardous due to the presence of heavy metals in the Toxicity Characteristic Leaching Procedure (TCLP) extract in excess of the limits specified in 40 CFR §261.24 (Toxicity Characteristic). Under the Toxicity Characteristic, the extract obtained from the TCLP is analyzed to determine if it possesses any of 39 toxic contaminants at levels identified by the U.S. Environmental Protection Agency (EPA) as being a risk to human health or the environment. If so, then the waste is

Table 1. Hazardous wastes treated with CCT byproducts.

Waste	Source
Battery sludge	Wastewater treatment plant sludge generated from treating wastewater from the production of lead acid storage batteries.
Munitions soil	Contaminated soil from a munitions depot where lead-containing munitions were stored.
Industrial soil	Contaminated soil from a city multi-use industrial site.
WWTP soil	Contaminated soil from sewage drying beds from a former hospital wastewater treatment plant site.
BOF dust	Baghouse dust from a BOF steel-making facility.
Incinerator dust	Fly ash collected by an electrostatic precipitator at a municipal waste incinerator.
Sandblast waste	Sandblast waste containing silica sand, lead-based paint chips, and wood particles from a building rehabilitation project.

considered hazardous and must be treated prior to being land disposed. Table 2 summarizes the eight metals currently regulated under the Toxicity Characteristic; the hazardous waste number assigned to each by EPA; the reference levels based on the National Interim Primary Drinking Water Standards, at which each of the metals exhibits chronic toxicity; and the regulatory levels above which the metal is at a hazardous concentration in a waste. It should be noted that the regulatory levels are 100 times the chronic toxicity regulatory levels. This 100-fold factor is a dilution and attenuation factor that estimates the dilution expected of the toxic constituents as they travel from the point of leachate generation (i.e., the landfill) to the point of human or environmental exposure (i.e., a drinking water well).⁵ Since this investigation only addresses wastes that are contaminated with inorganic compounds, the other 31 compounds regulated under the Toxicity Characteristic are not included in Table 2, and were not analyzed for throughout this investigation.

EXPERIMENTAL PROCEDURES

There were three goals of the experimental investigations: (1) characterization of the major physical and chemical properties of each of the CCT residues, (2) evaluation of the metal leachability of the seven hazardous wastes and the three byproducts, and (3) evaluation of the stabilization effectiveness of each of the three CCT residues when used to treat each of the seven hazardous wastes. Experimental procedures utilized, unless otherwise indicated, are standard methods presented in either SW-846⁶ or the Annual Book of ASTM Standards.⁷

Characterization of CCT Byproducts

Each of the three CCT byproducts was analyzed to determine a wide range of physical properties and chemical constituents. A thorough characterization and analysis of the byproducts was necessary to better understand the

Table 2. Metals regulated under the Toxicity Characteristic.

EPA HW No. ^a	Constituent	Chronic Toxicity Reference Level (mg/L)	Regulatory Level (mg/L)
D004	Arsenic	0.05	5.0
D005	Barium	1.0	100.0
D006	Cadmium	0.01	1.0
D022	Chromium	0.05	5.0
D008	Lead	0.05	5.0
D009	Mercury	0.002	0.2
D010	Selenium	0.01	1.0
D011	Silver	0.05	5.0

^aHazardous waste number.

chemical makeup of the residues, as well as to give an indication of their suitability for use in stabilization systems. Ten samples of the CONSOL spray drier residue, 10 samples of the Tidd PFBC residue, and 12 samples of the Ebsburg CFBC material were collected for evaluation. Evaluations conducted consisted of elemental chemical analyses, alkalinity and acid neutralization, physical properties, and measures of reactivity. The specific tests conducted are described below.

Elemental Chemical Analysis. Major elemental components were reported in the geochemical oxide format: CaO, MgO, Fe₂O₃, Al₂O₃, CO₂, SiO₂, sulfate sulfur as SO₃, sulfite sulfur as SO₂, and loss on ignition at 600 °C and 1100 °C. Standard wet analysis procedures of ASTM C-114 and ASTM C-25 were followed.

Alkalinity and Acid Neutralization. Parameters reported were pH, free or available lime, and total neutralizing power, also called calcium carbonate equivalency (CCE). ASTM C-25, ASTM D-1293, and ASTM C-602 procedures were followed for all analyses.

Physical Properties. The properties determined and the corresponding procedures utilized were

- density: particle-specific gravity (gas pycnometer); bulk density, loose, dry (ASTM C-33); bulk density, compact, dry (ASTM C-33); bulk density, as received;
- fineness: particle size distribution (minus 8 mesh); % passing no. 200 and no. 325 sieve (ASTM C-430); and
- surface area: BET specific surface area (ASTM D-4567); Blaine fineness (ASTM C-204).

Reactivity. Each of the byproducts was analyzed to gain a measure of its reactivity and an indication of its stabilization potential. The thermal reactivity or temperature rise from hydration of quicklime and anhydrite was measured by ASTM C-110. The heat generated is important for some stabilization objectives and to determine if available lime

is present as quicklime (anhydrous) or hydrated lime. The stabilization or fixation capacity of the byproducts with water was determined by a chemical waste management procedure called the mixed ratio, a comparative test used to determine how much material is needed to absorb one gallon of water. This test indicates the stabilization potential of the material. The lower the value of the mixed ratio, the higher the water-absorbing capacity of the material.

Metals Analysis of Hazardous Wastes and CCT Byproducts

Each of the seven hazardous wastes was analyzed to determine both the total concentrations and TCLP acid-leachable-concentrations of the eight metals currently regulated under the Toxicity Characteristic. Total metals evaluations, which involve vigorously digesting an aliquot of waste in a strong acid solution, give an indication of the total quantities of metals present in the sample. These quantities are reported on a mass per mass basis (μg metal per kg of waste). TCLP metals evaluations measure the concentration of metals that leach from the solid phase of a waste sample, which is extracted in an acetic acid solution. Two buffered acidic solutions are used, the choice of which depends upon the alkalinity and buffering capacity of the material being leached. The sample is extracted in a rotary extractor for a period of approximately 18 hr. The TCLP test is designed to simulate leaching conditions to which a waste disposed of in a municipal landfill may be exposed. Each of the TCLP extracts of the seven hazardous wastes was analyzed to determine the concentrations of the eight metals listed in Table 2, and to determine which of the metals was present in hazardous concentrations.

Each of the byproducts was also analyzed for total and TCLP metals. Although coal combustion byproducts are categorically exempt from regulation as solid wastes under 40 CFR §261.4 and usually do not exhibit Toxicity Characteristics for metals, it is useful to determine the environmental properties of these materials, since coal combustion residues can contain relatively high total concentrations of metals.

Evaluation of the Stabilization Effectiveness of CCT Byproducts

Treatability tests were conducted with each of the three byproducts to determine the extent to which the metals present in each of the hazardous wastes could be stabilized. These evaluations consisted of mixing proportionate amounts of each waste with each byproduct, adding sufficient water to wet each mixture, and performing a TCLP both immediately and after 24 hr. The immediate TCLP was conducted to determine the degree of metal stabilization that occurs within a few minutes after treatment. Immediate TCLPs are frequently used by waste

treaters to evaluate the effectiveness of the treatment process. If the immediate TCLP indicates that the treated waste has been rendered non-hazardous, the material can be prepared for shipment to the final disposal site. If the immediate TCLP indicates that the waste is still hazardous, then additional treatment is required. A 24-hr TCLP was also conducted on the treated wastes to confirm the treatment effectiveness. Many treaters store wastes for a 24-hr period and conduct a TCLP to confirm the treatment effectiveness prior to shipment to final disposal. Mixture proportions of the treatability studies consisted of mixing 200-gram aliquots of each of the seven wastes with 10, 30, and 50%, by weight, of each of the three byproducts. This produced a total of 63 mixtures, from which 126 TCLP extracts were prepared (both an immediate and a 24-hr TCLP for each mixture). Each of these TCLP extracts was analyzed for the eight metals listed in Table 2 to determine if the treatments rendered the wastes non-hazardous.

RESULTS

Characterization of CCT Byproducts

The results of the geochemical analysis of the three CCT byproducts are summarized in Table 3. This analysis indicates that each of the byproducts contains appreciable amounts of unreacted sorbents. The spray drier residue, which is a lime system, contains 25.41% CaO. The CFBC system, which uses limestone as a sorbent, contains 11.06% CaO in the residue. The PFBC system, which utilizes dolomite as a sorbent, has a large percentage of both MgO (14.38%) and CaO (22.13%) in the residue. Each of the three byproducts also contains large percentages of silicon, iron, and aluminum oxides, which can be attributed to the fly ash content of each. As expected, significant amounts of sulfur are present in each of the residues. The PFBC and CFBC residues contain sulfur predominantly in the sulfate phase, while the spray drier residue contains mostly sulfite sulfur. This is because the PFBC and CFBC residues are produced at much higher temperatures than the spray drier residues. As a result, the sulfur is oxidized to a higher extent in the PFBC and CFBC systems.

Table 4 summarizes the reactivity of each of the three byproducts. The temperature rise gives an indication of the amount of heat generated by the hydration of quicklime and anhydrite. A higher temperature rise usually indicates that more lime is present in the anhydrous (quicklime) state. The spray drier residue had the lowest temperature rise of the three byproducts. This is because this system uses a lime slurry, and even though the byproduct is dry, most of the free lime is still in the hydrated state. All three of the residues had high pH values, as well as high calcium carbonate equivalencies. The

Table 3. Geochemical analysis of CCT byproducts.

Parameter, % (wt/wt)	Spray Drier Residue	PFBC Residue	CFBC Residue
CaO	25.41	22.13	11.06
MgO	0.70	14.38	1.36
SiO ₂	22.33	19.93	46.64
Fe ₂ O ₃	6.23	9.02	7.08
Al ₂ O ₃	11.40	7.75	17.95
CO ₂	3.58	12.57	0.70
Total sulfur @ S	9.62	4.59	2.37
Sulfate sulfur @ SO ₃	1.79	10.60	5.46
Sulfite sulfur @ SO ₂	17.79	0.69	0.37
LOI @ 600 °C	3.17	Not analyzed	Not analyzed
LOI @ 1100 °C	14.68	13.54	4.16

spray drier residue and the PFBC residue had particularly high alkalinities, as is evidenced by the high values for CCE, indicating that these materials may be particularly useful for neutralizing highly acidic wastes. Each of the three byproducts had a high stabilization capacity as measured by the mixed ratio, with the spray drier residue having the highest stabilization capacity of the three.

Table 5 summarizes the physical properties of the three CCT byproducts. In general, the byproducts can be characterized as fine-grained, high surface-area materials. The spray drier residue has the greatest fineness of the three, as measured by both the Blaine air permeability apparatus and the percentage passing 80 mesh sieve, smallest average particle size, and the lowest specific gravity and lowest bulk density. The PFBC residue has the highest specific gravity and bulk density, as well as a high fineness measured as the percentage passing 80 mesh sieve. The CFBC material has the largest average particle size, due to its high bottom ash content. Measures of fineness, either through the use of the Blaine air permeability apparatus or a sieve analysis, give an important indication of reactivity. Fineness affects the rate at which heat is released during hydration as well as the rate of chemical reaction. Greater fineness increases the rate of hydration and thus accelerates the formation of pozzolanic compounds. Type I portland cement has a fineness of approximately 3700 cm²/gm as measured by the Blaine fineness, and 85–95% is finer than 45 microns.³ Fly ash typically has particle sizes in the range of 1–50 microns and a surface area in the range of 3000–5000 cm²/gm.³ In comparison, the byproducts have a Blaine fineness greater than both portland cement and fly ash. The average particle size of the spray drier residue and the PFBC residue is comparable to portland cement, while the average particle size of the CFBC material is greater than portland cement due to its bed ash content. Overall, the high fineness and small particle sizes of the byproducts indicate that they have

Table 4. Reactivity and acid neutralization analysis of CCT byproducts.

Parameter	Spray Drier Residue	PFBC Residue	CFBC Residue
Temperature rise, °F	2 ^a	5 ^a	8 ^a
Calcium carbonate			
Equivalency, %CaCO ₃	42.5	53.4	12.9
Available lime			
Index, %CaO	3.2	1.0	4.4
pH (soil)	12.36 @ 26 °C	11.92 @ 25 °C	12.52 @ 22 °C
Mixed ratio, lbs/gal	13 ^a	20 ^a	16 ^a

^aAverage of several samples.

the potential to rapidly enter into hydration reactions, which is a good indicator that they will be successful stabilization agents.

Metals Analysis of Wastes and Byproducts

Each of the seven hazardous wastes was analyzed to determine the total concentrations as well as the leachable concentrations of the eight metals regulated under the Toxicity Characteristic. These data are presented in Table 6. Each of the seven wastes contains considerable total concentrations of several metals, most notably cadmium, chromium, and lead. In each case, lead was the only metal that leached in excess of the TCLP regulatory limits.

The total metals and TCLP metals data of the three CCT byproducts are presented in Table 7. Arsenic, barium, and chromium were present in notable quantities in the byproducts, as indicated by the total metals concentrations. However, TCLP leachates of the byproducts indicate that none of these metals were leached to any significant degree. This is likely due to the high alkalinity of the materials, which can effectively neutralize the acidity of the TCLP extraction fluid.

Table 5. Physical properties of CCT byproducts.

Parameter	Spray Drier Residue	PFBC Residue	CFBC Residue
Specific gravity, g/cc	2.40	2.88	2.68
Bulk density (loose), lb/ft ³	35	64	58
Bulk density (tamped), lb/ft ³	42	70	66
Blaine fineness, cm ² /gm	13,190	5,610	7,410
% passing 200 mesh	96	92	46
% passing 325 mesh	83	85	37
Specific surface area, m ² /gm	6.57	2.65	9.41
Particle Size Distribution:			
Passing 80 mesh, %	99.6	94.0	48.9
10% passing, micron	1.66	2.87	3.50
50% passing, micron	4.61	13.39	29.42
90% passing, micron	32.90	58.33	124.30
Average particle size, micron	11.59	23.60	48.04

Table 6. Total and TCLP metals concentrations of hazardous wastes.

	Battery Sludge	Munitions Soil	Waste Type		Incinerator Dust	WWTP Soil	Sandblast Waste
			Industrial Soil	BOF Dust			
Arsenic							
Total (mg/kg)	<20	<20	<20	<20	84	<20	<20
TCLP (mg/l)	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
Barium							
Total (mg/kg)	13	130	130	34	550	84	60
TCLP (mg/l)	<5	<5	<5	<5	<5	<5	<5
Cadmium							
Total (mg/kg)	3	4.8	5.4	55	630	<2	2
TCLP (mg/l)	0.19	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium							
Total (mg/kg)	12	59	22	260	130	8.7	9.2
TCLP (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lead							
Total (mg/kg)	3,000	1,200	5,000	1,400	5,700	750	4,300
TCLP (mg/l)	20	26	80	14	20	7.8	350
Mercury							
Total (mg/kg)	0.14	0.2	3.2	0.3	4.7	0.36	0.19
TCLP (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium							
Total (mg/kg)	<0.2	<0.2	<0.2	<0.2	85	0.36	0.26
TCLP (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver							
Total (mg/kg)	<2	3.6	<2	<2	6.9	<2	<2
TCLP (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Stabilization Effectiveness of Clean Coal Technology Byproducts

Treatability tests were conducted to evaluate the ability of each of the three CCT byproducts to stabilize the heavy metals present in each of the seven hazardous wastes. Each of the wastes was treated with each of the byproducts at three different dosages (10, 30, and 50%, by weight). The appropriate extraction fluid for each mixture was determined, and TCLPs were conducted on each of the combinations both immediately and after a 24-hr mellowing period. Due to the high alkalinity of the byproducts, extraction fluid No. 2 was required for each of the 63 mixtures. Treatments were considered successful if the concentrations of the eight heavy metals regulated under the Toxicity Characteristic were below the established regulatory levels in an immediate TCLP and in a confirmation TCLP conducted after 24 hr.

Of the 63 mixtures evaluated, 21 produced treated residues that met the required criteria. The success of the stabilization evaluations varied for each of the three byproducts, as well as with each of the seven wastes. Table 8 illustrates each of the combinations evaluated and indicates the success or failure of each of the 63 mixtures. The spray drier residue was the most successful of the three stabilization agents, producing 15 non-hazardous mixtures out of 21 evaluations. The PFBC residue produced four non-hazardous mixtures out of 21 evaluations, and the CFBC residue only produced two non-hazardous mixtures out of 21

evaluations. Table 9 summarizes the concentrations of cadmium and lead (the only metals that had concentrations above TCLP limits) present in the treated wastes in both the initial and 24-hr TCLPs.

The spray drier residue was successful in reducing the leachable concentrations of the eight Toxicity Characteristic metals below regulatory levels both immediately and after 24 hr at all mixture ratios with five of the seven wastes treated: battery sludge, munitions soil, industrial site soil, wastewater treatment plant soil, and sandblast waste. Figure 1 illustrates the lead concentrations present in the immediate TCLP leachates of each of the 21 mixtures prepared with the spray drier residue. The reductions in lead concentrations in the leachates can easily be seen. In some instances, reductions were greater

than two orders of magnitude from the concentrations found in the leachates of the untreated wastes and well below the regulatory limit of 5 mg/l.

In general, differences in leachable metals concentrations between immediate and 24-hr TCLPs were minor. However, there were several instances where notable differences occurred. Mixtures of the spray drier residue with the Basic Oxygen Furnace (BOF) dust passed the immediate TCLP at the 10% dosage but failed to remain stabilized after 24 hr. The 30% mixture with this waste failed both the immediate and 24-hr TCLPs due to high lead concentrations, and the 50% mixture failed the immediate TCLP due to lead leachability but passed after 24 hr. The mixtures of this residue with the incinerator dust successfully stabilized the lead present in the waste but failed at all three mixture ratios both immediately and after 24 hr due to high cadmium concentrations in the leachates.

Without a detailed investigation on the microscopic scale, it is difficult to speculate on the reasons for the effectiveness of the spray drier residue as a stabilization agent. In general, the high surface area and the high fineness of the particles indicate that this material has the potential to be highly reactive. This high reactivity, coupled with the small average particle size of the residue, may allow the free lime and soluble silicates present in this material to rapidly combine with soluble metal species to form insoluble precipitates such as hydroxides, carbonates,

Table 7. Total and TCLP metals concentrations of flue gas desulfurization byproducts.

	By-Product Source		
	Spray Drier	PFBC	CFBC
Arsenic			
Total (mg/kg)	41	140	95
TCLP (mg/l)	<0.1	<0.1	0.9
Barium			
Total (mg/kg)	97	150	160
TCLP (mg/l)	<5	<5	<5
Cadmium			
Total (mg/kg)	6.6	4.8	10
TCLP (mg/l)	<0.1	<0.1	<0.1
Chromium			
Total (mg/kg)	29	15	50
TCLP (mg/l)	<0.1	<0.1	<0.1
Lead			
Total (mg/kg)	3.0	4.6	3.6
TCLP (mg/l)	<0.1	<0.1	<0.1
Mercury			
Total (mg/kg)	0.6	<0.1	1.1
TCLP (mg/l)	<0.01	<0.01	<0.01
Selenium			
Total (mg/kg)	<0.2	<0.2	<0.2
TCLP (mg/l)	<0.1	<0.1	<0.1
Silver			
Total (mg/kg)	<2	<2	<2
TCLP (mg/l)	<0.1	<0.1	<0.1

and silicates. In addition, encapsulation of the waste particles through pozzolanic reactions may physically isolate the waste particles from the leaching solution. The high alkalinity of this material can also effectively neutralize the acidity of the leaching solution, limiting solubilization of metal salts and precipitates.

Figure 2 illustrates the lead concentrations found in the leachates from the treatments using the PFBC material. The PFBC residue produced four treatment mixtures that passed both the immediate and 24-hr TCLPs. These successful treatments were 50% mixtures with the munitions soil, industrial soil, wastewater treatment plant soil, and sandblast waste. Mixtures of these four wastes treated at 10 and 30% dosages failed both immediate and 24-hr TCLPs because of high lead concentrations in the leachates. Comparing Figure 2 with Figure 1 shows that the PFBC residue was not as effective as the spray drier residue in reducing the leachable lead concentrations of the treated wastes. Treatments of the wastewater treatment plant soil, BOF dust, and incinerator ash with the PFBC residue showed little or no change from the untreated lead concentrations, while the other wastes showed decreases of approximately one order of magnitude. The exception was the sandblast waste, which decreased two orders of magnitude. Most decreases were only apparent at the highest dosage (50%).

As with the spray drier residue, most differences in metal leachabilities between the immediate and the 24-hr TCLPs were minor, with a few exceptions. Mixtures

Figure 1. Lead concentrations in immediate TCLP leachates of wastes treated with spray drier residue.

containing the battery sludge failed the 10 and 30% ratios both immediately and after 24 hr due to high lead contents, while the 50% mixture passed the immediate TCLP only to fail after 24 hr, again due to high lead concentrations. Mixtures of the BOF dust and the incinerator ash failed at all three mixture ratios both immediately and after 24 hr. Failures for the mixtures containing the BOF dust resulted from high lead concentrations, while those for the incinerator ash were due to both excess lead and cadmium.

The PFBC residue was not as effective as the spray drier residue in producing successful treatments. It successfully treated four of the seven wastes, although it was able to do this only at the highest dosages. In addition, treatments of the battery sludge at the highest dosage only exceeded the limit for lead by 0.1 mg/L, indicating that a slightly higher dosage may have successfully rendered this waste non-hazardous as well. The treatment effectiveness of the PFBC material can likely be attributed to the same types of mechanisms present with the spray drier residue (i.e., precipitation as hydroxides, carbonates, sulfates, etc.; neutralization of leachant acidity due to alkalinity; and encapsulation through pozzolanic reactions). However, since the PFBC residue does not have the same chemical composition as the spray drier residue (i.e., free lime in the PFBC residue is anhydrous, significant MgO is present, and sulfur is present almost exclusively in the sulfate phase), differences in the reaction chemistry are very likely.

Figure 3 illustrates the lead concentrations found in the leachates from the treatments that used the CFBC material. Treatments with the CFBC residue were the least successful of the three byproducts evaluated. There were only two mixtures that gave a non-hazardous residue after treatment: wastewater treatment plant soil, at byproduct dosages of 30 and 50%, and the munitions soil, which when treated at a 50% dosage contained a concentration of lead in the immediate TCLP of 5.6 mg/L, only 0.6 mg/L over the regulatory limit for lead. After 24 hr, the concentration of

Table 8. Success of byproduct/waste combinations.^a

Waste	Byproduct Source Mixture	Spray Drier			PFBC			CFBC		
		10%	30%	50%	10%	30%	50%	10%	30%	50%
Battery Sludge	Immediate	X	X	X			X			
	24 hr	X	X	X						
Munitions Soil	Immediate	X	X	X			X			
	24 hr	X	X	X			X			X
Industrial Soil	Immediate	X	X	X			X			X
	24 hr	X	X	X			X			
BOF Dust	Immediate	X								
	24 hr			X						
Incinerator Dust	Immediate									
	24 hr									
WWTP Soil	Immediate	X	X	X		X		X	X	X
	24 hr	X	X	X		X		X	X	
Sandblast Waste	Immediate	X	X	X		X				
	24 hr	X	X	X		X				

^aMixtures that contained concentrations of all eight Toxicity Characteristic metals below the established regulatory levels and, therefore, have been rendered non-hazardous are indicated with an "X."

lead in the TCLP extract of this mixture was 4.3 mg/L, indicating that the waste had been rendered non-hazardous after the 24-hr mellowing period. A mixture of the industrial soil treated at a 50% mixture ratio passed the immediate TCLP with a lead concentration of 0.85 mg/L, but the 24-hr TCLP failed to confirm the treatment effectiveness with a lead concentration of 5.4 mg/L. Treatments of the battery sludge, BOF dust, and sandblast waste all contained TCLP lead concentrations well in excess of the 5.0 mg/L standard at all three mixture ratios. Treatments of the incinerator dust contained concentrations of both lead and cadmium in excess of regulatory limits.

The general ineffectiveness of the CFBC material as a stabilization agent can most likely be attributed to its low free lime content. This material contains about 11% CaO, about half of the percentage available in the other byproducts. This material also has a low alkalinity, as indicated by the small calcium carbonate equivalency. Such a small amount of free lime may limit the formation of lead hydroxide, and the low alkalinity is most likely insufficient to buffer the acidity of the leaching solution, allowing the final leachate pH to be very low. Lead is amphoteric, and the solubility of lead hydroxide reaches a minimum at about pH 9.3.

At values below this, the solubility increases rapidly. Adding additional lime to the CFBC material to neutralize the acidity of the leaching solution and maintain the pH close to 9 would likely make this residue a successful treatment chemical.

While the spray drier residue was effective at all dosages, the PFBC material was only effective at the higher dosage of 50%, at which a significant portion of the treatment effectiveness can be attributed to simple dilution. In fact, given the same proportion of lead leachability in the treated wastes as the raw wastes, treatments of the wastewater treatment plant soil at the 50% dosage could reduce the lead levels below the 5 mg/l TCLP limit by dilution alone. Therefore, it is debatable whether mixtures containing this waste at 50% dosages can be considered treatment or dilution. With the other six wastes, however, some other mechanism besides dilution must occur to reduce lead levels below the TCLP limit.

It is important to note that, although none of the raw wastes exhibited toxicity characteristics for cadmium, all of the treated mixtures prepared with the incinerator dust failed the TCLP cadmium criteria. In addition, in several cases the TCLP lead concentrations of the treated wastes were actually higher than those exhibited by the raw wastes. This mobility of lead and cadmium is most likely attributable to the solubility changes that occurred due to the large change in pH caused during leaching by the highly alkaline byproducts. This mobility of metal species is one of the main problems associated with stabilization/solidification systems that rely heavily on solubility changes for metal control. In many cases, additional treatment chemicals

Figure 2. Lead concentrations in immediate TCLP leachates of wastes treated with PFBC residue.

Table 9. Metals concentrations of treated wastes.^a

Dosage:	Cadmium (mg/L)						Lead (mg/L)					
	10%	Immediate 30%	50%	10%	24 hr 30%	50%	10%	Immediate 30%	50%	10%	24 hr 30%	50%
Treatments w/ Spray Drier Residue												
Battery sludge	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.14	0.28	0.19	0.15	0.21	0.21
Munitions soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.37	0.41	0.28	0.41	0.35	0.28
Industrial soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.54	0.54	0.37	0.15	0.26	0.21
BOF dust	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.5	5.1	6.9	17.0	9.6	4.3
Incinerator dust	22.0	13.0	8.0	24.0	14.0	9.0	1.3	0.46	0.26	1.6	0.45	0.27
WWTP soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.39	0.57	0.46	0.47	0.56	0.55
Sandblast waste	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.38	0.15	0.13	0.44	0.13	0.11
Treatments w/ PFBC Residue												
Battery sludge	0.19	0.15	<0.1	0.18	0.14	<0.1	6.5	10.0	4.1	6.8	6.6	5.1
Munitions soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	10.0	13.0	1.2	16.0	23.0	0.34
Industrial soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	13.0	7.0	1.7	17.0	22.0	1.6
BOF dust	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	20.0	14.0	13.0	19.0	15.0	9.6
Incinerator dust	25.0	18.0	14.0	30.0	17.0	13.0	16.0	17.0	9.1	13.0	16.0	12.0
WWTP soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	21.0	9.4	2.3	23.0	11.0	2.1
Sandblast waste	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	6.1	14.0	2.0	21.0	21.0	0.49
Treatments w/ CFBC Residue												
Battery sludge	0.15	0.13	<0.1	0.15	0.12	<0.1	7.8	46.0	13.0	15.0	11.0	26.0
Munitions soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	34.0	17.0	5.6	20.0	9.1	4.3
Industrial soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	17.0	14.0	0.85	29.0	7.4	5.4
BOF dust	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	22.0	16.0	13.0	20.0	14.0	8.1
Incinerator dust	22.0	18.0	15.0	22.0	17.0	14.0	12.0	20.0	13.0	22.0	22.0	24.0
WWTP soil	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	4.9	4.6	0.31	11.0	<0.1	1.18
Sandblast waste	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	290	250	210	130	67	28

^aValues in bold type exceed current TCLP limits.

such as soluble silicates or phosphates must be added to effectively control these released metal species. Additional data and details of experimental protocols utilized in this investigation may be found in the thesis by Pritts.⁸

CONCLUSIONS

This research has shown that byproducts from advanced flue gas desulfurization systems have the potential to be effective stabilization agents for heavy metal contaminated

hazardous wastes. While the data presented herein cannot quantitatively describe the specific mechanisms responsible for metal control, they do present some baseline effectiveness data.

The effectiveness of these materials can be attributed to several mechanisms. Perhaps the most important of these is the high amounts of free lime that these materials contain, which can limit metal leachabilities by simple pH control. The reductions in metal leachabilities indicated in these evaluations cannot be attributed solely to pH control, so it is probable that soluble metals are also being controlled by other mechanisms. These mechanisms may include precipitation as various species such as carbonates, silicates, and sulfates; microencapsulation of the waste particles through pozzolanic reactions; and passivation through the formation of metal precipitates. The high concentration of $\text{CaSO}_4/\text{CaSO}_3$ present in these materials may promote the formation of hydrated calcium sulfo-aluminates (such as ettringite), which may coat the waste particles, causing decreased contact with the leachant. In addition, the presence of fly ash in these residues provides a source of soluble silicates necessary for the formation of calcium silicates and the subsequent formation

Figure 3. Lead concentrations in immediate TCLP leachates of wastes treated with CFBC residue.

of tobermorite gel. While the contribution of cementitious reactions to metal control following solidification is well documented, the overall contribution to metal control given by these various cementitious compounds in the first 24 hr after mixing is not well known. This is an area where additional research needs to be conducted.

This investigation has also illustrated some of the problems associated with the use of stabilization as a waste treatment technology. The most apparent problem is the mobilization of metal species by the addition of alkaline treatment materials. In several cases, concentrations of leachable metals were higher in the treated residues than in the raw wastes. Another potential problem is the large amount of material required in some instances to stabilize the waste material. The added material can significantly increase shipping and disposal costs for treated residues.

While the success of CCT byproducts as waste stabilization agents has been proven effective at the laboratory scale, their use at the commercial scale has seen only limited application. There are a number of economic and perceived liability barriers to using these materials commercially. Perhaps the greatest barrier to overcome is the reluctance of utility operators to allow the use of their residuals as treatment chemicals for hazardous waste due to potential future liability issues associated with land disposal. Another potential barrier is the lack of long-term data on the stabilization effectiveness of these materials. Waste managers may be reluctant to use innovative treatment chemicals without a demonstrated long-term performance record. There are also potential environmental problems associated with final disposal of these residues due to the high alkalinity and high sulfate content. The long-term chemistry of these systems is not well understood, but it is expected that significant changes will occur over time as the initially formed hydrate phases change to more thermodynamically stable phases. In addition, expansive sulfates can form, which will cause breakdown of the solidified matrix, possibly exposing previously isolated waste particles to the environment.

Despite these shortcomings, these materials do have merit as treatment chemicals. They are effective in some applications, can be cheap to obtain along established shipping routes, and their availability will likely increase as more advanced CCT systems are placed into service. Data describing the ability of CCT materials to control metals through solidification reactions are not presented here, but the literature holds several citations describing the ability of these materials to enter into pozzolanic reactions.^{2,8} This study has shown the applicability of CCT byproducts as treatment chemicals; however, continued research in this area is needed to better describe the various reactions that occur in these systems so that the behavior of stabilized wastes after

final disposal can be understood.

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Any ideas, opinions, conclusions, or recommendations expressed herein are solely those of the authors and do not necessarily express the ideas of EPA, DOE, or the federal government.

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APPENDIX C

NEW UNIVERSAL TREATMENT STANDARDS

III. Revised Land Disposal Restrictions (i.e., Universal Treatment Standards) for Metal Constituents in all Hazardous Wastes, Including Toxic Characteristic Metals

Summary

There are two purposes to today's new treatment standards for metal-containing wastes. First, EPA is revising the numerical standards because new data are available on which to base more accurate standards. Second, EPA is including a new set of wastes in the current treatment standard regime, continuing EPA's efforts to apply the same LDR treatment standards when technically and legally possible. (In a subsequent section of this rule, EPA is expanding the treatment standard regime to include yet another set of wastes. These are characteristic mineral processing wastes that are not currently subject to land disposal restrictions.)

The numerical standards that EPA is revising are the universal treatment standards (UTS) for 12 metal constituents. The new UTS will apply to nonwastewater forms of any listed or characteristic hazardous waste that is already required to meet the UTS for those constituents in the waste. The revised UTS are less stringent for 7 constituents, and more stringent for 5. The rule does not affect the UTS for wastewater forms of these wastes, and does not change the UTS for any other constituents, including any of the organics.

The new set of wastes that EPA is bringing into the current LDR regime is the group of 8 wastes known as TC metal wastes--wastes identified as hazardous because they exhibit the toxicity characteristic due to the presence of the metals enumerated in 261.24 (Waste codes D004-D011). These are wastes that exhibit the toxicity characteristic because of high toxic metal content. By today's rule, that key metal must be treated to the UTS for that metal. Furthermore, any underlying hazardous constituents (UHCs) must be treated to UTS levels as well, whether these UHCs are organics or metals. Both wastewater and nonwastewater forms of the TC metal wastes are affected by today's rule, except for arsenic, for which only the wastewater forms are affected.

Hazardous wastes that exhibit both the TC for metals and the predecessor characteristic based on the Extraction Procedure (EP) are presently only required to be treated to reduce metal levels to below the characteristic level. Today's rule, for the most part, will require additional treatment of these metal constituents before land disposal can occur.

The Agency also finds that the treatment standards established in

today's rule are not established below levels at which threats to human health and the environment are minimized. See *Hazardous Waste Treatment Council v. EPA*, 886 F.2d 355, 362 (D.C. Cir. 1990). That case held that the statute can be read to allow either technology-based or risk-based LDR treatment standards, and further held that technology-based standards are permissible so long as they are not established 'beyond the point at which there is no 'threat' to human health or the environment.' Id. at 362. EPA's finding that today's standards are not below a 'minimize threat' level is based on the Agency's inability at the present time to establish concentration levels for hazardous constituents which represent levels at which threats to human health and the environment are minimized. As the Agency has explained a number of times, determining these levels on a national basis--which requires determination of relevant exposure pathways and potential receptors for all hazardous constituents in hazardous wastes, with all the attendant uncertainties involved in such a national determination--has not yet proven possible. See, e.g., 55 FR at 6642 (February 26, 1990). Thus, the Agency continues to find that technology-based standards remain the best approach for the national treatment standards since such standards eliminate as much of the inherent uncertainty of hazardous waste land disposal and so fulfill the Congressional intent in promulgating the land disposal restrictions provisions. Id. However, the Agency believes that it may be possible to make valid determinations that threats to human health and the environment are minimized on an individualized basis in the context of certain site-specific remediations, and accordingly has provided in this rule a variance from technology-based treatment requirements for contaminated soils generated in certain remediations. See section VII below.

A. History of Metal Treatment Standards

Land disposal of hazardous wastes is largely prohibited by statute, unless the wastes meet the applicable treatment standards established by EPA prior to land disposal. See RCRA sections 3004(d)-(g), (m); (the exception for no-migration units is not relevant to today's rule). Until today's rule, metals that were characteristic because they failed the Toxicity Characteristic Leaching Procedure (TCLP) and also failed the Extraction Procedure (EP)--which preceded the use of the TCLP as a means of identifying whether a waste exhibited a characteristic of hazardous waste--were subject to treatment standards at levels equal to the TC levels (55 FR 22520, June 1, 1990). (Note that wastes that were characteristic according to the TCLP but did not fail the EP were considered, until promulgation of today's rule, to be newly identified wastes, and were not subject to the LDR requirements. Today's rule makes these wastes subject to LDR). However, the TC levels are typically higher than those treatment levels for which threats posed by land disposal of the wastes are minimized. (*Waste Management v. EPA*, 976 F.2d 2, 13-14, 26-27, 32 (D.C. Cir. 1992). Consequently, treatment to levels lower than the characteristic levels normally is required. Id.

In an effort to make treatment standards as uniform as possible while adhering to the fundamental requirement that the standards must minimize threats to human health and the environment, EPA developed the UTS. Under the UTS, whenever technically and legally possible, the Agency adopts the same technology-based numerical limit for a hazardous constituent regardless of the type of hazardous waste in which the

constituent is present (see 40 CFR 268.40; and 59 FR 47982, September 19, 1994). In the original Phase IV proposal, EPA proposed to apply the metal UTS, as measured by the TCLP (60 FR 43582, August 22, 1995; see 40 CFR 261.24), to all TC metal wastes. The TCLP measures the possibility that a waste may leach toxic metals above a designated concentration level under certain assumed disposal conditions, and so is a measure of the potential mobility of toxic metals in a waste.

Commenters in response to the original proposal took issue with the Agency's use of data previously used to establish metal UTS as a basis for establishing the treatment standards for characteristic metal wastes. The commenters raised three basic issues with regard to the data transfer. First, they said that characteristic metal wastes are extremely variable and the data used to calculate the treatment standards were not representative of the diversity of TC metal wastes. Second, the commenters said that although two treatment technologies--high temperature metals recovery (HTMR) and stabilization--were determined to be Best Demonstrated Available Technology (BDAT), the current metals UTS were based solely on HTMR, a technology not commercially available for many TC metal wastes. Finally, commenters asserted that individual metal UTS values were not uniformly achievable when waste streams with multiple toxic metals were being treated. In light of these concerns, the commenters urged the Agency to obtain additional data that would demonstrate the effectiveness of stabilization on TC metal waste streams and more fully characterize the diversity of treatment of these nonwastewaters. The following commenters provided the Agency with stabilization performance data: Battery Council International, American Foundrymen's Association, Chemical Waste Management, and the Environmental Treatment Council. While extensive, the data unfortunately was based on composite samples and could not be used as the basis for treatment standards (see USEPA, Final Best Demonstrated Available Technology (BDAT) Background Document for Quality Assurance/Quality Control Procedures and Methodology, Office of Solid Waste, October 23, 1991 and 62 FR 26041 for a discussion of grab and composite sampling).

The Agency, however, was convinced that additional data were needed to further assess the treatment of TC metal nonwastewaters. During September 1996, EPA conducted site visits at three hazardous waste treatment facilities and collected additional treatment performance data. One facility was a large commercial TSDF that employed conventional stabilization techniques to treat a wide array of inorganic metal wastes. Another was an on-site treatment facility that focused on the stabilization of inorganic metal slag. A third facility was commercial and focused on stabilization of inorganic materials using non-conventional stabilization techniques. During these site visits, the Agency either gathered performance data from company records or requested the collection of actual treatment performance data through sampling and analysis.

Treatment data were collected for the following types of hazardous waste: mineral processing waste, baghouse dust, battery slag, soils, pot solids, recycling by-products, and sludge. See the memorandum, Final Revised Calculation of Treatment Standards Using Data Obtained From Rollins Environmental's Highway 36 Commercial Waste Treatment Facility and GNB's Frisco, Texas Waste Treatment Facility, March 10, 1997 and the memorandum, Transferability of UTS to Mineral Processing Wastes, January 28, 1997 for a complete description of the waste constituents and concentrations. Most of the wastes contained multiple metals in various concentrations while some had

significant concentrations of typically two metal combinations, including lead and cadmium, barium and lead, and chromium and antimony. In addition, between October 1994 and December 1995, the Agency obtained performance data from one HTMR facility; (other HTMR data became available very late in 1997). The assessment of the new data sets began with the calculation of treatment standards for each of the two data sets representing stabilization and HTMR. The same methodology, sometimes called "'C 99,'" and used in past LDR rulemakings, was used to calculate the treatment levels (see 56 FR 41164, August 18, 1991, and the BDAT Background Document for K061, dated August, 1991). Next, the Agency compared the treatment levels for stabilization verses HTMR. Based on this comparison, the Agency selected the highest level for each metal as the proposed UTS to allow for waste and process variability and detection limit difficulties. This approach is consistent with the legislative goal of providing substantial treatment through standards that are achievable by an array of well-performing, available treatment technologies. See 130 Cong. Rec. S 9184 (Daily ed., July 25, 1984) (statement of Senator Chafee).

As a result, the Agency issued a Second Supplemental Proposal on May 12, 1997 (62 FR 26041). In it, EPA proposed to change the numerical limits for all nonwastewater wastes containing the following metal constituents: antimony, barium, beryllium, cadmium, chromium, lead, nickel, selenium, silver, and thallium. (62 FR at 26047, May 12, 1997). The Agency also repropoed to change the numerical limits for vanadium in P119 and P120 nonwastewaters, and for zinc in K061 nonwastewaters. (62 FR at 26047, May 12, 1997). EPA also proposed these same UTS treatment standards for TC metal wastes identified as hazardous due to concentrations of barium, cadmium, chromium, lead, selenium and silver.

The Agency would like to correct in today's rule a prior error that was discovered in calculating the metals treatment levels using the HTMR treatment data. As previously stated, in the Second Supplemental and in today's preamble, in determining the treatment levels for each metal constituent, the Agency compared the treatment standards calculated with data from HTMR and stabilization. Based on this comparison, the highest level for each metal was chosen as the treatment standard. In reviewing the calculations from the HTMR data set, the Agency discovered an error in the calculations. When applying the methodology presented in USEPA, "'Final Best Demonstrated Technology (BDAT) Background Document for Quality Assurance/Quality Control Procedures and Methodology,'" dated October 23, 1991, it was discovered that the Agency failed to conduct a "'Z-score test'" to remove any outliers--data that is either so high or so low that it is not considered to be representative of the population from which the data are drawn. EPA uses this statistical method to confirm that certain data do not represent treatment by a well-operated system, or reflect anomalously low levels which are not typically achievable. This error was found to have occurred only in the calculation of the treatment standards based on the performance of HTMR; the treatment standards based on the performance of stabilization were properly calculated. The proposed treatment standards for cadmium, chromium, nickel, and silver were affected. The application of the Z-score outlier test resulted in 2 data points out of 40 being eliminated as outliers for both cadmium and chromium. For nickel, 5 out of 122 data points were identified as outliers.

For silver, 3 out of 114 data points were identified as outliers. Three of the resulting, calculated treatment standards changed slightly and are slightly more stringent than the proposed standards: cadmium from proposed 0.20 to corrected 0.11 mg/L TCLP; chromium from proposed 0.85 to corrected 0.60 mg/L TCLP; and nickel from proposed 13.6 to corrected 11 mg/L TCLP. Silver, on the other hand, changed from the proposed 0.11 mg/L TCLP to a corrected, slightly less stringent 0.14 mg/L TCLP. (Note: In re-calculating this standard, the Agency added an additional 74 data points which were submitted by the INMETCO Company (a high temperature metal reclaimer) in their comments to the May 12 supplemental proposal.) The Agency believes that these re-calculations are not significant because these four revised standards are each still achievable. See Memorandum, "Calculation of Universal Treatment Standard (UTS) for HTMR Residues Using Data Submitted by Horsehead Research Development (HRD) Co., Inc. And INMETCO," December 17, 1997.

B. Applicability of Metal Treatment Standards

As noted earlier, today's rule finalizes LDR treatment standards in two ways. First, it revises the UTS levels for 10 metal constituents in nonwastewater forms of hazardous wastes. The 10 include antimony, barium, beryllium, cadmium, chromium, lead, nickel, selenium, silver, and thallium. These treatment standards will replace the existing UTS values. In addition, EPA is applying UTS for the first time to 8 TC metal wastes: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The UTS apply to both wastewater and nonwastewater forms of the wastes (except for TC arsenic wastes, for which the UTS apply to wastewater forms only), and to both organic and metal underlying hazardous constituents in them. No TC metal wastes have had to meet standards for underlying hazardous constituents before today, and wastes exhibiting only the TC and not the EP were not yet prohibited. (Note, some subcategories of mercury and arsenic TC metal wastes have treatment methods requiring use of a specified technology, and are not affected by today's rule.) The Agency is also adjusting the treatment standards for vanadium in P019 and P020 nonwastewaters as well as zinc in K061 nonwastewaters.

The metal treatment standards being promulgated today have broad applicability. They apply to the following metal-containing hazardous wastes: (1) characteristic metal wastes, including both the newly identified wastes that, heretofore, were not prohibited from land disposal; and metal wastes that were identified as hazardous under the predecessor leaching protocol, the Extraction Procedure (EP), which remain hazardous because they also exhibit the TC by the TCLP; (2) mineral processing wastes which exhibit the toxicity characteristic for metal (this is actually a subset of wastes in (1) above); (3) listed hazardous wastes which have metal constituents; (4) underlying hazardous constituents (UHCs) that are metals in any characteristic hazardous waste (including mineral processing waste which exhibit a characteristic) that is disposed in other than a Clean Water Act (CWA) or CWA-equivalent wastewater treatment system (see 40 CFR 268.2(i); 59 FR 47982, September 19, 1994); and (5) radioactive wastes mixed with the wastes mentioned in (1)-(4) above.

UTS (prior to August 24, 1998)

K061	Emission control dust/sludge from the primary production of steel in electric furnaces:	Antimony	7440-36-0	NA	2.1 mg/l TCLP
		Arsenic	7440-38-2	NA	5.0 mg/l TCLP
		Barium	7440-39-3	NA	7.6 mg/l TCLP
		Beryllium	7440-41-7	NA	0.014 mg/l TCLP
		Cadmium	7440-43-9	0.89	0.19 mg/l TCLP
		Chromium (Total)	7440-47-3	2.77	0.88 mg/l TCLP
		Lead	7439-92-1	0.69	0.37 mg/l TCLP
		Mercury	7439-97-6	NA	0.025 mg/l TCLP
		Nickel	7440-02-0	3.98	5.0 mg/l TCLP
		Selenium	7782-49-2	NA	0.16 mg/l TCLP
		Silver	7440-22-4	NA	0.30 mg/l TCLP
		Thallium	7440-28-0	NA	0.078 mg/l TCLP
		Zinc	7440-66-6	NA	5.3 mg/l TCLP

UTS (after August 24, 1998)

Note: NA means not applicable.

Waste code	Waste description and treatment/regulatory subcategory ¹	Regulated hazardous constituent		Wastewaters	Nonwastewaters
		Common name	CAS ² No.		
K061	Emission control dust/sludge from the primary production of steel in electric furnaces.	Phenol	108-95-2	0.039	6.2
		Cyanides (Total) ⁷	57-12-5	1.2	590
		Antimony	7440-36-0	NA	1.15 mg/l TCLP
		Arsenic	7440-38-2	NA	5.0 mg/l TCLP
		Barium	7440-39-3	NA	21 mg/l TCLP
		Beryllium	7440-41-7	NA	1.22 mg/l TCLP
		Cadmium	7440-43-9	0.69	0.11 mg/l TCLP
		Chromium (Total)	7440-47-3	2.77	0.60 mg/l TCLP
		Lead	7439-92-1	0.69	0.75 mg/l TCLP
		Mercury	7439-97-6	NA	0.025 mg/l TCLP
		Nickel	7440-02-0	3.98	11 mg/l TCLP
		Selenium	7782-49-2	NA	5.7 mg/l TCLP
		Silver	7440-22-4	NA	0.14 mg/l TCLP
		Thallium	7440-28-0	NA	0.20 mg/l TCLP
		Zinc	7440-66-6	NA	4.3 mg/l TCLP

APPENDIX D

ENVIRONMENTAL QUESTIONNAIRE FOR PHASE 2 AT THE UNIVERSITY OF PITTSBURGH

ENVIRONMENTAL QUESTIONNAIRE

I. BACKGROUND

The Department of Energy's (DOE) National Environmental Policy Act (NEPA) Implementing Procedures (10 CFR 1021) require careful consideration of the potential environmental consequences of all proposed actions during the early planning stages. DOE must determine at the earliest possible time whether such actions require either an Environmental Assessment or an Environmental Impact Statement, or whether they qualify for Categorical Exclusion. To comply with these requirements, an Environmental Questionnaire must be completed for each proposed action to provide DOE with the information necessary to determine the appropriate level of NEPA review.

II. INSTRUCTIONS

Separate copies of this Environmental Questionnaire should be completed by the principal offeror and each proposed subcontractor. In addition, if the proposed project includes activities at different locations, an independent questionnaire should be prepared for each location. Supporting information can be provided as attachments.

In completing this questionnaire, the proposer is requested to provide specific quantities regarding air emissions, wastewater discharges, solid wastes, etc., to facilitate the necessary review. In addition, the proposer should identify the exact location of the project and specifically describe the activities that would occur at that location.

To expedite completion of this questionnaire, diskette copies in WordPerfect 6.1 are available upon request. Questions regarding the type of information requested or the approach to preparing responses should be referred to Lloyd Lorenzi, U.S. Department of Energy, Federal Energy Technology Center, by phone (412) 892-6159, fax (412) 892-6127, or E-mail (lorenzi@fetc.doe.gov).

III. QUESTIONNAIRE

A. PROJECT SUMMARY

1. Solicitation Number: DE-FC21-94MC31175
2. Proposer & all Proposed Subcontractors: University of Pittsburgh (Prime Contractor)
MAX Environmental Technologies, Inc. (Subcontractor)
3. Principal Investigator: James T. Cobb, Jr., P.E.
Telephone Number: (412) 624-7443
4. Project Title: Treatment of Metal-laden Hazardous Wastes with Advanced
Clean Coal
Technology By-Products, Phase Two
5. Duration: 12 months (10/1/99 — 9/30/00)
6. Location (city/township, county, state): Pittsburgh, Allegheny, Pennsylvania
7. Indicate the type or scale of project:

a. ☒ Computer Modeling	b. ☐ Library/Literature Search
c. ☒ Paper Study	d. ☐ Workshop/Conference
e. ☒ Laboratory (Batch) Research	f. ☐ Bench-scale Research
g. ☒ Pilot- or Proof-of-Concept-Scale Research	h. ☐ Pilot Plant Construction/Operation
i. ☒ Full-scale Demonstration	j. ☐ Other (please describe):

If either item a, b, c, or d was selected for Question A.7, proceed to Section IV (CERTIFICATION BY PROPOSER); submittal of the intervening parts of this questionnaire is not required.

However, if either item e, f, g, h, i or j was selected, continue with Question A.8.

8. Indicate the size of the proposed project and the primary material processed (e.g., 200 tph of coal).

_____	tph (of _____)	_____	MM Btu/hr
_____	scfm (of _____)	_____	MW ☐ electric ☐ thermal
_____	acfm (of _____)	<u> X </u>	Other: <u>Approximately 0.5 ton of</u>

5-lb cylinders of stabilized waste (10 each from the treatment of up to 25 batches of hazardous waste using advanced clean coal technology by-products) would be produced at the Mill Service Yukon Plant.

- 9a. Summarize the proposed work. List all activities or tasks planned at the location covered by this Environmental Questionnaire. During the Phase Two demonstration project, up to approximately 250 5-lb cylinders would be transferred to the University of Pittsburgh and tested there for compressive strength.
- 9b. Characterize the work site at this location (check all that apply).
☒ Existing Building (indoors) ☐ Developed site ☐ Undeveloped site
10. List all other locations where work would be performed. (**Note: Submit a separate Environmental Questionnaire for each location.**) Mill Service Yukon Plant, MAX Environmental Technologies, Inc., Yukon, Westmoreland County, Pennsylvania
11. Describe the objectives of the proposed project.
To determine and document the utility of the product of the stabilization of metal-laden hazardous wastes using advanced clean coal technology by-products (CCTBs) as structural materials.
12. Identify the planned number of tests, the frequency of testing (e.g., tests per week), and the duration of tests by type (e.g., laboratory tests, pilot unit runs, etc.).
25 commercial-scale tests are planned at MSYP, two per week between April and July 1999. During each test consideration will be given to producing ten cylinders. Those produced will be cured and tested at the the University of Pittsburgh during the year following their production.
13. Identify all materials that would be used and produced by the project (materials can be grouped by category) and estimate their total quantities over the entire duration of the proposed project.

Materials Used (total quantity)		Materials Produced (total quantity)	
☐	coal (_____)	☐	wastewater (_____)
☐	natural gas (_____)	☐	air emissions (_____)
☐	oil (_____)	☒	solid waste (<u>0.5 ton</u>)
☐	electricity (_____)	☐	hazardous waste (_____)
☐	water (_____)	☐	salable by-
☐	air (_____)		list and note
☐	organic solvents (_____)		
☒	others -- list and note quantity: 0.5 ton stabilized waste cylinders	☐	others -- list and note quantity:
☐	None	☐	None

B. PROPOSED PROJECT AND ITS ALTERNATIVES

1. List all alternative approaches considered to achieve the objectives described in A.11 and discuss the anticipated environmental effects of each. (Place the selected approach at the top of the list.)
Approach #1. Test stabilized wastes, produced at Mill Service Yukon Plant (MSYP), at the University of Pittsburgh and return tested material to MSYP. Up to 0.5 ton of stabilized wastes will be returned to the current isposal site at MSYP.
Approach #2. Test stabilized wastes, produced at Mill Service Yukon Plant (MSYP), at the University of Pittsburgh. Up to 0.5 ton of stabilized wastes will be diverted from the current disposal site at MSYP to the permitted industrial landfill used by the University of Pittsburgh for disposal of its non-hazardous wastes.
Approach #3. Test stabilized wastes, produced at MSYP, at a private testing company. Up to 0.5 ton of stabilized wastes would be diverted from the current disposal site at MSYP to the permitted industrial landfill used by that company for disposal of its non-hazardous wastes.
2. Identify the environmental consequences of not implementing this project (e.g., emission increase).
The use of stabilized wastes produced by treating metal-laden hazardous wastes with advanced clean coal technology products would not be practiced.

C. PROJECT LOCATION

1. Provide a brief description of the project location (physical location, surrounding area, adjacent structures).
The cylinders will be produced at the MSYP. They will be cured and tested for strength in the concrete testing laboratory of the Civil and Environmental Engineering Department of the School of Engineering, located in Benedum Hall on the campus of the University of Pittsburgh. The Pittsburgh Campus of the University of Pittsburgh is located approximately 2 miles from downtown Pittsburgh in the suburb of Oakland. The University is completely surrounded by the Oakland community and is not directly bordered by any major surface streams or tributary waters of the Commonwealth of Pennsylvania. Benedum Hall is located in the Ccenter of the Campus on the corner of O'Hara and N. Bouquet streets.
2. Attach a site plan or topographic map of the area that would be affected by the project and highlight (or otherwise identify) the specific location where the project would be performed.
All detailed maps of the City of Pittsburgh show the location of the University of Pittsburgh.

D. ENVIRONMENTAL IMPACTS

This section is designed to obtain information for objectively assessing the environmental impacts of a proposed project. NEPA procedures require evaluations of all possible effects (including: land use, energy requirements, natural or depletable resource use, historic and cultural resources, and pollutants) from proposed projects on the environment. Answer the following questions as completely as possible. Also, for "yes" or "no" questions, answer "yes" if there would be any effect, or if there may be an effect. (Failure to answer the questions completely could produce delays in project awards.)

1. Land Use

- a. Identify the location of the proposed project (i.e., city, county, state).
The University of Pittsburgh is located in the Oakland district of Pittsburgh, Allegheny County, Pennsylvania.
- b. Identify the total size of the facility and the portion would be used for the proposed project.
Benedum Hall is a twelve-story tower, having an additional two levels below-ground. The concrete testing laboratory is located in the sub-basement.
- c. Characterize present land use where the proposed project would be located.

☐ Urban	☐ Industrial
☐ Commercial	☐ Agricultural
☐ Suburban	☐ Rural
☐ Residential	☐ Research Facility
☐ Forest	☒ University Campus
☐ Other:	

- d. Describe how land use would be affected by planned construction activities.
☒ No construction would be anticipated for this project.
- e. Describe how land use would be affected by operational activities associated with the proposed project.
Land use would not be affected by operational activities associated with the project.
- f. Describe any plans to reclaim and/or revegetate areas that would be affected by the proposed project.
☒ No land areas would be affected ☐ None
- g. Would changes resulting from the proposed project affect future uses of the site or surrounding areas?
☒ No ☐ Yes (describe)
- h. Would the proposed project affect any unique or unusual landforms (e.g., cliffs, waterfalls, etc.)?
☒ No ☐ Yes (describe)
- i. Would the proposed project affect existing or future recreational opportunities in the area?
☒ No ☐ Yes (describe)
- j. Would the proposed project be located in or near a national park or wilderness area?
☒ No ☐ Yes (describe)

If the project would involve only laboratory or bench-scale research and be conducted within an existing building, proceed to Part D.8 (Atmospheric Conditions/Air Quality). If the project would be larger than bench-scale, continue with Part D.2.

2. Construction Activities and/or Operation

- a. Describe the topography at the project site, including any significant landforms, etc.
- b. Identify any transmission lines and/or pipelines that traverse the proposed site and clearly mark them on the site plan or topographic map.
☐ None
- c. Would the proposed project require the construction of settling ponds?
☐ No ☐ Yes (describe, identify location, and estimate surface area disturbed)
- d. Would the proposed project affect any existing body of water?
☐ No ☐ Yes (describe)
- e. Would the proposed project be located in or impact a floodplain?
☐ No ☐ Yes (describe)
- f. Would the proposed project be located on (or near) or impact wetlands?
☐ No ☐ Yes (describe)
- g. Would the proposed project be likely to cause erosion?
☐ No ☐ Yes (describe)
- h. Would any wetlands be impacted by the discharge of wastewater from project activities?

☐ No ☐ Yes (describe)

I. Would any construction activities planned under the proposed project result in stream diversion?

☐ No planned construction ☐ No ☐ Yes (describe)

3. Geological/Soil Conditions

a. Describe any instability (e.g., subsidence) in the topography near the proposed project.

b. Is there faulting in the vicinity of the proposed project area?

☐ No ☐ Yes (describe)

c. Describe the soil in the vicinity of the proposed project in terms of productivity, presence of unique species, and susceptibility to erosion.

d. Would any construction activities planned under the proposed project result in subsidence or changes in soil permeability/filtration?

☐ No planned construction ☐ No ☐ Yes (describe)

4. Vegetation and Wildlife Resources

a. Describe the indigenous flora and fauna in the vicinity of the proposed project.

b. Identify any state- or Federal-listed endangered or threatened species in the vicinity of the proposed project.

☐ None

c. Would any threatened or endangered species or their habitat be affected by the proposed project?

☐ No ☐ Yes (describe)

d. Describe any impacts that construction would have on sensitive or unique habitats.

☐ No planned construction ☐ No habitats ☐ None (discuss) ☐ Impact (describe)

e. Would any species or subspecies, not indigenous to the area, be introduced as a result of the project (e.g., introducing a new bacterial strain, as in microbial desulfurization projects)?

☐ No ☐ Yes (describe)

f. Would any migratory corridors be impacted or disrupted by the proposed project?

☐ No ☐ Yes (describe)

g. What regulatory authority maintains cognizance over indigenous wildlife species?

5. Socioeconomic and Infrastructure Conditions

a. What is the population in the vicinity of the proposed project and in communities near the project site?

b. Describe employment and labor mix in the vicinity of the proposed project.

c. Would changes (increases/decreases) in regional labor requirements be created by the proposed project?

☐ No ☐ Yes (describe)

d. Would the proposed project alter present traffic patterns?

☐ No ☐ Yes (describe)

e. Would the proposed project require new transportation access (roads, rail, etc.)?

☐ No ☐ Yes (describe)

f. Would the proposed project create an increase in local energy usage?

☐ No ☐ Yes (describe)

g. Would the proposed project increase local energy efficiency?

☐ No ☐ Yes (describe)

h. Would the proposed project significantly impact local fuel or energy supply?

☐ No ☐ Yes (describe)

I. Would any new transmission lines be required?

☐ No ☐ Yes (describe location, voltage, and length of line)

6. Historical/Cultural Resources

a. Describe any historical or cultural places in the vicinity of the proposed project; note any sites included on the National Register of Historic Places.

☐ None ☐ The following historical/cultural places are located in the project area:

b. Are there any known archeological sites in the vicinity of the proposed project?

☐ No ☐ Yes (describe)

c. Would construction or operational activities planned under the proposed project disturb any historical or cultural sites?

☐ No planned construction ☐ No historic sites ☐ No impact (discuss) ☐ Yes (describe)

d. Has the State Historic Preservation Office been contacted with regard to this project?

☐ No ☐ Yes (describe)

7. Visual Resources

a. Describe any scenic vistas or aesthetic landscaping in the vicinity of the proposed project?

☐ None ☐ The following visual resources exist in the project area:

b. Would the proposed project interfere with visual resources (e.g., eliminate scenic views) or alter the present landscape?

☐ No ☐ Yes (describe)

c. Would any facilities constructed under the proposed project contrast with the present landscape?

☐ No construction planned ☐ No ☐ Yes (describe)

For all proposed projects involving laboratory, bench-scale, or larger research and development activities, respond to the following questions.

8. Atmospheric Conditions/Air Quality

a. Describe the local climate.

July average precipitation = 3.75 in. July average low temperature = 62°F. July average high temperature =

83

°F. January average precipitation = 2.54 in. January average low temperature = 19°F. January average high temperature = 34°F.

- b. Identify air quality conditions in the immediate vicinity of the proposed project with regard to attainment of National Ambient Air Quality Standards. (This information should be available from the county environmental agency.)

	<u>Attainment</u>	<u>Non-Attainment</u>
O ₃	☐	☒
SO _x	☒	☐
PM ₁₀	☒	☐
CO	☒	☐
NO ₂	☒	☐
Lead	☒	☐

- c. Would the proposed project be in compliance with the National Emissions Standards for Hazardous Air Pollutants?
☐ No (explain) ☒ Yes
- d. Would the proposed project be classified as either a New Source or a major modification to an existing source?
☒ No ☐ Yes (describe)
- e. Would the proposed project be in compliance with the New Source Performance Standards?
☒ Not applicable ☐ No (explain) ☐ Yes
- f. Would the proposed project be subject to prevention of signification determination review?
☒ Not applicable ☐ No (explain) ☐ Yes (describe)
- g. What authority regulates air quality in the project area (identify Federal, state, and local authorities)?
Federal: Environmental Protection Agency, Region 3; State: Pennsylvania Department of Environmental Protection, Bureau of Air Quality; Local: Allegheny County Health Department
- h. Identify the contact person, address, and telephone number for each authority.
Federal: U. S. Environmental Protection Agency, Region e, Air and Toxics Section (3RC11), 215-814-2691;
State: Pennsylvania Department of Environmental Protection, Bureau of Air Quality, Joseph Pezze, Air Quality Program Manager, 412-442-4161; Local: Allegheny county Health Department, 412-687-ACHD
- i. When were these authorities contacted regarding the proposed project (if necessary)? Include results of discussions.
☒ Not contacted
- j. How does each regulator (authority) define a major source (e.g., greater than 100 ton/year; thermal input of 250 MMBtu/hr)?
Allegheny County Health Department (local authority having jurisdiction) defines a “major source” in Article XXI as “For stationary sources (or group of stationary sources) 10 tons per year (tpy) or more of any hazardous air pollutant, 25 tpy or more of any combination of such air pollutants, or 100 tpy or more of any air pollutant.”
This project will not fall under this designation.
- k. Would any types of emission control or particulate collection devices be used?
☒ No ☐ Yes (describe, including collection efficiencies)
- l. If no control devices are used, how would emissions be vented?
No emissions will be produced.

- m. What types of air emissions, including fugitive emissions, would be anticipated from the proposed project, and what would be the total quantity and maximum annual rate of emissions over the duration of the project?

☒ None	(Maximum per year)	(Total for project)
☐ SO _x	_____	_____
☐ NO _x	_____	_____
☐ PM ₁₀	_____	_____
☐ CO	_____	_____
☐ Lead	_____	_____
☐ H ₂ S	_____	_____
☐ organic solvent vapors or other volatile organic compounds -- list		
☐ hazardous air pollutants -- list		
☐ other -- list		

- n. Would the proposed project reduce the amount of air emissions in the area?
☒ No ☐ Yes (describe)

- o. Identify Federal, state, and local air quality regulations that govern emissions in the project area.
Federal air quality regulations: *Clean Air Act*; **Local air quality regulations:** *County of Allegheny, Pennsylvania, Ordinance No. 16782, and Allegheny County Health Department Rules and Regulations, Article XXI, Air Pollution Control.*

9. Hydrologic Conditions/Water Quality

- a. What is the closest body of water to the proposed project area and what is its distance from the project site? Indicate on the site plan, if provided.
The Pittsburgh Campus of the University of Pittsburgh is located approximately 2 miles from downtown Pittsburgh in the suburb of Oakland. The University is completely surrounded by the Oakland community and is not directly bordered by any major surface streams or tributary waters of the Commonwealth of Pennsylvania. The closest body of water is the Monongahela River. The project site is approximately one mile from this river.
- b. What sources would supply potable and process water for the proposed project? Identify quantities consumed and uses. Identify the names of municipal or other water systems that would be used.
The City of Pittsburgh Water and Sewer Authority (ALCOSAN)
- c. Quantify the total amount of wastewater that would be generated by the proposed project.

☒	None	
☐	non-contact cooling water	(gallons)
☐	process water	(gallons)
☐	sanitary and/or grey water	(gallons)
☐	other -- describe	(gallons)

- d. What would be the components of each type of wastewater (e.g., coal fines)?

Not applicable — no wastewater from the project.

- e. Identify the local treatment facility that would receive wastewater from the proposed project.
☒ No discharges to local treatment facility.
Allegheny County Sanitary Authority
- f. Describe how wastewater would be collected and treated.
All wastewater and sanitary sewage from the Pittsburgh Campus of the University of Pittsburgh (including this project) is transported via the City of Pittsburgh sewage collection system to the Allegheny County Sanitary Authority (ALCOSAN) for ultimate treatment and discharge. Therefore, the Pittsburgh Campus does not treat or directly discharge sanitary or industrial wastewater into any waters of the Commonwealth of Pennsylvania and is not required to participate in the NPDES permit program.
- g. What Federal, state, and local authorities regulate water quality in the proposed project area?
Federal: U. S. Environmental Protection Agency; **State/Local:** Pennsylvania Department of Environmental Protection, Southwest Regional Office
- h. Identify the contact person, address, and telephone number for each authority.
State/Local: Pennsylvania Department of Environmental Protection, Southwest Regional Office, Bureau of Water Quality, Tim Dreier, Water Quality Program Manager, 412-442-4028
- i. When were these authorities contacted regarding the proposed project (if necessary)? Include results of discussions.
☒ Not contacted
- j. Would any run-off or leachates be produced from storage piles or waste disposal sites?
☒ No ☐ Yes (describe sources, nature of flow, and collection techniques)
- k. Identify Federal, state, and local regulations that govern water effluents/water quality in the project area.
Federal Regulations: *Clean Water Act*; **State Regulations:** *PA Code, Title 25. Environmental Resources — Chapter 71: Administration of Sewage Facilities Planning Program; Chapter 72: Administration of Sewage Facilities Permitting Program; Chapter 73: Standards for Sewage Disposal Facilities; Chapter 92: NPDES; Chapter 93: Water Quality Standards; Chapter 95: Wastewater Treatment Requirements; Chapter 101: Special Water Pollution Regulations*; **Local Requirements:** *ALCOSAN discharge effluent requirements.*
- l. Where would wastewater effluents from the proposed project be discharged?
Not applicable — no wastewater from the project.
- m. Would the proposed project be permitted to discharge effluents into an existing body of water?
☒ No ☐ Yes (describe water use and effluent impact)
Benedum Hall does not directly discharge into any body of water.
- n. Would a new or modified National Pollutant Discharge Elimination System (NPDES) permit be required?
☒ No ☐ Yes (describe)
- o. Would the proposed project increase or decrease the surface area of an existing body of water?
☒ No ☐ Yes (describe)
- p. Would the proposed project adversely affect the quality or movement of groundwater?
☒ No ☐ Yes (describe)

10. Solid and Hazardous Wastes

- a. Describe in detail and provide the total quantity of all nonhazardous wastes that would be generated from the project. Solid wastes are defined in RCRA as any solid, liquid, semi-solid, or contained gaseous material that is discarded, has served its intended purpose, or is a manufacturing or mining by-product (40 CFR 260, Appendix I).

	<u>Quantity</u>
☐ None	
☐ municipal solid waste, i.e., paper, plastic, etc.	( )
☐ coal or coal by-products	( )
☒ other -- identify	( )
<u>Broken cylinders of stabilized waste</u>	<u>(0.5 ton)</u>
_____	( )

- b. Describe in detail and provide the total quantity of all hazardous wastes (40 CFR 261.3) that would be generated, used, or stored under this project.

☒ None   ☐ The following hazardous wastes would be generated, used, or stored:

- c. How and where would solid waste disposal be accomplished?

☐ On-site (identify and describe location)   ☒ Off-site (identify location and describe facility and treatment)

All samples for this project will be returned to Mill Service Yukon Plant and disposed at their facility, Impoundment #6, under PA DEP permit number 301071.

- d. How would wastes for disposal be transported?

Dump trailer or roll-off container.

- e. How many trips would be required for landfill disposal?

☐ None   ☒ Number of trips: One

- f. What volume of the landfill would the solid waste occupy?

☐ None   ☒ Volume cubic feet

- g. What Federal, State, and local waste management authorities would have permit authority for the landfill?

Federal: United States Environmental Protection Agency, Region 3; **State/Local:** Pennsylvania Department of Environmental Protection.

- h. Identify the contact person, address, and telephone number for each authority.

Federal: No active contact; **State/Local:** Pennsylvania Department of Environmental Protection, Carl Spadaro 400 Waterfront Drive, Pittsburgh, PA 15222, 412-442-4120.

- i. When were these authorities contacted regarding the proposed project (if necessary)? Include results of discussions.

☒ Not contacted

- j. How would hazardous or toxic products be collected and stored?

Not applicable — no hazardous or toxic products will be collected or stored.

- k. If hazardous/toxic solid wastes are subject to land disposal restrictions, how would collection, treatment, and disposal of the wastes be accomplished?

☐ Not subject to RCRA land disposal restrictions.   ☐ Subject to RCRA land disposal restrictions (explain):

Not applicable

- l. If hazardous wastes would require off-site disposal, have arrangements been made with a certified TSD (Treatment, Storage, and Disposal) facility?

☒ Not required   ☐ Arrangements not yet made   ☐ Arrangements made with a certified TSD facility (identify):

- m. How would hazardous waste(s) be transported?
☒ No hazardous wastes would be generated
- n. What treatment/storage/disposal methods would be used for hazardous wastes?
☒ No hazardous wastes would be generated   ☐ Unknown   ☐ Methods that would be used (describe):

11. Health/Safety Factors

- a. Identify any hazardous or toxic substances that would be used in the proposed project.
☒ None   ☐ Hazardous or toxic substances that would be used (identify):
- b. What would be the likely impacts of these substances on human health and the environment?
Not applicable — no hazardous or toxic substances will be used.
- c. Would there be any potential for workers to be exposed to toxic/hazardous chemicals or wastes?
☒ No   ☐ Yes (describe)
- d. Would there be any potential for exposure to extreme temperatures?
☒ No   ☐ Yes (describe)
- e. Would there be any special physical hazards associated with the project?
☐ No   ☒ Yes (describe)
Use of strength testing machine. Potential for flying pieces of crushed cylinders
- f. Would personal protective equipment or clothing be required?
☐ No   ☒ Yes (describe)
Eye, face and hand protection
- g. Does a worker safety program exist at the location of the proposed project?
☐ No   ☒ Yes (describe)
The University of Pittsburgh Department of Environmental Health and Safety (EH&S) provides several programs that are applicable to the safety of laboratory workers at the University of Pittsburgh, including the

General Health and Safety Program and Chemical Hygiene Plan.
- h. Would safety training be necessary for any laboratory, equipment, or processes involved with the project?
☐ No   ☒ Yes (describe)
The University of Pittsburgh Chemical Hygiene Program has been designed to help University faculty, staff and students to use chemicals safely and in a manner which complies with prevailing State and Federal regulations and protocols. The purpose of the University Chemical Hygiene Program, and specifically the Chemical Hygiene Plan,” is to describe proper practices, procedures, equipment and facilities that function together to help ensure that all affected individuals are protected from the effects of hazardous chemicals in their work area. All University faculty, staff and students working with chemicals are provided with Chemical Hygiene training by the EH&S Department.
- I. Describe any increases in ambient noise levels from construction and operational activities.
☒ None   ☐ Increase in ambient noise level (describe)
- j. Would project construction result in the removal of natural barriers that act as noise screens?
☒ No construction planned   ☐ No   ☐ Yes (describe)
- k. Identify the highest expected highest decibel level at the closest point of public access.
The level is unknown, but it would not be changed as a result of the proposed action.
- l. Identify the highest expected decibel level in the work area.
The level would be less than 85 decibels (TWA), and it would not be changed as a result of the proposed action.
- m. Would hearing protection be required for workers?
☒ No   ☐ Yes (describe)

12. Environmental Restoration and/or Waste Management

- a. Would the proposed project include CERCLA removals or similar actions under RCRA or other authorities, meeting CERCLA cost/time limits?
☐ No ☐ Yes (describe)
- b. Would the proposed project include siting, construction, and operation of temporary pilot-scale waste collection and treatment facilities or pilot-scale waste stabilization and containment facilities?
☐ No ☐ Yes (describe)
- c. Would the proposed project involve improvements to environmental monitoring and control systems of an existing structure or building?
☐ No ☐ Yes (describe)
- d. Would the proposed project involve siting, construction, operation, and decommissioning of a facility for storing packaged hazardous waste for 90 days or less?
☐ No ☐ Yes (describe)

E. REGULATORY COMPLIANCE

1. For the following laws, describe any new or modified permits, manifests, contacts, etc., that would be required for the proposed project:
- a. Resource Conservation and Recovery Act (RCRA):
☐ None ☐ Required (describe)
- b. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA):
☐ None ☐ Required (describe)
- c. Toxic Substance Control Act (TSCA):
☐ None ☐ Required (describe)
- d. Water Pollution Control Act (WPCA):
☐ None ☐ Required (describe)
- e. Clean Air Act (CAA):
☐ None ☐ Required (describe)
- f. Endangered Species Act (ESA):
☐ None ☐ Required (describe)
- g. Floodplains and Wetlands Regulations:
☐ None ☐ Required (describe)
- h. Fish and Wildlife Coordination Act (FWCA):
☐ None ☐ Required (describe)
- I. Farmland Protection Policy Act (FPPA):
☐ None ☐ Required (describe)
- j. National Historic Preservation Act (NHPA):
☐ None ☐ Required (describe)
- k. Coastal Zone Management Act (CZMA):
☐ None ☐ Required (describe)

l. American Indian Religions Freedom Act (AIRFA):
☒ None ☐ Required (describe)

m. Wild and Scenic Rivers Act (WSRA):
☒ None ☐ Required (describe)

2. Identify any other environmental laws and regulations (Federal, state, and local) for which compliance would be necessary for this project, and describe the permits, manifests, and contacts that would be required.
None.

F. **DESCRIBE ANY ISSUES THAT WOULD GENERATE PUBLIC CONTROVERSY REGARDING THE PROPOSED PROJECT.**
☒ None

G. **WOULD THE PROPOSED PROJECT PRODUCE ADDITIONAL DEVELOPMENT, OR ARE OTHER MAJOR DEVELOPMENTS PLANNED OR UNDERWAY, IN THE PROJECT AREA?**
☒ No ☐ Yes (describe)

H. **SUMMARIZE THE SIGNIFICANT IMPACTS THAT WOULD RESULT FROM THE PROPOSED PROJECT.**
☐ None (provide supporting detail) ☒ Significant impacts (describe)
Utilization of treatment products as closure caps.

IV. CERTIFICATION BY PROPOSER

I hereby certify that the information provided herein is current, accurate, and complete as of the date shown immediately below.

DATE: 1 / 14 / 00
month day year

SIGNATURE: _____

TYPED NAME: Lawrence W. Keller, CIH, CSP

TITLE: Director, Environmental Health and Safety

ORGANIZATION: University of Pittsburgh

V. REVIEW AND APPROVAL BY DOE

I hereby certify that I have reviewed the information provided in this questionnaire, have determined that all questions have been appropriately answered, and judge the responses to be consistent with the efforts proposed. Based on the information in the questionnaire, I conclude the following (check the appropriate box):

- ☐ The proposed action falls under one or more of the categorical exclusions (CXs) listed in Appendix A or B of Subpart D of the DOE NEPA Implementing Procedures and would not (1) violate applicable ES&H requirements, (2) require siting of waste TSD or recovery facilities, (3) disturb hazardous substances (excluding naturally occurring petroleum and natural gas), thus producing uncontrolled or unpermitted releases, and (4) adversely affect environmentally sensitive resources.

Additionally, the proposed action (1) would not present any extraordinary circumstances such that the action might have a significant impact upon the human environment, (2) is not connected to other actions with potentially significant impacts, and (3) is not related to other actions with cumulatively significant impacts.

Based on the Environmental Questionnaire and these conclusions, Categorical Exclusion of the proposed action would be appropriate.

- ☐ The proposed action does not qualify as a CX as identified in Subpart D of DOE's NEPA Implementing Procedures; therefore, the proposed action may require further documentation in the form of an Environmental Assessment or Environmental Impact Statement.

Project Manager: _____

Date: _____

APPENDIX E

ENVIRONMENTAL QUESTIONNAIRE FOR PHASE 2 AT THE MILL SERVICE YUKON PLANT

ENVIRONMENTAL QUESTIONNAIRE

I.BACKGROUND

The Department of Energy's (DOE) National Environmental Policy Act (NEPA) Implementing Procedures (10 CFR 1021) require careful consideration of the potential environmental consequences of all proposed actions during the early planning stages. DOE must determine at the earliest possible time whether such actions require either an Environmental Assessment or an Environmental Impact Statement, or whether they qualify for Categorical Exclusion. To comply with these requirements, an Environmental Questionnaire must be completed for each proposed action to provide DOE with the information necessary to determine the appropriate level of NEPA review.

II.INSTRUCTIONS

Separate copies of this Environmental Questionnaire should be completed by the principal offeror and each proposed subcontractor. In addition, if the proposed project includes activities at different locations, an independent questionnaire should be prepared for each location. Supporting information can be provided as attachments.

In completing this questionnaire, the proposer is requested to provide specific quantities regarding air emissions, wastewater discharges, solid wastes, etc., to facilitate the necessary review. In addition, the proposer should identify the exact location of the project and specifically describe the activities that would occur at that location.

To expedite completion of this questionnaire, diskette copies in WordPerfect 6.1 are available upon request. Questions regarding the type of information requested or the approach to preparing responses should be referred to Lloyd Lorenzi, U.S. Department of Energy, Federal Energy Technology Center, by phone (412) 892-6159, fax (412) 892-6127, or E-mail (lorenzi@fetc.doe.gov).

III.QUESTIONNAIRE

A. PROJECT SUMMARY

1. Solicitation Number: DE-FC21-94MC31175
2. Proposer & all Proposed Subcontractors: University of Pittsburgh (Prime Contractor)
MAX Environmental Technologies, Inc. (Subcontractor)
3. Principal Investigator: James T. Cobb, Jr., P.E.
Telephone Number: (412) 624-7443
4. Project Title: Treatment of Metal-laden Hazardous Wastes with Advanced
Clean Coal Technology By-Products, Phase Two
5. Duration: 12 months (10/1/99 — 9/30/00)
6. Location (city/township, county, state): South Huntingdon (Yukon), Westmoreland, Pennsylvania
7. Indicate the type or scale of project:

a. ☒ Computer Modeling	b. ☐ Library/Literature Search
c. ☒ Paper Study	d. ☐ Workshop/Conference
e. ☒ Laboratory (Batch) Research	f. ☐ Bench-scale Research
g. ☒ Pilot- or Proof-of-Concept-Scale Research	h. ☐ Pilot Plant Construction/Operation
i. ☒ Full-scale Demonstration	j. ☐ Other (please describe):

If either item a, b, c, or d was selected for Question A.7, proceed to Section IV (CERTIFICATION BY PROPOSER);submittal of the intervening parts of this questionnaire is not required.

However, if either item e, f, g, h, i or j was selected, continue with Question A.8.

8. Indicate the size of the proposed project and the primary material processed (e.g., 200 tph of coal).

_____ tph (of _____)   _____ MM Btu/hr
_____ scfm (of _____)   _____ MW   ☐ electric   ☐ thermal
_____ acfm (of _____)   _____ X   Other: Approximately 1000 tons of
metal-laden hazardous waste (25 batches
using up to 40 tons each) would be used
during the Phase Two demonstration
project.

- 9a. Summarize the proposed work. List all activities or tasks planned at the location covered by this Environmental Questionnaire.

The Phase Two demonstration project includes up to 10 commercial-scale treatments of metal-laden hazardous wastes using approximately 250 tons of solid by-products generated through advanced clean coal technologies (25 batches using up to 10 tons each).

- 9b. Characterize the work site at this location (check all that apply).

☒ Existing Building (indoors)   ☒ Developed site   ☐ Undeveloped site

10. List all other locations where work would be performed. (**Note: Submit a separate Environmental Questionnaire for each location.**)

University of Pittsburgh, Pittsburgh, Allegheny County, Pennsylvania

11. Describe the objectives of the proposed project.

To determine and publicly document the marketability of advanced clean coal technology by-products (CCTBs) as commodity chemicals for the treatment of metal-laden hazardous wastes. To publicly demonstrate at commercial scale the technical viability of the treatment of metal-laden wastes using advanced CCTBs. To establish advanced clean coal technology by-products as regular treatment chemicals at the Mill Service Yukon(MSYP) of MAX Environmental Technologies, Inc. Note: Phase One of this project has publicly shown at bench-scale the technical viability of the treatment of metal-laden wastes using advanced CCTBs.

12. Identify the planned number of tests, the frequency of testing (e.g., tests per week), and the duration of tests by type (e.g., laboratory tests, pilot unit runs, etc.).

25 commercial-scale tests are planned, two per week between April and July 1999. Each test will take several hours.

13. Identify all materials that would be used and produced by the project (materials can be grouped by category) and estimate their total quantities over the entire duration of the proposed project.

Materials Used (total quantity)		Materials Produced (total quantity)	
☐	coal (_____)	☐	wastewater (_____)
☐	natural gas (_____)	☒	air emissions (_____)
☐	oil (_____)	☒	solid waste (1250 T)
☐	electricity (_____)	☐	hazardous waste (_____)
☒	water (_____)	☐	salable by-
☐	air (_____)		list and note
☐	organic solvents (_____)		
☒	others -- list and note quantity: Metal-laden hazardous waste -- stes -- 1000 tons; CCTBs -- 250 tons	☐	others -- list and note quantity:
☐	None	☐	None

Petroleum products and electricity will be used indirectly, such as fuel for vehicles and equipment to haul and and process materials.

B. PROPOSED PROJECT AND ITS ALTERNATIVES

1. List all alternative approaches considered to achieve the objectives described in A.11 and discuss the anticipated environmental effects of each. (Place the selected approach at the top of the list.)
Approach #1. Treat selected metal-laden hazardous wastes at Mill Service Yukon Plant (MSYP) with selected by-products. Up to 250 tons of by-products will be diverted from current disposal sites to the permitted industrial landfill used by MSYP for disposal of its non-hazardous treated wastes. **Approach #2.** Treat selected metal-laden hazardous wastes with selected by-products at another company's plant. Up to 250 tons of by-products would be diverted from current disposal sites to the permitted industrial landfill used by that plant for disposal of its non-hazardous treated wastes. **Approach #3.** Purchase a report on on-going, confidential, non- published commercial treatment of metal-laden hazardous wastes with by-products at another company's plant. There would be no net environmental effect of this approach.
2. Identify the environmental consequences of not implementing this project (e.g., emission increase).
The effective use of advanced clean coal technology by-products would be minimized through lack of promotion. The amounts not used nationwide for this expanded market would continue to be disposed directly to landfill without its economic chemical value being utilized.

C. PROJECT LOCATION

1. Provide a brief description of the project location (physical location, surrounding area, adjacent structures).
The MSYP is a 160-acre permitted RCRA treatment plant. The surrounding area is rural. 12 residential population are within 0.2 miles of the plant's boundaries.
2. Attach a site plan or topographic map of the area that would be affected by the project and highlight (or otherwise identify) the specific location where the project would be performed.
A site plan is attached.

D. ENVIRONMENTAL IMPACTS

This section is designed to obtain information for objectively assessing the environmental impacts of a proposed project. NEPA procedures require evaluations of all possible effects (including: land use, energy requirements, natural or depletable resource use, historic and cultural resources, and pollutants) from proposed projects on the environment. Answer the following questions as completely as possible. Also, for "yes" or "no" questions, answer "yes" if there would be any effect, or if there may be an effect. (Failure to answer the questions completely could produce delays in project awards.)

1. Land Use

- a. Identify the location of the proposed project (i.e., city, county, state).
The Mill Service Yukon Plant (MSYP) is located approximately 0.5 miles west of the Village of Yukon in South Huntingdon Township, Westmoreland County, Pennsylvania.
- b. Identify the total size of the facility and the portion would be used for the proposed project.
The total size of the Yukon Plant site is approximately 160 acres. The proposed action area (laboratory, silo, mixing pits, and container area) is less than 2 acres of the site.
- c. Characterize present land use where the proposed project would be located.

☐ Urban	☒ Industrial
☐ Commercial	☐ Agricultural
☐ Suburban	☐ Rural
☐ Residential	☐ Research Facility
☐ Forest	☐ University Campus
☐ Other:	

- d. Describe how land use would be affected by planned construction activities.
☐ No construction would be anticipated for this project.
The land use will continue to be industrial.
- e. Describe how land use would be affected by operational activities associated with the proposed project.
The land use will continue to be industrial.
- f. Describe any plans to reclaim and/or revegetate areas that would be affected by the proposed project.
☒ No land areas would be affected ☐ None
- g. Would changes resulting from the proposed project affect future uses of the site or surrounding areas?
☒ No ☐ Yes (describe)
- h. Would the proposed project affect any unique or unusual landforms (e.g., cliffs, waterfalls, etc.)?
☒ No ☐ Yes (describe)
- i. Would the proposed project affect existing or future recreational opportunities in the area?
☒ No ☐ Yes (describe)
- j. Would the proposed project be located in or near a national park or wilderness area?
☒ No ☐ Yes (describe)

If the project would involve only laboratory or bench-scale research and be conducted within an existing building, proceed to Part D.8 (Atmospheric Conditions/Air Quality). If the project would be larger than bench-scale, continue with Part D.2.

2. Construction Activities and/or Operation

- a. Describe the topography at the project site, including any significant landforms, etc.
The project site is in the Appalachian foothills. The site was previously a coal strip mine. Presently the site has four closed waste impoundments and one active waste impoundment.
- b. Identify any transmission lines and/or pipelines that traverse the proposed site and clearly mark them on the site plan or topographic map.
☒ None
- c. Would the proposed project require the construction of settling ponds?
☒ No ☐ Yes (describe, identify location, and estimate surface area disturbed)
- d. Would the proposed project affect any existing body of water?
☒ No ☐ Yes (describe)
- e. Would the proposed project be located in or impact a floodplain?
☒ No ☐ Yes (describe)
- f. Would the proposed project be located on (or near) or impact wetlands?
☒ No ☐ Yes (describe)
- g. Would the proposed project be likely to cause erosion?
☒ No ☐ Yes (describe)
- h. Would any wetlands be impacted by the discharge of wastewater from project activities?
☒ No ☐ Yes (describe)
- I. Would any construction activities planned under the proposed project result in stream diversion?
☐ No planned construction ☒ No ☐ Yes (describe)

3. Geological/Soil Conditions

- a. Describe any instability (e.g., subsidence) in the topography near the proposed project.
The site was subsurface mined for the Pittsburgh coal seam. Some mine subsidence exists in the area. No subsidence exists on the MSYP property.
- b. Is there faulting in the vicinity of the proposed project area?
☒ No ☐ Yes (describe)
- c. Describe the soil in the vicinity of the proposed project in terms of productivity, presence of unique species, and susceptibility to erosion.
Soil on the portion of the property on which the project will be placed is disturbed from past facility activity.
A majority of the soil on the property is disturbed from past facility activities.
- d. Would any construction activities planned under the proposed project result in subsidence or changes in soil permeability/filtration?
☐ No planned construction ☒ No ☐ Yes (describe)

4. Vegetation and Wildlife Resources

- a. Describe the indigenous flora and fauna in the vicinity of the proposed project.
A majority of the site is closed impoundment with non-native vegetation growing on it. The remainder of the property contains typical temperate species.
- b. Identify any state- or Federal-listed endangered or threatened species in the vicinity of the proposed project.
☒ None
- c. Would any threatened or endangered species or their habitat be affected by the proposed project?
☒ No ☐ Yes (describe)
- d. Describe any impacts that construction would have on sensitive or unique habitats.
☐ No planned construction ☒ No habitats ☐ None (discuss) ☐ Impact (describe)
- e. Would any species or subspecies, not indigenous to the area, be introduced as a result of the project (e.g., introducing a new bacterial strain, as in microbial desulfurization projects)?
☒ No ☐ Yes (describe)
- f. Would any migratory corridors be impacted or disrupted by the proposed project?
☒ No ☐ Yes (describe)
- g. What regulatory authority maintains cognizance over indigenous wildlife species?
Commonwealth of Pennsylvania Department of Environmental Protection

5. Socioeconomic and Infrastructure Conditions

- a. What is the population in the vicinity of the proposed project and in communities near the project site?
4400 residential population live within 2.2 miles of the property.
- b. Describe employment and labor mix in the vicinity of the proposed project.
The employment and labor mix is estimated to be 5-15% farming, 40-60% commercial and 35-45% industrial.
- c. Would changes (increases/decreases) in regional labor requirements be created by the proposed project?
☒ No ☐ Yes (describe)
- d. Would the proposed project alter present traffic patterns?
☒ No ☐ Yes (describe)

e. Would the proposed project require new transportation access (roads, rail, etc.)?
☒ No ☐ Yes (describe)

f. Would the proposed project create an increase in local energy usage?
☒ No ☐ Yes (describe)

g. Would the proposed project increase local energy efficiency?
☒ No ☐ Yes (describe)

h. Would the proposed project significantly impact local fuel or energy supply?
☒ No ☐ Yes (describe)

I. Would any new transmission lines be required?
☒ No ☐ Yes (describe location, voltage, and length of line)

6. Historical/Cultural Resources

a. Describe any historical or cultural places in the vicinity of the proposed project; note any sites included on the National Register of Historic Places.

☒ None ☐ The following historical/cultural places are located in the project area:

b. Are there any known archeological sites in the vicinity of the proposed project?
☒ No ☐ Yes (describe)

c. Would construction or operational activities planned under the proposed project disturb any historical or cultural sites?

☐ No planned construction ☒ No historic sites ☐ No impact (discuss) ☐ Yes (describe)

d. Has the State Historic Preservation Office been contacted with regard to this project?
☐ No ☒ Yes (describe)

Dr. Kurte Carr, Chief, Division of Archeology and Protection, Bureau for Historic Preservation, Harrisburg, PA was contacted by letter on August 23, 1995. A reply was received from Dr. Carr, dated October 3, 1995. Both documents were reproduced in Appendix D of the topical report on Phase 1, dated March 1, 1996.

7. Visual Resources

a. Describe any scenic vistas or aesthetic landscaping in the vicinity of the proposed project?
☒ None ☐ The following visual resources exist in the project area:

b. Would the proposed project interfere with visual resources (e.g., eliminate scenic views) or alter the present landscape?

☒ No ☐ Yes (describe)

c. Would any facilities constructed under the proposed project contrast with the present landscape?

☐ No construction planned ☒ No ☐ Yes (describe)

For all proposed projects involving laboratory, bench-scale, or larger research and development activities, respond to the following questions.

8. Atmospheric Conditions/Air Quality

a. Describe the local climate.

The local climate is temperate. Prevailing winds are from west to east.

- b. Identify air quality conditions in the immediate vicinity of the proposed project with regard to attainment of National Ambient Air Quality Standards. (This information should be available from the county environmental agency.)

	<u>Attainment</u>	<u>Non-Attainment</u>
O ₃	☐	☒
SO _x	☒	☐
PM ₁₀	☒	☐
CO	☒	☐
NO ₂	☒	☐
Lead	☒	☐

- c. Would the proposed project be in compliance with the National Emissions Standards for Hazardous Air Pollutants?
☐ No (explain) ☒ Yes

- d. Would the proposed project be classified as either a New Source or a major modification to an existing source?
☒ No ☐ Yes (describe)

- e. Would the proposed project be in compliance with the New Source Performance Standards?
☐ Not applicable ☐ No (explain) ☒ Yes

- f. Would the proposed project be subject to prevention of signification determination review?
☒ Not applicable ☐ No (explain) ☐ Yes (describe)

- g. What authority regulates air quality in the project area (identify Federal, state, and local authorities)?
United States Environmental Protection Agency, Region III; Commonwealth of Pennsylvania Department of Environmental Protection; no local authority

- h. Identify the contact person, address, and telephone number for each authority.
USEPA — no active contact; PADEP — Barbara R. Hatch, 400 Waterfront Drive, Pittsburgh, PA 15222, (412) 442-4000

- i. When were these authorities contacted regarding the proposed project (if necessary)? Include results of discussions.
☐ Not contacted
On August 3, 1998 a permit application was submitted. On August 31, 1999 an exemption request was received for the dusty treatment reagent storage silo.

- j. How does each regulator (authority) define a major source (e.g., greater than 100 ton/year; thermal input of 250 MMBtu/hr)?
Ambient air emissions \$ 100 tpy for any criteria pollutant, \$ 50 tpy for VOCs, \$ 10 tpy for a single HAP, or \$ 25 tpy for any combination of HAPs (same definition for both federal and state authorities).

- k. Would any types of emission control or particulate collection devices be used?
☐ No ☒ Yes (describe, including collection efficiencies)
Vent collectors will be installed on the silo; they will remove greater than 99% of the potential emissions. If necessary, portable covers will be provided over tanks, and water sprays will be available for dust suppression.

- l. If no control devices are used, how would emissions be vented? Not applicable.

- m. What types of air emissions, including fugitive emissions, would be anticipated from the proposed project, and what would be the total quantity and maximum annual rate of emissions over the duration of the project?

☐ None	(Maximum per year)	(Total for project)
☐ SO _x	_____	_____
☐ NO _x	_____	_____
☒ PM ₁₀	13.63 Ton*	0.105 Ton**
☐ CO	_____	_____
☐ Lead	_____	_____
☐ H ₂ S	_____	_____
☐ organic solvent vapors or other volatile organic compounds -- list		
☐ hazardous air pollutants -- list		
☐ other -- list		
* potential site controlled emission		** potential project controlled emission

- n. Would the proposed project reduce the amount of air emissions in the area?

☒ No ☐ Yes (describe)

- o. Identify Federal, state, and local air quality regulations that govern emissions in the project area.
Federal — 40 CFR Subchapter C; Pennsylvania — Title 25 PA Code Article III

9. Hydrologic Conditions/Water Quality

- a. What is the closest body of water to the proposed project area and what is its distance from the project site?
 Indicate on the site plan, if provided.
Sewickley Creek.
- b. What sources would supply potable and process water for the proposed project? Identify quantities consumed and uses. Identify the names of municipal or other water systems that would be used.
Water for the project will come from the Municipal Authority of Westmoreland County, Beaver Run Water Treatment Plant. Several thousand gallons may be used for decontamination of the mixing pit and dust suppression/reagent activation.
- c. Quantify the total amount of wastewater that would be generated by the proposed project.

☒	None	
☐	non-contact cooling water	(gallons)
☐	process water	(gallons)
☐	sanitary and/or grey water	(gallons)
☐	other -- describe	(gallons)

No wastewater (all process water will combine with dry by-products, activating chemical constituents).

- d. What would be the components of each type of wastewater (e.g., coal fines)?
Not applicable — no wastewater from the project.

	<u>Quantity</u>
☐ None	
☐ municipal solid waste, i.e., paper, plastic, etc.	( )
☐ coal or coal by-products	( )
☒ other -- identify	( )
<u>Treatment residue</u>	(1250 T)
_____	( )

- b. Describe in detail and provide the total quantity of all hazardous wastes (40 CFR 261.3) that would be generated, used, or stored under this project.
☐ None ☒ The following hazardous wastes would be generated, used, or stored:
1000 tons of metal-laden hazardous waste will be stored and used under this project. None would be generated.
- c. How and where would solid waste disposal be accomplished?
☒ On-site (identify and describe location) ☐ Off-site (identify location and describe facility and treatment)
On-site — Impoundment #6, under PA DEP permit number 301071; off-site — Greenridge Reclamation Facility, Scottdale, PA, under PA DEP permit number 100281.
- d. How would wastes for disposal be transported?
Dump trailer or roll-off container.
- e. How many trips would be required for landfill disposal?
☐ None ☒ Number of trips: 65
- f. What volume of the landfill would the solid waste occupy?
☐ None ☒ Volume: 12,500
- g. What Federal, State, and local waste management authorities would have permit authority for the landfill?
United States Environmental Protection Agency, Region III; Commonwealth of Pennsylvania Department of Environmental Protection; no local authority
- h. Identify the contact person, address, and telephone number for each authority.
USEPA — no active contact; PADEP — Carl Spadaro, 400 Waterfront Drive, Pittsburgh, PA 15222, (412) 442-4000
- i. When were these authorities contacted regarding the proposed project (if necessary)? Include results of discussions.
☐ Not contacted
A minor permit modification reapplication response to PADEP comments was submitted in October 1999.
- j. How would hazardous or toxic products be collected and stored?
1000 tons of **manifested** hazardous materials will be delivered to MSYP by truck. They will be stored in double-lined covered containers until treatment.
- k. If hazardous/toxic solid wastes are subject to land disposal restrictions, how would collection, treatment, and disposal of the wastes be accomplished?
☐ Not subject to RCRA land disposal restrictions. ☒ Subject to RCRA land disposal restrictions (explain):
They will be treated by ongoing permitted commercial processes. None will be collected, generated or disposed.
- l. If hazardous wastes would require off-site disposal, have arrangements been made with a certified TSD (Treatment, Storage, and Disposal) facility?
☒ Not required ☐ Arrangements not yet made ☐ Arrangements made with a certified TSD facility (identify):
- m. How would hazardous waste(s) be transported?
☒ No hazardous wastes would be generated
- n. What treatment/storage/disposal methods would be used for hazardous wastes?
☒ No hazardous wastes would be generated ☐ Unknown ☐ Methods that would be used (describe):

11. Health/Safety Factors

- a. Identify any hazardous or toxic substances that would be used in the proposed project.
☐ None ☒ Hazardous or toxic substances that would be used (identify):
Refer to D10b above.

- b. What would be the likely impacts of these substances on human health and the environment?
Controls are established to limit exposure and migration to within permitted levels.
- c. Would there be any potential for workers to be exposed to toxic/hazardous chemicals or wastes?
☐ No ☒ Yes (describe)
The Phase Two demonstration would not present any additional exposure risks than are typically associated with commercial operations at MSYP. Under Phase Two, workers would be potentially exposed to metal-laden hazardous wastes, stabilizing agents, and chemicals in the laboratory.
- d. Would there be any potential for exposure to extreme temperatures?
☒ No ☐ Yes (describe)
- e. Would there be any special physical hazards associated with the project?
☒ No ☐ Yes (describe)
The Phase Two demonstration would not present any special physical hazards other than those typically associated with heavy equipment machinery and vehicles used in commercial operations at the site.
- f. Would personal protective equipment or clothing be required?
☐ No ☒ Yes (describe)
MSYP's Health and Safety Plan for the site currently addresses activities requiring the use of personal protective equipment and clothing. These guidelines would be strictly adhered to during the Phase Two demonstration.
- g. Does a worker safety program exist at the location of the proposed project?
☐ No ☒ Yes (describe)
The MSYP currently has in place a Health and Safety Plan for the site and a Chemical Hygiene Plan for the laboratory.
- h. Would safety training be necessary for any laboratory, equipment, or processes involved with the project?
☐ No ☒ Yes (describe)
The OSHA 40-hour Health and Safety Training is provided to plant and laboratory workers.
- I. Describe any increases in ambient noise levels from construction and operational activities.
☒ None ☐ Increase in ambient noise level (describe)
- j. Would project construction result in the removal of natural barriers that act as noise screens?
☒ No construction planned ☐ No ☐ Yes (describe)
- k. Identify the highest expected highest decibel level at the closest point of public access.
The level is unknown, but it would not be changed as a result of the proposed action.
- l. Identify the highest expected decibel level in the work area.
The level would be less than 85 decibels (TWA), and it would not be changed as a result of the proposed action.
- m. Would hearing protection be required for workers?
☒ No ☐ Yes (describe)
This is not anticipated to be required. However, should periodic monitoring indicate that the 85 decibel (TWA) threshold is exceeded, a suitable hearing conservation program would be implemented.

12. Environmental Restoration and/or Waste Management

- a. Would the proposed project include CERCLA removals or similar actions under RCRA or other authorities, meeting CERCLA cost/time limits?
☒ No ☐ Yes (describe)
- b. Would the proposed project include siting, construction, and operation of temporary pilot-scale waste collection and treatment facilities or pilot-scale waste stabilization and containment facilities?
☒ No ☐ Yes (describe)

c. Would the proposed project involve improvements to environmental monitoring and control systems of an existing structure or building?
☒ No ☐ Yes (describe)

d. Would the proposed project involve siting, construction, operation, and decommissioning of a facility for storing packaged hazardous waste for 90 days or less?
☒ No ☐ Yes (describe)

E. REGULATORY COMPLIANCE

1. For the following laws, describe any new or modified permits, manifests, contacts, etc., that would be required for the proposed project:

a. Resource Conservation and Recovery Act (RCRA):
☒ None ☐ Required (describe)

b. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA):
☒ None ☐ Required (describe)

c. Toxic Substance Control Act (TSCA):
☒ None ☐ Required (describe)

d. Water Pollution Control Act (WPCA):
☒ None ☐ Required (describe)

e. Clean Air Act (CAA):
☐ None ☒ Required (describe)
See D8i above.

f. Endangered Species Act (ESA):
☒ None ☐ Required (describe)

g. Floodplains and Wetlands Regulations:
☒ None ☐ Required (describe)

h. Fish and Wildlife Coordination Act (FWCA):
☒ None ☐ Required (describe)

i. Farmland Protection Policy Act (FPPA):
☒ None ☐ Required (describe)

j. National Historic Preservation Act (NHPA):
☒ None ☐ Required (describe)

k. Coastal Zone Management Act (CZMA):
☒ None ☐ Required (describe)

l. American Indian Religions Freedom Act (AIRFA):
☒ None ☐ Required (describe)

m. Wild and Scenic Rivers Act (WSRA):
☒ None ☐ Required (describe)

2. Identify any other environmental laws and regulations (Federal, state, and local) for which compliance would be necessary for this project, and describe the permits, manifests, and contacts that would be required.
None.

F. DESCRIBE ANY ISSUES THAT WOULD GENERATE PUBLIC CONTROVERSY REGARDING THE PROPOSED PROJECT.

☒ None

G. WOULD THE PROPOSED PROJECT PRODUCE ADDITIONAL DEVELOPMENT, OR ARE OTHER MAJOR DEVELOPMENTS PLANNED OR UNDERWAY, IN THE PROJECT AREA?

☐ No ☒ Yes (describe)

A successful full-scale demonstration would provide information and data on the ability of by-products from advanced clean coal technologies to effectively stabilize and solidify metal.-laden hazardous wastes.

Ultimately, this project would: (1) enable the hazardous waste management community to use new sources of treatment material, (2) provide new uses for clean coal technology by-products, and (3) lessen the need to landfill these by-products.

H. SUMMARIZE THE SIGNIFICANT IMPACTS THAT WOULD RESULT FROM THE PROPOSED PROJECT.

☐ None (provide supporting detail) ☒ Significant impacts (describe)

Replacement of other treatment reagents.

IV. CERTIFICATION BY PROPOSER

I hereby certify that the information provided herein is current, accurate, and complete as of the date shown immediately below.

DATE: 1 / 13 / 2000
                    month   day   year

SIGNATURE: _____

TYPED NAME: Henry A. Springer

TITLE: Director of Compliance & Engineering

ORGANIZATION: Mill Service Yukon Plant, MAX Environmental Technologies, Inc.

V. REVIEW AND APPROVAL BY DOE

I hereby certify that I have reviewed the information provided in this questionnaire, have determined that all questions have been appropriately answered, and judge the responses to be consistent with the efforts proposed. Based on the information in the questionnaire, I conclude the following (check the appropriate box):

- ☐ The proposed action falls under one or more of the categorical exclusions (CXs) listed in Appendix A or B of Subpart D of the DOE NEPA Implementing Procedures and would not (1) violate applicable ES&H requirements, (2) require siting of waste TSD or recovery facilities, (3) disturb hazardous substances (excluding naturally occurring petroleum and natural gas), thus producing uncontrolled or unpermitted releases, and (4) adversely affect environmentally sensitive resources.

Additionally, the proposed action (1) would not present any extraordinary circumstances such that the action might have a significant impact upon the human environment, (2) is not connected to other actions with potentially significant impacts, and (3) is not related to other actions with cumulatively significant impacts.

Based on the Environmental Questionnaire and these conclusions, Categorical Exclusion of the proposed action would be appropriate.

- ☐ The proposed action does not qualify as a CX as identified in Subpart D of DOE's NEPA Implementing Procedures; therefore, the proposed action may require further documentation in the form of an Environmental Assessment or Environmental Impact Statement.

Project Manager: _____ Date: _____

APPENDIX F

COMPREHENSIVE TEST PLAN FOR PHASE 2

TREATMENT OF METAL-LADEN HAZARDOUS
WASTES
WITH
ADVANCED CLEAN COAL TECHNOLOGY BY-
PRODUCTS

COMPREHENSIVE COMMERCIAL-SCALE
FIELD TEST PLAN FOR PHASE II FROM
OCTOBER 1, 1999 TO SEPTEMBER 30, 2000

James T. Cobb, Jr., Principal Investigator and Project Director
Ronald D. Neufeld, Co-Principal Investigator
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MAX Environmental Technologies, Inc.

January 12, 2000

AWARD NUMBER DE-FG21-94MC31175

for

U.S. Department of Energy
National Energy Technology Laboratory
Morgantown, West Virginia
and
Pittsburgh, Pennsylvania

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Pittsburgh, PA 15261

TREATMENT OF METAL-LADEN HAZARDOUS WASTES
WITH
ADVANCED CLEAN COAL TECHNOLOGY BY-PRODUCTS

COMPREHENSIVE COMMERCIAL-SCALE
FIELD TEST PLAN FOR PHASE II FROM
OCTOBER 1, 1999 TO SEPTEMBER 30, 2000

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TREATMENT OF METAL-LADEN HAZARDOUS WASTES WITH ADVANCED CLEAN COAL TECHNOLOGY BY-PRODUCTS COMPREHENSIVE COMMERCIAL-SCALE FIELD TEST PLAN FOR PHASE II FROM OCTOBER 1, 1999 TO SEPTEMBER 30, 2000

OBJECTIVES OF THE PROJECT

The general objective of the laboratory studies in Phase One and subsequent field studies in Phase Two of this project is to provide useful information and data on the ability of new sources of chemical treatment materials, in this case by-products from advanced clean coal technologies, to be used by the hazardous waste management community.

These studies fall into two categories - characterization of selected critical properties of the by-products and observation of their ability to stabilize and solidify characteristic metal-laden solid hazardous wastes. The characterization studies, the focus of Phase 1, were designed to assess the chemical, mineralogical, physical and engineering properties of dry combustion/desulfurization by-products. To the extent possible, given the number of by-product samples collected during this portion of the project, the following two issues were examined: (1) how the measured properties were affected by the type of process utilized and (2) how specific operating conditions within the various processes affected the measured properties of the by-products. The stabilization and solidification studies of Phase 1 were designed to assess the ability of these by-products to immobilize the metals present in the waste and to assess the compressive strength of the resulting non-hazardous product.

The more commercial objective of Phase 2 of the project is to link the producers of by-products with operators of hazardous waste treatment facilities in a mutually profitable manner. From the treatment facility operators' side, new sources of treatment material, which can stabilize and solidify their feed wastes, will be added to their material source list. From the producers' side of the equation, new uses for by-products of their advanced coal combustors and desulfurizers will be added to their customer lists. These producers have implemented various emission control technologies at their coal-fired electric power plants and are studying a number of others. The technologies currently in use generate significant amounts of by-products with limited commercial value. Consequently, much of the by-product has to be disposed as solid wastes. In particular, companies employing wet scrubber technologies for the desulfurization of flue gases have found few alternatives to disposal for the sludges generated in the processes due to the excess moisture present in the by-product. The development of dry desulfurization technologies offers more promise that the process by-products may have some beneficial application, such as that being studied in this project.

The specific objective of the project, as provided in the "Statement of Cooperative Agreement Objectives" of the contract document is:

The objective of this project is to evaluate treatment of [characteristic] metal-laden hazardous wastes using solid by-products generated by Clean Coal Technologies (CCT). The project is divided into two phases. In Phase 1, the participant will evaluate up to 10 sources of [characteristic] metal-laden hazardous wastes and up to 4 sources of CCT solid by-products in laboratory-scale tests. In Phase 2, the participant will evaluate treatment of the

[characteristic] metal-laden hazardous waste using CCT solid by-products in [40-ton to 80-ton] batches. Complete physical and chemical characterization of the CCT solid by-products, and treated and untreated [characteristic] metal-laden hazardous waste will be performed in both phases. An economic analysis is included in both phases to assess the commercial viability of treating metal-laden hazardous waste with CCT solid by-products.

Phase One

In Phase 1, samples of three clean coal technology by-products were collected and characterized. Seven samples of characteristic metal-laden hazardous wastes were collected and characterized. Laboratory-scale treatments of each of the seven wastes with each of the three by-products were performed at the Mill Service Yukon Plant (MSYP) of MAX Environmental Technologies, Inc. (MAX), in a manner identical to the commercial treatability tests used at that site. Finally, the products of those treatments were characterized for stabilization and solidification at the University of Pittsburgh (Pitt).

MAX performed laboratory-scale treatments of seven metal-laden hazardous wastes using CCT by-products from three sources in Phase 1. The wastes treated included an industrial wastewater treatment residue from a battery manufacturing plant, a contaminated soil from a remediation project conducted at a munitions depot, a contaminated soil from a remediation project conducted at an abandoned industrial site, a contaminated soil from a remediation project conducted at a former sewage treatment plant site, an air pollution control dust from a basic oxygen furnace at a steel production facility, an air pollution control ash from a municipal waste incinerator, and a sandblast residue from a paint-removal project. All of the wastes exhibited the lead toxicity characteristic.¹ The CCT by-products used in the treatments included a residue from a spray dryer identified as CONSOL #1, a residue from a coal-fired pressurized fluid bed combustor identified as Tidd #2, and a residue from a waste coal-fired circulating fluid bed combustor identified as EPC #3. Each waste was mixed with each of the CCT by-products at weight ratios of 10:1, 10:3 and 2:1 (waste:by-product). A small amount of water was also used to "activate" the reagent.

The laboratory-scale testing performed during Phase 1 suggested that several of the CCT by-products could be used to treat certain types of metal-laden hazardous wastes. Using the treatment standards of the U.S. Environmental Protection Agency's (USEPA) then-current Land Disposal Restrictions (LDR) for wastes that exhibit the metal toxicity characteristics as the measure of success, the successful waste/by-product combinations were:

- Mixture of the sewage treatment plant site soil with the EPC #3 by-product at waste:by-product weight ratios of 10:3 and 2:1.
- Mixture of the munitions depot soil with the Tidd #2 by-product at a waste:by-product weight ratio of 2:1.
- Mixture of the multi-use industrial site soil with the Tidd #2 by-product at a waste:by-product weight ratio of 2:1.
- Mixture of the sewage treatment plant site soil with the Tidd #2 by-product at a waste:by-product weight ratio of 2:1.
- Mixture of the battery manufacturing wastewater treatment sludge with the CONSOL #1 by-product at waste:by-product weight ratios of 10:1, 10:3 and 2:1.
- Mixture of the munitions depot soil with the CONSOL #1 by-product at waste:by-product

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¹ Most of the wastes, as generated, also contained high concentrations of other metals that did not leach under the conditions of the Toxicity Characteristic Leaching Procedure (TCLP).

weight ratios of 10:1, 10:3 and 2:1.

- Mixture of the multi-use industrial site soil with the CONSOL #1 by-product at waste:by-product weight ratios of 10:1, 10:3 and 2:1.
- Mixture of the sewage treatment plant site soil with the CONSOL #1 by-product at waste:by-product weight ratios of 10:1, 10:3 and 2:1.

Less success was demonstrated by the Phase 1 testing when the results were compared against the then-proposed USEPA LDR treatment standards for wastes that exhibit the metal toxicity characteristics.² Using these criteria as the measure of success, the successful waste/by-product combinations were:

- Mixture of the sewage treatment plant site soil with the EPC #3 by-product at a waste:by-product weight ratio of 2:1.
- Mixture of the battery manufacturing wastewater treatment sludge with the CONSOL #1 by-product at waste:by-product weight ratios of 10:1, 10:3 and 2:1.
- Mixture of the munitions depot soil with the CONSOL #1 by-product at a waste:by-product weight ratio of 2:1.
- Mixture of the multi-use industrial site soil with the CONSOL #1 by-product at a waste:by-product weight ratio of 2:1.³

On pages 98 and 99 of the topical report of Phase 1, several important conclusions were drawn about the commercial operation envisioned at that point:

The hazardous waste treatment business that MAX operates must use treatment chemicals that immediately stabilize metals. The company can ship (with a tipping fee to a permitted, non-hazardous, industrial landfill) only treated wastes whose characteristic hazard has been eliminated. A treatment chemical which requires some days to remove the characteristic hazard [currently] is not economically useful to MAX. Thus, only immediate stabilization has been examined so far in the tests conducted by the project team. On this basis, the CONSOL #1 by-product has been found to be a very effective treatment chemical. The EPC #3 by-product was the least effective, while the Tidd #2 by-product was more effective than EPC #3 by-product, but still not sufficient to be considered [currently] of commercial interest to MAX. None of the by-products were particularly successful in stabilizing the wastes generated by high-temperature processes (BOF dust and municipal incinerator dust).

The project team [currently] sees the possibility that an economically successful hazardous waste treatment business might be devised, however, in which treatment of hazardous waste is obtained using a slow stabilization chemical. The economics would be obtained if the treated waste, after proof of its having become characteristically non-hazardous by the end of a "curing" time, would be sold as a structural fill to a nearby construction project. For a use such as this, a "successful" treatment chemical will stabilize the metals within a reasonable curing time. This slower rate of stabilization is one area for further research in Phase 2.

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² The proposed treatment standards are part of a proposed rule, known as the Land Disposal Restrictions - Phase IV, which was published in the *Federal Register* on August 22, 1995 (60 FR 43654) and enacted in August 1998.

³ This waste/by-product mixture failed to achieve the LDR treatment standard for zinc. However, the Phase IV LDR treatment standard proposal retains the provision in the current treatment standards that exempts characteristic wastes from compliance with the zinc standard. The current treatment standards also exempt other characteristic wastes from compliance with the vanadium treatment standard.

The results of Phase 1 were recently published in the *Journal of the Air & Waste Management Association*. A copy is provided in Appendix A.

Phase Two

In Phase 2 of the project, up to twenty-five commercial-scale treatments (22 to 80-ton batches each containing appropriate ratios of waste — usually in 20-ton truckloads — and by-product) will be conducted at the MSYP. As in Phase 1, Pitt will perform solidification characterization of up to ten of the commercial recipes for treated wastes.

Since the end of Phase 1, the then-current USEPA LDR treatment standards for wastes that exhibit the metal toxicity characteristics have been modified. Consequently, MAX is most interested in evaluating the full-scale success of the by-products in treating metal-laden hazardous wastes based on the new criteria.

Here is a more detailed description of the work to be conducted in Phase 2.

The first (and principal) major element of Phase 2 centers on field studies. The field studies at the MSYP will be conducted as a normal activity of this RCRA hazardous waste treatment facility operating under permits from the Pennsylvania Department of Environmental Protection (PADER). It should be noted that the by-products being examined in this project all are residues from systems that operate with sorbents having no bulk moisture associated with them, except in some cases during their injection into the combustor, ductwork or scrubber. Thus as product materials they have a significant potential for dust emissions. The MSYP is about to install new equipment to allow it to employ these dusty treatment chemicals in a routine manner for the first time.

Up to twenty-five of the by-product/waste combinations giving immediate successful stabilization as evaluated during the laboratory studies of Phase 1 will be considered. To the extent possible, the treatments will be performed using types of wastes evaluated in the laboratory treatability studies of Phase 1. However, MSYP is unable to guarantee that those same wastes will be available at the time the full-scale treatments are to be conducted. Only wastes authorized for management at the Yukon facility will be used in the full-scale tests. For each combination, one commercial batch of waste will be treated with by-product by the MSYP and analyzed there for leachable (TCLP) concentrations to verify that the waste has been successfully stabilized.

The treatment recipe for each of the up to twenty-five waste/by-product combinations selected will be determined in the MSYP laboratory. The recipe will be set at the optimum of three dosages as determined by laboratory treatability studies. In the event the laboratory testing of a particular waste/by-product combination does not indicate that the levels of the metals of concern and underlying hazardous constituents in each of the wastes can be reduced to below the Phase IV hazardous level, no full-scale testing of that waste/by-product combination will be conducted.

Following a successful demonstration, the treatment residues from both MSYP and Pitt will be disposed in a proper fashion either at the MSYP or at an authorized facility.

A question might naturally arise at this point concerning the possibility of one or more field test batches of treated hazardous waste not being rendered non-hazardous, because of the ineffectiveness of by-product at large scale. Provision for such an occurrence is standard at the Yukon facility. Any batch that the MSYP fails to render non-hazardous is retreated by the MSYP. The same will be done with any batches from this project that fail to be rendered non-hazardous by treatment with by-product, or if necessary, the waste will be retreated with conventional reagents employed by MSYP.

The second major element of Phase 2 will be fundamental solidification laboratory work conducted at Pitt. A fundamental question has been developed in Phase 1, relating to solidification leading to the use of the product as structural fill. This question needs to be explored, as MAX is giving serious consideration to using the treated material as capping closure material for several of

its old impoundments. Up to ten by-product/waste combinations giving successful solidification as evaluated during the laboratory studies of Phase 1 will be examined for solidification.

For treatment combinations giving immediate stabilization, 3" by 6" cylinders for measuring compressive strength will be cast at the MSYP immediately following commercial treatment. The cylinders will be taken to Pitt and tested there for compressive strength (3-day, 7-day, 14-day and 28-day). For certain of the combinations, 4" or 6" cylinders for measuring compressive strength and stress behavior may also be cast, and the cylinders tested.

EQUIPMENT

The MSYP is an industrial waste treatment, storage and disposal (TSD) facility operating under permits from the PADEP. The facility is authorized to treat and store certain hazardous wastes by Hazardous Waste Permit No. PAD004835146. Following a nearly four-year application process, this permit was modified in July 1998 to allow the commercial use of dusty, dry clean coal technology by-products as stabilization/solidification treatment chemicals at the MSYP. The Yukon facility is also authorized to treat, store and dispose certain non-hazardous wastes by Solid Waste Permit No. 301071.

An approval package is submitted to the PADEP for every metal toxicity characteristic waste that MSYP intends to accept for treatment, in advance of actual acceptance for treatment. Once this completed approval request package is received by the PADEP, the waste is approved, if the package is complete and the waste stream meets the permit approved wastes acceptance criteria. As part of the complete approval package, a treatment evaluation of the waste must be performed to determine if the waste can be treated to below the applicable treatment standards. This treatability evaluation is conducted in MSYP's on-site laboratory, which is required to file all the required notifications.⁴

Metal-bearing wastes generally are transported from the site of their generation to the MSYP on bulk solid transport vehicles. These wastes are contained in roll-off containers or dump trailers. Some wastes are delivered in drums. Before a waste shipment is accepted for treatment and/or storage at the facility, it must be inspected and the contents of each shipping container must conform to a pre-established waste description developed for each specific waste stream. If the waste does not conform to the description, it is rejected and/or the generator is contacted to provide justification for the change in physical characteristics.

Clean coal technology by-products also are transported from the site of their generation or from a transportation terminal to the MSYP on bulk solid transport vehicles. The Tidd by-product has already been received in supersacks delivered by flatbed trucks. It is currently stored on a pad at the MSYP under a tarpaulin awaiting use in Phase 2. The other two by-products will be delivered either in pneumatic transport trucks or dump trucks. They will be transferred from the delivery vehicles to a storage silo that will be installed soon at the MSYP.

The installation of the silo and its ancillary systems for receiving and transferring the by-products and for air pollution control (baghouse) has been designed. An application has been submitted to PADEP for minor modifications to the facility's Hazardous Waste Permit No. PAD004835146 for their installation. Two additional applications have also been submitted: (1) a revision to the air permit to operate the baghouse on the silo and (2) a modification to the facility's Solid Waste Permit No. 301071 to dispose of the solid waste produced by treatment with the new chemicals.

It should be noted that all across Pennsylvania the PADEP is in the process of consolidating

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⁴ See 40 CFR 261.4(f) and 25 Pa Code 261.4(d).

all air permits on a given site. Currently, the MSYP has five active air permits. MSYP submitted the consolidation application in November 1997 and is awaiting approval. The air permit application for the silo's baghouse was issued separately from the consolidated permit on August 31, 1999. MSYP had expected that the modification to the solid waste permit would be issued also by the end of November 1999. The MSYP has received permission to begin construction of the modifications necessary to continue this project.

The wastes and by-products will be transferred for treatment to the Solid Waste Stabilization and Solidification (SWSS) unit at the MSYP. The SWSS unit consists of three double-walled, in-ground, open-top tanks that are operated in parallel. Each tank has the capacity to manage approximately 133 cubic yards of waste and reagents. An excavator bucket is used to blend the waste and treatment chemicals in the SWSS unit.

Portable containers (roll-off containers or dump trailers) are available to receive the treated waste from the SWSS unit. Once the TCLP analysis confirms successful treatment, the containers are used to transport successfully treated waste to its disposal site.

The laboratory tests to be conducted in Phase 2 of this project are generally standard bench-scale laboratory analyses defined by EPA and ASTM protocols. As such, the equipment utilized is that which has been installed in the laboratories of Pitt, the MSYP, Antech Ltd, and K-Chem Laboratories, the regular analytical service contractor for the MSYP. The analyses are identified in the following section on "Procedures."

PROCEDURES

This section describes the various procedures that will be used in Phase 2 by Pitt and the MSYP.

Standard Analytical Procedures

This subsection contains a listing of the standard analytical procedures that are being applied, or are expected to be applied, by Pitt, the MSYP, Antech Ltd, and K-Chem.

MSYP - By-Product, Waste and Treated Waste Evaluations

- Digestions according to EPA SW-846, Methods 3010A, 3020A, or 3050A;
- TCLP (Toxicity Characteristic Leaching Procedure) Extractions by EPA SW-846, Method 1311;
- Metals Analysis by EPA SW-846, Method 6010 or by the series of EPA Methods 7061A, 7080, 7130, 7190, 7210, 7420, 7470, 7471, 7520, 7741, 7760A and 7950⁵;
- Production of 3"x6" cylinders by ASTM-C311-87a;
- Production of 4" or 6" diameter cylinders by ASTM-D698-91 or ASTM-D1557-91.

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⁵ Should a hazardous metal be present in the waste in a quantity small enough that its entire dissolution would produce a concentration below the regulated level, the concentration of that metal will not be sought in the extract. In the event of interferences or the appearance of other metals of concern, other recognized procedures may be required. Should such an event occur, modifications will be recommended to the COR.

Pitt - Treated Waste Evaluations

- Curing of 3"x6" cylinders and 4" or 6" diameter cylinders by ASTM-C311-87a;
- Compressive strength testing by ASTM-C311-87a.

Chemical Characterization Of Wastes

In Phase 1 of the project, the MSYP screened the wastes it intended to use to verify that they actually exhibited a hazardous waste metal characteristic. Those wastes that failed to exhibit a hazardous metal characteristic were not used in the project. Storage constraints do not allow the MSYP this luxury for the Phase 2 testing. Consequently, the MSYP will select the wastes for use in the full-scale treatments based on the waste generator's determination that the waste exhibits a hazardous metal characteristic. Chemical characterization of the wastes will be performed as part of the Phase 2 testing program. However, the MSYP will not be able to use this data to reject specific shipments of waste from use in the project since they will have already been subject to treatment using the by-products. The Phase 2 chemical characterizations performed on the untreated wastes will instead be used to establish the baseline contaminant information to which the stabilized waste characteristics will be compared.

Samples of the wastes to be used in the full-scale waste treatments will be collected for chemical characterization from the vehicles used to transport the wastes from their site of generation to the MSYP. The sampling procedure to be employed is that typically used at the facility for waste shipment screening. Such screening is performed on each waste shipment to confirm that the waste matches an established profile. Wastes that do not match the profile are not accepted for management at the facility unless the reason for the discrepancy is determined to the satisfaction of the MSYP and the waste remains suitable for management at the facility. The sampling procedure described below assumes that the wastes to be used in the Phase 2 testing will be delivered to the facility in bulk (roll-off containers or dump trailers). A different sampling procedure will be employed if the wastes are delivered in drums.

Waste shipment samples are obtained from bulk solids transport vehicles using either of two devices. Moist materials that have a relatively even distribution of small particles, such as wastewater treatment plant sludges, are sampled with a trier. This device consists of a hollow plastic or stainless steel tube, which may be slotted along one side. The tube is forced into the material to be sampled and a "core" of the material withdrawn. The sample is then rodded or scraped from the sampling device into a clean plastic or stainless steel container.

Dry materials and materials with large or uneven particle sizes are sampled using a shovel or scoop. Since these devices only allow sampling near the surface of the waste, multiple samples are collected and composited in a clean plastic container from different depths when a shovel or scoop is used.

In order to ensure that the samples collected from bulk solid waste shipments are representative, multiple points within the shipping container are sampled. A minimum of three sampling locations evenly distributed along the length of the container are selected, samples obtained at each of the locations using the procedures described above, and the individual samples composited. Additional sampling locations are utilized if insufficient sample is collected from the initial three locations for testing purposes or if the appearance of the shipment suggests a wider distribution of material. The composite sample is then delivered to the on-site laboratory for physical and chemical characterization and comparison to the waste profile.

Assuming that a waste selected for use in the Phase 2 testing is found to conform to the waste profile, the remainder of the sample collected for shipment verification will be distributed

among sample containers for subsequent, additional chemical characterization.⁶ Approximately 200 grams of waste will be placed into a container for subsequent analysis by MSYP⁷ for the following total metals:

Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Zinc

Another 200 grams of waste will be placed into a container for subsequent extraction by the MSYP. The extract obtained will be properly preserved. The extract sample will be retained by the MSYP for analysis. The parameters to be analyzed by the laboratory are the same parameters as are to be analyzed in the waste shipment samples.

Any sample remaining from the waste shipment sampling event will be retained at the Yukon facility until the analytical results are received and accepted as accurate.

The extractions and analyses will be performed using the methods specified by the USEPA in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) Third Edition". These methods are commonly employed for waste evaluations throughout the industry and are mandated in certain situations. The specific methods to be used are

<u>Parameter/Procedure</u>	<u>Method</u>
TCLP Extraction	1311
Digestion (TCLP)	3010A, 3015, or 3020A
Digestion (Total)	3050A or 3051
Antimony	7041
Arsenic	6010A or 7061A
Barium	6010A or 7080A
Beryllium	7091
Cadmium	6010A or 7130
Chromium	6010A or 7190
Copper	6010A or 7210
Lead	6010A or 7420
Mercury	7470A or 7471A
Nickel	6010A or 7520
Selenium	6010A or 7741A
Silver	6010A or 7760A
Thallium	7841
Vanadium	7911
Zinc	6010A or 7950

The sample holding times recommended in the literature will be strictly adhered to in order

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⁶ The waste samples will be thoroughly mixed prior to distribution among the sample containers.

⁷ MSYP will likely use its contract laboratory, Antech, Ltd. of Export, PA, for the Phase II characterizations as it did for the Phase I characterizations.

to ensure the validity of the results.

All hazardous waste samples provided to the laboratories for analysis will be accompanied by Chain of Custody documents containing the following information:

- Sample collector's name, mailing address, and telephone number
- Laboratory's name, mailing address, and telephone number
- Quantity of sample
- Date of shipment
- Description of sample

The quality of the laboratory data will be assured through the performance of data validation checks, such as blank TCLP extractions, and analysis of method blanks, spikes and duplicates. The frequencies will vary based on the practices of the laboratory. These practices are detailed in documents provided as part of the Phase 1 work plan.

Waste Stabilization

The mixing of the selected hazardous wastes with the by-products will be performed in the SWSS units at the MSYP.

Waste treatment in the SWSS unit is conducted on a batch basis. One or more loads (bulk shipments) of waste are initially unloaded from the transport vehicle(s) into one of the SWSS tanks⁸, then the chemicals to be used to treat the waste are added. The MSYP generally treats only wastes from the same source in a given batch but may combine wastes from multiple sources together in one batch if the wastes are compatible and can be treated using the same chemicals. The amount of treatment chemicals added are predetermined based on the results of treatability tests performed before the waste is initially managed at the facility and on the success of prior treatment batches. Depending on the moisture content of the waste, water may also be added to the batch to activate the treatment chemicals and/or to control dusting. The waste, chemicals and water are then blended by repeated kneading and turning with the excavator bucket until the mixture has a uniform appearance. Depending on the consistency of the materials and the amount of waste/chemicals included in the batch, several hours of blending may be required to achieve a uniform distribution of the materials.

After the blending operation is complete, a representative sample of the batch is collected and delivered to the on-site laboratory for characterization. The treated waste is then transferred from the SWSS tank into one or more of the portable containers. The loaded containers are labeled and placed in a secure area pending the results of the treated waste characterization. If that characterization determines the treatment to be successful, the containers are then transported to an authorized facility and disposed. If the laboratory determines that the treatment was not successful, the wastes are returned to the SWSS unit and retreated. A given batch is successfully treated if it no longer exhibits a hazardous waste characteristic, meets any applicable LDR treatment standards, and meets the acceptance criteria of the ultimate disposal facility.

The Phase 2 treatments using the CCT by-products will be conducted in the manner described above except that each waste/by-product combination will be managed individually. The transport vehicle containing the selected waste will be weighed at a certified weigh station located

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⁸ In the unloading process, the transport vehicle is backed to the edge of the tank, the tailgate on the waste compartment opened, and the bed raised to allow the waste to flow from the compartment into the tank.

near the MSYP, then positioned at the designated SWSS tank and the waste unloaded. The SWSS tank to be used for the treatment test will be inspected prior to placing the waste into the tank to ensure that it is essentially free of residuals from the prior treatment batch. The waste transport vehicle will then return to the certified weigh station to obtain a light weight so an accurate record of the amount of waste used in the treatment test can be maintained. The appropriate amount of by-product and a small amount of water (if needed) will then be added.

Chemical Characterization of Stabilized Waste

Following completion of the treatment batch, a representative sample of the treated waste will be obtained from the SWSS tank. The sample collection procedure to be employed for this project is the one routinely employed for treated waste sample collection at the SWSS tanks. Using the excavator bucket as a sampling device, samples are collected from a minimum of four locations spaced evenly along the length of the tank. An aliquot is removed from each backhoe bucket by MSYP personnel using a scoop and the four aliquots are composited into a clean sample container. The composite sample is then thoroughly mixed and delivered to the on-site laboratory for characterization.

Upon receipt at the laboratory, the composite sample will again be mixed. MSYP laboratory personnel will then remove 100 grams of the composite sample for immediate extraction and place the remainder of the sample in a clean sample container.⁹ After 24 hours, another 100-gram aliquot will be removed from the reserved portion of the composite sample and another extraction performed. Any sample remaining from the treated waste sampling event at this point will be retained at the Yukon facility until the results of the analyses performed on the extracts are received and accepted as accurate.

The extracts obtained from the immediate and 24-hour extractions will then be placed in 1-liter sample containers and the samples properly preserved. The extract samples will be retained by MSYP for analysis. The parameters to be analyzed by the laboratory are the same parameters as identified above for the untreated waste characterization program. These are

Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium

Silver
Zinc

The extractions and analyses will be performed using the same methods as identified above for the untreated waste characterization program. The sample holding times recommended in the literature will be strictly adhered to in order to ensure the validity of the results, Chain of Custody documents will be used to track sample movement, and appropriate quality control measures will be practiced by the analytical laboratories involved.

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⁹ MSYP laboratory personnel may also need to use additional treated waste sample for other purposes related to the ultimate disposal of the waste.

Solidification Studies

The solidification test for each commercial waste/by-product dosage will use a 50-pound aliquot of the waste and sufficient water to obtain the appropriate consistency needed for filling and rodding the molds. The treated waste will then be loaded into twenty 3-inch diameter by 6-inch long test cylinders and delivered to Pitt for compressive strength testing. The cylinders will be transported by ground vehicle to Benedum Hall, University of Pittsburgh and an identification will be number assigned to cylinders, and recorded in sample log book.

Sample holding times will be carefully adhered to in order to ensure the acceptability of the results. The solidification tests will proceed over a three-month period. Cylinders will be stored during this period in the environmentally controlled room inside Room SB82 of Benedum Hall. The 3" by 6" cylinders will be tested at Pitt for compressive strength to determine the extent of solidification effected by the treatments. Breaks of four cylinders each will be made at three, seven, fourteen, twenty-eight and ninety days, using the test machine in Room SB82. The strengths developed will be compared with those reported by others and will be used to determine the usefulness of the treatment product as cap material.

Disposal of Stabilized Waste

The results of the chemical characterizations performed on the treated wastes will be compared to the criteria the MSYP normally employs in evaluating the success of the waste treatments performed in the SWSS unit. If the results confirm that these criteria have been achieved, the container(s) holding the treated waste will be transported to an approved facility and land disposed. If the results do not confirm that the successful treatment criteria have been achieved, the container(s) holding the treated waste will be unloaded back into one of the SWSS tanks and the waste re-treated using the conventional treatment chemicals employed at the Yukon facility. Note that the stabilized wastes actually produced in Phase 2 will not be considered for cap material. It will be wastes stabilized in any resulting commercial operation using CCT by-products that will be considered for this service.

BY-PRODUCTS

Identification for Phase One

Three by-products were collected and utilized as treatment chemicals in Phase 1. They were:

Dry Scrubber Residue. This material was supplied by CONSOL Inc. from a Joy Niro Spray Drier. It was produced by the cogeneration project of Chambers Cogeneration Limited Partnership, operated by U. S. Operating Services Company at the Cameys Point Cogeneration Plant on the grounds of DuPonts Chambers Works in New Jersey. CONSOL Inc. supplies the coal used in the plant and, as part of the purchase agreement, backhauls the residue to its mines in western Pennsylvania and West Virginia in special pneumatic rail cars. Some or all of the approximately 100,000 tons/year of this by-product could be easily diverted to hazardous waste treatment plants along the general rail route from New Jersey to western Pennsylvania and West Virginia. The residue contains 45% fly ash, 36% $\text{CaSO}_3/\text{CaSO}_4$, 10% $\text{Ca}(\text{OH})_2$, 2% CaCO_3 , and 7% other inert material. It is comprised of agglomerates of fine materials formed in the scrubber.

Residue from a Coal-Waste-Fired CFBC. Approximately 200,000 tons/year of this material is produced in a unit operated by the Ebensburg Power Company (EBC) at Ebensburg, Pennsylvania. Currently it is being trucked back to the mines from which the coal wastes are derived. Some or all of this by-product could be diverted to nearby sites for beneficial use if they could be identified. The residue contains 82% ash, 12.5% limestone equivalent and 5.5% $\text{CaSO}_3/\text{CaSO}_4$. It is a relatively coarse material, as it contains both bottom and fly ash from the boiler.

Residue from a Coal-Fired Pressurized Fluid Bed Combustor (PFBC). This material was produced at the Tidd Station of Ohio Power Company, a subsidiary of American Electric Power Corporation, at Brilliant, OH. This demonstration facility was constructed and operated in cooperation with the U.S. Department of Energy in Round I of the Clean Coal Technology Program. The sorbent fed to the plant, rather than lime or limestone, was dolomite. By operating at high pressure, little of the dolomite in the residue is in the oxide form - most is present as carbonate. The residue could be obtained as bottom ash, fly ash, or a mixture. For this project the fly ash was obtained. The dolomitic character of the sorbent yields a residue that is lower in pH than that produced from lime-based sorbents. This characteristic is particularly useful in stabilizing arsenic-laden waste solids. The chemical composition of the residue is 50-60% equivalent CaCO_3 and 1-2% available (free or uncombined) CaO .

Acquisition of Samples for Phase One

Samples of the three by-products were collected during the first three quarters of Phase 1. Here is a synopsis of the sampling activity.

Carneys Point Cogeneration Plant. Ten samples of the spray drier fly ash were collected at CONSOL's Blacksville receiving terminal near Waynesburg, Pennsylvania. Car numbers of the covered hopper rail cars and dates loaded were recorded.

Ebensburg Power Company. Ten dry samples were collected from the storage silo for the characterization program. The silo samples are a blend of bed ash and cyclone ash. Additional separate samples of bed ash and cyclone ash were obtained for comparison. No significant problems in sampling occurred to prevent obtaining grab samples of dry ash from the silo that are representative of good operating conditions.

Tidd Station. Ten samples from the dry cyclone ash silo were collected. The silo had a one-day capacity when the unit was operating at its full rating. The ash from the silo also included the electrostatic precipitator ash. Verbal communication with the plant engineers determined that boiler operations were stable and producing power during the sampling periods.

Identification for Phase Two

The Carneys Point station is still in operation. However, CONSOL has requested that an alternate source of spray-drier scrubber by-product be sought. On the recommendation of Deborah Pflughoeft-Hassett of the University of North Dakota Energy and Environmental Research Center the project team has contacted Mineral Solutions Inc (MSYP) of Eagan, Minnesota. They are brokering spray-drier by-product from Shinks Unit #3 of Northern States Power. MSYP has expressed an interest in discussing the use of this material in Phase 2. Upon approval of this test plan the project team will enter into discussion with MSYP about acquiring and transporting by-product from Shinks Unit #3 to the MSYP for use in Phase 2.

The EPC circulating AFBC at Ebensburg is still in operation. Upon approval of this test plan the project team will enter into discussion with EPC about acquiring and transporting by-product from EBC to the MSYP for use in Phase 2.

The PFBC at the Tidd Station was permanently shutdown in early spring 1995. Therefore in late February 1995 the project team collected the 50-ton sample of this by-product for use in Phase 2.

Acquisition for Phase Two

The by-products will be delivered to the facility as follows:

Shinks #1. MSYP will contract with its current bulk lime supplier, Stutzman Enterprises of Indiana, PA. Stutzman will dispatch pneumatic trucks to Shinks Unit #3, pick up 40 tons of Shinks #1 by-product, transport the by-product back to the MSYP, and off-load the by-product into the by-product storage silo. After the waste has been placed into one of the SWSS tanks, the by-product will be transferred to the tank. The amount of by-product will be monitored to generate accurate records of its use in the test.

Tidd #2. The initial thought as to how to collect the 50-ton sample of Tidd by-product was to install a new fill nozzle on the cyclone ash silo to connect to super-sacks. However, the material in the silo was kept at 300-400°F to assure that no moisture will condense on the ash, which could lead to plugging. The super-sacks could not tolerate temperatures this high. Therefore it was decided to use the existing elephant trunk to transfer the hot ash to pneumatic tanker trucks, provided by Bulk Transit Company.

Several approaches were considered for transferring the by-product from the tanker trucks to the super-sacks. Two that were discarded were (1) direct filling at the Cardinal Station's disposal site (where the Tidd ash was also being disposed) and (2) staged filling from a second silo. The first discarded approach was deemed insufficiently robust and a potential dust emission source too difficult to control. The second failed for lack of an easily obtained suitable silo.

The approach that was finally used involved travel of the tanker trucks to a commercial bagger, Aimcor in Aurora, Indiana, which has the capability of removing the ash from the tanker trucks, cooling it, filling the super-sacks and placing them on pallets for transport back to Dravo Lime Company (DLC) in Pittsburgh for storage.

DLC cleared a portion of a building at their Research Center to house the super-sacks until they were shipped to the MSYP in the fall of 1998. Until needed for Phase 2 testing, the sacks are being stored in a tarped roll-off container placed in a secure area of the facility. When needed for a waste stabilization test, MSYP will position the roll-off container adjacent to the SWSS tank to be used in the test, remove the appropriate number of sacks from the container based on the weight of by-product needed for the test, and set the loaded sacks into the tank atop the waste. A MSYP employee will then enter the SWSS tank and open the sack to allow the by-product to escape. The empty sack will be removed from the SWSS tank before the waste and by-product blending process

begins.

EPC #3. MSYP intends to involve Stutzman in the management of the EPC by-product in similar manner to their proposed involvement with the Shinks #1 by-product except that Stutzman will not deliver the by-product to the storage silo at the MSYP. Rather, Stutzman will obtain the material from the EPC by-product storage facility located near Ebensburg, PA when needed for use in a treatment test and deliver the material directly to the Yukon facility. On demand, Stutzman will dispatch the vehicle equipped with a mechanical unloading conveyor to the EPC by-product storage facility and load the specified amount of the EPC #3 by-product from the EPC storage silo into the vehicle. Stutzman will then deliver the material to the MSYP Yukon facility on the day of the test. After the waste has been placed into one of the SWSS tanks, the by-product vehicle will be positioned at the tank, fitted with the "sock", and the unloading conveyor activated. The rate of unloading will be controlled to minimize dusting. The vehicle will be weighed before and after unloading to generate accurate records of the amount of by-product used in the test.

WASTES

Identification for Phase One

During Phase 1 the MSYP evaluated eleven characteristic metal-haden hazardous wastes for use in Phase 1. Five of the wastes were determined to be unsuitable and six were determined to be suitable. Laboratory treatments of the six suitable wastes with the three by-products were performed.

Included in the eleven wastes examined were two industrial wastewater treatment plant residues, six contaminated soils, two air pollution control dusts, and one sandblast waste. 250-pound samples of each waste were obtained from the generators of the waste or collected from shipments of the waste received at the MSYP. A representative aliquot of each waste was then removed for analysis. A 100-gram portion of each aliquot was extracted according to the TCLP protocol and the extract generated for each waste was then distributed into two 1-liter sample bottles and preserved with nitric acid for subsequent analysis. One of the extract samples was then delivered to Antech, Ltd. for analysis to determine if the waste exhibited the expected hazardous waste characteristic(s). Five of the wastes sampled were disqualified from use in the project on the basis that analysis of their TCLP extracts did not verify that the wastes exhibited the expected hazardous waste characteristic(s). On this basis, six of the wastes qualified for use in the project. The wastes that qualified, and the hazardous characteristics exhibited by each, were:

<u>Waste</u>	<u>Characteristic(s)</u>
Industrial Wastewater Treatment Residue from a Battery Manufacturing Plant	Lead
Contaminated Soil from a Remediation Project Conducted at a Munitions Depot	Lead
Contaminated Soil from a Remediation Project Conducted at an Abandoned Industrial Site	Lead
Contaminated Soil from a Remediation Project Conducted at a Former Sewage Treatment Plant	Lead
Air Pollution Control Dust from Basic Oxygen Furnace Steel Production	Lead

The MSYP then authorized Antech to perform the remaining analyses on the TCLP extracts generated from the qualified wastes and provided Antech with a 250-gram sample of each of these wastes (part of the representative aliquot originally collected) for total metals analysis as well. Pitt was also provided with a 1-liter TCLP extract sample and a 100-gram sample of each waste for analysis.

The results of the waste analyses performed by Antech, Ltd. and by Pitt showed that none of the wastes exhibited any other toxicity characteristics than are identified above. However, each of the wastes did contain some total metals at concentrations greater than or equal to 20 times the toxicity characteristic limits or greater than or equal to 20 times the Land Disposal Restriction (LDR) treatment standards. Metal concentrations at these levels in the wastes were of concern due to the potential that they would leach under the altered conditions present in the treated waste samples generated during the waste treatment portion of this project. The parameters of concern in each of the wastes were:

- Industrial Wastewater Treatment Residue from Battery Manufacturing Plant
Cd, Pb, Sb
- Contaminated Soil from a Remediation Project Conducted at a Munitions Depot
Ba, Cd, Cr, Pb, Zn, Be, V
- Contaminated Soil from a Remediation Project Conducted at an Abandoned Industrial Site
Ba, Cd, Cr, Pb, Hg, Zn, Be, V
- Contaminated Soil from a Remediation Project Conducted at a Former Sewage Treatment Plant
Pb, Zn
- Air Pollution Control Dust from Basic Oxygen Furnace Steel Production
Cd, Cr, Pb, Ni, Zn, V
- Air Pollution Control Ash from Municipal Waste Incineration
As, Ba, Cd, Cr, Pb, Hg, Ni, Se, Ag, Zn, Sb, Be, V

Identification for Phase Two

Only wastes authorized for management at the MSYP will be used in the full-scale tests. To the extent possible, the same types of waste as those evaluated in Phase 1 will be used in Phase 2. However, MAX is unable to provide the same identical wastes that were available in Phase 1. Of the wastes tested during Phase 1 of the project that were successfully treated, only the battery manufacturing wastewater treatment sludge is currently being generated. All of the other wastes that were successfully treated in Phase 1 were generated from remediation projects that were completed long ago. Consequently, except for the one waste¹⁰, the MSYP is unable to test the same identical wastes in Phase 2 of the project that it tested in Phase 1.

Taking this into consideration, as well as the fact that the Phase 1 testing demonstrated the

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¹⁰ Assumes that the generator of the battery sludge is still a customer of MSYP at the time the Phase II testing is scheduled to commence.

by-products to be generally effective in treating contaminated soils, the MSYP has selected the following generic wastes for full-scale evaluation:

- A Battery Manufacturing Wastewater Treatment Sludge
- Battery Recycling Site Cleanup Soils
- Lead-Contaminated Soils
- Lead-Cadmium Contaminated Soils
- Chromium Contaminated Soils

TREATMENTS

For up to twenty-five by-product/waste combinations, one commercial batch of waste will be treated with by-product by the MSYP and analyzed there for leachable (TCLP) concentrations to determine whether the waste has been stabilized. If additional temporary storage space is permitted (the application is being considered at the present time), several product/waste combinations giving slow successful stabilization as evaluated during the laboratory studies of Phase 1 will be substituted.

The up to twenty-five waste/by-product combinations selected will be mixed at the optimum of the three dosages as determined by the laboratory treatability studies. In the event the laboratory testing of a particular waste/by-product combination does not indicate that the levels of the metals of concern in each of the wastes can be reduced to below the hazardous level, no full-scale testing of that waste/by-product combination will be conducted. All mixing of wastes and by-products will be performed in the Solid Waste Stabilization and Solidification Unit at the MSYP. As in the laboratory, water will be added to activate the reaction between the waste and by-product.

The full-scale treatments will be performed on batches consisting of up to 20 tons of treated waste. Following treatment, the waste will be loaded into containers for storage pending the results of TCLP analysis. As in the laboratory tests, TCLP testing and metals (11) analyses will be conducted immediately following treatment and after a 24 hour holding period. For slow stabilization (if permitted) a third TCLP test will be conducted at the end of the curing period. An aliquot of the treated waste will also be provided to Pitt for compressive strength (3-day, 7-day, 14-day and 28-day) and stress analyses (as appropriate). After each test the treatment residue will be properly disposed at an authorized facility.

The field studies at the MSYP match precisely with its normal activities as a RCRA hazardous waste treatment facility under PADER permits with one possible exception. A particular new problem that may be encountered during the field studies there is that of fugitive dust. The by-products being examined in this project all are residues from systems that operate with sorbents having no bulk moisture associated with them, except in some cases during their injection into the combustor, ductwork or scrubber. Thus as product materials they have a significant potential for dust emissions. This potential will have to be carefully evaluated and dust suppression methods employed properly when they are being used by the MSYP as treatment materials.

The water required for the treatment batches will be obtained from a tap on a potable water line at the MSYP, metered as needed for dust control. Assuming that dust control does not require the addition of more water than is called for in the specific test protocol, the required amount of water will be added to the batch. Records of the amount of water added to each batch will be maintained.

SOLIDIFICATION

For combinations giving immediate stabilization, Pitt will consider casting 3" by 6" cylinders for measuring compressive strength will be cast from the large-scale batch at the time of treatment. If made, the cylinders will be taken to Pitt and tested there. For any combinations giving slow stabilization, Pitt will consider casting 4" or 6" cylinders for measuring compressive strength and stress behavior. If made, the cylinders will be taken to Pitt and tested there.

For each immediately successful combination of waste and by-products (up to 40 combinations in all) a set of 3" by 6" cylinders will be prepared at the MSYP and tested at Pitt for compressive strength to determine the extent of solidification effected by the treatments. The strengths developed will be compared with those reported by others, either in the literature or in personal communications, using the by-products alone.

Sample holding times will be carefully adhered to in order to ensure the acceptability of the results. The solidification tests will proceed over a three-month period. Cylinders will be stored during this period in the environmentally controlled room inside Room SB82 of Benedum Hall. Breaks of four cylinders each will be made at three, seven, fourteen, twenty-eight and ninety days, using the test machine in Room SB82. Disposal of all material examined at Pitt will be carried out as in Phase 1.

EVALUATION

Economic

An economic evaluation will be developed from the results of the field tests. Transportation and disposal costs, waste tipping fees and prices for by-products will be developed. A base case will be developed for each waste/by-product combination, assuming a specific transportation distance, mode of transportation, ash conditioning, tipping fee and other factors influencing the cost for disposal or treatment of the by-product and metal-laden hazardous waste. A sensitivity analysis for each factor will then be performed. Comparisons will be made with the cost of current commercial practices.

Indemnification

A final aspect of a commercial project using by-product to treat hazardous waste is the need for proper indemnification and insurance for the by-product against any future liability arising from the disposal of the stabilized waste. The cost of this type of insurance and the present value of any litigation that might arise in the future will be estimated and factored into the economic analysis. The experience that similar projects have had with these problems will be examined.

It should be noted that the MSYP, the operator of the treatment plant, has no liability in this matter. The MSYP will pay \$1 per ton for chemicals. The generator pays then for transportation and a management fee.

Success of Field Test

Four measures of success may be applied to this project. The first is a specific measurement, while the others are increasingly more general in the order listed.

The specific measurement is simply the discovery for each by-product/waste combination of that amount of by-product which is just sufficient to render the hazardous waste either non-hazardous and acceptable for land disposal under current RCRA regulations or slowly but eventually non-hazardous and potentially acceptable for structural fill.

Further success is achieved if an economic advantage is observed by the use of a hypothetical "nearby" by-product to treat the waste.

The third measure of success is the agreement in principle that proper indemnification is achieved for the nearest available by-product to a commercial waste treatment plant.

Finally, the project will be a total success if one or more by-product producers find continuing markets for their materials as waste treatment agents.

Draft and Final Report Development

The draft report will be submitted to Pitt and the COR in 60 days from receipt of written authorization from the Contracting Officer. Final report development activities will include incorporation of comments and questions from Pitt and MAX staff. The final report will be submitted within two weeks of notice of acceptability of the draft report.

Dissemination of Results

As with the results of Phase 1, the project team will present the results of Phase 2 at several appropriate technical conferences, such as those sponsored by the University of Pittsburgh, the University of Kentucky and the American Coal Ash Association. The team will also assist the E50.03 Subcommittee of the E-50 Committee of the American Society for Testing and Materials (ASTM) as the subcommittee develops an ASTM Standard Guide for Use of Coal Combustion By-Products for Stabilization of Inorganic Wastes.

Taking all of these factors into consideration, the MSYP has selected the following wastes/by-product mixtures for full-scale evaluation:

- Test #1: Treatment Of The Battery Manufacturing Wastewater Treatment Sludge With Shinks #1 By-Product At A 10:1 Weight Ratio
- Test #2: Treatment Of The Battery Manufacturing Wastewater Treatment Sludge With Shinks #1 By-Product At A 2:1 Weight Ratio
- Test #3: Treatment Of A Lead-Contaminated Soil With Shinks #1 By-Product At A 10:1 Weight Ratio
- Test #4: Treatment Of A Lead-Contaminated Soil (same soil as in Test #3) With Shinks #1 By-Product At A 2:1 Weight Ratio
- Test #5: Treatment Of A Lead-Contaminated Soil (same soil as in Test #3) With Tidd #2 By-Product At A 2:1 Weight Ratio
- Test #6: Treatment Of A Lead-Contaminated Soil (same soil as in Test #3) With EPC #3 By-Product At A 2:1 Weight Ratio
- Test #7: Treatment Of A Second Lead-Contaminated Soil With Shinks #1 By-Product At A 10:1 Weight Ratio
- Test #8: Treatment Of The Second Lead-Contaminated Soil (same soil as in Test #7) With Shinks #1 By-Product At A 2:1 Weight Ratio
- Test #9: Treatment Of The Second Lead-Contaminated Soil (same soil as in Test #7) With Tidd #2 By-Product At A 2:1 Weight Ratio
- Test #10: Treatment Of The Lead-Contaminated Soil (same soil as in Test #7) With EPC #3 By-Product At A 2:1 Weight Ratio

In all, six tests are proposed using the Shinks #1 by-product, which is expected to be the most successful of the three by-products, based upon Phase 1 of the project, and two tests are proposed using each of the other by-products, Tidd #2 and EPC #3.

The approximate quantities of waste, CCT by-product and water to be used in each of the tests is presented below. The by-product quantities are based on the assumption that the waste shipment will contain 22 tons of material. This may result in a slight overdose of by-product if the shipment contains less waste or a slight underdose of by-product if the shipment contains more

waste. The water quantities are based on the quantities used in the laboratory-scale tests performed during Phase 1. The actual quantities used in Phase 2 may differ if more water is required for dust control or if the addition of the specified amount of water would cause the treated waste to contain free liquids.¹¹

Test #1: Treatment Of The Battery Manufacturing Wastewater Treatment Sludge With Shinks #1 By-Product At A 10:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 2.2 Tons

Water: 0.0 Tons

Test #2: Treatment Of The Battery Manufacturing Wastewater Treatment Sludge With Shinks #1 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 1.5 Tons

Test #3: Treatment Of A Lead-Contaminated Soil With Shinks #1 By-Product At A 10:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 2.2 Tons

Water: 1.0 Tons

Test #4: Treatment Of A Lead-Contaminated Soil (same soil as in Test #3) With Shinks #1 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 2.8 Tons

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¹¹ The presence of free liquids in the treated waste will prohibit the disposal of the waste in a local landfill.

Test #5: Treatment Of A Lead-Contaminated Soil (same soil as in Test #3) With Tidd #2 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 0.5 Tons

Test #6: Treatment Of A Lead-Contaminated Soil (same soil as in Test #3) With EPC #3 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 1.5 Tons

Test #7: Treatment Of A Second Lead-Contaminated Soil With Shinks #1 By-Product At A 10:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 2.2 Tons

Water: 1.0 Tons

Test #8: Treatment Of The Second Lead-Contaminated Soil (same soil as in Test #7) With Shinks #1 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 2.8 Tons

Test #9: Treatment Of The Second Lead-Contaminated Soil (same soil as in Test #7) With Tidd #2 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 0.5 Tons

Test #10: Treatment Of The Lead-Contaminated Soil (same soil as in Test #7) With EPC #3 By-Product At A 2:1 Weight Ratio

Ingredients

Waste: 22 Tons

By-product: 11 Tons

Water: 1.5 Tons

Based on the above, approximately 40 tons of the Shinks #1 by-product, approximately 22 tons of the Tidd #2 and EPC #3 by-products, and approximately 13 tons (3,100 gallons) of *water will be required for use in the Phase 2 testing.*

APPENDIX G

METALS ANALYSES OF TCLP EXTRACTS OF TREATED SANDBLAST WASTES

METC PROJECT TREATABILITY TEST RESULTS
SANDBLAST WASTE

By-Product Dosage	UNTREATED	CONSOL #1 10%	CONSOL #1 30%	CONSOL #1 50%	EPC #3 10%	EPC #3 30%	EPC #3 50%	Tidd #2 10%	Tidd #2 30%	Tidd #2 50%
Parameter	Units	IMMEDIATE								
Antimony	mg/l	0.051	<	0.02	<	0.02	0.023	<	0.02	<
Arsenic	mg/l	<	0.10	0.37	0.39	<	0.11	<	0.1	<
Barium	mg/l	<	5.0	<	5	<	5	<	5	<
Beryllium	mg/l	<	0.001	0.0033	0.0042	<	0.001	<	0.001	<
Cadmium	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Chromium	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Copper	mg/l	0.28	<	1	<	1	<	1	<	1
Lead	mg/l	350	0.38	0.15	0.13	290	<	8.1	14	0.96
Mercury	mg/l	<	0.010	<	0.01	<	0.01	<	0.01	<
Nickel	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Selenium	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Silver	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Thallium	mg/l	<	0.005	<	0.005	<	0.005	<	0.005	<
Vanadium	mg/l	0.01	0.033	0.1	0.134	0.01	<	0.01	<	<
Zinc	mg/l	1.7	1.4	1.4	1.1	1.9	1.6	1	1	1

Extraction Fluid
Initial pH
Final pH

By-Product Dosage	UNTREATED	CONSOL #1 10%	CONSOL #1 30%	CONSOL #1 50%	EPC #3 10%	EPC #3 30%	EPC #3 50%	Tidd #2 10%	Tidd #2 30%	Tidd #2 50%
Parameter	Units	AFTER 24 HOURS								
Antimony	mg/l	0.051	<	0.02	<	0.02	0.027	<	0.02	<
Arsenic	mg/l	<	0.18	0.41	0.41	<	0.1	<	0.1	<
Barium	mg/l	<	5.0	<	5	<	5	<	5	<
Beryllium	mg/l	<	0.001	0.0029	0.0039	<	0.001	<	0.001	<
Cadmium	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Chromium	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Copper	mg/l	0.28	<	1	<	1	<	1	<	1
Lead	mg/l	350	0.44	0.13	0.11	130	<	210	24	0.49
Mercury	mg/l	<	0.010	<	0.01	<	0.01	<	0.01	<
Nickel	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Selenium	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Silver	mg/l	<	0.10	<	0.1	<	0.1	<	0.1	<
Thallium	mg/l	<	0.005	<	0.005	<	0.005	<	0.005	<
Vanadium	mg/l	0.01	0.029	0.098	0.119	0.01	<	0.01	<	<
Zinc	mg/l	1.7	1.4	1.4	1	1.2	1	1.7	1.6	1

Extraction Fluid
Initial pH
Final pH

APPENDIX H

TREATMENT OF SANDBLAST WASTE WITH BY-PRODUCTS FROM CLEAN COAL TECHNOLOGIES

Treatment Of Sandblast Waste With By-Products From Clean Coal Technologies

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ABSTRACT:

The purpose of this work is to treat hazardous waste with clean coal technology by-products in order to stabilize and decrease risks from exposure to this hazardous waste. The clean coal technologies were developed to reduce the atmospheric emission of SO_2 . In the process by-products are generated which contain lime. Due to their lime content, these by-products have relatively high pH values. These high pH values may help limit the solubility of many of the metals. If successful, the heavy metals can then be stabilized and these by-products can be used as commercial treatment products, instead of being solid wastes which must be placed in a landfill.

TITLE: Treatment Of Sandblast Waste With By-Products From Clean Coal Technologies.

OBJECTIVE: To treat hazardous waste with clean coal technology by-products in order to stabilize and decrease risks from exposure to this hazardous waste.

BACKGROUND: The by-products that were used to treat the Sandblast Waste have been collected from a spray dry scrubber and fluid bed combuster. "A fluidized bed combustion (FBC) is a process of burning crushed coal in a bed of limestone particles held in suspension by the upward flow of combustion air entering a chamber through a perforated air distribution grid below the fluidized bed."¹ However, "... the dry scrubber residue is collected from a process, where ash laden flue gas enters the bottom of the spray drier and all of the sulfur-capture residue rises through the upper port with fly ash."¹

These clean coal technology by-products are different from regular coal fly ash in that they contain lime. The use of lime limits the SO₂ in the stack gas leaving the power plants and thus reduces acid rain. Due to their lime content the pH values of these by-products are high. This results in a favorable characteristic for treating metal-laden hazardous wastes, as many metals are less soluble at high pH values.

Sandblast Waste is the residue from sandblasted lead paint. The sandblasting procedure consists of mixing sand and water, then the mixture is blasted on the painted area at a high pressure. Thus causing the paint to chip and fall off. The awareness of lead hazards has increased due to the publicity of lead poisoning and the creation of the Occupational Safety and Health Administration's (OSHA) Lead Standard Act, 29 CFR1926.62.²

Lead paint is so harmful as a result of its adverse affects on small children. Lead poisoning in small children causes unnecessary and unfavorable elevated blood lead levels among children, thus causing numerous ailments and disabilities. Accordingly in 1971 Congress passed "The Lead Bases Paint Poisoning Prevention Act" whose purpose was to remove lead paint from houses and prohibit the use of lead-based paint.

Likewise the Consumer Product Safety Commission (CPSC) determined that the new paint can contain only 0.06% lead by weight. Accordingly paint and similar coatings with a lead content in excess of 0.06% lead by weight are considered "lead-based paints" which are hazardous materials. Also the permissible exposure limit (PEL) for lead in the air in the construction industry is 50 ug/m³ averaged over an 8-hour period. "In conjunction OSHA set the lead action level at 30 ug/m³, which is in line with the General Industry Standard."² For further reference the lead standards for drinking water is 5 mg/L.

Nonetheless a total of 15 metals were analyzed to see if any hazardous metal levels exist. Therefore, refer to the table titled Metal Analysis Of Wastes to see introductory metal levels.

MATERIALS & METHODS:

The Sandblast Waste was collected from Mill Service, a hazardous waste treatment facility. The Sandblast Waste was then mixed with 50% of the fluid bed combustor by-product and another batch of the waste was mixed with 30% of the spray dry scrubber by-product. The treated waste was then brought back to the University of Pittsburgh to be analyzed. The solid wastes were extracted with water, then the extracted wastes were filtered. These procedures were followed by acid digestions. After the digestion, the wastes were analyzed on the Atomic Absorption Spectrophotometer (AA).

The metals were analyzed on the AA using three different methods. The first method, graphite furnace atomic absorption was used to examine the following metals: antimony, arsenic, barium, beryllium, selenium, thallium, and vanadium. The second method used, flame atomic absorption successfully analyzed these metals: cadmium, chromium, copper, lead, nickel, silver, and zinc. While the cold vapor atomic absorption technique only examined mercury. In total 15 metals were analyzed.

A quality control plan was used to verify the results. This plan consisted of spiked blanks, DI water blanks, and duplicate samples.

RESULTS:

Refer to the table Metal Analysis Of The By-Product/Waste Mixtures for results. As expected lead was the only

metal of concern.

There are no standards to compare the American Society for Testing Materials (ASTM) results, however to get a relative idea of what these numbers mean one should compare the results to the drinking water and the Best Demonstrated Available Technology (BDAT) standards. BDAT standards are used to compare the treated waste results prior to disposal of the wastes in a landfill. The BDAT standards apply to an acid leachate, known as Toxicity Characteristic Leaching Procedure (TCLP). While the ASTM samples are water leachate. These two standards are simply presented to only give some comparison to the ASTM values obtained.

DISCUSSION:

The lead results were not what was expected. They were higher than expected. To verify these results the experiment was performed again. The second trial produced the same results. It was also expected that the sample treated with the spray dry scrubber by-product would yield lower values than the other by-product. This was expected because the results from Mill Service concluded this. Nonetheless this was not the case with our samples.

The pH of the sample was calculated between 10.6 and 11.6 for both by-products. This is much higher than the pH of the point of lowest solubility which is approximately 9.3. The pH obtained for the by-products was on the higher side of the solubility curve. This suggests that the lead in the samples was more soluble, than expected. This increase in solubility prohibited our samples from stabilizing as expected. Enclosed is the solubility curve for lead.

REFERENCES:

Cobb, James T., et al (February 1995). "Treatment Of Metal-Laden Hazardous Wastes With Advanced Clean Coal Technology By-Products." U. S. Department of Energy DE-FC21-94MC31175, Quarterly Report.

Coluccio, Vincent M. Lead-Based Paint Hazards. Van Nostrand Reinhold: New York, New York. 1994.

TABLE 1: METALS ANALYSIS OF THE WASTE

	Property	Units	BDAT Standard		Sandblast Waste
			Current	Future	
Total Metals	Antimony (Sb)	mg/kg			5.1
	Arsenic (As)	mg/kg			<20
	Barium (Ba)	mg/kg			60
	Beryllium (Be)	mg/kg			<0.089
	Cadmium (Cd)	mg/kg			2
	Chromium (Cr)	mg/kg			9.2
	Copper (Cu)	mg/kg			29
	Lead (Pb)	mg/kg			43000
	Mercury (Hg)	mg/kg			0.19
	Nickel (Ni)	mg/kg			<10
	Selenium (Se)	mg/kg			0.26
	Silver (Ag)	mg/kg			<2.0
	Thallium (Tl)	mg/kg			<0.45
	Vanadium (V)	mg/kg			1.29
	Zinc (Zn)	mg/kg			59
TCLP Metal	Antimony (Sb)	mg/L	---	2.1	0.051
	Arsenic (As)	mg/L	5.0	5.0	<.10
	Barium (Ba)	mg/L	100.0	7.6	<5.0
	Beryllium (Be)	mg/L	---	0.014	<0.001
	Cadmium (Cd)	mg/L	1.0	0.19	<.10
	Chromium (Cr)	mg/L	5.0	0.86	<.10
	Copper (Cu)	mg/L	---	---	0.28
	Lead (Pb)	mg/L	5.0	0.37	350
	Mercury (Hg)	mg/L	0.2	0.20/0.025	<.010
	Nickel (Ni)	mg/L	---	5.1	<.10
	Selenium (Se)	mg/L	1.0	0.16	<.10
	Silver (Ag)	mg/L	5.0	0.3	<.10
	Thallium (Tl)	mg/L	---	0.078	<0.005
	Vanadium (V)	mg/L	---	0.23	<0.01
	Zinc (Zn)	mg/L	---	5.3	1.7

* BDAT standards do not apply to shaded areas.

TABLE 2: Metal Analysis Of The By-Product/ Waste Mixtures

	Property	Units	Sandblast Waste w/ 30% Consol	Sandblast Waste w/50% Tidd
ASTM Metals	Antimony (Sb)	mg/L	<0.02	<0.02
24 hours	Arsenic (As)	mg/L	<0.01	<0.01
	Barium (Ba)	mg/L	0.15	0.46
	Beryllium (Be)	mg/L	<0.001	<0.001
	Cadmium (Cd)	mg/L	<0.05	<0.05
	Chromium (Cr)	mg/L	<0.5	<0.5
	Copper (Cu)	mg/L	<0.05	<0.05
	Lead (Pb)	mg/L	75.3	4.8
	Mercury (Hg)	mg/L	<0.0025	<0.0025
	Nickel (Ni)	mg/L	<0.3	<0.3
	Selenium (Se)	mg/L	<0.01	0.013
	Silver (Ag)	mg/L	<0.05	<0.05
	Thallium (Tl)	mg/L	<0.005	<0.005
	Vanadium (V)	mg/L	<0.01	<0.01
	Zinc (Zn)	mg/L	0.05	<0.05

Figure 3-2 Solubilities of metal hydroxides as a function of pH. (From EPA [17].)

APPENDIX I

**SELECTIONS FROM M. S. THESIS ON
“THE STABILIZATION OF A HAZARDOUS
SANDBLAST WASTE WITH ADVANCED
CLEAN COAL TECHNOLOGY BY-PRODUCTS”**

4.1.3 Chemistry and Microstructure

Characterization of the three CCT by-products was performed using scanning electron microscopy (SEM) and x-ray diffraction (XRD) in order to provide valuable insight into the chemistry and microstructure of these materials. Elemental chemical analysis of the by-products was performed by SEM. Of equal importance to the bulk chemistry of the by-products is the mineralogy. Mineralogical characterization was performed by XRD to determine the crystalline phases present in the by-products. The results of both the elemental and mineralogical analyses of each of the three by-products are summarized in Table 18.

Elemental analysis of the by-products by SEM revealed that they each consist of nine major elements: calcium, sulfur, silicon, aluminum, iron, magnesium, carbon, and oxygen. These elements are consistent with the elemental compositions of fly ash, sulfur sorbents, and sulfur sorbent reaction products, which together comprise the by-products. From the literature review, it was found that fly ash is comprised mostly of SiO_2 , Al_2O_3 , and Fe_2O_3 , with smaller amounts of MgO and CaO . In addition to fly ash, these by-products also contain excess sorbent (either lime or dolomite) and reaction products (such as calcium sulfite and calcium sulfate), thereby contributing to the elemental compositions of the calcium, magnesium, and sulfur found. Potassium and titanium were also found in a couple of the by-product samples analyzed, but not in the abundance of the other elements. The potassium is most likely from the coal ash composition of the by-products, as Table 1 in the literature review revealed that trace amounts of K_2O were found in some fly ashes.

Figure 5 SEM Spectrum of the Spray Dry Scrubber Residue

Although minor amounts of potassium and titanium were identified in a couple of the by-product samples, no corresponding mineral phases were positively identified. This would imply that potassium and titanium constitute less than 1% of the by-product, which is below the detection limits of XRD. Those crystalline phases that could be identified unambiguously from the diffraction patterns by identifying the 3 peaks of strongest intensity for each phase, as given by reference patterns, are presented in Table 18.

For each of the by-products, the sulfur sorption reaction product was positively identified. The spray dry scrubber residue was found to consist primarily of calcium sulfite hemihydrate ($\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$), whereas the two FBC residues consist of anhydrite (CaSO_4). This difference is mainly due to the lower flue gas reaction temperatures of the spray dry scrubber process. When anhydrite is heated above 300-400 °F, as is the case for the two FBC residues, it is converted to an insoluble form as the CaSO_4 does not readily hydrate upon contact with water vapor. This process, in which the anhydrite in the two FBC residues does not readily hydrate to hemihydrate ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) or further to gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) as a result of exposure to the high temperatures in a boiler, is referred to as “dead burning” and yields a less reactive end-product. These differences in the composition of the reaction products were expected from the literature review and are consistent with the by-product characterization previously presented in Table 15.

Another noticeable difference in the by-product mineralogy is the presence of magnesium-containing minerals in the PFBC residue. The presence of dolomite and periclase in this by-product is a direct result of the use of dolomite as the sorbent in the CCT process, instead of lime or limestone. The identification of dolomite indicates that there is excess

sorbent present in the by-product, which was to be expected. These results are consistent with the results of the by-product characterization presented in Table 15, which shows the PFBC residue as having a significantly larger MgO content of 12.89% as compared to the spray dry scrubber and CFBC residues which contain 0.70% and 1.26% MgO respectively.

Four other crystalline phases were also positively identified: quartz, hematite, corundum, and mullite. These phases are made up of elements from the ash content of the by-products. Again, these phases are consistent with the by-product characterization that was presented in Table 15, which showed that all three by-products contain significant quantities of quartz, with smaller amounts of corundum and hematite. Mullite, identified in the spray dry scrubber residue, is known to be a dominant mineral formed from the combustion of bituminous coal.

Any additional phases could not be identified due to the complexity of the powder diffraction patterns. An extensive computer search failed to match with certainty the remaining peaks with any well-characterized phases in the powder diffraction files.⁽⁵⁶⁾ Possible matches were made among expected phases, such as calcite (CaCO_3), however missing peaks and intensity differences precluded making positive identification.

Surface characterization of these three CCT by-products by SEM reveals very different morphology. Figure 7 shows a SEM photomicrograph of the spray dry scrubber residue. It is apparent that this by-product is highly crystalline, and that there are at least three distinctly different crystal morphologies. The agglomerate of very fine, small particles, approximately 1 μm in size, seen here was found to contain calcium, sulfur, silicon, and oxygen. Several spherical particles of unreacted fly ash, ranging from 3-7 μm in size, are also

Figure 7 SEM Photomicrograph of the Spray Dry Scrubber Residue

observed in this photomicrograph. These fly ash spheres were found to contain mostly silicon and aluminum, with minor amounts of calcium and iron. The photomicrograph in Figure 7 also shows a particle of quartz, approximately 5 μm in size, containing silicon and oxygen. Figures 8 and 9 show SEM photomicrographs of the PFBC and CFBC residues, respectively. The morphology of the PFBC residue, shown in Figure 8, is not as easy to differentiate as was the spray dry scrubber residue. In general, however, this material seems to be a dense, sintered mass containing slightly larger particles. There were no fly ash spheres observed in this by-product. The CFBC residue, shown in Figure 9, is comprised of plate-like particles containing silicon and aluminum, with significantly larger particles of quartz. The larger average particle size of this by-product, compared to the spray dry

Figure 8 SEM Photomicrograph of the PFBC Residue

Figure 9 SEM Photomicrograph of the CFBC Residue

scrubber and PFBC residues, is in accordance with the physical properties characteristic to these by-products as was presented previously in Table 15. This larger average particle size is primarily due to the bottom ash content of this by-product.

It should be noted that photomicrographs for every by-product sample studied using scanning electron microscopy have not been reproduced in this document to avoid unnecessary repetition. The SEM photomicrographs presented here, however, are characteristically representative of all those obtained during the course of this evaluation and are consistent in composition and morphology with those found during a comprehensive literature review.

The observed smaller particle size of the finer spray dry scrubber residue may be responsible for increased reactivity and decreased porosity. These are desirable characteristics for hazardous waste stabilization. The entrapment of contaminated particles, and thereby the prevention of their release into the environment, is highly dependent upon porosity. Low permeability prevents or retards the release of hazardous constituents into leaching fluids. Low permeability can be associated with either or both low porosity or, more importantly, a pore size distribution fine enough to minimize the transport of leaching fluids containing hazardous constituents.⁽⁵⁷⁾

standard. For this reason, lead is considered to be a metal of concern. As none of the other fourteen metals in Table 20 have the potential to leach in excess of the corresponding current BDAT standard, lead will be considered the only metal of concern in the subsequent treatability studies.

4.2.2 Chemistry and Microstructure

Obviously, it is desirable to know the speciation of the hazardous constituent in the raw waste. For this reason, characterization of the sandblast waste was performed by both SEM and XRD analysis. The results of these analyses are presented and discussed below.

Elemental analysis of the sandblast waste by SEM revealed the presence of four dominant elements: silicon, lead, carbon, and oxygen. A representative SEM spectrum of the sandblast waste is shown in Figure 10. This spectrum shows the dominant presence of lead, which is from the lead-based paint removed during the course of the building rehabilitation project, and silicon from the use silica sand as the abrasive blasting media. Additional minor elements identified in the waste included iron, aluminum, calcium, potassium, and chlorine, however, these were not found in the abundance of the other elements. The iron found in the sandblast waste could conceivably be from the steel reinforcements which support the wooden roof from which the lead-based paint was mechanically removed. As previously mentioned, the unlabeled peak to the left of the calcium peak is palladium, the coating material used to prevent the sample from charging while under the microscope.

Figure 10 SEM Spectrum of the Sandblast Waste

Mineralogical analysis by XRD revealed that quartz (SiO_2) and hydrocerussite $[\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2]$ were the corresponding dominant crystalline phases present. The presence of quartz was expected as the abrasive blasting media used in the lead-based paint removal process was silica sand. The discovery of hydrocerussite indicates that the original form of lead in the lead-based paint is a basic lead carbonate. This is a reasonable deduction as the literature review revealed the use of lead carbonate, also known as white lead, as a common additive to paints as a white hiding pigment. Although SEM analysis revealed the presence of five other minor elements in the sandblast waste, no corresponding mineral phases were positively identified using XRD. The results of both the elemental and mineralogical analyses of the sandblast waste are summarized below in Table 21.

Table 21

Elemental and Mineralogical Analyses of the Sandblast Waste

Sample	Elemental Analysis	Mineralogical Analysis
Sandblast Waste	Si, Pb, C, O (major)	Quartz (SiO_2)
	Al, Fe, Ca, K, Cl (minor)	Hydrocerussite $[\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2]$

Surface characterization of the sandblast waste was performed by SEM analysis. Under the microscope, particles of quartz and slivers of wood were observed in the sandblast waste at low magnifications. The quartz present was from the spent blasting abrasives and the wood slivers were from the wooden roof of the building from which the lead-based paint was removed. A representative SEM photomicrograph of the sandblast waste showing silica

sand particles and wood slivers is given in Figure 11. This photomicrograph was taken in the backscatter electron mode, as compared to the secondary electron mode which reveals topographical contrast based on relief. The backscatter electron mode, which uses a component of contrast due to atomic number difference, was used to locate the lead metal within the waste sample. This technique relies on the basis that electron yield increases with the average atomic number of the region under the beam. As the atomic number of lead is 82, significantly higher than any of the other elements present in the raw materials, it was possible to locate the lead metal within the waste. The bright areas in the SEM photomicrograph presented in Figure 11 show the location of the lead metal within the waste sample.

Figure 11 Backscatter Electron SEM Photomicrograph of the Sandblast Waste

The surface of the grain of silica sand labeled A at the top of Figure 11 has been magnified and is shown below in Figure 12. The magnified image of the surface of this grain of silica sand shows that it has lead carbonate particles and wood slivers embedded in it after impacting the surface from which the lead-based paint was removed. Again, the bright areas in this photomicrograph, or those areas which appear to be white, indicate the location of the lead metal.

Figure 12 Magnified Image of Wood Slivers and Lead Carbonate Particles Embedded in the Surface of a Grain of Silica Sand

4.3.3 Chemistry and Microstructure

The composition and morphology of the two treated sandblast waste mixtures prepared for solidification testing were evaluated by SEM and XRD techniques. A summary of the resulting elemental analyses and the corresponding mineral phases which could be positively identified is presented below in Table 26.

Table 26

Elemental and Mineralogical Analyses of the Treated Waste Mixtures

Sample Identification	Elemental Analysis	Mineralogical Analysis
Sandblast Waste w/30% Spray Dry Scrubber Residue	Ca, S, Si (major) Al, Fe, Mg, Pb, C, O K, Ti, Cl (minor)	Quartz (SiO_2) Calcium Sulfite Hemihydrate ($\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$)
Sandblast Waste w/50% PFBC Residue	Ca, S, Si (major) Mg, Pb, C, O Al, Fe K, Ti (minor)	Quartz (SiO_2) Anhydrite (CaSO_4) Dolomite [$\text{CaMg}(\text{CO}_3)_2$] Periclase (MgO) Hydrocerussite [$\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$] Hematite (Fe_2O_3) Calcium Silicate Hydrate ($\text{Ca}_2\text{SiO}_4 \cdot 0.35\text{H}_2\text{O}$)

Elemental analyses by SEM show that calcium, sulfur, and silicon are the major components present in the sandblast waste treated with 30% spray dry scrubber residue.

Mineralogical analysis of the sandblast waste treated with 30% spray dry scrubber residue was performed by XRD. Corresponding mineral phases were positively identified for the major elements present in this treated waste mixture. The dominant crystalline phases were quartz and the sulfur sorption reaction product calcium sulfite hemihydrate. This is consistent with the mineralogy of the raw materials used in the treated waste mixture, as quartz was found to be the dominant element present in the sandblast waste and calcium sulfite hemihydrate was found to be the dominant sulfur sorption reaction product present in the spray dry scrubber residue. No corresponding mineral phases could be positively identified (by matching the position and intensity of the 3 strongest peaks for any given phase in the diffraction patterns) for any of the remaining minor elements present. Although mullite was identified in the spray dry scrubber residue, and aluminum was found in the resulting treated waste mixture, this crystalline phase could not be positively identified in the resulting diffraction patterns. In addition, elemental analysis revealed the presence of lead within the treated waste mixture, however, basic lead carbonate was not positively identified in the resulting XRD patterns. In every case, the quartz particles in the sandblast waste dominated the diffraction patterns. The complex nature of the matrix made identifying any other phases very difficult. It was possible, however, to observe that there were no obvious significant phase changes in the diffraction patterns of this treated waste mixture over the 28-day curing period.

Figure 15 shows a representative diffraction pattern of the sandblast waste treated with 30% spray dry scrubber residue after curing for a period of 3 days. This x-ray pattern demonstrates the dominant presence of quartz and calcium sulfite hemihydrate in the treated

Figure 15 XRD Pattern of the Sandblast Waste with 30% Spray Dry Scrubber Residue

waste mixture. The diffraction pattern given in Figure 15 also shows the presence of many smaller peaks which could not be positively identified.

A greater number of different mineral phases were positively identified in the sandblast waste treated with 50% PFBC residue, as was shown in Table 22. Elemental analysis by SEM revealed the presence of several dominant constituents including calcium, sulfur, silicon, magnesium, lead, carbon, and oxygen. Several corresponding crystalline phases were positively identified (again, by matching the position and intensity of the 3 strongest peaks of a given phase with known diffraction patterns) by XRD for each of the major elements present including quartz, anhydrite, dolomite, periclase, hydrocerussite, and calcium silicate hydrate. Aluminum and iron were also found in the treated waste mixture, but not in the abundance of the other elements. Hematite was the mineral phase identified corresponding to the presence of iron in the sample. Finally, trace amounts of both potassium and titanium were also identified during the elemental analyses, however, no corresponding mineral phases were positively identified by XRD. This is not surprising considering the detection limits of XRD are of the order of 1-3%. Overall, these results are consistent with the composition of both the PFBC residue and the sandblast waste. It was expected that a significant phase change would be observed in the diffraction patterns between curing periods of 14 and 28 days, correlating to the time of increase in leachable lead concentration of the treated waste cylinders. No obvious significant phase changes were observed in the diffraction patterns, however, over the 28-day curing period.

A representative XRD pattern of the sandblast waste treated with 50% PFBC residue, taken after a 3-day curing period, is shown in Figure 16. This x-ray pattern shows the

Figure 16 XRD Pattern of the Sandblast Waste with 50% PFBC Residue

dominant presence of quartz, anhydrite, dolomite, periclase, hydrocerussite, hematite, and calcium silicate hydrate in the treated waste mixture. In addition, it is possible to observe the presence of many unidentified peaks in the diffraction pattern in Figure 16.

The presence of calcium silicate hydrate in the sandblast waste with 50% PFBC residue, although expected, is a significant discovery. This compound is known for providing strength in cementitious systems. Lime is one of the most important components of these CCT by-products in that it initiates reaction with SiO_2 to form calcium silicate. The calcium silicate then reacts with water to form calcium silicate hydrate gel. The free water is chemically bound by this reaction to form hardened calcium silicate hydrate filaments that interlock to provide strength and fill the spaces between particles that were formerly filled by the water. In addition to the development of strength, heavy metal contaminants can be encapsulated in the calcium silicate gel that forms. The benefit of this kind of encapsulation is that the contaminants are physically entrapped and, hence, prevented from leaching. In addition, if the protective structure is degraded, the physical disruption of the particle will only expose the contaminants directly at the surface, providing continued protection of the contaminants in other parts of the particle.

It is this type of encapsulation by a calcium silicate gel that is most likely the dominant mechanism responsible for stabilization in this treatability study. In this manner, the basic lead carbonate (present in both the raw waste and resulting treated wastes mixtures) does not undergo chemical reaction, but rather physical encapsulation. The lead is still in the same form as it was in the raw waste, however, it is protected by the calcium silicate gel coating. Basic lead carbonate is soluble in nitric acid, however, if the leaching fluid is prevented from

directly contacting the contaminant, the release of lead will be prevented. Even though calcium silicate hydrate was not positively identified by XRD in the sandblast waste treated with 30% spray dry scrubber residue, and this treatment product did not develop the corresponding compressive strength, elemental analysis by SEM did reveal the presence of calcium and silicon. It is hypothesized that a similar type of calcium silicate gel forms, which encapsulates the lead carbonate particles and prevents the release of lead into the environment. It is difficult to prove this hypothesis by XRD however, as gels are not usually well crystallized and thus do not produce sharp, recognizable x-ray patterns that are easy to identify. If the chemistry of the treated waste is analyzed in conjunction with the microstructure, however, it is possible to infer that the mechanism of stabilization is indeed physical encapsulation.

The morphology of the two treated waste mixtures was qualitatively evaluated by SEM analysis. Figure 17 shows a SEM photomicrograph of the sandblast waste treated with 30% spray dry scrubber residue after curing for 24 hours. This same image is presented below in Figure 18 using the backscatter electron mode, for which the contrast increases directly with the average atomic number of the phase under the beam, to show the location of the lead metal. The bright spot or white area in the center of this second photomicrograph is an agglomerate of microscopic lead carbonate particles. The very fine material surrounding the lead carbonate particles is comprised of calcium, silicon, and sulfur. The morphology of the encapsulated area is better observed in the photomicrograph presented in Figure 17, which was taken in the secondary electron mode, whereas Figure 18 is presented solely to show the location of the lead within the waste. Another example of the physical entrapment

Figure 17 Secondary Electron SEM Photomicrograph of the 1-Day Sandblast Waste Treated with 30% Spray Dry Scrubber Residue

Figure 18 Backscatter Electron SEM Photomicrograph of the 1-Day Sandblast Waste Treated with 30% Spray Dry Scrubber Residue

of hazardous constituents at a higher magnification is presented in Figures 19 and 20. These SEM photomicrographs were taken of the sandblast waste with 30% spray dry scrubber residue after curing for 14 days. While the bright area in the center of Figure 20 shows the presence of lead carbonate, Figure 19 shows that the hazardous constituent is completely surrounded by a matrix of very fine material consisting of calcium, silicon, and sulfur.

The same encapsulation process is demonstrated with the sandblast waste treated with 50% PFBC residue as shown in Figure 21. This SEM photomicrograph was taken of the treated waste mixture after 28 days of curing. Using the backscatter electron mode, it was possible to show that the agglomerate of microscopic lead carbonate particles in the center of the photomicrograph is physically surrounded by an encapsulating matrix of calcium, silica, and sulfur. In comparison with the previous photomicrographs of the waste treated with the spray dry scrubber residue, there is a noticeable difference in the particle size distribution of the waste treated with the PFBC residue. This larger particle size allows for greater porosity and permeability of the surrounding matrix, thus increasing susceptibility to leaching. This could explain why the sandblast waste treated with the PFBC residue was found to have greater leachable lead concentrations.

As was shown in Figure 13, the leachable lead concentration of the sandblast waste treated with 50% PFBC residue significantly increased after 28 days of curing. It was hoped that a significant phase change would be observed corresponding to this increased leachable lead concentration, however, comparison of the x-ray patterns for all five curing times failed to reveal any significant phase changes that could be unambiguously identified over this time period. The first appearance of crystal growth in this treated waste mixture, however, was

Figure 19 Secondary Electron SEM Photomicrograph of the 14-Day Sandblast Waste Treated with 30% Spray Dry Scrubber Residue

Figure 20 Backscatter Electron SEM Photomicrograph of the 14-Day Sandblast Waste Treated with 30% Spray Dry Scrubber Residue

Figure 21 Backscatter Electron SEM Photomicrograph of the 28-Day Sandblast Waste Treated with 50% PFBC Residue

detected under the microscope at 28 days, directly corresponding to the increase in leachable lead concentration. Figure 22 shows the first appearance of crystal growth at 28 days in the sandblast waste treated with 50% PFBC residue. A magnified image of these same crystals is presented in Figure 23.

From the literature review, it was expected that ettringite crystals would form in the treated waste mixtures. Although the elemental composition of the crystals observed in Figure 23 could not be positively determined at such high magnification, it is not believed that they are ettringite. The observed crystal formation does not resemble the long, thin, needle-like crystal structures that are characteristic to ettringite formation. In addition, ettringite was not identified in the XRD patterns of any of the treated waste mixtures after

Figure 22 SEM Photomicrograph of the First Appearance of Crystal Growth in the 28-Day Sandblast Waste Treated with 50% PFBC Residue

Figure 23 Magnified Image of Crystal Structure of the 28-Day Sandblast Waste Treated with 50% PFBC Residue

curing times of 1, 3, 7, 14, and 28 days. Ettringite is known to form during the first 7 days of curing, however, the first appearance of the crystal growth observed in Figures 22 and 23 did not occur until 28 days. The first appearance of these crystals do, however, correspond with the increased leachable lead concentration of sandblast waste with 50% PFBC residue after 28 days. Crystal growth, such as that observed in Figures 22 and 23, and the expansion of sulfur containing compounds could cause the protective encapsulating gel to crack, thus allowing the leaching fluid to gain contact with the contaminants at the fracture surface. This degradation of the encapsulating matrix is most likely responsible for the increased leachable lead concentration observed in the 28-day sandblast waste treated with 50% PFBC residue.

In summary, agglomerates of microscopic lead particles could be located using the backscatter electron mode and, in every case, these agglomerates were surrounded by a matrix of fine material consisting of calcium, silicon, and sulfur. XRD patterns revealed that lead was present in the treated waste mixtures in its original form in the raw waste, as basic lead carbonate. In addition, XRD analysis of the sandblast waste treated with 50% PFBC residue revealed the presence of calcium silicate hydrate. These results imply that a calcium silicate gel matrix is formed. This matrix has the potential to bind the hazardous constituent in a stable crystalline lattice by microencapsulation. This system could then close the pore structure of the resulting treated waste product and reduce permeability, thereby preventing leaching fluid from coming in direct contact with the basic lead carbonate particles. The net result would be the microencapsulation of the waste in a gel having low porosity. Thus it can be inferred that the fixation mechanism responsible for successful stabilization is not a chemical process, but rather physical encapsulation as was demonstrated in Figures 17-21.

APPENDIX J

STABILIZATION/SOLIDIFICATION TECHNOLOGY – LITERATURE REVIEW

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Literature Review

1.0 S/S Technology Overview

Stabilization/solidification is normally a two step treatment process. First, the waste is initially chemically stabilized, to concentrate the hazardous components in the waste into an insoluble form. Solidification occurs, due to a second set of chemical reactions initiated by the addition of cementitious additives to the stabilized waste. In order to ensure an adequate level of performance, and to avoid some of the apparent failures of this technology in the past, it is essential to understand these two key processes which are fundamental to the production of an acceptable solidified waste [3].

Containment of hazardous components is the most important characteristic of solidified wastes, and has been extensively investigated, particularly for simple systems. Studies indicate that a number of retention mechanisms operate, such as bonding to an insoluble substrate, sorption, chemisorption, passivation, ion exchange, and inorganic complexation [3], but it is not clear whether these make a significant contribution to metal containment in commercially produced solidified materials.

Stabilization/solidification technologies can be broadly categorized as either inorganic or organic systems, based on the nature of the solidification chemicals used, not the waste composition. Inorganic systems are used for the chemical fixation and solidification of complex wastes in order to produce a nontoxic, environmentally safe product that can be used as landfill material. These processes use inorganic reagents, such as lime, cement and flyash, which react with certain waste components and with

themselves to form chemically and mechanically stable products. Organic systems are not often used for industrial wastes except in the area of radioactive waste solidification. These systems are sometimes hydrophobic in nature and therefore create difficulty when mixed with water based wastes [3].

Inorganic processes are generally grouped into two categories: those that use bulking agents, such as flyash, and those that do not. Bulking agents are those materials which, when added to the mixture, add to the total solids and viscosity of the waste. Bulking agents may prevent the settling out of the suspended waste components before solidification can occur and/or help produce a solid with better physical properties. Bulking agents may either be inert, or may have reactive capability or pozzolanic activity. Pozzolans are materials that do not demonstrate cementing capabilities when used alone, but when used in combination with other materials, such as Portland cement or lime, will interact with these materials to form a cementitious product. As Portland cement crystallizes, calcium hydroxide is released, which, in the presence of pozzolanic materials reacts to form calcium aluminum silicates that harden much as the Portland cement does. The most important inorganic systems in use are: Portland cement, lime/flyash, kiln dust, Portland cement/flyash, Portland cement/lime, Portland cement/sodium silicate [3].

A wide variety of both radioactive and chemically hazardous wastes are treatable with S/S technology. These include liquids, sludges, filter cakes, contaminated soils, and ash. S/S technologies are often used with chemically hazardous wastes contaminated with metals and are routinely used with low-level radioactive wastes of all types.

The physical and chemical properties of each waste must be studied to determine which S/S technology is best suited for treatment of that waste. Important properties of the waste to consider in choosing a S/S technology are as follows: toxicity and amounts of the hazardous constituents, medium, solids content, particle size, distribution and shape, inhibitors and accelerators [3].

Toxicity (or potential toxicity) of a waste is of primary importance in choosing the proper S/S technology. Toxic components of the waste can be described either as leachable or non-leachable depending on the particular leaching test and leachant being applied [3]. Though most concern has been about the leachable toxic constituents in the waste, the nonsoluble components are also of concern as the actual leaching conditions in the environment may be different than those tested in the laboratory.

Particle size, distribution, and shape in waste materials directly effect the mechanical properties of the solid produced by the S/S process. The presence of agglomerates of waste particles or large waste particles decrease surface area available for stabilization reactions to occur. These physical properties can also effect the solidification reactions for certain particulates and process types.

Since the S/S chemicals must be mixed with the waste in order to achieve the solidified waste, the specific gravity and viscosity of the waste are of primary concern. These waste properties often affect the choice of the equipment and energy to use for mixing.

The chemical nature of a waste obviously effects the choice of a S/S technology. There are three basic types of chemical interactions between the waste and the S/S

system that affect solidification: (1) inhibition, (2) acceleration, and (3) biological activity [3]. Chemical inhibitors in the waste tend to slow the rate of setting and thus effect the hardening of the solidified product. Conversely, chemical accelerators work to speed of the setting time of the solidified matrix.

2.0 Mechanisms of Stabilization

The stabilization process serves to minimize leaching by isolating the hazardous constituents in the waste from the environment, especially groundwater, so that it has less tendency to migrate. This is accomplished by physically isolating the waste, reducing its solubility, and/or decreasing its surface area. A number of chemical and physical mechanisms affect the degree of immobilization, or fixation, of hazardous constituents within a waste. Successful stabilization usually employs one or more of the following mechanisms: pH control, redox potential control, precipitation, passivation, and/or encapsulation. A brief description of each of these mechanisms is given below.

2.1 pH Control

pH control is the most common stabilization mechanism in the treatment of metal-laden hazardous wastes. pH control is a necessary condition for metal fixation in most stabilization systems. Normally, high pH is desirable as metal hydroxides have minimum solubility in the range of pH 7.5-11. Solubility curves for various metal hydroxides in water are given in Figure 1 [3]. Not all metals reach minimum solubility at

the same pH. Figure 1 shows that while the optimum pH for minimum cadmium solubility is approximately 11.2, the optimum pH for minimum zinc solubility is approximately 9.2. For this reason, the optimum pH of a complex waste mixture must be a compromise. In addition, the hydroxide of certain metals, such as lead, exhibit solubilities above the current TCLP limit even at optimum pH. It should be noted that the pH of interest is not really that of the waste form itself, but of the leaching solution after extraction.

Figure 1: Solubilities of Metal Hydroxides as a Function of pH. (From U. S. EPA Federal Register. 52(155): 29999 (Aug. 12, 1987)).

Calcium hydroxide $[\text{Ca}(\text{OH})_2]$, lime, and magnesium hydroxide $[\text{Mg}(\text{OH})_2]$ are two examples of reagents that can be used for pH control. Lime is the most widely used fixation agent, along with other additives, such as flyash, as required. Lime operates by

controlling the pH of the waste form so that the metals are kept in a range where they are less soluble. Stabilization systems are seldom designed to rely solely on pH control for metal fixation, however, as the solubility of many heavy metals increases significantly with only minor changes in pH, in simpler systems with fewer reacting species. As a result, stabilization usually relies on a combination of fixation mechanisms. For example, lead can also be stabilized by being precipitated as a carbonate, which is relatively insoluble at alkaline pH.

2.2 Redox Potential Control for Metals with Multiple Valences

The redox potential, E_h , is the oxidation-reduction potential referred to the hydrogen scale, expressed in millivolts [3]. Chemical reduction-oxidation (redox) involves the gain or loss of oxygen. A reaction that adds oxygen to a compound is oxidation, likewise, loss of oxygen is termed reduction. Oxidation can also be defined as a reaction that results in the loss of electrons by a chemical, whereby the chemical donating the electron is oxidized. The converse, gaining an electron, is referred to as reduction. The presence of strong oxidants and reductants can change the valence state of a number of metals, thus affecting their chemical speciation and resulting mobilities by orders of magnitude [3]. Redox potential control is mostly applicable to the stabilization of arsenic, chromium, iron, mercury, manganese, nickel, and selenium. These seven metals are commonly found to have more than one valence state in stabilization systems.

2.3 Precipitation

Certain stabilization processes will precipitate contaminants from the waste resulting in more stable forms of the constituents within the waste, and thereby reducing their solubility and leachability. Through chemical reaction, metals can be precipitated as low-solubility hydroxides, sulfides, silicates, carbonates, and other simple or complex species. Precipitates can then be contained within the stabilized mass as part of the material structure. The chemical reactions responsible for precipitation can either be components of the binders used for stabilization or additives to the binders.

In the example above, hydroxide precipitation occurs through pH control. Most heavy metals are soluble in acidic solutions. Furthermore, sulfide precipitation of heavy metals occurs through the addition of sulfides to treated waste mixtures. Sulfides have solubilities several orders of magnitude lower than hydroxides and are not as sensitive to changes in pH [13].

The chemical reaction of heavy metals with silicates can reduce the solubility of metals in waste treatment. Heavy metal silicates do not actually exist in solution as specific compounds, but rather exist as metals in combination with a variety of polymeric silicate species. These species form silica gel when silicate is exposed to divalent metal compounds. The solubility of heavy metal silicates, therefore, can be approximated by the solubility of the silica gel [1]. The metal oxide-silicates formed in the gel are less soluble over lower pH ranges than heavy metal hydroxides, and are held within a polymeric structure that is resistant to acid attack [1].

Metals can also be precipitated as metallic carbonates. For example, lead can

be precipitated out with the use of alkaline lime and dolomite [$\text{CaMg}(\text{CO}_3)_2$] to yield lead carbonate. Metal carbonates are typically less soluble than metal hydroxides and, at high pH, metal carbonates can be formed from metal hydroxides [13]. The permanence of the fixation of a metal as a metallic carbonate is highly dependent upon pH. Although metallic carbonates are quite stable at high pH, under strongly acidic conditions the metal may be redissolved and become free to migrate as a solute into the environment.

2.4 Passivation

Passivation is another important stabilization mechanism. Metal ions dissolving from a solid surface may re-precipitate on the surface after contacting an anion in solution that forms a less soluble species [3]. If the precipitate forms an impermeable layer, it may block or inhibit further reaction at the surface. One such system is that of the formation of silica gel on the surface of metal salts exposed to a soluble silicate solution. The gel layer prevents the passage of further metal ions into solution, thus slowing dissolution. It also acts as a semipermeable membrane, however, allowing the passage of water that builds osmotic pressure on the solid side. The membrane then ruptures, spilling concentrated metal solution into the liquid phase. Depending on the pH and relative concentrations of the constituents and their stoichiometry, metals may precipitate as low-solubility silicates and hydroxides, or may remain in solution. In some cases, this process may repeat itself periodically, possibly giving rise to fluctuations in leaching rate with time.

2.5 Encapsulation

Encapsulation is one of the primary mechanisms responsible for stabilization. As the name implies, encapsulation is used to coat wastes with an impervious material so that they are isolated from their surroundings.

Microencapsulation refers to the coating of individual microscopic particles, whereas imbedding larger aggregates of material in such a matrix is referred to as macroencapsulation.

In microencapsulation, hazardous waste constituents are entrapped within the crystalline structure of a solidified matrix at a microscopic level. The sizes of the microencapsulated particles may range from very small occlusions to larger agglomerates visible under low-power light microscopy. In this process, individual particles or agglomerates retain their identities but are entrapped by an impervious material. The presence of microscopically concentrated regions of raw waste dispersed throughout the solidified matrix can be observed with scanning electron microscopy. As a result of microencapsulation, even if the stabilized materials degrade into relatively small aggregates, most of the hazardous constituents will remain entrapped. Since the waste is not chemically altered or bound, the rates of contaminant release from the stabilized mass may increase as the particle size decreases and more surface area is exposed [10].

In macroencapsulation, hazardous waste constituents are physically entrapped in a larger structural matrix. The hazardous waste constituents are held in discontinuous pores within the fixation materials. The stabilized mass may breakdown over time due to imposed environmental stresses. These stresses include: repeated

cycles of wetting and drying or freezing and thawing, introduction of percolating fluids, and physical loading stresses [10]. Upon physical degradation of the stabilized material, even to relatively large particle sizes, the entrapped materials are free to migrate. Thus, contaminants stabilized by macroencapsulation alone may find their way into the environment if the integrity of the matrix is not maintained.

These two stabilization mechanisms exemplify the manner in which a hazardous waste constituent can be physically isolated from the environment. If encapsulation is the only operative stabilization mechanism, however, the degree of protection to the environment is determined entirely by the matrix and its continuing ability to isolate the waste from the environment. Isolation, in turn, depends primarily on the permeability of the matrix [3].

3.0 Cementitious Reactions in S/S Technology

Solidification reactions occurring in stabilized waste forms are primarily cementitious reactions. An explanation of the pertinent reactions for the setting of the S/S waste are included herein.

Portland cement is basically a calcium silicate mixture containing predominantly tricalcium and dicalcium silicates, which are represented as C_3S and C_2S , respectively¹, with smaller amounts of tricalcium aluminate and a calcium aluminoferrite with the approximate formulas C_3A and C_4AF , respectively. Typical weight proportions in an

---

¹This notation system represents calcium, silicon, aluminum, and iron oxides by C, S, A, and F, respectively. The subscripts denote the relative mole ratios of each component, for example, $2CaO \cdot SiO_2$ is C_2S .

ordinary cement are 50 percent C_3S , 25 percent C_2S , 10 percent C_3A , 10 percent C_4AF , and 5 percent other oxides.

In the presence of water, the four major crystalline compounds hydrate. The calcium silicates, C_3S and C_2S , hydrate to form the compounds calcium hydroxide and calcium silicate hydrate (tobermorite gel). Hydrated cement contains about 25% calcium hydroxide and 50% tobermorite gel by weight. The strength and other properties of hydrated cement are due primarily to the tobermorite gel. C_3A reacts with water and calcium hydroxide to form tetracalcium aluminate hydrate. C_4AF reacts with water to form calcium aluminoferrite hydrate. C_3A , gypsum, and water may combine to form calcium sulfoaluminate hydrate. The overall contribution of aluminate and ferrite hydrates to the strength of the system is thought to be minor [3]. The basic transformations are as follows [12]:

If sufficient sulfate is present, the reaction product of the last reaction is hydrated calcium aluminate sulfate (ettringite: $3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$) which coats the surfaces of the particles, preventing rapid further hydration. This is why gypsum retards

setting. If no gypsum is present, calcium aluminum hydrates form immediately and the system sets, according to the first three reactions above.

The relative rates and importance of the above reactions in Portland cement based S/S systems varies for each particular waste type. Typically, upon mixing wastes with Portland cement and water, any soluble metals will be precipitated as hydroxides. The amount of hydroxide precipitation can be increased by the addition of lime. If sufficient gypsum is present, either from the Portland cement itself or from the waste, then calcium aluminate sulfates will form almost immediately. These compounds tend to coat the waste particles, cement particles, and any agglomerates of metal precipitates present. This coating slows the various other hydration reactions that would normally occur. Calcium aluminum hydrates may not form for a few hours, and calcium silicate hydrates may not begin to form for up to a day. Metal control in the early stages of these types of systems is therefore a function of (1) the reduced solubility of the metal hydroxides, (2) maintenance of a high pH due to the alkalinity present, and (3) reduced contact of leachant with waste particles due to the coating of calcium sulfoaluminates. If there is insufficient gypsum present, then calcium aluminum hydrates and calcium silicate hydrates form almost immediately and the system sets. As the system sets, soluble metals, agglomerates of metal precipitates, and waste particles can be physically isolated within the silica gel matrix, thus preventing contact with any leachant.

4.0 Chemistry of Hazardous Metals in Cementitious S/S Wastes

Recent studies by Cocke and Mollah [2], have provided insight into the chemical binding and interactions between hazardous metal substances and Portland cement.

Specifically, priority metal pollutants such as, zinc, lead, cadmium, chromium, mercury, and barium, were studied to determine the models for the interaction of each metal with the cement matrix. Figure 2, below is a pictorial summary of their findings.

Figure 2: A Summary of Models for the Interaction of Priority Metal Pollutants with Cement (From Cocke and Mollah. *Chemistry and Microstructure of Solidified Waste Forms*, Roger Spence, ed., Lewis Publishers, Boca Raton, 1993.)

As shown, cadmium, zinc and lead form mixed hydroxides and adsorb to the surface at high pH. Mercury may be present as a surface particulate, HgO , while barium may be present as the sulfate and carbonate. Chromium was found to incorporate into the calcium silicate hydrate (C-S-H) matrix in some fashion. Leaching tests showed that the zinc on the outer surface is effectively removed during acid attack.

For those metals deposited on the surface of the cement particles in the mixed hydroxide form, prior mixing with a phosphate material, such as triple super phosphate (TSP), would cause the formation of the highly insoluble metal phosphate forms.

These metal phosphates, then, when deposited on the surface of the cement particle, would be more resistant to subsequent leaching.

5.0 Metal Precipitates and Solubility

Precipitation of many metals can be achieved by the use of hydroxide precipitation and is effective for cadmium, chromium(III), copper, iron, manganese, nickel, lead and zinc [12]. The formulas for the various metal precipitates with more common valencies are as follows [12],

Considering the relative theoretical solubilities of a given metal precipitate form as represented above in water at 25°C, their general respective order of solubilities, from most soluble to least soluble would be [12]:

Without taking into consideration metals which are amphoteric and have minimum solubilities at a specific pH, solubilities of some metals, in various precipitate forms, have been calculated by Grosse from their respective solubility products in Table 1 [6].

Table 1 - Comparative Solubilities of Metal Hydroxides, Carbonates and Sulfides

Metal Precipitate Solubility (mg/L)			
Metal	Hydroxide Form	Carbonate Form	Sulfide Form
Cadmium (Cd^{2+})	2.3×10^{-5}	1.0×10^{-4}	6.7×10^{-10}
Chromium (Cr^{3+})	8.4×10^{-4}	---	No precipitate
Cobalt (Co^{2+})	2.2×10^{-1}	---	1.0×10^{-8}
Copper (Cu^{2+})	2.2×10^{-2}	---	5.8×10^{-18}
Iron (Fe^{2+})	8.9×10^{-1}	---	3.4×10^{-5}
Lead (Pb^{2+})	2.1	7.0×10^{-3}	3.8×10^{-9}
Manganese (Mn^{2+})	1.2	---	2.1×10^{-3}
Mercury (Hg^{2+})	3.9×10^{-4}	3.9×10^{-2}	9.0×10^{-20}
Nickel (Ni^{2+})	6.9×10^{-3}	1.9×10^{-1}	6.9×10^{-8}
Silver (Ag^{+})	13.3	2.1×10^{-1}	7.4×10^{-12}
Tin (Sn^{2+})	1.1×10^{-4}	---	3.8×10^{-8}
Zinc (Zn^{2+})	1.1	7.0×10^{-4}	2.3×10^{-7}

Table 1 presents the theoretical solubilities of selected metal hydroxides, sulfides, and carbonates (in pure water at standard conditions) for comparison purposes and generally supports the above statement of the order of metal precipitates' solubilities.

6.0 Effects of Additives on Cement Based S/S Technologies

Many inorganic species that may be present as a component of a complex aqueous waste can have an adverse effect upon the set of cements and subsequent properties of a final waste form product. Chemical species such as sulfates, aluminates, borates, phosphates, and zinc, especially when present in combination,

can result in false sets (premature stiffening with little evolution of heat), flash sets (premature stiffening with the evolution of heat), and expansive mineral losses along with many other unwanted changes in physical properties [12]. A review of the literature on the interaction of select inorganic species on the set and properties of Portland cement provides interesting insight into this fundamental area of research.

The four main phases comprising Portland cement are, namely, tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF). Of these, C_3S and C_3A are the most important in the setting of neat cement, and thus, these are the two phases discussed here.

The reaction of carbonates upon the set of Portland cement has not been studied extensively. Research shows that Na_2CO_3 and $CaCO_3$ are accelerators for C_3S hydration, but the mechanism of their effect is not well understood [12]. Alkali carbonates produce a very strong acceleration of the set and addition of 1 to 2% can reduce the initial set time to only a few minutes. Sodium carbonate, when added to a cement with a normal set time, will cause a flash set. In larger quantities, sodium carbonate does not effect the normal set, however with still larger amounts, a flash set will again be obtained. Though the mechanism of sodium carbonate's effect is not well understood, one theory is that in a solution containing sodium or calcium carbonate, the formation of ettringite, a set regulator, will decrease thus accelerating the set.

Calcium sulfate is used in the industry as an additive to clinker in order to control the rate of set and the hydration of the aluminate phase. Although beneficial when used to control the set of cement, calcium sulfate can be among the most dangerous waste species due to its adverse effect upon the durability of the waste form. The

presence of calcium sulfate and aluminate hydrates leads to the formation of the expansive mineral ettringite, discussed above.

Magnesium sulfate can also have severe effects upon the durability of the waste form. This salt will destroy the hydrated silicate of calcium (CSH), which is the main bonding phase in a hydrated cement paste [12].

7.0 Use of Phosphates for Metal Fixation

Little work has been completed thus far on the use of phosphates for metal fixation. As Conner points out, the chemistry associated with the formation of phosphate species is very complex [4]. The term phosphate is broadly used to describe all compounds in which phosphorus atoms are surrounded by four oxygen atoms in a tetrahedron configuration. The linear formula for phosphates is $M_{n+2}P_nO_{3n+1}$. For $n=1$, the term orthophosphate applies. Linear chains are called polyphosphates, for $n=2,3$, cyclic rings are called metaphosphates, and branched or caged configurations are known as ultraphosphates.

The simple phosphate salts of hazardous metals are highly insoluble in water. Phosphate species with $n>1$ have the potential to trap the metals as water soluble species, as commonly applied to detergent and water treatment applications of phosphates. Thus, for the stabilization/solidification studies proposed herein, the added phosphate material will have the simple orthophosphate configuration.

The phosphate material to be used in this study is triple superphosphate (TSP). TSP is basically impure monocalcium phosphate monohydrate, $Ca(H_2PO_4)_2 \cdot H_2O$, and is commercially made by acidulating phosphate rock with phosphoric acid by the following

reaction:

This reaction results in 45-47% P_2O_5 content in TSP, compared to 16-20% P_2O_5 content in normal superphosphate, which is acidulated using sulfuric acid. The range of constituents in commercial TSP, produced according to the above method, is:

$\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$, 63-73%; CaSO_4 , 3-6%; CaHPO_4 and Fe and Al phosphates, 13-18%; silica, fluorsilicates, unreacted rock, and organic matter, 5-10%; and free moisture, 1-4% [9].

A study completed by Conner evaluated the effect of a proprietary additive in a cementitious system on four different lead-containing EPA-listed K061 wastes. K061 wastes are defined as emission control dust/sludge from the primary production of steel in electric furnaces. The results are shown in Figure 3, below. The results depicted therein show that the K061 level can be met at any pH between about 8 and 11+, and the lowest land disposal restriction (LDR) level can be met between approximately pH 9.5 and 10.5. The author points out that the result is not simply a pH adjustment or buffering effect, but that the effect of the proprietary additive is to "respeciate the lead to a less soluble, less pH-sensitive form" [4].

Figure 3: Lead leaching vs. final leachate pH (with additive). (From Conner, J. R. "Chemistry of Cementitious Waste Forms," in *Chemistry and Microstructure of Solidified Wastes*. Spence, R., ed., Lewis Publishers, Boca Raton, 1993.)

These findings demonstrate that the use of additives in a cementitious system does effect the leaching of metals from the matrix.

According to Mattus, et al., phosphates are generally not very soluble in solutions containing alkaline earth cations such as calcium and magnesium or even multivalent metals such as ferric ion. This phenomena is attributed to the fact that these species are known to form highly insoluble precipitates with many phosphate forms, especially orthophosphate, PO_4^{3-} [12]. Some more complex phosphate forms function not to precipitate normally insoluble alkaline earth metals but to maintain them in solution. Another general equation to represent the phosphate precipitation, with M representing a metal follows:

environmental toxicity of certain types of heavy metal wastes. Generally, residues from spray dryers appear to be more effective than residues from pressurized fluidized bed combustors (PFBCs) or circulating fluidized bed combustors (CFBCs), although each type has certain applications. Wastes formed by high temperature processes were typically more difficult to treat than sludges or soils. Analysis by scanning electron microscopy (SEM) and x-ray diffractometry (XRD) indicated that ettringite crystals are formed. The CCT by-products can also effectively solidify wastes, making mixtures useful for grouting, landfill cap, structural fills and slope stability improvement.

The focus of recent studies at the University of Pittsburgh has been the determination of the effects of age on the durability of the waste form. Leaching tests have been completed on samples up to two years old which were initially prepared by mixing hazardous metal-laden wastes with Clean Coal Technology (CCT) by-products. The samples were originally subjected to an EPA leaching test, namely, the Toxicity Characteristic Leaching Procedure (TCLP), which uses an acetic acid extraction fluid; and the ASTM D 3987 leaching test which uses deionized water as the extraction fluid. These two tests were rerun after a period of one or two years to determine if a change in the leachability of metals occurs. Since lead and zinc were the metals of most concern in the waste samples, the aging studies have focused on these metals.

The results of the TCLP tests showed that for most treated waste mixtures, the leachability of lead and zinc decreased or remained nearly constant after two years. One parameter to check, in explaining these results, is the pH of the TCLP leachate. Table 3, below, compares the TCLP leachate pH with the lead concentration for several of the samples.

Table 3-Comparison of Leachate pH and Lead Concentration in CCT Stabilized Wastes

Sample Identification	Initial		Two Year	
	Leachate pH	Lead (mg/L)	Leachate pH	Lead (mg/L)
Munitions Soil w/ 50% Consol By-product	4.54	<0.01	6.19	2.17
Munitions Soil w/ 50% Tidd By-product	7.08	1.20	5.85	1.25
Munitions Soil w/ 100% Ebensburg By-product	n/a	5.60	4.90	5.59
WWTP Soil w/ 50% Tidd By-product	6.36	2.30	5.93	0.75
WWTP Soil w/ 50% Ebensburg By-product	8.06	0.31	6.09	0.33
Industrial Soil w/ 50% Tidd By-Product	7.08	1.70	6.16	5.87

The data shown in the table do not provide a sufficient and conclusive explanation for the changes in the leachability of lead from the waste matrix with the passage of time. However, these results point to some interesting phenomena occurring in the solidified waste matrix. Solid phase reactions are, obviously, progressing in the treated waste and have an effect on the binding characteristics of the metals matrix.

The results of the ASTM leaching test for lead indicate that the lead concentration in the leachate has decreased with time. In contrast, the zinc concentration in the ASTM leachate has increased with time. These results indicate

that the lead and zinc, in the stabilized wastes, are not chemically bound within the matrix the same way. Further analysis of these samples will be completed to determine the manner in which lead and zinc have been incorporated into the stabilized waste.

The focus of the research has now shifted to identifying the solid phase reactions occurring in the waste matrix. A series of experiments will provide information in defining the mineral phases present in the waste matrix, and in what form the metal species are bound within the matrix. Experiments will involve the creation of a baseline analysis of similar s/s wastes treated with CCT by-products, for comparison to the aged samples. In addition, chemical and mineralogical analyses, using scanning electron microscopy (SEM) and x-ray diffractometry (XRD), are planned to aid in the understanding of the chemical and mineralogical changes occurring with time in the waste matrix.

9.0 Arsenic Contaminated Waste Treatment

Arsenic is classified as a nonmetal or metalloid, according to its placement in the periodic table. However, it is grouped with the metals for environmental purposes. The chemistry of arsenic is unique, in comparison to the other metals. Its principle valence states are +3, +5, and -3. Arsenic often combines with other metals to form arsenides.

The toxicity of most arsenic compounds has caused the metal to be closely regulated. Currently, the US EPA is considering lowering the maximum contaminant level (MCL) for arsenic in discharge waters. As a result of the more stringent regulations, water treatment facilities have altered there processes to comply with the new MCLs. When arsenic compounds are removed from the water, they become

concentrated in the sludge removed from the treatment facility. This sludge must then be treated to prevent the arsenic compounds re-release into the environment. Since stabilization/solidification techniques have been successful in treating metal bearing wastes in the future, s/s may be a viable option for treating arsenic bearing sludges.

As mentioned above, arsenic chemistry is somewhat complex, and arsenic oxides (or arsenites) are often present as complexes with other metals, such as iron or copper [7]. In water treatment systems, arsenic is difficult to remove since it is commonly present in the aqueous state as an oxidized anion. Therefore, arsenic must first be reduced to the cationic state [8].

Other sources of arsenic contaminated wastes are also common and include: filter cake from the production of food-grade phosphoric acid, residues from the manufacture of organic herbicides, and flue dusts from nonferrous smelting operations [3]. The most common arsenic compounds found in these waste streams are arsenic trisulfide, As_2S_3 , and arsenic trioxide, As_2O_3 .

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APPENDIX K

**SELECTIONS FROM M. S. THESIS ON
“AN EVALUATION OF THE LONG-TERM
LEACHING CHARACTERISTICS OF METALS
FROM SOLIDIFIED/STABILIZED WASTES”**

4.0 EXPERIMENTAL METHODS

4.1 Leaching Tests

4.1.1 Toxicity Characteristic Leaching Procedure (TCLP)

The TCLP is designed to evaluate the leaching of metals, volatile and semivolatile organic compounds, and pesticides from wastes that are categorized under RCRA as characteristically toxic and can be used on other waste types. In the TCLP, the particle size of the waste is reduced (if waste particles are unable to pass through a 9.5-mm standard sieve) and the solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid used is a function of the alkalinity of the solid phase of the waste. Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8-mm glass fiber filter. The filtered sample is then known as the "TCLP extract" and is ready for chemical analysis.

The TCLP test has been most commonly used by the US EPA and state agencies to evaluate the leaching potential of stabilized wastes. In addition, the TCLP is the test required by RCRA implementing regulations for determining toxicity.

4.1.2 Shake Extraction Test

The Shake Extraction Test (ASTM D3987-85 "Standard Test Method for Shake Extraction of Solid Waste with Water) is a leaching test in which distilled deionized water is used as the extraction fluid. As in the TCLP, the solid waste is first ground to reduce the particle size of the solid sample to approximately 9.5 mm. The crushed solid is then extracted with an amount of extraction fluid equal to 20 times weight of the solid phase. The solid waste is then extracted using a rotary agitator to mix the solid with the extraction fluid for 18 hours. The leachate is then filtered prior to analysis for inorganic constituents. The shake extraction test is designed to provide a rapid means of obtaining an aqueous extract.

4.2 Analytical Procedures and Techniques

4.2.1 Sample Grinding/Preparation

According to the TCLP and the shake extraction test, solidified samples must be ground to achieve a particle size less than 9.5 mm prior to extraction. In order to accomplish the particle size reduction required by the leaching tests, the s/s cylinders were first crushed with a hammer into smaller pieces. The smaller pieces of the sample were then easily ground using the Thomas Wiley Model 4 grinder, available in the Department of Civil and Environmental Engineering. Ground

samples were then ready for extraction according to the TCLP and the shake extraction test.

4.2.2 Digestion Procedure

The goal of the digestion of aqueous extracts is to chemically reduce the complexed species in the leachate to simpler and more readily analyzable compounds. The extracts of both the TCLP and the shake extraction tests were prepared for metals analysis using a digestion procedure (EPA SW-846 Method 3010A: Acid Digestion of Aqueous Samples and Extracts for Total Metals Analysis by FLAA or ICP Spectroscopy). The procedure stipulates that concentrated nitric acid be added to a portion of the extract. The mixture is gently heated and reduced. The volume is then recovered with the addition of distilled deionized water. The resulting digested sample is then ready for analysis by atomic absorption spectroscopy (AAS).

4.2.3 Flame Atomic Absorption (FLAA) Spectroscopy

Flame Atomic Absorption Spectroscopy analysis was completed using the Perkin-Elmer 1100B Atomic Absorption Spectrophotometer in the Department of

Civil and Environmental Engineering. Directions for the setup and calibration of the machine as well as for sample analysis are provided in the document, "Using the Perkin-Elmer 1100B AA Spectrophotometer," which is attached as Appendix C.⁽⁷²⁾

4.3 Quality Assurance/Quality Control (QA/QC) Methods

In order to ensure the comparability of the analytical data collected during the present study with the analytical data from the prior study, the same analytical tools, techniques, and procedures were used. The techniques for QA/QC applied during the present study were those described in the document, "Quality Assurance Project Plan for Treatment of Metal-Laden Hazardous Wastes with Advanced Clean-Coal Technology By-Products," (QA Project Plan) prepared by J. T. Cobb, Jr., Ph.D. in September 1994. The QA Project Plan was developed for use during the prior study, and was applied during the present project. The QA Project Plan describes objectives for measurement data, sampling, calibration, and analytical procedures, and methods for data reporting. The QA Project Plan is attached as Appendix D.

5.0 RESULTS AND DISCUSSION

5.1 Leaching Test Results

Two different leaching tests were used to characterize the mobility of metals in the s/s wastes for this study. Both the TCLP and the shake extraction test were used so that data from this study could be compared to that of the prior study at the University of Pittsburgh. However, a comparison of the leaching data from the two extraction tests also provides interesting insight into the mobility of metals from within the s/s wastes. Of the 15 metals examined during the prior research study, cadmium, chromium, lead and zinc were designated as metals of concern and were thus further examined in the present study.

5.1.1 Cadmium

The analysis of cadmium leaching from the s/s wastes subjected to the TCLP indicates that cadmium remains immobilized in the s/s matrix after two years. This result is in direct agreement with those published by Poon and Perry, and by Cartledge, et al. discussed in the previous sections. Cadmium concentrations in the TCLP leachate from day 1 through year 2 remain two orders of magnitude below the BDAT standard of 1.0 mg/L for each of the s/s wastes examined in this study. The results are tabulated in Table B1 of Appendix B.

The shake extraction test uses DI water as the extraction fluid and is therefore much less harsh as compared to the acidic TCLP leaching fluid. As expected, the concentrations of cadmium measured in the respective shake extraction test leachates were less than in the TCLP leachates. Cadmium concentrations in the shake extraction test leachate were below the detection limits in each of the s/s wastes examined in this study.

5.1.2 Chromium

Chromium mobility was also evaluated as part of this study. The concentration of chromium in the TCLP leachates measured 1 day after stabilization indicated chromium levels below the detection limit. The concentrations measured in the TCLP leachate as part of this study after two years indicated chromium levels one to two orders of magnitude below the BDAT standard of 5.0 mg/L for chromium. The results are tabulated in Table B2 of Appendix B. This result is in agreement with studies discussed previously, notably that of Bonen and Sarkar ⁽⁷³⁾ who reported excellent retention of Cr^{3+} related to the formation of $\text{Cr}(\text{OH})_3 \cdot n\text{H}_2\text{O}$.

The results of the shake extraction test leachate analysis for chromium were similar to those for cadmium. Chromium concentrations in the shake extraction test leachate were below the detection limits for each of the s/s wastes analyzed in this study.

5.1.3 Lead

The results of lead leaching from the s/s wastes subjected to the TCLP varied for each of the s/s wastes examined. Figure 5 presents the lead concentration in the TCLP leachates with respect to time. In four of the six samples, the concentration of lead increased through the 90 day or 1 year analysis, but decreased in the year two analysis. In one of the samples, the lead concentration increased from day one to year two, however, it should be noted that the year two concentration was below the BDAT standard of 5.0 mg/L for lead. The sixth sample, not previously mentioned, exhibited slight fluctuations in the lead concentration in the TCLP leachate.

These results are in agreement with the general results expected based on previous research studies. According to reports by Thomas ⁽⁷⁴⁾ and Cartledge, et al. ⁽⁷⁵⁾, the mechanism of lead stabilization in s/s wastes is by solubilization and reprecipitation as the pH fluctuates throughout the cement hydration reactions. Cocke and Mollah ⁽⁷⁶⁾ also point out that lead species are reprecipitated onto the surfaces of cement particles, making them more available to leaching fluid.

An analysis of the shake extraction test leachate for lead indicated that the concentration of lead present in the leachate decreased from day 1 to year 2 for all samples. It should be noted that the shake extraction test analysis was not completed during the interim between the day 1 and year 2 analyses. As noted in the Figure 6 below, the pH range for the samples measured on day 1 was 10-11.

However, the pH range for the samples measured at year 2 decreased to between 8.5 to 9. One explanation for the decrease in lead mobility may be related to the decreasing pH among the samples at year 2. If lead is indeed bound in its hydroxide form, then its solubility can be compared with Figure 1, which demonstrates a decrease in the concentration of lead leached with decreasing pH between 10 and 8. The complexity of the s/s waste systems for this study could account for the differences in solubility in Figure 1 (which was developed for a simple aqueous system).

Figure 5 Lead Concentration versus Time
for TCLP Extracts

Figure 6 Lead Concentration versus Time
for Shake Extraction Test Extracts

5.1.4 Zinc

Analysis of the TCLP leachate for zinc for the six samples indicated that zinc mobility varied for each of the s/s wastes examined. Figure 7, which follows, shows the results of the TCLP leachate analysis for zinc with time. For most of the samples, the concentration decreased between day 1 and day 90, however, in two of the samples, the concentrations increased at 2 years. The remaining samples showed a slight decrease or exhibited the same concentration of zinc in the TCLP leachate after two years. Studies by Cocke and Mollah ⁽⁷⁷⁾ and by Poon and Perry ⁽⁷⁸⁾ suggest that zinc is deposited as a mixed hydroxide and adsorbs to the surface of cement grains. Given this mechanism, combined with the acidic pH of the TCLP leaching fluid, it may be expected that zinc would readily leach from the s/s wastes. However, the TCLP leaching test results for the samples examined in this study do not wholly support this notion.

Interestingly, the shake extraction test leachate analyses for these six samples indicate that the concentration of zinc in the leachate increased from day 1 to year 2. Figure 8, below, shows the zinc concentration in the shake extraction test leachate with time. As was the case for lead, no intermediate shake extraction test analyses were completed on these samples between day 1 and year 2. As noted in the figure, the pH range for the samples measured on day 1 was 10-11. However, the pH range for the samples measured at year 2 decreased to between 8.5 to 9. One explanation for the increase in zinc mobility may be related to the

decreasing pH among the samples at year 2. If zinc is indeed bound in its hydroxide form, then, according to Figure 1, it may be noted that the leftmost portion of the Zn curve is applicable in this system. The complexity of the s/s waste systems for this study could account for the differences in solubility and pH range in Figure 1 (which was developed for a simple aqueous system).

Figure 7 Zinc Concentration versus Time
for TCLP Extracts

**Figure 8 Zinc Concentration versus Time
for Shake Extraction Test Extracts**

6.0 SUMMARY AND CONCLUSIONS

Though solidification/stabilization technologies are increasingly used to treat a variety of hazardous wastes, little research has been conducted to examine the permanence of metal immobilization in the s/s wastes. This study was conducted to evaluate the long-term leaching characteristics of cadmium, chromium, lead and zinc from metal-laden wastes treated with Clean-Coal Technology by-products. Prior research conducted at the University of Pittsburgh, which serves as the foundation for this study, has been described and noted in the report. The conclusions of this study are summarized in the following bulleted items below.

- ▶ Cadmium and chromium, as measured in TCLP leachates of the six samples considered in this study, remained immobilized after two years curing time. The concentrations of cadmium chromium in the TCLP leachates from day 1 to year 2 remained below the current BDAT standard of 1.0 mg/L and 5 mg/L, respectively. These results are in agreement with previously published studies cited in this report which suggest that cadmium and chromium are tightly bound within the s/s matrix.
- ▶ The immobilization of lead and zinc within the s/s matrices varied among the six samples considered for this study. The lead concentrations in two of the samples were slightly above the BDAT standard of 5 mg/L for lead after two

years. Concentrations of zinc in the TCLP leachate did not significantly increase after 2 years.

- ▶ In general, the leaching test analyses provided information about the leaching characteristics of cadmium, chromium, lead, and zinc in the six samples examined for this study and the results were consistent with previously published studies. However, an explanation of the mechanisms by which these metals were immobilized within the wastes could not be determined without the use of microscopic techniques for evaluation of the changing mineral phases present in the s/s wastes.
- ▶ Also, the results of the TCLP analyses indicate that the Clean Coal Technology by-products are effective in immobilizing cadmium and chromium after two years. Though the concentration of lead in the TCLP leachates of two of the six samples studied exceeded the BDAT standard after two years, the result is not significant enough to discount the effectiveness of CCT by-products for lead stabilization. Also, the CCT by-products were effective in immobilizing zinc after two years. Though zinc is not currently a RCRA-regulated metal, the concentrations of zinc in the TCLP leachate after two years did not significantly increase as compared to the one day measurements.

7.0 RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

In order to improve the present study, TCLP analyses of the six samples could have been performed multiple times in order to determine a mean and standard deviation for the concentrations of the metals in the TCLP leachates. This suggestion would help to verify the results of the present study, and insure that the results were not based on the measurement of a "hot spot." In addition, other methods for analyzing the samples, including leaching tests and microscopic analyses could have been completed in order to better characterize the changes in metals leachability with time. However, long term stabilization issues were not within the scope of the original project begun at the University of Pittsburgh, and these methods of analysis were not conducted on the samples at day 1. Therefore, no comparison could have been made with the two year samples, had these analyses been conducted.

The issue of long-term stabilization/solidification of metals contaminated wastes, though not presently important in decision-making scenarios, is extremely relevant with regard to liability for the disposers of these materials. Solidified/Stabilized wastes are known to continue to undergo solid phase chemical reactions after the initial set of the material is achieved. With these reactions, come changes in the mineralogy of the sample, causing changes in the microstructure, and subsequently, changes in the leachability of the hazardous constituents. The focus of s/s research is beginning to shift toward identifying the solid phase

reactions occurring in the waste matrix in order to evaluate long-term effectiveness of s/s technologies. Experiments which provide information about the mineral phases present in the waste matrix, and the changes in the mineral phases are needed to characterize the effects of aging and weathering on s/s wastes. Chemical and mineralogical analyses, using various microscopic techniques, will aid in understanding the chemical and mineralogical changes occurring as the s/s waste weathers.

In addition, analysis of the durability of s/s wastes should be completed on field samples wherever possible. Environmental factors which affect the weathering of s/s wastes are site-specific, therefore field studies of weathered samples would give better information on the effects of weathering than would simulated weathering tests completed in the laboratory. As well, the development of leaching tests to better characterize the durability of s/s wastes over time are needed, as the TCLP test was not designed for that purpose.

APPENDIX B

Table B1 TCLP Extracts - Cadmium Analysis

Time (days)	Current BDAT Standard	Future BDAT Standard	Munitions Soil w/ 100% EPC	WWTP Soil w/ 50% EPC	WWTP Soil w/ 50% Tidd	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 50% Consol	Industrial Soil w/ 50% Tidd
1	1	0.19	ND	ND	ND	ND	ND	ND
90	1	0.19	0.02	0.01	0.01	0.01	0.02	ND
730	1	0.19	0.05	0.02	0.03	0.04	0.03	0.03

Table B2 TCLP Extracts - Chromium Analysis

Time (days)	Current BDAT Standard	Future BDAT Standard	Munitions Soil w/ 100% EPC	WWTP Soil w/ 50% EPC	WWTP Soil w/ 50% Tidd	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 50% Consol	Industrial Soil w/ 50% Tidd
1	5	0.86	ND	ND	0.16	ND	ND	ND
90	5	0.86	0.18	0.18	0.02	0.05	0.24	ND
730	5	0.86	0.27	0.03	0.04	0.04	0.02	0.01

Table B3 TCLP Extracts - Lead Analysis

Time (days)	Current BDAT Standard	Future BDAT Standard	Munitions Soil w/ 100% EPC	WWTP Soil w/ 50% EPC	WWTP Soil w/ 50% Tidd	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 50% Consol	Industrial Soil w/ 50% Tidd
1	5	0.37	4.3	0.18	2.1	0.34	0.28	1.6
90	5	0.37	9.03	5.96	0.56	1.21	0.87	14
365	5	0.37	n/a	0.65	1.12	1.74	1.07	20.48
730	5	0.37	5.59	0.33	0.75	1.25	2.17	5.87

Table B4 Shake Extraction Test - Lead Analysis

Time (days)	Munitions Soil w/ 100% EPC	WWTP Soil w/ 50% EPC	WWTP Soil w/ 50% Tidd	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 50% Consol	Industrial Soil w/ 50% Tidd
1	0.56	0.94	0.34	0.15	0.29	0.51
730	0.09	0	0.01	0	0.12	0.37

Table B5 TCLP Extracts - Zinc Analysis

Time (days)	Current BDAT Standard	Future BDAT Standard	Munitions Soil w/ 100% EPC	WWTP Soil w/ 50% EPC	WWTP Soil w/ 50% Tidd	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 50% Consol	Industrial Soil w/ 50% Tidd
1	---	5.3	1.8	0.1	1	0.1	5.1	2.4
90	---	5.3	0.32	0.26	0.08	0.23	0.56	1.1
730	---	5.3	3.59	0.27	0.21	0.39	0.09	1.09

Table B6 Shake Extraction Test - Zinc Analysis

Time (days)	Munitions Soil w/ 100% EPC	WWTP Soil w/ 50% EPC	WWTP Soil w/ 50% Tidd	Munitions Soil w/ 50% Tidd	Munitions Soil w/ 50% Consol	Industrial Soil w/ 50% Tidd
1	0.07	0.03	0.02	0.04	0.1	0.04
730	0.2	0.21	0.25	0.19	0.16	0.21

Table B7 TCLP Leachate Metal Concentration versus TCLP Leachate pH

Sample Identification	TCLP Leachate pH	Time (days)	Metal Concentration in TCLP Leachate (mg/L)			
			Cadmium	Chromium	Lead	Zinc
Industrial Soil w/ 50% Tidd	6.52	1	ND	ND	1.6	2.4
Industrial Soil w/ 50% Tidd	5.9	90	ND	ND	14	1.1
Industrial Soil w/ 50% Tidd	6	365	N/A	N/A	20.48	N/A
Industrial Soil w/ 50% Tidd	6.16	730	0.03	0.01	5.87	1.09
WWTP Soil w/ 50% EPC	9.52	1	ND	ND	0.18	ND
WWTP Soil w/ 50% EPC	4.8	90	0.01	0.18	5.96	0.26
WWTP Soil w/ 50% EPC	6.4	365	N/A	N/A	0.65	N/A
WWTP Soil w/ 50% EPC	6.09	730	0.02	0.03	0.33	0.27
WWTP Soil w/ 50% Tidd	6.49	1	ND	0.16	2.1	1
WWTP Soil w/ 50% Tidd	6.4	90	0.01	0.02	0.56	0.08
WWTP Soil w/ 50% Tidd	6.1	365	N/A	N/A	1.12	N/A
WWTP Soil w/ 50% Tidd	5.93	730	0.03	0.04	0.75	0.21
Munitions Soil w/ 100% EPC	N/A	1	ND	ND	4.3	1.8
Munitions Soil w/ 100% EPC	N/A	90	0.02	0.18	9.03	0.32
Munitions Soil w/ 100% EPC	N/A	365	N/A	N/A	N/A	N/A
Munitions Soil w/ 100% EPC	4.9	730	0.05	0.27	5.59	3.59
Munitions Soil w/ 50% Tidd	6.86	1	ND	ND	0.34	ND
Munitions Soil w/ 50% Tidd	N/A	90	0.01	0.05	1.21	0.23
Munitions Soil w/ 50% Tidd	6	365	N/A	N/A	1.74	N/A
Munitions Soil w/ 50% Tidd	5.85	730	0.04	0.04	1.25	0.39
Munitions Soil w/ 50% Consol	4.7	1	ND	ND	0.28	5.1
Munitions Soil w/ 50% Consol	4.7	90	0.02	0.24	0.87	0.56
Munitions Soil w/ 50% Consol	6.1	365	N/A	N/A	1.07	N/A
Munitions Soil w/ 50% Consol	6.19	730	0.03	0.02	2.17	0.09

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APPENDIX L

PAPER ON “STABILIZATION OF METAL-LADEN HAZARDOUS WASTES USING LIME-CONTAINING ASH FROM TWO FBC’S AND A SPRAY-DRIER”

STABILIZATION OF METAL-LADEN HAZARDOUS WASTES USING LIME-CONTAINING ASH FROM TWO FBC's AND A SPRAY-DRIER

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ABSTRACT

Clean coal technology by-products, collected from commercial operations under steady state conditions, are reacted at bench-scale with metal-laden hazardous wastes. Reaction conditions involve mixing calibrated weight ratios of by-product to hazardous waste with attention to minimizing added moisture. Of the 15 heavy metals monitored, lead appeared to be the element of greatest concern both from a leaching and a regulatory point of view. While leaching information is focused on lead stabilization, similar information exists for other metals as well. Stabilized solid products of reactions are sampled for TCLP evaluations. For samples showing evidence of metal stabilization, further experimentation was conducted evaluating optimum moisture content and development of physical strength (measured as compressive strength) over time of curing. Results show that certain hazardous wastes are highly amenable to chemical stabilization, while others are not; certain by-products provided superior stabilization, but did not allow for strength generation over time.

INTRODUCTION

The general objective this two-year project (*which has just completed the first year*) is to provide useful information and data on the ability of new and emerging sources of chemical treatment substances, in this case by-products from advanced clean coal technologies, to be used by the hazardous waste management community. These studies fall into two categories: (i) characterization of selected critical properties of by-products and (ii) observation of their ability to stabilize and solidify characteristic metal-laden solid hazardous wastes. A more commercial objective of the project is to link the producers of by-product with operators of hazardous waste treatment facilities in a mutually profitable manner. From the treatment facility operators' point of view, new sources of treatment material with abilities to stabilize and solidify their feed wastes can be added to their material source list. From the producers' point of view, new uses for by-products of their advanced coal combustors and desulfurizers will be developed and demonstrated. These producers have implemented various emission control technologies at coal-fired (and coal waste fired) electric power plants and are studying a number of others. The technologies currently in use generate significant amounts of by-products with limited commercial value. Consequently, much of the by-products are disposed as solid wastes. In particular, companies employing wet scrubber technologies for the desulfurization of flue gases have found few alternatives to disposal for the sludges generated in the processes due to the excess moisture present in the by-product. On the other hand, the contemporary development of dry desulfurization technologies offers great promise that these process by-products may have beneficial commercial application, such as those studied as part of this project.

Background: The project focuses on characteristic metal-laden hazardous waste. Federal regulations and many state regulations require generators of solid wastes to determine if the wastes they produce are hazardous. The determination process requires the generators to analyze leachates produced when the wastes are mixed with an extraction fluid and compare the results of that analysis to a published list that defines which parameters are of concern and the extract concentrations at which a waste containing those parameters is considered hazardous. Wastes that contain extract constituents on the list at concentrations that equal or exceed the published concentrations are considered to be characteristically hazardous (unless they are specifically excluded) and said to exhibit the "toxicity characteristic". Among the parameters included on the toxicity characteristic list published in the Federal regulations¹ are eight metals; the

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¹ See 40 CFR 261.24.

concentrations at which a waste extract containing them is considered hazardous, are:

<u>Metal Parameter</u>	<u>Hazardous Concentration in Leachate (mg/l)</u>
Arsenic (As)	5.0
Barium (Ba)	100.0
Cadmium (Cd)	1.0
Chromium (Cr)	5.0
Lead (Pb)	5.0
Mercury (Hg)	0.2
Selenium (Se)	1.0
Silver (Ag)	5.0

Once a waste is determined to be hazardous, generators are restricted from directly disposing that waste anywhere in the United States. Prior to disposal, the waste must be treated to an extent that renders the resulting waste non-hazardous. The purpose of the treatment prior to disposal is to reduce the likelihood of migration of hazardous waste constituents from the waste. Wastes that are treated to meet the established standards can be disposed.

For purposes of this first-year research, toxic metal-laden wastes were treated at bench-scale by stabilization and solidification methods. Stabilization/solidification is a treatment technology used to reduce the hazard potential of a waste by converting the contaminants into their least soluble, mobile, or toxic form. Solidification refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. Solidification does not necessarily involve a chemical interaction between the wastes and the solidifying reagents but may mechanically bind the waste into the monolith. Similarly, stabilization does not necessarily involve solidification, since precipitation and complexation are also mechanisms of stabilization.

BY-PRODUCTS

The Clean Coal Technology (CCT) Program is a cooperative effort to demonstrate a new generation of innovative coal processes, which are environmentally cleaner and more efficient than conventional coal-burning processes [US DOE, 1991]. In dry CCT systems, a calcium-based sorbent (usually slaked lime, limestone, or dolomite) is injected directly into a furnace, ductwork, precipitator, or scrubber vessel that produces powdered or granular by-products, as opposed to the slurries associated with traditional wet scrubber systems. All these processes produce a by-product which is removed in the particulate control equipment. Dry by-products from lime or limestone injected into the furnace, such as in FBC systems, have neutralizing, sorptive, and cementitious properties that make them interesting as potential reagents for hazardous waste stabilization because of their high free quicklime (CaO) and anhydrous calcium sulfate (CaSO_4) contents. The specific composition of a particular type of by-product may vary widely depending upon the CCT process employed, the coal and sorbent composition, and the plant operating conditions. Since the chemical, physical, and engineering properties of dry CCT by-products are directly related to their history of use within the system and specific mineralogy, it is essential to accurately determine the mineralogical composition of these wastes and process configurations if safe and economical uses are to be defined.

Four clean-coal technology by-products were originally identified, but only the first three were used in this research.

1- Dry Scrubber Residue, supplied by CONSOL Inc. This material is from a spray drier at the outlet of a pulverized coal boiler burning high-sulfur eastern coal. Within the process, ash laden flue gas enters the bottom of the spray drier and all of the sulfur-capture residue rises through the upper port with the fly ash. The residue contains 45% fly ash, 36% $\text{CaSO}_3/\text{CaSO}_4$, 10% $\text{Ca}(\text{OH})_2$, 2% CaCO_3 , and 7% other inert material with moisture content of 2% or less.

2- Residue from a Coal-Fired Pressurized Fluid Bed Combustor (PFBC) at the Tidd Station of Ohio Power Company. This demonstration facility was constructed and is operated in cooperation with the U.S. Department of Energy in Round I of the Clean Coal Technology Program. The sorbent fed to the plant, rather than lime or limestone, is dolomite. Dolomite is used at the Tidd Station because it is both more porous (and thus more reactive) and easier to handle without bridging in the piping system. By operating

at high pressure, little of the dolomite in the residue is in the oxide form - most is present as carbonate. The dolomitic character of the sorbent yields a residue that is lower in pH than that produced from lime-based sorbents. This characteristic is particularly advantageous in stabilizing arsenic-laden waste solids. As this by-product contains magnesium, it will buffer the stronger lime alkalinity. The chemical composition of the residue is 50-60% equivalent CaCO_3 and 1-2% available (free or uncombined) CaO .

3- Residue from a Coal-Waste-Fired CFBC operated by the Ebensburg Power Company. Approximately 200,000 tons/year of this material is trucked back to the mines from which the coal wastes are derived. Some or all of this by-product could be diverted to nearby sites for beneficial use if they could be identified. The coal waste fed to the boiler has a sulfur content between 1.4 and 2.0 percent. The limestone is 83% CaCO_3 . It is sized at 12 mesh x 0 and contains between 5 and 10 percent through 140 mesh. The fly ash 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. Thus, the by-product is a relatively coarse material containing 82% ash, 12.5% limestone equivalent and 5.5% $\text{CaSO}_3/\text{CaSO}_4$.

4- Residue from a Coal-Fired Circulating Fluid Bed Combustor (CFBC), supplied by Anker Energy Corporation. This material is produced by the cogeneration project of Applied Energy Service at its Thames River Plant near Uncasville, Connecticut. Anker Energy Corporation supplies the coal used in the plant and through early 1995 had to backhaul the residue to its mines in West Virginia. It was anticipated that some or all of the approximately 100,000 tons/year of this by-product could be easily diverted to hazardous waste treatment plants along the general rail route from Connecticut to West Virginia. The AES Thames River Plant is base-loaded, operating at 95-96 percent of capacity constantly, thus the ash from it is very uniform. The residue is a relatively coarse material, as it contains both bottom and fly ash from the boiler, and contains 45% limestone equivalent, 28% ash and 27% $\text{CaSO}_3/\text{CaSO}_4$. Dravo Lime Company provided assistance in obtaining and transporting multiple representative samples from each clean coal technology site in accordance with ASTM-C-311. Samples were split for analysis and use at the University of Pittsburgh and the Dravo Lime Company.

HAZARDOUS WASTES

Six different hazardous wastes have been selected for examination by Mill Service, Inc., a regional centralized hazardous waste treater, from among the materials processed commercially at their facility. The table below outlines significant properties of each hazardous waste: note that lead is the contaminant of primary concern since it is the TCLP lead levels that exceed appropriate limits.

HAZARDOUS WASTES STABILIZED

Hazardous Waste Source	Hazardous Constituents of Concern	Total Concentration (mg/kg solids)	TCLP Concentration (mg/l)	TCLP Regulatory Limit (mg/l)
Sludge from Lead-Acid Storage Battery Production	Lead	3,000	20	5.0
	Cadmium	3	0.19	1.0
	Chromium	12	—	5.0
Contaminated Soil from a Munitions Depot	Lead	1,200	28	5.0
	Cadmium	4.8	—	1.0
	Chromium	59	—	5.0
	Copper	210	1.6	—
	Zinc	580	8.2	—
Contaminated Soil from a Multi-Use Industrial Site	Lead	5,000	80	5.0
	Cadmium	5.4	—	1.0
	Chromium	22	—	5.0
	Copper	260	—	—
	Zinc	660	17	—

Baghouse Dust from Basic Oxygen Furnace (BOF) Steelmaking	Lead	1,400	14	5.0
	Cadmium	55	—	1.0
	Chromium	260	—	5.0
	Copper	57	—	—
	Nickel	130	—	—
	Vanadium	76	—	—
	Zinc	41,000	4.4	—
Ash from a Municipal Solid Waste Incinerator	Lead	5,700	20	5.0
	Barium	550	—	100
	Cadmium	630	—	1.0
	Chromium	130	—	5.0
	Copper	1,300	—	—
	Zinc	23,000	2.1	—
Contaminated Soil from a Former Waste Water Treatment Plant	Lead	750	7.8	5.0

RESULTS & CONCLUSIONS

Bench-scale stabilization experiments consisted of mixing by-products with hazardous wastes at weight ratios ranging from 0 to 1:2 with minimal moisture addition. Sampling of the stabilized mass was done immediately after treatment for evaluation of TCLP leachate compositions. As may be expected, some combinations of by-product/wastes exhibited stabilization more consistently than others. Figures 1 and 2 provide contrasting resultant information for two representative sets of stabilization experiments: figure 1 shows information illustrating lead stabilization while figure 2 shows failure to stabilize lead.

Figure 1
Successful Lead Stabilization

Figure 2
Unsuccessful Lead Stabilization

Solidification/Strength Development: In addition to chemical stabilization, aliquots of hazardous waste and by-products were evaluated for development of strength over time when prepared at optimal moisture contents. Optimal moisture values were determined to be that at which the "stiffened" mass would produce a "slump" in the neighborhood of 1 inch to 2 inches when tested in accordance with standard concrete testing procedures. Figure 3, a representative plot of compressive strength development over time, indicates that for some samples, strength development is considerable while little strength development is achieved for others.

Figure 3
Strength Development over Time

SUMMARY

- Clean Coal Technology by-products may be used for heavy metal stabilization of a number of hazardous waste sources, however laboratory evaluations must be conducted to assure final product quality.
- Pozzolanic properties of clean coal technology by-products are useful in making a hardened product for reuse or disposal.
- By-products producing a highly stabilized materials do not often produce the strongest product. Thus, evaluation of final product use and/or disposal options must be made on a case-by-case basis.
- Commercial-scale stabilization testing will be undertaken during the second year of this project in conjunction with developing an understanding of underlying principles governing the behavior of these new treatment chemicals.

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APPENDIX M

PAPER ON “PREPARATION OF A COMMERCIAL TEST OF THE TREATMENT OF METAL-LADEN HAZARDOUS WASTES WITH CLEAN COAL TECHNOLOGIES BY-PRODUCTS”

PREPARATION OF A COMMERCIAL TEST OF THE TREATMENT OF METAL-LADEN HAZARDOUS WASTES WITH CLEAN COAL TECHNOLOGY BY-PRODUCTS

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INTRODUCTION

During the third quarter of 1994 an investigation began at the University of Pittsburgh into the stabilization of metal-laden hazardous wastes using by-products from several of the new advanced clean-coal technologies, recently installed at U.S. coal-fired utility and cogeneration plants. The objectives of this program are (1) to provide useful information and data on the ability of these new treatment chemicals to stabilize waste streams of commercial interest, and (2) to demonstrate the performance of several waste/by-product mixtures at commercial scale. The program's goal is the development of a new market for coal combustion by-products, namely, the enhanced sale of ash by electric utilities and power cogenerators to hazardous waste treaters.

During the first two years of the program, bench-scale treatability studies were performed to show the effectiveness of several advanced clean-coal technology by-products as treatment chemicals for metal-laden hazardous wastes [1,2]. Those by-product/waste sets showing promise for stabilization were examined for solidification characteristics. Several were also viewed by X-ray diffraction and scanning electron microscopy to learn the method of solidification/stabilization [3].

When sufficient information was available in late 1995 to show that some of the stabilizations were effective, a search began for a commercial partner, at whose plant the demonstration would be conducted. That search has continued through early 1997 and has been made difficult by a number of factors — long-term legal liability, public exposure, business competition, capital requirements, and long-term economic viability. In 1994 the U.S. Department of Energy evaluated many of these barriers to increased beneficial use of coal combustion/desulfurization by-products.

This paper will summarize the results the bench-scale studies, describe the search for a commercial partner, and discuss the barriers to increased beneficial use of by-products.

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. The residue contains 45% fly ash, 36% $\text{CaSO}_3/\text{CaSO}_4$, 10% $\text{Ca}(\text{OH})_2$, 2% CaCO_3 , and 7% other inert material with moisture content of 2% or less.

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. The residue contains 50-60% equivalent CaCO_3 and 1-2% available (free or uncombined) CaO .

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% CaCO_3 . 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. Thus, the by-product is a relatively coarse material containing 82% ash, 12.5% limestone equivalent and 5.5% $\text{CaSO}_3/\text{CaSO}_4$.

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, Inc., 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

The principal hazardous constituent of concern for all seven wastes was 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.

The stabilization of all eight of these metals — lead, cadmium, chromium, barium, copper, zinc, nickel and vanadium — by the three by-products were determined in the bench-scale studies.

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. Table I summarizes the results. 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.

TABLE I—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	

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 II. For the PFBC and CFBC residues, these were in the same ratio as shown in Table I — 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 II 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 II—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

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.

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 I, 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. At the writing of this paper (during the second quarter of 1997), the search continues. The next portion of this paper offers a brief history of the search and of barriers to its success, which were experienced. Others have experienced these barriers also, and the last portion of the paper reviews their general observations.

The hazardous waste treater first approached by the University of Pittsburgh was already considering the use of coal combustion by-products (CCBs) as treatment chemicals. 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 shifted to the review of the project's response to an environmental questionnaire. Consideration of the questionnaire does not include the opportunity for 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 the first company with whom it had discussed the demonstration. It 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 renewing negotiations. Those negotiations are continuing at this time (midway through the second quarter of 1997).

BARRIERS TO BENEFICIAL USE OF CCBs

Before embarking upon a general 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 [4]. 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 [5]. 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.

CONCLUSION

Advanced clean coal technology by-products are effective treatment chemicals for the stabilization of metal-laden hazardous wastes. Bench-scale tests have shown this. A demonstration is required to prove their technical, economic and regulatory capability at commercial scale. There appear to be a number of barriers to be overcome to bring this technology to full commercialization. The University of Pittsburgh is committed to continue its project by organizing a demonstration of this technology to prove its feasibility at the commercial scale.

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APPENDIX - BARRIERS TO INCREASED BYPRODUCT 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" [4].

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.

APPENDIX N

PAPER ON “LABORATORY EVALUATION AND COMMERCIAL DEMONSTRATION OF HAZARDOUS WASTE TREATMENT USING CLEAN COAL TECHNOLOGY BY-PRODUCTS”

Laboratory Evaluation and Commercial Demonstration of Hazardous Waste Treatment Using Clean Coal Technology By-Products

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INTRODUCTION

With the support of the U.S. Department of Energy the University of Pittsburgh has 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. 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.

During the first two years of the program, Dravo Lime Company collected and thoroughly analyzed multiple samples of three by-products.¹ Bench-scale treatability studies were performed to show the effectiveness of the three by-products as treatment chemicals for seven metal-laden wastes.^{2,3} 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.⁴

For the past twenty months a very difficult search has been underway for a commercial partner at whose plant the demonstration will be conducted.⁵ As this paper is being written (late July 1997) the project team appears to be nearing a successful conclusion of its search.

This paper will provide the results of the analyses of the by-products, summarize the results of the bench-scale studies, and comment upon the particular difficulty caused by the entry of the words "hazardous waste" into the necessary vocabulary of the project.

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% CaCO_3 . 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.

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. The analyses utilized are thoroughly described in References 1 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 SiO_2 , Al_2O_3 , and Fe_2O_3 , 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 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.

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 (: m)	2.0	2.6	3.4
50% passing (: m)	11.88	10.95	26.59
90% passing (: m)	42.17	55.49	110.49
Average Particle Size (: m)	17.74	21.39	42.67

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 μ m. 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

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.

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.

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 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, Inc., 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

The principal hazardous constituent of concern for all seven wastes was 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. The stabilization of lead by the three by-products were determined in the bench-scale studies.

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. Table 4 summarizes the results. 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.

TABLE 4—SUCCESS OF BY-PRODUCT/WASTE COMBINATIONS

<u>Waste</u>	<u>Spray-Drier Residue</u>	<u>PFBC Residue</u>	<u>CFBC Residue</u>
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	

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.

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. At the writing of this paper (midway through the third quarter of 1997) the search continues.

Five companies have been approached during the search. The first was the original partner for the project, Mill Service, Inc., in whose laboratory the key bench-scale treatability studies were performed. It was unable to remain on the project when a federal-level environmental assessment (EA) of the demonstration was determined to be necessary. The next two companies approached by the project team declined for the same basic reason. At this point the need for the EA was eliminated.

However, the fourth company approached declined because it was outside the Appalachian coal province and could find no economic benefit to its participation. A fifth company did not respond to a detailed invitation.

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 re-contracted the first company with whom it had discussed the demonstration. It 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 renewing negotiations. Those negotiations are continuing at this time.

BARRIERS TO BENEFICIAL USE OF CCBs

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 1994⁶.

CONCLUSION

Advanced clean coal technology by-products are effective treatment chemicals for the stabilization of metal-laden hazardous wastes. Bench-scale tests have shown this. A demonstration is required to prove their technical, economic and regulatory capability at commercial scale. The University of Pittsburgh is committed to continue its project by organizing a demonstration of this technology to prove its feasibility at the commercial scale.

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APPENDIX O

PAPER ON “CLEAN COAL TECHNOLOGY BY-PRODUCTS AS TREATMENT CHEMICALS FOR HAZARDOUS WASTES”

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% CaCO_3 . 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 (: m)	2.0	2.6	3.4
50% passing (: m)	11.88	10.95	26.59
90% passing (: m)	42.17	55.49	110.49
Average Particle Size (: m)	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 : m. 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.

APPENDIX P

ACRONYMS

ASTM	American Society for Testing and Materials
BDAT	Best Demonstrated Available Technology
CCTB	Clean Coal Technology By-Product
CFBC	Circulating Fluidized Bed Combuster
COR	Contracting Officer's Representative
EA	Environmental Assessment
EPC	Ebensburg Power Corporation
FBC	Fluidized Bed Combuster
LDR	Land Disposal Restrictions
METC	Morgantown Energy Technology Center
MSI	Mineral Solutions, Inc.
MSYP	Mill Service Yukon Plant
NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
PADEP	Pennsylvania Department of Environmental Protection
PC	Pulverized Coal
PFBC	Pressurized Fluidized Bed Combuster
PI	Principal Investigator
RCRA	Resource Conservation and Recovery Act
SEM	Scanning Electron Microscope
TCLP	Toxicity Characteristic Leaching Procedure
TOSCA	Toxic Substance and Control Act
TVA	Tennessee Valley Authority
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
UTS	Universal Treatment Standards
XRD	Xray Diffraction