PROCEEDINGS

FLUE GAS DESULFURIZATION BYPRODUCTS AT COAL MINES & RESPONSES TO THE NATIONAL ACADEMY OF SCIENCES

FINAL REPORT

"MANAGING COAL COMBUSTION RESIDUES IN MINES"

November 14-16, 2006

Edited by Kimery C. Vories and Anna Harrington

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Proceedings of

Flue Gas Desulfurization (FGD) By-Products at Coal Mines and Responses to the National Academy of Sciences Final Report “Managing Coal Combustion Residues in Mines”: A Technical Interactive Forum

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FOREWORD

In the United States, the beneficial use of Coal Combustion By-Products (CCBs) (i.e. fly ash, bottom ash, flue gas desulphurization material, and fluidized bed combustion material) in coal mines has become an area of intense interest, research, activity, and controversy for more than a decade. The Office of Surface Mining (OSM), universities, National Energy Technology Laboratory (NETL), and industrial research organizations have taken an active role in encouraging and promoting technological advances, research, and technology transfer related to the placement of CCBs at mines. Beneficial uses include: (1) a seal to contain acid forming materials and prevent the formation of acid mine drainage; (2) an agricultural supplement to create productive artificial soils on abandoned mine lands where native soils are not available; (3) a flowable fill that seals and stabilizes abandoned underground mines to prevent subsidence and the production of acid mine drainage; (4) a construction material for dams or other earth like materials where such materials are needed as a compact and durable base; and (5) a non-toxic, earthlike fill material for final pits and within the spoil area.

Extensive state regulatory authority water quality monitoring data and university research data indicates that the placement of these materials, under the permitting and performance standard requirements at a mine regulated under the Surface Mining Control and Reclamation Act (SMCRA), usually results in a beneficial impact to human health and the environment when it is used to mitigate other existing potential mining hazards. In the 29 years of SMCRA, there have been no proven Environmental Protection Agency (EPA) damage cases on SMCRA mines. State Regulatory Authority quarterly water monitoring data has not reported a single instance of damage to a drinking water supply or damage to a surface aquatic ecosystem.

The volume of CCB placement at SMCRA mines is generally controlled by economics. Current or foreseeable economics of CCB placement at mines is restricted to: (1) situations of low transportation costs (i.e. mine mouth power plants); (2) very small power plants that can not afford to develop their own Resource Conservation & Recovery Act (RCRA) solid waste landfill due to the low volume of material and then only if a coal mine is close enough so that transportation is affordable; (3) a unique beneficial application at the mine justifies additional transportation cost such as use of CCBs for road building or other construction material, encapsulation of acid forming materials, and subsidence control and mitigation of acid mine drainage. In the last two situations, the volume of CCBs placed at the mine represent less than 5% of the volume of coal removed. In the first or highest possible volume situation, the volume of CCBs placed at a mine mouth power plant may represent up to 25% of the coal removed. The American Coal Ash Association data show that for 2004, 122,465,119 tons of CCBs were produced. Mine placement used 1,692,313 tons. This means that only 1.38% of the CCBs produced are placed back at mines. The U.S. Department of Energy data show that for 2004, 1,112,100,000 tons of coal was mined. This means that CCBs placed at mines on a national basis in 2004 represent no more that 0.15% of the tons of coal removed.

Beginning in May of 1994, the Office of Surface Mining (OSM) has taken an active role in encouraging and promoting technological advances, research, and technology transfer related to the use and disposal of coal combustion by-products (CCBs) at mines. The primary activities and accomplishments of OSM in this area have been the establishment of a multi-interest group steering committee that has:

(1) conducted national technical interactive forums on:
  - "Coal Combustion By-Products Associated with Coal Mining" in October, 1996 at Southern Illinois University;
  - "The Use and Disposal of Coal Combustion By-Products at Coal Mines" in April, 2000 at the National Energy Technology Laboratory (NETL) in Morgantown, West Virginia;
  - "Coal Combustion By-Products and Western Coal Mines" in April, 2002 in Golden, Colorado;
  - "Office of Surface Mining Coal Combustion By-Product Government/Regulatory Panel: University of Kentucky International Ash Utilization Symposium" in October, 2003 in Lexington, Kentucky;
  - "State Regulation of CCB Placement at Mines Sites" in May, 2004 in Harrisburg, Pennsylvania;
  - "Regulation, Risk, and Reclamation with CCBs at Mines" in April, 2005 in Lexington, Kentucky;
  - And now "Flue Gas Desulfurization (FGD) By-Products at Coal Mines and Responses to the

National Academy of Sciences Final Report ‘Managing Coal Combustion Residues in Mines’ in November, 2006 in Columbus, Ohio.

(2) edited, published, and distributed thousands of copies of the forum proceedings;

(3) provided technical assistance to the American Society for Testing Methods (ASTM) on draft guidance for CCBs on mine sites; and

(4) developed and managed an Internet Website dedicated to providing a user friendly guide to CCB literature, organizations, EPA rule-making, and educational events.

The topics that will be explored at the 6th technical interactive forum on this issue will address: (1) the increasing amount of Flue Gas Desulfurization (FGD) By-Product that is being generated due to the increased utilization of scrubbers to remove SOx and NOx from utility air emissions and its potential for beneficial use at mines; (2) efforts to improve the predictability of leachate protocols for more accurate assessment of potential hydrologic impacts (3) a peer review by Coal Combustion By-Product (CCB) experts of the report by the National Academy of Science (NAS) on CCBs and mining; and (4) the impact of the NAS report on CCBs and its implications for rulemaking by the Environmental Protection Agency (EPA) that could impact Office of Surface Mining (OSM) and State coal mining programs.

Based on the results of the above efforts, OSM will assess the outcomes of the forum and other CCB activities and make recommendations for potential revisions to OSM policy or regulations and plan for enhancement of additional technology transfer events. I would like to sincerely thank the steering committee, invited speakers, and participants for their time and efforts in making this program a success.

Kimery C. Vories
CCB Steering Committee Chairperson

STEERING COMMITTEE MEMBERS

Kimery C. Vories (Forum Chairperson)
Mid-Continent Region
USDOI Office of Surface Mining

Dave Goss
American Coal Ash Association

Robert Bessette
Council of Industrial Boiler Owners

Dan Wheeler
Illinois Department of Commerce and Economic Opportunity
Office of Coal Development

Albert Dalberto
Pennsylvania Bureau of Mines and Reclamation

John Mead
Coal Research Center
Southern Illinois University Carbondale

Dr. Tarunjit S. Butalia
The Ohio State University

Sid Stroud
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USDOI Office of Surface Mining

Randall Mills
Mid Continent Region
USDOI Office of Surface Mining

Hendric G. van Oss
USGS Minerals Information Team

James Roewer
Utility Solid Waste Activities Group

Harold (Rocky) Parsons
West Virginia Department of Environmental Protection

COAL COMBUSTION BY-PRODUCTS STEERING COMMITTEE RECOMMENDATIONS

IMPROVEMENT SUGGESTIONS FOR FUTURE FORUMS

1. Review Power Point presentations prior to event as shown on a screen to determine appropriate colors are used for visibility on screen.
2. Need to include field guide in proceedings.
3. Consider possible ¼ day sessions rather than losing focus with less-related talks.
4. Advertise continuing education credits with SIUC.
5. Provide detailed guidance to speakers on ensuring professional, easily readable MS Power Point presentations.

FUTURE FORUM TOPICS

1. Continued use of focused field trip to energize the event.
2. Case studies on success stories.
3. Economics of placement options.
4. Movement of boron in leachate and spoil.

SPONSORS AND SUPPORTERS

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U.S. DOI, Office of Surface Mining
U.S. DOE, National Energy Technology Laboratory
American Coal Ash Association
American Electric Power
Midwest Coal Ash Association
TXU Service
Ohio Coal Association
Ohio Mined Land Partnership
The Ohio State University CCP Extension Program

FIELD TOUR

The Ohio State University
CCP Extension Program

PROCEEDINGS PRODUCTION & EDITING

U.S. DOI, Office of Surface Mining
Coal Research Center, Southern Illinois University Carbondale

In memory of
Dr. Mary Wilder Stoertz

March 6, 1957 - February 26, 2007

The Coal Combustion By-Products Steering Committee would like to pay tribute to a distinguished colleague who passed away within three months of presenting her excellent research findings in Session 1 at our forum entitled **Flue Gas Desulfurization (FGD) as an Impermeable Cap for Coal Waste.**

Born March 6, 1957, in Washington, D.C., she was the daughter of Cynthia Riggs and the late George E. Stoertz. She was raised in Anacostia (Washington D.C.) and began her geology career as a high school student with a glaciology internship at the Juneau Icefield in Alaska funded by the National Science Foundation. She attended the University of Washington where she majored in geology, receiving her B.S. degree in 1980. While an undergraduate, she conducted research on Mt. St. Helens and was also a member of the crew team which won the PAC-10 championship and placed second at the NCAA National Championship Regatta. Following a research project in Swedish Lapland, she entered graduate school at the University of Wisconsin where she received her M.S. and Ph.D. degrees in geology, working on the flow and recharge of groundwater systems. She began working at Ohio University in 1992 as a faculty member in the Department of Geological Sciences and dedicated her teaching, student mentoring, research and service to the restoration of streams and rivers in southeast Ohio, including reclamation of Rock Run gob pile using a flue gas desulfurization material cap.

She was active in numerous community organizations including the Hocking River Commission, the Sunday Creek Watershed Group, the Monday Creek Watershed Restoration Project, the Raccoon Creek Improvement Project, the Buckeye Forest Council, and the Athens Youth Hockey Association.

Mary Wilder Stoertz, 49, of Athens, passed away on February 26, 2007, at O'Bleness Memorial Hospital. She is survived by her husband Douglas H. Green, her mother Cynthia Riggs, sons Kevin and Duncan Green, brothers William, James, and Robert, and sister Ann.

RETIREMENT

Alfred Dalberto, who has been employed as an engineer for the Pennsylvania Department of Environmental Protection for 35 years, is retiring on June 22, 2007. He has been a long-time member of the OSM Coal Combustion By-Products Steering Committee and has been invaluable in assisting OSM in numerous initiatives related to CCB placement on mines, in addition to serving as session chair person on several technical forums. He has served as a member of the Coal Combustion By-Product Steering Committee since 2000.

He has worked in the Pennsylvania coal ash beneficial use at the mines program since 1994. In this capacity, he has helped develop regulations and technical guidance for coal ash use at mines. He has also reviewed coal ash beneficial use projects. He served as an author and on the editorial committee for the 2004 publication, “Coal Ash Beneficial Use in Mine Reclamation and Acid Mine Drainage Remediation in Pennsylvania.” Most recently his expertise was incorporated into the report for the U.S. EPA and the US Department of Energy on “Review of Pennsylvania Regulations, Standards, and Practices Related to the Use of Coal Combustion Products.”

The leadership, wisdom, professionalism, and statesmanship demonstrated by Mr. Dalberto has been a significant factor in the high level of quality public service found in the Pennsylvania mining and reclamation program for protecting the public and environment.

WELCOME

Mike Robinson
Appalachian Region
Office of Surface Mining

Good morning and welcome to the sixth in a series of OSM sponsored Technical Interactive Forums on the Placement of Coal Combustion By-Products at Coal Mines. It is indeed a pleasure to be here today at the beginning of two days of discussion and information-sharing on this important environmental topic. I am glad that so many people from so many parts of the country are participating, from all levels of government, industry, universities, and the general public. This is an excellent opportunity for communicating problems, solutions, and concerns related to placement of Coal Combustion By-Products at mine sites.

The goal of the first two forums in 1996 and 2000 was to establish a national state of the art on CCB placement at coal mine sites. The 3rd forum in 2002 was designed to look at the issue from the perspective of the semi-arid Western U.S. The 4th forum in 2004 focused on: (1) mines where State Mining Programs are the primary regulator; (2) the unique application of Fluidized Bed Combustion Ash, produced from recycling waste coal into electrical energy, and then beneficially applying it to the remediation of acid mine drainage and the reclamation of abandoned mines; and (3) on proven environmental damage cases, how they happened and what we should do to avoid them in the future. The 5th forum focused on coal mine application case studies with detailed hydrologic data and the evaluation of leachate protocols and their applicability to coal mining operations. The current forum will address: (1) the increasing amount of Flue Gas Desulfurization (FGD) By-Product that is being generated due to the increased utilization of scrubbers to remove SOx and NOx from utility air emissions and its potential for beneficial uses at mines; (2) efforts to improve the predictability of leachate protocols for more accurate assessment of potential hydrologic impacts (3) a peer review by Coal Combustion By-Product (CCB) experts of the report by the National Academy of Science (NAS) on CCBs and mining; and (4) the impact of the report on CCBs by the NAS and its implications for rulemaking by the Environmental Protection Agency (EPA), the Office of Surface Mining (OSM), and State coal mining programs.

We are already off to a very good start after that excellent field tour yesterday where you were able to visit: (1) a power plant equipped with FGD systems and an associated FGD landfill; (2) a coal preparation plant where FGD material is being used as: a) an alkaline amendment and final cover material in the coal refuse disposal area; and b) a mine seal and structural fill material to reclaim an AML highwall; (3) a State wildlife area with an FGD mine seal project and an FGD parking lot base project.

Dr. Tarunjit Butalia and his associates at The Ohio State University CCP extension program have been absolutely tireless in making sure that the field trip has been very successful. We would like to express our appreciation to American Electric Power at the Conesville Plant for hosting much of our field tour. They have shown us real world applications that most of us would not otherwise experience.

I would like to commend the support and commitment of our cosponsors The Ohio State University, American Coal Ash Association, American Electric Power, Midwest Coal Ash Association, TXU, Ohio Coal Development Office, Ohio Coal Association, and the Ohio Mineland Partnership whose sponsorship support has been essential in ensuring that we can provide all of the ingredients for a quality experience.

I would also like to thank the CCB Steering Committee who have been working hard to organize this event since June of 2005. They include:

- Dave Goss of the American Coal Ash Association
- Robert Bessette of the Council of Industrial Boiler Owners
- Dan Wheeler of the Illinois Department of Commerce & Economic Opportunity, Office of Coal Development
- John Mead of the Coal Research Center at Southern Illinois University
- Dr. Tarunjit Butalia of The Ohio State University
- Alfred Dalberto of the Pennsylvania Bureau of Mining and Reclamation

- Sid Stroud with TXU
- Debra Pflughoeft-Hassett with the University of North Dakota Energy & Environmental Research Center
- Bill Aljoe with the National Energy Technology Laboratory
- Jim Roewer with the Utility Solid Waste Activity Group
- Hendric van Oss with the USGS Minerals Information Team
- Rocky Parsons of the West Virginia Department of Environmental Protection
- Jackie Bird of the Ohio Coal Development Office
- and the staff of OSM Brenda Steele, Peter Michael, Randall Mills, and Kimery Vories

Please feel free to contact any of the steering committee with questions or concerns about this or future events.

It is always true that the more we know, the more options we have. I am optimistic that constructive dialogues, such as those held here, will lead to a better understanding of the benefits and risks involved with the beneficial placement of coal combustion by-products at coal mines.

I commend all the forum participants for being part of this valuable information exchange. The public and the coalfield residents can only benefit from the information that is shared and the knowledge that is gained at this event. I thank you for applying your minds to the task and I wish you success in your efforts on behalf of the coalfield environment.

WHAT IS A TECHNICAL INTERACTIVE FORUM?

Kimery C. Vories
USDOI Office of Surface Mining
Alton, Illinois

I would like to set the stage for what our expectations should be for this event. This is the sixth in a series of technical interactive forums co-sponsored by OSM on aspects of Coal Combustion By-Product (CCB) placement at mine sites. Copies of these earlier forums are available on OSM's technology transfer CD and at the CCB Information Network Website at www.mcrcc.osmre.gov/ccb.

The steering committee has worked hard to provide you with the opportunity for a free, frank, and open discussion on the state of the art in CCB placement at mine sites that is both professional and productive.

Our rationale for the format of the technical interactive forum is that, unlike other professional symposia, we measure the success of the event on the ability of the participants to question, comment, challenge, and provide information in addition to that provided by the speakers. We anticipate that, by the end of the event, a consensus will emerge concerning the topics presented and discussed and that the final proceedings will truly represent the state of the art in placement of flue gas desulfurization materials in mines and merits of the national academy of science report on CCB placement in mines.

During the course of these discussions we have the opportunity to talk about technical, regional, and local issues, while examining new and existing methods for finding solutions, identifying problems, and resolving controversies. The forum gives us the opportunity to:

- share our experiences and expertise concerning CCB placement at mines,
- outline our reasons for taking specific actions, and
- give a rationale for our actions concerning testing, permitting, water monitoring, material handling, reclamation, and protection of the environment concerning CCB placement at mines.

A basic assumption of the interactive forum is that no person present has all the answers or understands all of the issues. It is also assumed that some of these issues, solutions, and concerns may be very site, region, or CCB type specific.

The purpose of the forum is to:

- present you with the best possible ideas and knowledge during each of the sessions, and
- promote the opportunity for questions and discussion by you, the participants.

The format of the forum strives to improve the efficiency of the discussion by:

- providing a copy of the abstract and biography for each speaker that you may want to read before hand in order to improve your familiarity with the subject matter and the background of the speaker;
- recording the talks and discussions for later inclusion in the post forum publication so that you do not have to worry about taking notes. For this reason, we will require that all participants speak into a microphone during the discussions;
- In order for us to make the most efficient use of time, and ensure that you, the participants, have the opportunity to provide questions and comments, we require our session chairpersons to strictly keep to the time schedule;
- A ***green light*** will be displayed at the beginning of the talk. A ***yellow light*** will be displayed for the last 5 minutes of the talk. A ***dim red light*** will be displayed for 30 seconds followed by a ***blinking red light*** that will signal that the talk is over and the speaker has 5 minutes for questions.
- In the post forum publication, issues raised during the discussions will be organized based on similar topic areas and will not identify individual names. OSM will mail all registrants a copy of the proceeding. This publication will be very similar to the proceedings of earlier forums conducted by OSM and are available for your viewing at the OSM exhibit.

It is important to remember that there are four separate opportunities for you, the participants, to be heard:

- Five minutes will be provided for questions at the end of each speaker's talk;
- 25 plus minutes of participant discussion is provided at the end of each topic session. The chairperson will recognize each participant that wishes to speak and they will be requested to identify themselves and speak into one of the portable microphones so that everyone can hear the question;
- At the end of the forum, we will conduct an open discussion on where we should go from here; and
- A yellow forum evaluation form has been provided in your folder. This will help us to evaluate how well we did our job and recommend improvements for future forums or workshops. Please take the time to fill out the yellow evaluation form as the forum progresses and provide any additional comments or ideas. These should be turned in at the registration desk at the end of the forum.

One of the reasons for providing refreshments during the breaks and lunch is to keep people from wandering off and missing the next session. In addition, the breaks and lunch provide a better atmosphere and opportunity for you to meet with and discuss concerns with the speakers or other participants. Please take advantage of the opportunity at break time to visit the exhibits and posters in the break area. When the meeting adjourns today, all participants are invited to a social reception where refreshments will be provided.

Finally, the steering committee and I would like to thank all of the speakers who have been so gracious to help us with this effort and whose only reward has been the virtue of the effort. I would also like to thank each of you, the participants, for your willingness to participate and work with us on this important issue. Thank you.

Session 1

FGD PLACEMENT AT MINES

Session Chairperson:
Dr. Tarunjit Butalia
The Ohio State University
Columbus, Ohio

An Overview of FGD By-Product Characteristics, Production, and Use: Prognosis for Mine Placement
William W. Aljoe[1.], Charles E. Miller[1.], Thomas J. Feeley, III[1.], Andrea T. McNemar[2.], Andrew P. Jones[2.], and James T. Murphy[2.], [1.] U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, Pennsylvania and [2.] Science Applications International Corporation

FGD as an Impermeable Cap for Coal Waste
Mary W. Stoertz[1], Mitchell E. Farley[2], Brian Bullock[3], Pearl Pereira[4] and Brett Laverty[5], [1]Department of Geological Sciences, Ohio University, Athens, Ohio*
[2]Ohio DNR, Division of Mineral Resources Management, Jackson, Ohio
[3]Former OU student, now with Apache Corp., Houston, Texas
[4]Former OU student, now with Camp Dresser & McKee, California
[5]Former OU student, now with Vinton County SWCD, Ohio

FGD as an Alkaline Amendment for Coal Waste
Dennis Noll, Earthtech Inc., Johnstown, Pennsylvania

Flue Gas Desulfurization (FGD) Product as a Soil Amendment for Mine Reclamation
Dr. Warren A. Dick, The Ohio State University, Wooster, Ohio

Groundwater Effects of Coal Combustion By-Product Placement in Coal Mines
Dr. Paul Ziemkiewicz, National Mine Land Reclamation Center, West Virginia University, Morgantown, West Virginia

FGD for Highwall Reclamation
Barry Thacker, P.E., Geo/Environmental Associates, Inc., Knoxville, Tennessee and Ted Morrow, American Electric Power Service Corporation, Columbus, Ohio

AN OVERVIEW OF FGD BY-PRODUCT CHARACTERISTICS, PRODUCTION, AND USE: PROGNOSIS FOR MINE PLACEMENT

William W. Aljoe[1], Charles E. Miller[1], Thomas J. Feeley, III[1],
Andrea T. McNemar[2], Andrew P. Jones[2], and James T. Murphy[2]
[1] U.S. Department of Energy, National Energy Technology Laboratory
[2] Science Applications International Corporation

View Presentation

Abstract

This paper provides an overview of the different types of flue gas desulfurization (FGD) processes currently in use at coal-fired power generating facilities, with an emphasis on the differences in the characteristics of the solid by-products that result from these processes. Wet FGD systems produce by-products whose characteristics depend on the degree of oxidation occurring within the system; for example, systems with little oxidation produce calcium sulfite sludges that do not dewater easily and must be stabilized, usually with a combination of fly ash and lime, before disposal or beneficial use takes place. Highly-oxidizing FGD systems produce calcium sulfates (FGD gypsum) that dewater more readily and are more suitable for direct disposal or re-use. Dry FGD systems and fluidized bed combustion systems produce relatively inseparable mixtures of fly ash and FGD by-products whose characteristics depend on both the coal being used and the other variables associated with the desulfurization processes. The inherent characteristics of the solid by-products determine the recycling markets for which they are best suited, and, in turn, affect the extent to which these by-products will become available for placement at mine sites. From a by-product producer's perspective, it is reasonable to assume that mine placement of FGD by-products will continue to represent a relatively low-value re-use market compared to "preferred" markets such as wallboard (for FGD gypsum), structural fills, and as a feedstock for various manufacturing processes. However, FGD by-product production at electric utilities is likely to increase substantially in the near future in response to recent air pollution control regulations. Moreover, in cases where the FGD system is used as a means of mercury removal from the power plant flue gas, some of the "preferred" re-use markets for the FGD by-products may be challenged by the negative perceptions associated with the presence of mercury. The ever-increasing cost of disposing of FGD by-products in dedicated landfills and surface impoundments makes it imperative that a wide variety of re-use alternatives, including mine placement, be evaluated and developed to the greatest extent possible. It is therefore important that the "recipients" of these by-products – the mine sites – become familiar with the types and characteristics of the materials they receive, and work with the material suppliers to achieve a placement scenario that benefits all parties.

Introduction

Coal-fired electric power generating facilities employ a variety of combustion systems and flue gas treatment configurations. The exact configuration at a given plant depends on a wide range of factors including coal characteristics, availability of water, the type and amount of air pollutant control required, etc. Each piece of equipment used for power generation and/or air pollution control will affect the characteristics of the solid by-products produced by that piece of equipment, and may affect the by-products of all other downstream components of the system. Devices whose primary purpose is flue gas desulfurization (FGD) can be located at various points within the combustion/flue gas treatment train. This paper will help to explain how the combustion system and the location of the FGD system within the treatment train affect the by-product characteristics, how mine placement of FGD by-products may be impacted by the specific characteristics of these materials, and how the volumes and characteristics of FGD by-products may change as new air pollution control regulations are implemented at coal-fired power plants.

Effect of Flue Gas Desulfurization Technology on FGD By-Product Characteristics

The basic FGD process involves spraying an alkaline reagent into the combustion flue gas to react with SO_2 and water to form a precipitated salt by-product. The by-product can be filtered from the system and either disposed in landfills or recycled for beneficial use. Lime or limestone is typically used as the reagent; although sodium-based reagents can also be used for FGD, they are used by only a few U.S. power plants. Depending on the type of FGD process, the predominant by-product is calcium sulfite, hydrated calcium sulfate (gypsum), non-hydrated calcium sulfate (anhydrite), or some mixture of the three salts. Unused alkaline reagent in varying amounts can also be carried through to the by-product stream. The FGD process can be further classified as either wet or dry, depending on the amount of water used to spray the reagent into the flue gas. Fluidized bed combustion (FBC), which involves the combustion of coal in the direct presence of limestone, can also be viewed as a type of “FGD system” because it captures SO_2 within the combustion device itself. The following sections describe the basic elements of each type of FGD system and discuss the impacts these systems have on the overall characteristics of the solid by-products.

Wet FGD Systems

Data provided by the American Coal Ash Association (ACAA)[1] shows that over 90% of all the FGD by-products generated in the U.S. in 2005 came from wet FGD systems. They are especially preferred at facilities that burn high-sulfur coals where high-efficiency SO_2 removal is required. The capital cost of wet FGD systems is quite high at \$172/kW[2], but SO_2 removal efficiencies are typically greater than 95%. Figure 1 illustrates a typical wet FGD system consisting of a set of “absorber” vessels located downstream of the primary particulate removal device, usually an electrostatic precipitator (ESP) or fabric filter (baghouse). In such a configuration, the FGD by-product comprises only the salts formed by the FGD reaction, along with some reagent carryover and water.

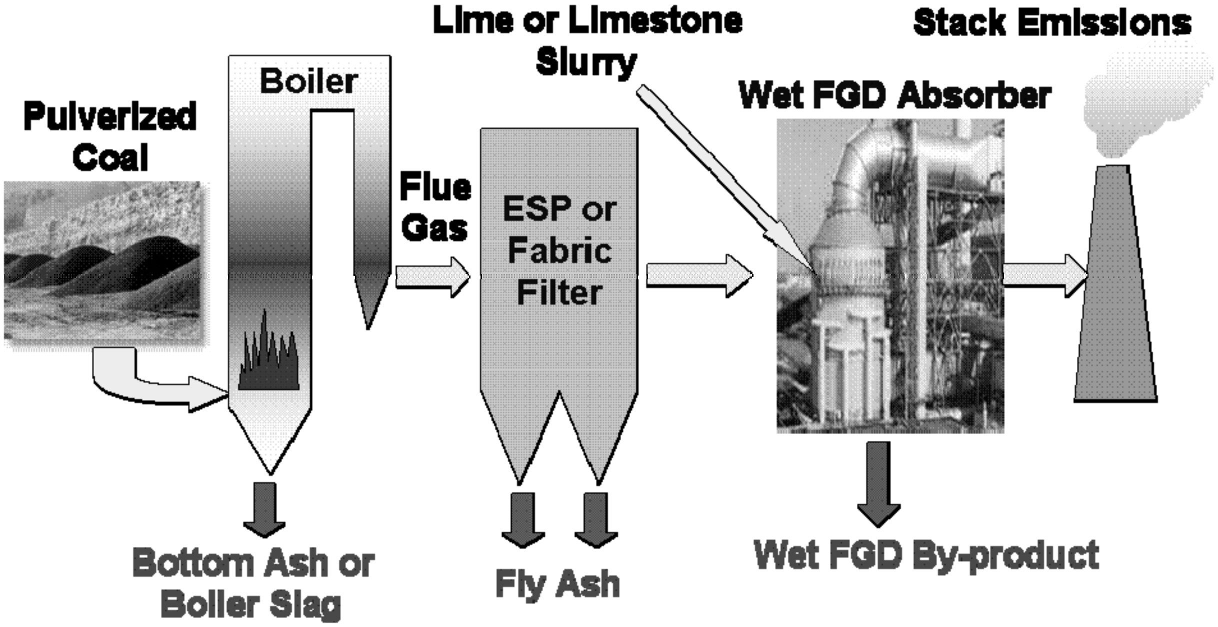

Figure 1. Typical wet FGD system configuration.

The type of salt formed by the SO_2 conversion reaction depends on the degree of oxidation introduced into the FGD system. Gypsum ($CaSO_4 \cdot 2H_2O$) is formed when oxidation is enhanced (Figure 2a), while calcium sulfite ($CaSO_3 \cdot \frac{1}{2} H_2O$) is the dominant salt when oxidation is inhibited (Figure 2b). Oxidation to produce FGD gypsum can be achieved either by introducing excess air into the absorber vessel or employing an external oxidation tank (see Figure 2a). Most modern wet FGD systems are designed to produce gypsum because it can be recycled more easily than calcium sulfite. Moreover, FGD gypsum has an advantage in disposal scenarios because it can be dewatered more easily than calcium sulfite, and does not require stabilization or “fixation” before it is disposed or re-used. Figure 2b shows that the typical method of stabilizing calcium sulfite is to mix it with fly ash and lime. If it were not stabilized, the calcium sulfite would have the consistency of toothpaste and would tend to liquefy when being handled prior to disposal.

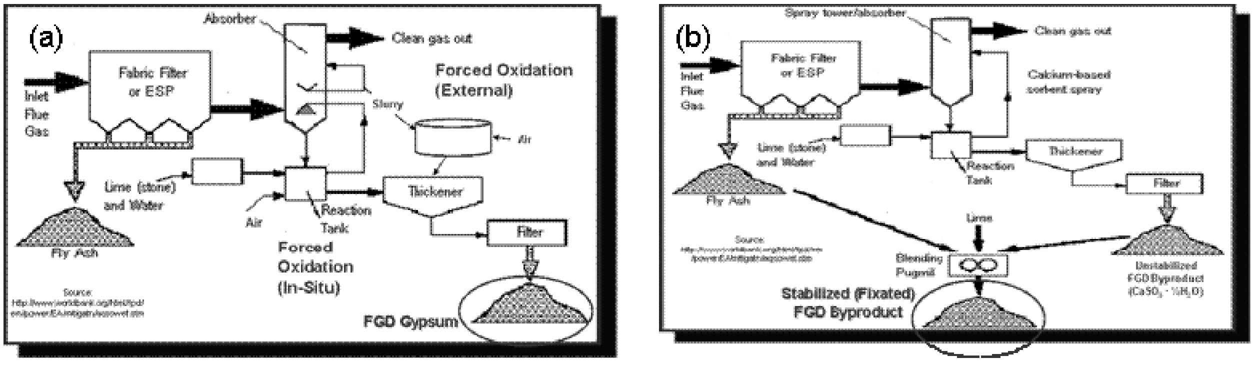

Figure 2. Wet FGD by-product types: (a) FGD gypsum; (b) stabilized calcium sulfite. Illus. c/o World Bank - Wet flue gas desulfurization, www.worldbank.org/html/fpd/em/power/EA/mitigatn/aqsowet.stm.

FGD gypsum is used most commonly as a raw material for the manufacture of wallboard, and it can also be readily re-used as an agricultural supplement or in the manufacture of cement. In fact, ACAA data (Figure 3) show that over 75% of the FGD gypsum produced in 2005 was recycled in some manner. Conversely, calcium sulfite-based by-products currently have very few re-use applications; ACAA data show that less than 5% of "other" wet FGD by-products were beneficially re-used in 2005. In addition, the need to use fly ash from the plant to stabilize the calcium sulfite prevents the fly ash from being sold for more lucrative purposes such as a replacement for Portland cement.

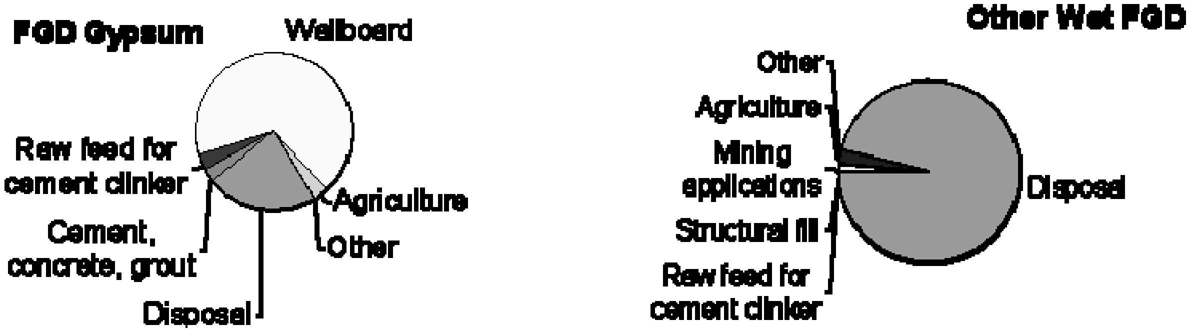

Figure 3. Use and disposal of wet FGD by-products (ACAA 2005).

It is worth noting that some older power plants still employ "particulate scrubbers," which do not involve ESPs or fabric filters. Instead, the alkaline slurry is added to the flue gas through venturi orifices, which simultaneously reduces SO_2 via absorption and removes particulates via water impingement. The solid by-products from particulate scrubbers are therefore inseparable mixtures of fly ash, SO_2 reaction salts, and unused alkaline reagent; as with stabilized calcium sulfite by-products, few re-use markets currently exist for these mixtures. Since particulate scrubbers are not as efficient as ESPs or fabric filters in terms of particulate removal, they are not used at newer power plants, and it is doubtful that FGD by-products from these units will increase significantly in the future. However, plants with particulate scrubbers may continue to operate for years to come, so some demand for by-product disposal capacity, and potentially mine placement, will still exist.

Dry FGD Systems

The term "dry" is somewhat of a misnomer when applied to FGD systems. Although the by-products are "dry," the FGD system does require water. The most common type of dry FGD system, called a spray dryer, introduces the alkaline reagent as a slurry. Enough water is applied to cool the flue gas and distribute the reagent across the flue gas duct. Essentially all the water in the slurry evaporates during this process, leaving by-products that do not have to be dewatered prior to re-use or disposal. Another key difference between wet and dry FGD systems is that the SO_2 absorber vessel in a spray dryer is located upstream rather than downstream of the particulate removal device (Figure 4). This allows a single ESP or fabric filter to remove both the fly ash and the salts (most commonly calcium sulfite) formed by the lime-SO_2 reaction. This design minimizes the overall capital cost of the FGD system and eliminates the need to re-mix the calcium sulfite with fly ash and lime for stabilization prior to re-use or disposal. However, it also precludes the formation of FGD gypsum, and produces an inseparable mixture of fly ash, reaction salts, and unused reagent. As with stabilized calcium sulfite by-products from wet FGD systems, the types and volumes of beneficial re-use markets available for dry FGD by-products are somewhat limited.

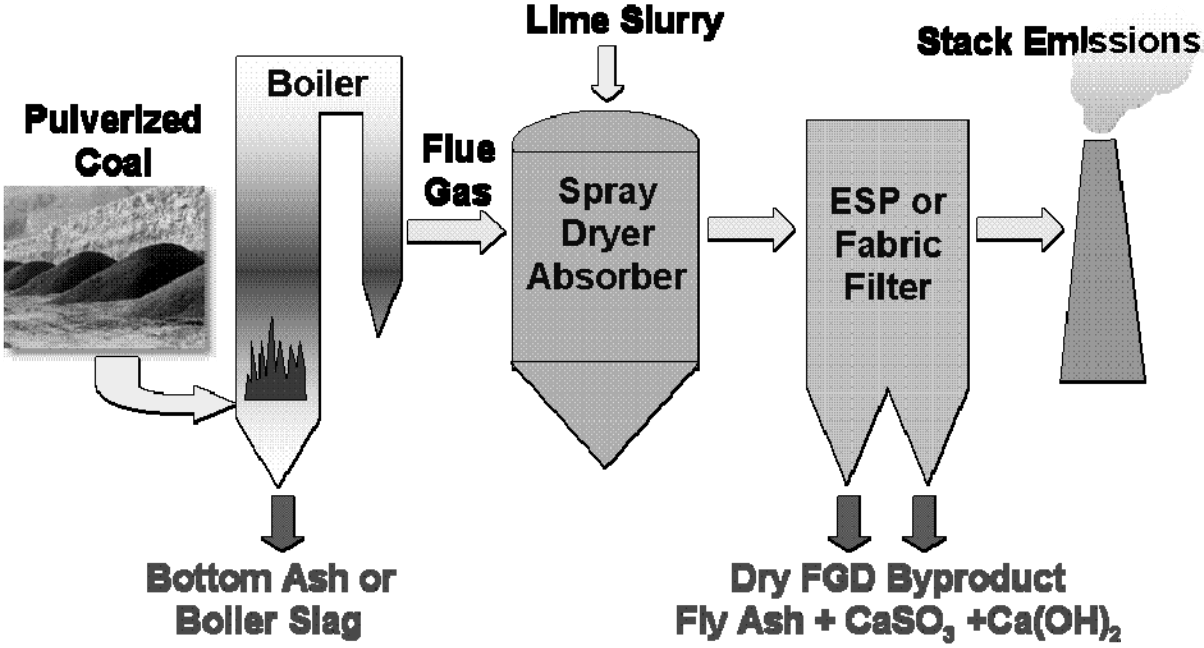

Figure 4. Typical by-products from dry FGD (Spray Dryer) systems.

The inherent characteristics of dry FGD by-products may be a disadvantage in terms of the variety of recycling options, but these characteristics may not inhibit the ability to use the materials for mine placement. For example, ACAA data (Figure 5) show that only about 11% of dry FGD by-products generated during 2005 were beneficially re-used. However, of the approximately 159,000 tons that were beneficially re-used, 112,000 tons (about 70%) were re-used in mining applications.

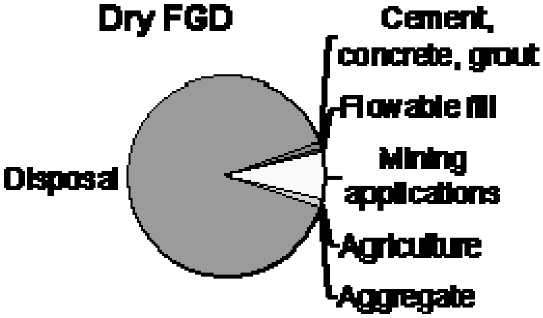

Figure 5. Use and disposal of dry FGD by-Products (ACAA 2005).

One characteristic of dry FGD by-products that may make them desirable for mining applications is the presence of unused alkaline sorbent (hydrated lime) in the by-product mixture. Although this represents an inefficiency in terms of the SO_2 removal system (maximum efficiencies of lime spray dryer systems are typically about 90% compared to >95% for wet FGD), the free lime may be viewed as useful for mitigating the natural acidity that often characterizes mine sites. Experience with dry FGD products has also shown that they can perform reasonably well as low-strength structural fill materials when properly conditioned (via water addition), placed, and compacted. However, testing of the material should be conducted prior to placement in a fill to ensure that delayed swelling and expansion of the material will not occur over time due to latent formation of ettringite.[3] As long as proper testing and placement procedures are followed, it is reasonable to expect that mine placement of dry FGD by-products will continue to be a significant re-use option for the foreseeable future.

Fluidized Bed Combustion Systems

Fluidized bed combustion (FBC) at coal power plants involves the turbulent mixing of gas and solids – both coal and injected powdered limestone – suspended as a bed above a grate by upward-blowing jets of air during the combustion process (Figure 6). The tumbling action, much like a bubbling fluid, provides effective chemical reactions and heat transfer. The coal is burned at temperatures of 1,400 to 1,700 degrees F, well below the threshold where nitrogen oxides form (at approximately 2,500 degrees F). The mixing action of the fluidized bed also brings the flue gases into intimate contact with the limestone particles, resulting in removal of up to 95 percent of the sulfur dioxide produced by the combustion process. The solid by-products are removed from the system either as "bed ash" from the bottom of the combustor or as fly ash from the downstream ESP or fabric filter. The bed ash and fly ash from FBC systems are often very similar in chemical composition, but the fly ash usually has a finer size composition. In some cases the bed ash and fly ash are mixed and managed together as a single by-product stream.

Like other dry FGD by-products, FBC by-products are inseparable mixtures of ash, reaction salts (calcium sulfite and sulfate), and unreacted sorbent (limestone). However, one potentially important difference between dry FGD by-products and FBC by-products is the ash component of the by-product mixture. Due to the inherent fuel flexibility of FBC technology, almost any combustible material, from coal to municipal waste, can be burned. For example, FBC systems have become extremely popular for burning low-BTU coal refuse from acid-producing abandoned mine sites, with the FBC by-products returned to the mine site as an alkaline amendment material. This win-win situation, wherein the power plant gets a cheap fuel while the mine site gets "free" alkaline materials for reclamation, has resulted in substantial mine placement of FBC by-products in states such as Pennsylvania, where abandoned coal refuse sites are plentiful. An association of independent power producers in that region (ARIPPA) estimates that upwards of 5 million tons of FBC ash annually are placed at mine sites in Pennsylvania and West Virginia.[4]

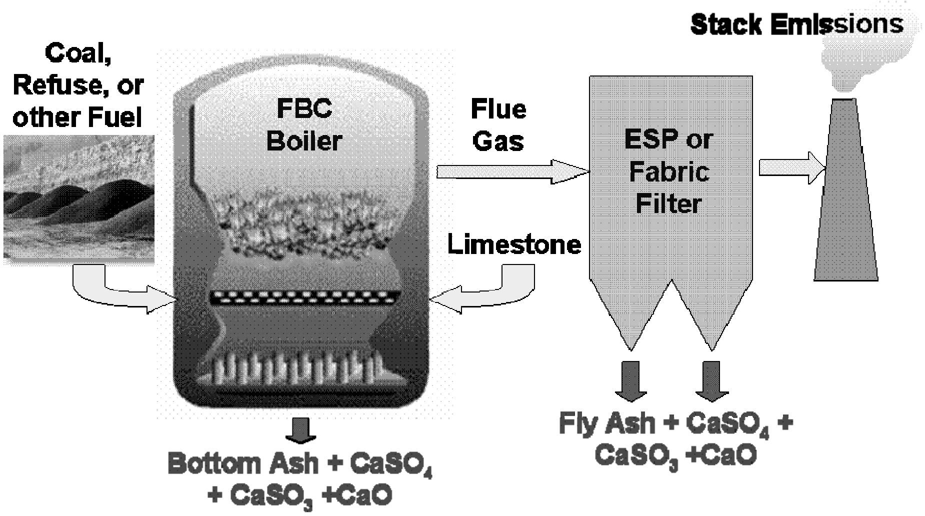

Figure 6. By-products from fluidized bed combustion (FBC) systems.

The ability to burn "high-ash" fuels in FBC boilers can result in by-products that are proportionally much higher in ash content (as opposed to reaction salts and unreacted sorbent) compared to other dry FGD by-products. This can make FBC ashes suitable for a wider variety of re-use applications than dry FGD by-products; indeed, data compiled by the ACAA (Figure 7) show that almost 70% of the FBC by-products generated in 2005 were beneficially re-used in applications such as flowable fills, structural fills, road bases, soil modification, and waste stabilization.

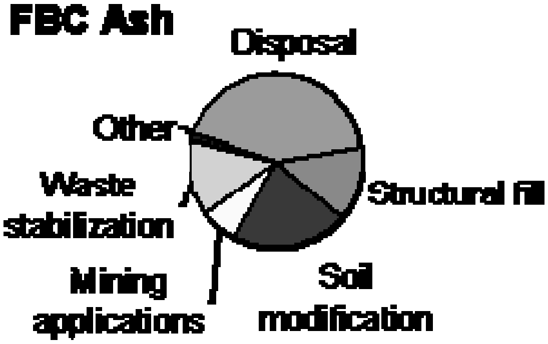

Figure 7. Use and disposal of FBC by-products (ACAA 2005).

From the perspective of mine placement, it is interesting to note that in the years prior to 2005, "Mining Applications" was listed by ACAA as the single largest use category of FBC by-products. Given that the haulback of alkaline FBC ashes to mine refuse sites has become a relatively common practice, it is possible that the wide range of beneficial uses depicted in Figure 7 may actually reflect mine site utilization, i.e., respondents to ACAA's 2005 survey may have reported the specific uses of the material at mine sites (e.g., soil modification, waste stabilization) more diligently than in prior years. It should also be noted that the chart in Figure 7 does not include the millions of tons of FBC ash placed at mine sites by ARIPPA members.

It should be noted that the wide variety of potential fuel feedstocks to the FBC boiler may potentially result in undesirable variations or unwanted components in the by-product mixture. For example, environmental agencies often express concern over the "trace metals" that may be present in, and potentially leach from, FGD by-products. Since the only by-products resulting from the FGD process itself are reaction salts and unreacted sorbent, it is clear that any trace metals in FGD by-products must originate in the fly ash portion of the by-product mixture. Therefore, FGD by-products with higher ash content, like FBC ashes, are likely to have higher inherent concentrations of trace metals than those with lower ash content, like FGD gypsum. Conversely, the trace metal concentrations of the FBC ash are likely to be much lower than those of the coal refuse it is replacing in a haulback application, and the alkaline character of the FBC ash is more likely to inhibit trace metal solubility. In general, the mineral composition of the FBC by-products should be characterized thoroughly prior to implementing any re-use strategy, and the potential beneficial effect of replacing acidic mine refuse with alkaline FBC ash should be considered when evaluating mine placement options.

Another potentially important difference between FBC by-products and dry FGD by-products is the nature of the unreacted sorbent and reaction salt. Because spray dryers use hydrated lime ($Ca(OH)_2$) as the SO_2 sorbent, and the reaction takes place at relatively low temperatures (300-600 degrees F), the unreacted sorbent in the by-product mixture is likely to be hydrated lime. With FBC systems, however, the SO_2 absorption reaction takes place at much higher temperatures, which could result in some of the limestone being calcined into quicklime (CaO), and some of the salt by-product being converted into anhydrite ($CaSO_4$). Also, unreacted sorbent in the FBC byproduct will be limestone rather than hydrated lime. FBC by-products may therefore behave differently than other dry FGD by-products in specific re-use applications, or when being conditioned with water prior to placement or re-use. Again, it is important that the by-products be characterized thoroughly for their alkaline content prior to implementing any re-use strategy.

Future Trends in FGD By-Product Production, Characteristics, and Mine Placement

Currently about 100 GW of coal-fired power plant capacity in the United States is equipped with FGD technology. It is anticipated that in response to the SO_2 emission limits under the Clean Air Interstate Rule (CAIR) and the co-benefit removal of mercury driven by the Clean Air Mercury Rule (CAMR), many coal-fired power plants will install FGD systems over the next 10 years. While CAIR is likely to affect only the quantity of FGD by-products generated, and not their chemical characteristics, CAMR may affect both the quantity and chemical composition of the FGD by-product materials. The following sections discuss the potential effects of these two Federal regulations on FGD by-products.

Effect of Clean Air Interstate Rule (CAIR)

CAIR requires a 44% reduction in SO_2 emissions by 2010 and a 56% reduction by 2015. Total FGD capacity is projected by the EPA to increase to 231 GW by 2020.[5] As shown in Figure 8, the total volume of FGD by-products may increase to over 80 million tons per year by that time.[6] Based on previous Integrated Planning Model (IPM) runs conducted for the proposed CAIR rule, EPA projected that dry FGD capacity would increase from 10 GW to 21 GW by 2015 with the balance of new and retrofitted FGD being wet systems. Therefore, even though the annual production of dry FGD by-products may be expected to more than double by 2020, wet FGD by-products will continue to comprise over 90% of the total FGD by-product stream.

Despite the fact that FGD gypsum will be almost exclusively the by-product of choice for new wet FGD installations, and older systems will continue to be converted to produce gypsum rather than calcium sulfite, it is likely that calcium sulfite by-products will continue to be generated in substantial quantities in the foreseeable future. In fact, ACAA data show that in 2005, over 17 million tons of "other" wet FGD by-products were generated compared to less than 12 million tons of FGD gypsum. Many of the sulfite-producing FGD systems are installed on large, base-load power producing facilities that cannot be retired without causing power supply disruptions; also, conversion of a system to produce FGD gypsum is expensive and may not be economical unless a large portion of the investment can be recovered via the sale of gypsum and fly ash.

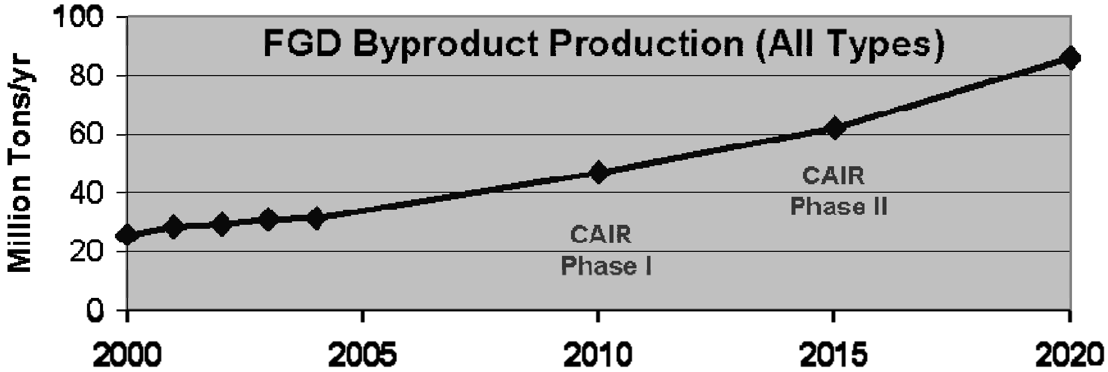

Figure 8. Projected increases in FGD by-product production.

These trends have significant implications in terms of the future demand for mine placement of wet FGD by-products. For example, plants producing FGD gypsum will pursue mine placement only after all other options for re-use in existing, higher-value markets have been exhausted. Although mines may purchase FGD gypsum as an agricultural supplement for reclamation and soil-conditioning purposes, the quantity of FGD gypsum used in this manner at any given mine site will be limited. In addition, questions have been raised about the suitability of FGD gypsum as a bulk fill material at mine sites and elsewhere; there is some concern that the relatively high solubility of gypsum could cause unpredictable subsurface dissolution of the material and consequent long-term loss of structural integrity of the fill.[7] Conversely, when properly stabilized, and enhanced via extra lime addition, calcium sulfite by-products have been shown to perform reasonably well as low-strength structural fill materials, and would be suitable for mine placement in most cases. Current trends suggest that steady production volumes of calcium sulfite by-products will persist; therefore, if public resistance to (and consequent expense of) new landfill capacity continues to increase, and high-value re-use markets for calcium sulfite by-products are not developed, plants producing these by-products may increasingly view mine placement as a desirable management alternative. To the extent that existing re-use markets cannot handle the rapidly increasing volumes of FGD gypsum, demand for mine placement of "excess" FGD gypsum may increase as well.

The only potential change to the chemical composition of FGD by-products resulting from the implementation of CAIR will be the possible presence of ammonia. Many utilities will install Selective Catalytic Reduction (SCR) or Selective Non-Catalytic Reduction (SNCR) systems as a means of controlling NOx emissions as required by CAIR. In both SCR and SNCR systems, urea or anhydrous ammonia is injected into either the boiler or the flue gas at the boiler exit to serve as a reactant in the NOx reduction process. In practice, it is very difficult to avoid the presence of excess reactant in the form of ammonia or ammonium salts (commonly called "ammonia slip") in the downstream flue gas. Since ammonia is highly soluble, and its salts are easily removed by the particulate collection device, the presence of ammonia in the solid by-products of wet FGD systems should not be a significant problem unless ammonia-bearing fly ash is subsequently mixed with calcium sulfite during the stabilization process. However, if SCR or SNCR is installed on a boiler with a dry FGD system, the amount of ammonia in the spray dryer by-product could be significantly higher than if the SCR or SNCR were not present. If the by-product is subsequently wetted in a high-pH environment, as will be the case if significant amounts of unreacted lime are also present, ammonia gas could be released from the by-product. This could cause significant discomfort for workers who must handle the spray dryer by-product in disposal, mine placement, or other re-use settings. Such problems can often be avoided if all parties are aware of the situation and make efforts to minimize the potential for ammonia release; however, recipients of dry FGD by-products should be aware of this potential, especially in new SCR or SNCR installations where operating personnel may not have sufficient experience in dealing with the problem.

Effect Of Clean Air Mercury Rule (CAMR)

CAMR seeks to reduce air emissions of mercury from coal-fired electric utilities from the current levels of about 48 tons per year to 15 tons per year by the year 2018. Assuming that the use of coal for electric power will continue, and that the mercury will not be removed from the coal prior to combustion, virtually all mercury removed from the flue gas will report to the solid by-products. Current estimates suggest that the annual coal combustion by-product stream (bottom ash, fly ash, and FGD by-products combined) will contain about 52 tons more mercury than it does today. Since mercury concentrations in existing by-products are quite low, and the by-product volumes are large, the "average" concentrations of mercury in the by-product materials are not expected to increase dramatically. However, there is understandable concern over whether the concentrations of mercury in specific types of by-products will increase at levels that exceed the "average, "and whether the captured mercury will be re-released from the by-products into the environment. In order to understand the potential effects of CAMR on the volume and characteristics of FGD by-products, it is necessary to examine how mercury gets into the by-products today, and how the situation is likely to change after CAMR is implemented.

Mercury is present in the flue gas of coal-fired power plants in varying percentages of three general forms: particulate-bound mercury, oxidized mercury (primarily mercuric chloride – $HgCl_2$), and elemental mercury. Previous testing has demonstrated that elemental mercury is not readily captured by any existing air pollution control device; conversely, particulate-bound mercury is captured efficiently by ESPs and fabric filters, while oxidized mercury is water-soluble and therefore readily captured in wet FGD systems. Consequently, the mercury capture efficiency of wet FGD systems, and the resulting mercury content of the FGD by-products, depend largely on the fraction of oxidized mercury at the FGD inlet. In cases where most or all of the mercury is in the oxidized form, and sufficient chlorine is present in the flue gas to form $HgCl_2$, over 90% of the Hg at the flue gas inlet can report to the FGD by-products; therefore, the "effect of CAMR" on these FGD by-products will be negligible.

Conversely, the Hg capture efficiency of the FGD system can be near zero if almost all the Hg at the FGD inlet is in the elemental form. Also, in some wet FGD systems, significant conversion of Hg from the oxidized to the elemental form, and subsequent release though the stack, has been observed. The effect of CAMR on FGD by-products will therefore depend largely on how much mercury is currently in the by-products, along with the design of the mercury removal system chosen by the plant.

For coal-fired boilers that already employ wet FGD systems but possess primarily elemental mercury at the inlet to the FGD absorbers, a reasonable response to CAMR may be to try to convert elemental mercury to oxidized mercury upstream of the FGD inlet, thereby increasing the mercury capture efficiency of the FGD absorbers. Prior experience suggests this can be done in two ways: (1) installing a selective catalytic reduction (SCR) system to reduce NOx emissions, which has been found, for bituminous coals, to simultaneously promote Hg oxidation in the flue gas; and (2) introducing a special "mercury oxidation enhancement additive" into the coal feed, boiler system, or flue gas stream. Figure 9 depicts these possibilities, and their potential effects on the amount of mercury in the FGD by-products are discussed below.

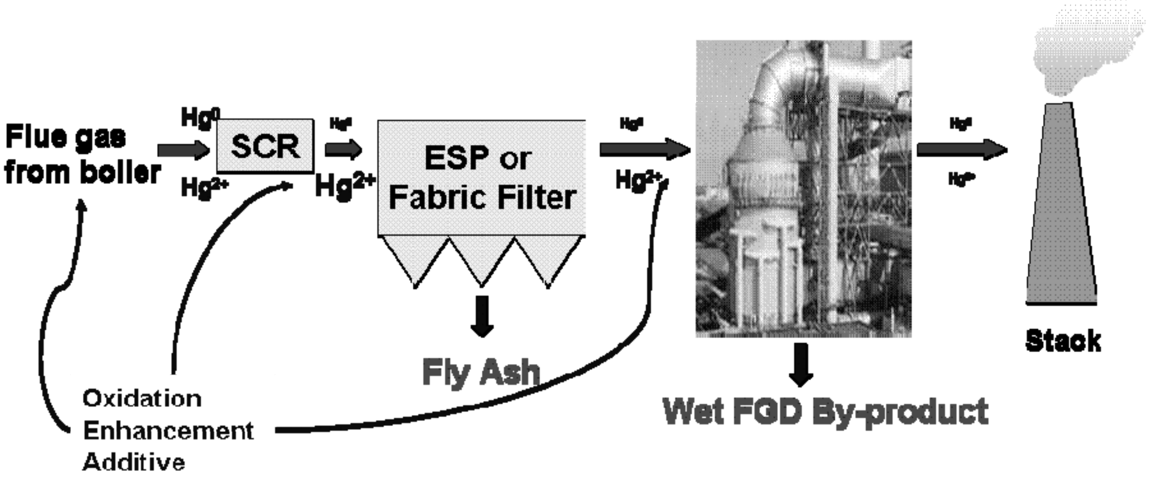

Figure 9. Hg oxidation enhancement to improve mercury removal efficiency of wet FGD systems.

If conversion from elemental to oxidized mercury occurs upstream of the particulate removal device, the mercury removal efficiency of the particulate removal device itself may be improved. That is, once the mercury has been oxidized, more mercury may report to the fly ash than if the SCR or oxidation additives were absent. Mercury collected with the fly ash will therefore not be present in the FGD by-product unless the fly ash and FGD reaction products are re-mixed prior to utilization or disposal. However, if the oxidation enhancement additive is inserted downstream of the particulate removal device, or if the particulate removal device is ineffective in removing the previously-oxidized mercury, then the mercury content of the FGD by-product will increase proportionately with the mercury removal efficiency of the FGD absorber. The Hg content of the FGD by-product will also increase in cases where chemical reagents are added as a means of preventing the conversion of oxidized to elemental mercury within the FGD absorber. The net effect of these possibilities on the increase (if any) in the Hg content of the FGD by-product will vary greatly from installation to installation and cannot be predicted without detailed, site-specific information.

Another possible response to CAMR by electric utilities may actually result in less mercury in FGD by-products than exists today. Considerable efforts have been made to develop powdered sorbents (e.g., activated carbons) that both oxidize and capture mercury on particle surfaces within the flue gas stream, allowing the mercury to be removed by the particulate control device. Use of such mercury sorbent injection systems thus reduces or eliminates the dependence on the FGD system as the primary means of mercury removal. Mercury collected by the sorbent is removed from the flue gas either via simultaneous collection with the fly ash (figure 10a) or by collecting the fly ash and mercury-containing sorbent in series (figure 10b) to preserve a supply of “clean” fly ash for subsequent sale as a cement replacement. In either case, the mercury concentration at the FGD inlet would be lower than if the sorbents were not used; therefore, unless the solid by-products in figure 10 are subsequently mixed prior to re-use or disposal, the net result will be a decrease in the Hg content of the FGD by-products compared to the “pre-CAMR” situation.

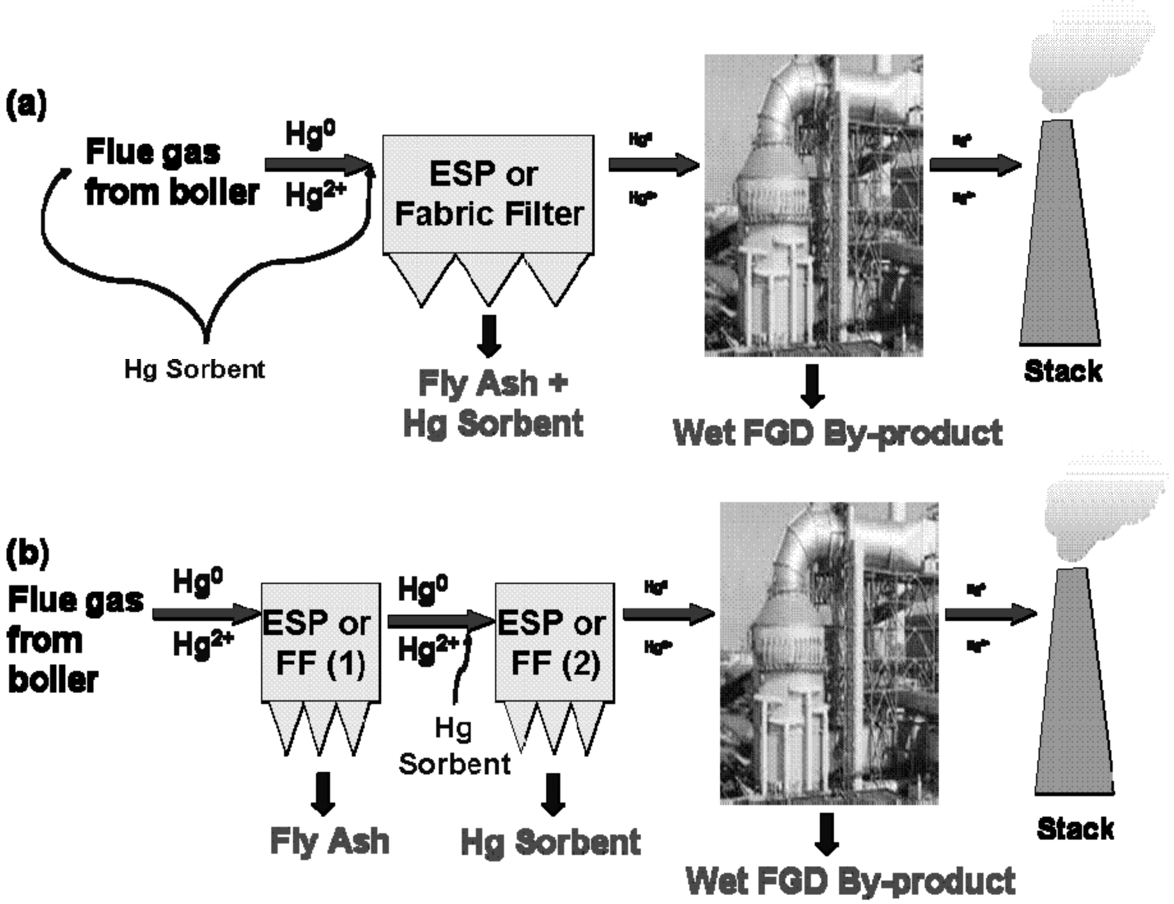

Figure 10. Powdered sorbent injection for mercury removal upstream of wet FGD systems: (a) single particulate removal device; (b) two particulate removal devices in series.

For power plants with dry FGD systems, the most likely response to CAMR is to employ powdered mercury sorbents as shown in figure 11. The sorbent materials may be injected upstream or downstream of the spray dryer absorber vessel, but they will almost certainly be injected upstream of the particulate collection device. Installations employing dry FGD systems are unlikely to install dual particulate removal systems akin to figure 10b because the fly ash already contains substantial amounts of FGD reaction salts and unused lime which render it unsuitable for use as a cement replacement. The addition of mercury-containing sorbents to this mixture may or may not affect the ability to beneficially re-use the materials, depending on the amount of Hg-sorbent used and the intended use of the by-products. However, it is likely that any effects associated with the additional mercury will be outweighed by the effects of the sorbent material (e.g., activated carbon) added to the by-product mixture. The properties of the sorbent, independent of the mercury it contains, may alter the physical and chemical properties of the resulting by-product mixture in a way that could affect its behavior during re-use, mine placement, or disposal. As stated above, these effects may vary greatly from installation to installation and cannot be predicted without detailed, site-specific information.

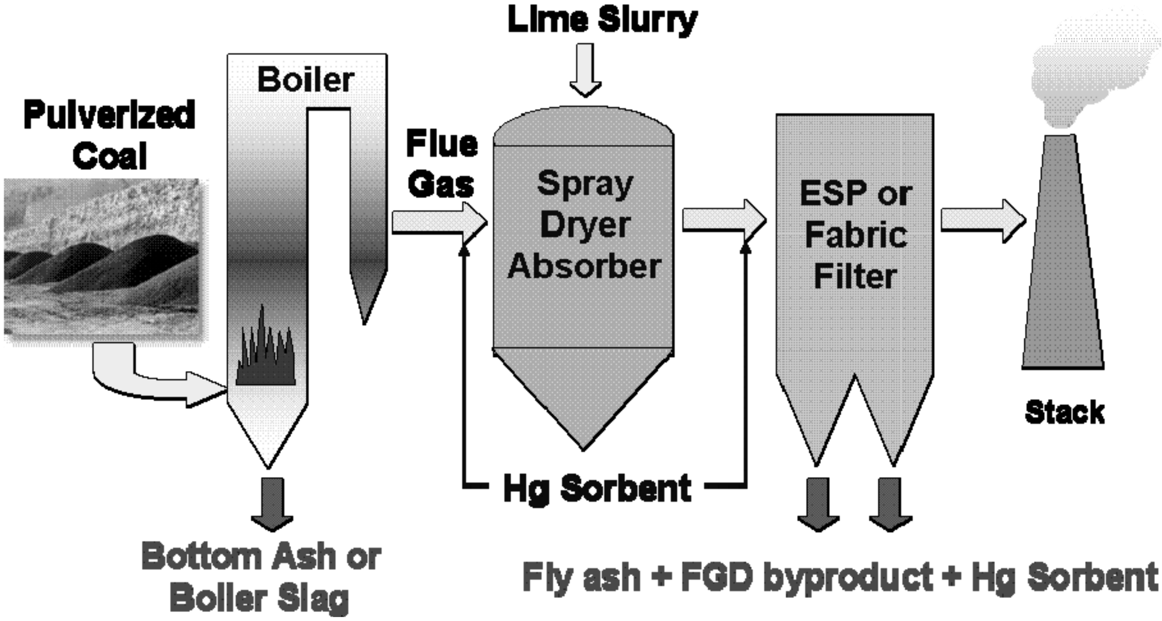

Figure 11. Powdered sorbent injection for mercury removal in dry FGD systems.

If mercury removal in response to CAMR is pursued at installations with fluidized bed combustion systems, the mercury removal system may involve the use of powdered Hg-sorbents in a manner similar to that depicted in Figure 10a. However, the utility industry has very little experience in removing mercury from FBC flue gases, so no generalizations can be made yet as to the effect of CAMR on the re-use, mine placement, or disposal of FBC by-products.

Research on the Fate of Mercury in FGD By-Products: Implications for Mine Placement

The continued regulatory categorization of FGD by-products as non-hazardous solid wastes is an important factor in minimizing the cost of disposal and mine placement. It is critical to the marketability of the materials for beneficial use applications. Perhaps the greatest threat to this regulatory status, and the greatest area of uncertainty affecting the future use of FGD by-products, is the eventual fate of mercury after it has been moved from the flue gases to the by-products. Because mercury, unlike most other metals, has the potential to bioaccumulate in ecosystems, and because the effects of human exposure to mercury have been widely-publicized, its mere presence in FGD by-products can create a negative perception that could jeopardize all future utilization, mine placement, or disposal of the materials. The stakes associated with maintaining an accurate regulatory designation of FGD by-product materials are quite high. DOE has estimated that the total economic impact of disposing all FGD by-products generated in year 2020 would range from approximately \$814 million per year for non-hazardous disposal (at \$15/ton) to \$16.7 billion per year for hazardous disposal (at \$200/ton).[6]

In order to address the uncertainties associated with control of mercury from coal power plants, DOE/NETL is carrying out comprehensive research under the DOE Office of Fossil Energy's Innovations for Existing Plants (IEP) program. IEP needs to develop mercury emissions control technologies and explore the fate of mercury in all types of coal utilization by-products (CUBs), including fly ash, bottom ash, and FGD by-products. NETL's research has greatly advanced our understanding of the transformation, capture, and fate of mercury in flue gas from coal-fired power plants. NETL works collaboratively with power plant operators, EPRI, academia, state and local agencies, and EPA to accomplish this research. NETL CUB research includes: (1) projects performed under contracts, grants, and cooperative agreements funded directly by the IEP program; (2) projects selected by the NETL-sponsored Combustion By-Products Recycling Consortium (CBRC); and (3) research conducted in-house by NETL's Office of Research and Development (NETL-ORD).

Descriptions of specific projects associated with the NETL R&D program on the fate of mercury in CUBs are beyond the scope of this paper. They can be found by visiting the NETL IEP-CUB website (http://www.netl.doe.gov/technologies/coalpower/ewr/coal_utilization_byproducts/) or the CBRC website (http://wvwri.nrcce.wvu.edu/programs/cbrc). However, key research that is especially germane to the mine placement of FGD by-products has been performed by NETL-ORD. A summary of this research is provided below.

Characterization And Management Of Mercury In FGD By-Products

NETL's Office of Research and Development is conducting a comprehensive in-house research effort directed at the fate of mercury in FGD by-products.[8] This activity focuses on four topics: (1) mercury stability during FGD-gypsum drying; (2) FGD-mercury stability during wallboard production; (3) mercury leachability from FGD; and (4) the mercury-binding phase in FGD gypsum. Of these, topics (3) and (4) have the most direct application to the mine placement of FGD by-products. However, given that topics (1) and (2) are of critical importance to the continued use of FGD gypsum in wallboard – the largest single re-use market – the knowledge gained from this research may have an indirect effect on the amount of FGD gypsum that is eventually placed at mine sites.

Mercury stability during FGD gypsum drying was studied by analyzing FGD gypsum samples before and after use of a natural gas-fired dryer that reduces the moisture content of the FGD solids for ease of handling during the manufacturing process. Results indicate that within analytical precision, no mercury was lost during the drying, which is consistent with previous studies indicating that little or no mercury is released from FGD gypsum at temperatures below 170°F.

Analysis of the stability of mercury in FGD during wallboard production was achieved by analyzing samples of feed FGD-gypsum and samples from corresponding wallboard products from five wallboard manufacturing plants. The amount of mercury retained during manufacturing varied among the plants with three of the plants showing high or complete mercury retention during the manufacturing process. One plant displayed some moderate mercury release while another showed significant losses. It is likely that the amount and thermal stability of the mercury in the gypsum and wallboard depend on the origin of the gypsum and/or the nature of the processing.

Analysis of the leachability of mercury from FGD products is being conducted using a continuous, stirred-tank extractor (CSTX). The continuous stirring provides constant mixing as occurs in more traditional batch-leaching tests while the continuous flow provides data over a wide range of pH values and liquid/solid ratios such as those seen in column leaching studies. Exhaustive leaching of the FGD gypsum in the tank has been found to remove essentially all of the gypsum and to leave behind an iron and aluminum rich insoluble residue that appears to be the phase responsible for mercury retention in most samples. Researchers have found little mercury to be released over the course of leaching.

The research concluded that mercury binds primarily with iron in FGD gypsum based on: (1) results of metals analyses of the wallboard products discussed above; (2) settling experiments performed on FGD slurry samples; and (3) leaching experiments. This research led to the metals analysis results presented in Figure 12, showing the general correlation between iron and mercury contents. Settling experiments found mercury to be most concentrated in the top, slower-settling layer of the slurry. The top layer was also enriched with several metals, including iron. Leaching tests on the FGD-gypsum and wallboard did not mobilize the mercury. This is indicative of a strong chemisorption rather than physical adsorption of the mercury. Based on all of these results, it was postulated that an iron-containing phase was associated with the mercury.

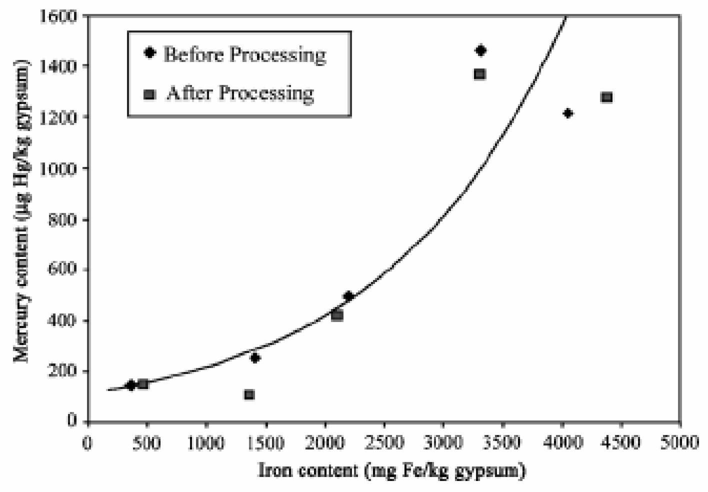

Figure 12. Mercury versus iron content of FGD by-products in NETL-ORD experiments.

Research is continuing in this area in order to better understand the association of mercury in FGD materials and to develop, as needed, management strategies that would prevent the release of mercury to the environment from FGD materials. For example, the finding that mercury is most likely bound to an iron complex in the FGD gypsum could provide for possible separation at the power plant of captured mercury from the FGD gypsum. Separation at the power plant would then minimize mercury transferred to wallboard or to FGD by-products used for mine placement or other beneficial purposes.

Summary

Given the wide variety of materials that can be labeled as "FGD by-products," it is imperative that the origin of the materials be well understood and that the physical and chemical properties of the materials be thoroughly characterized before using the by-products for mine placement or reclamation purposes. These characteristics will determine the specific applications for which they are best suited. For example, FGD gypsum may be an ideal soil supplement for promoting vegetation on reclaimed mine sites, but may not be the best choice as a bulk fill material. Conversely, properly stabilized calcium sulfite by-products may make a desirable fill material but may not be appropriate for application to soil surfaces. Highly alkaline materials such as spray dryer ashes and FBC ashes may be ideal for mixing with acid-producing materials at coal refuse sites, but may not be well-suited for other purposes. It is also important to remember that from a by-product producer's perspective, mine placement of FGD by-products will continue to represent a relatively low-value re-use market compared to "preferred" markets such as wallboard (for FGD gypsum), structural fills, and as a feedstock for various manufacturing processes. However, FGD by-product production at electric utilities is likely to increase substantially in the near future in response to CAIR, and may exceed the capacity of existing re-use markets. Also, in cases where the FGD system is used as the primary means of mercury removal from the power plant flue gas, some of the "preferred" re-use markets for the FGD by-products may be challenged by the negative perceptions associated with the presence of mercury. The ever-increasing cost of disposing of FGD by-products in dedicated landfills and surface impoundments makes it imperative that a wide variety of re-use alternatives, including mine placement, be evaluated and developed to the greatest extent possible. It is therefore important that the "recipients" of these by-products – the mine sites – become familiar with the types and characteristics of the materials they receive, and work with the material suppliers to achieve a placement scenario that benefits all parties.

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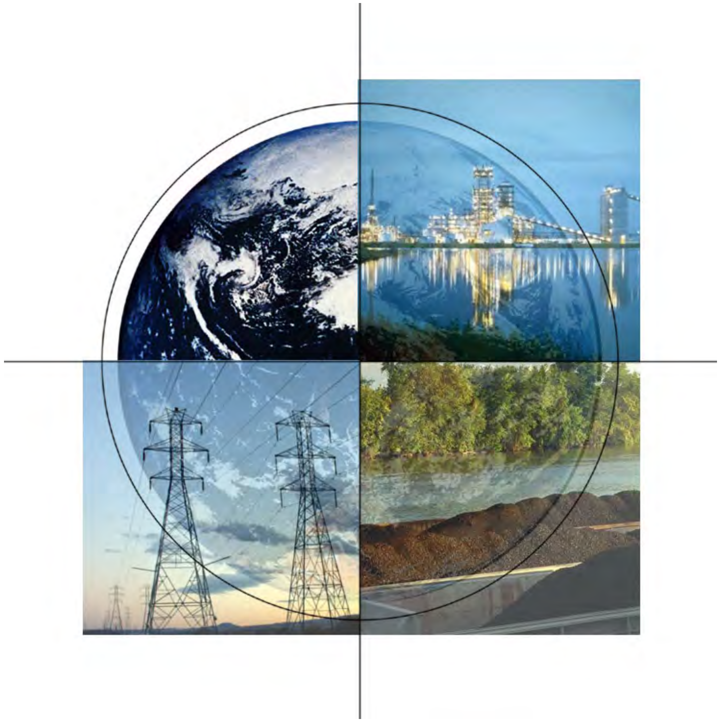
[8] Kairies, Candace; Schroeder, Karl; Cardone, Carol, NETL. *Mercury in Gypsum Produced from Flue Gas Desulfurization*. FUEL, 2006

William W. Aljoe P.E. is the Project Manager, Environmental Projects Division, Strategic Center for Coal, U. S. Department of Energy, National Energy Technology Laboratory (NETL). Duties include providing technical and project management expertise on environmental issues related to coal-based power systems, evaluating technological and regulatory trends, formulating criteria for technological advancement, identifying the most promising approaches for advancing program objectives, and assessing the effectiveness of new concepts and ideas for achieving programmatic missions and regulatory goals. He has served as the coordinator and primary point-of-contact for NETL R&D programs related to coal utilization by-products and air quality. He has also managed research projects on coal byproduct utilization, power plant emission control technology, air quality measurement, air pollutant transport and deposition, and health impacts of air pollution. Previously he worked for the U.S. Bureau of Mines (1983-1996) - Mine hydrogeology and geochemistry of mine drainage; noise control and human engineering of mining equipment. He holds a B. S. in Mining Engineering, Penn State University, 1978; M.S. Civil Engineering, University of Pittsburgh, 1992. U.S. Department of Energy (1997- 2004)

An Overview of FGD By-product Characteristics, Production, and Use: Prognosis for Mine Placement



Flue Gas Desulfurization (FGD) By-product and CCB Regulation at Coal Mines - Response to the National Academy of Science Final Report:

A Technical Interactive Forum

Columbus, OH
November 15, 2006

William W. Aljoe, Project Manager
U.S. Department of Energy, National Energy Technology Laboratory

DOE Terminology: CUBs

- **Coal Utilization By-products**
  - Includes Fly ash, Bottom ash, Boiler slag, FGD solids
  - Other acronyms: CCBs, CCPs, CCW, FFCW, CCR ...
- **Utilization includes:**
  - Combustion
  - Gasification & Hybrid systems
- **By-products because:**
  - $ from electricity sales >> $ from CUB sales
  - Become “Products” when sold or beneficially used
  - Become “Wastes” when sent to a permanent disposal site
    - Can still become “products” after disposal

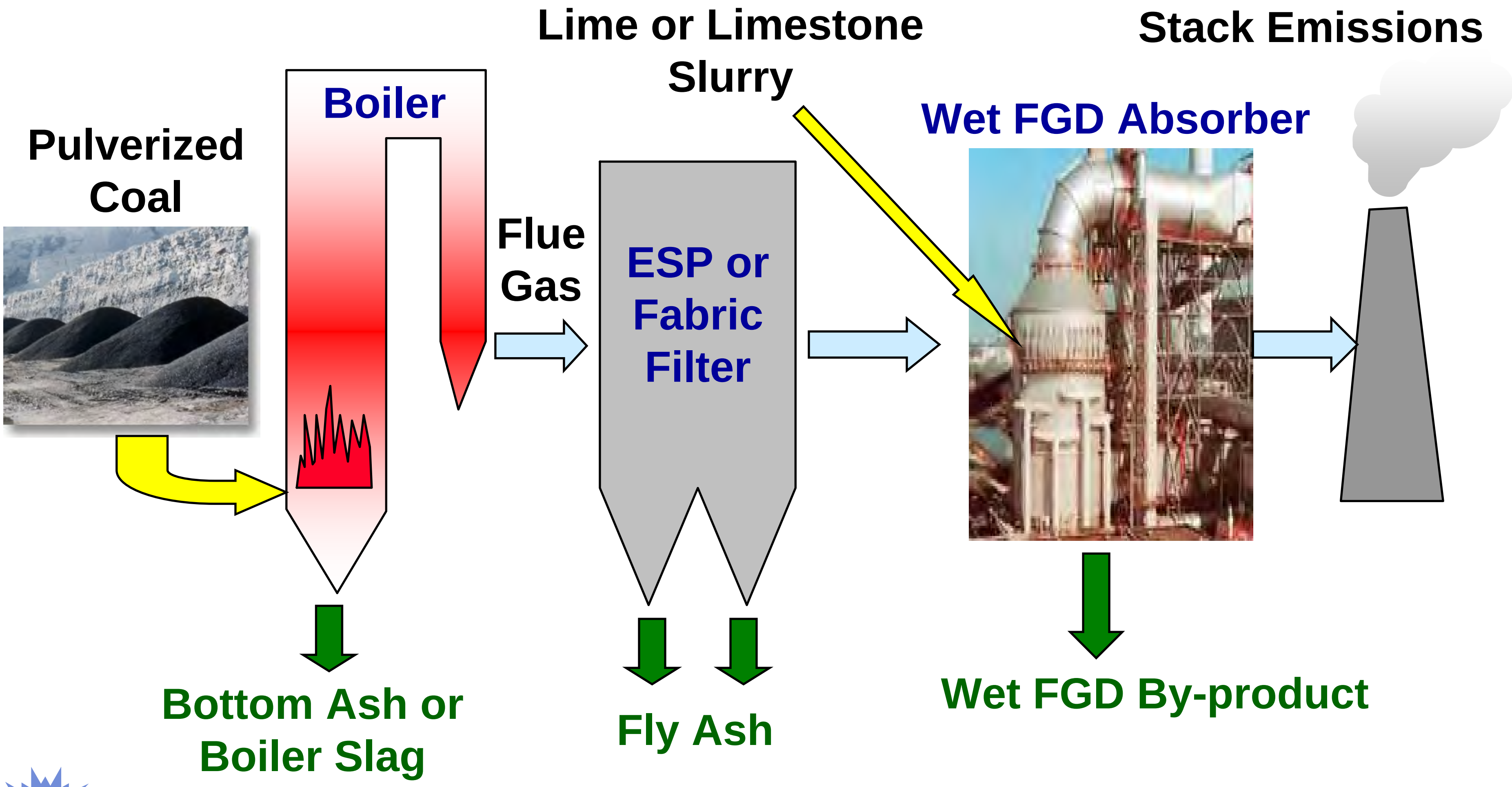
Outline

- **Types of FGD Systems & By-products**
  - – Wet FGD Systems
  - – Dry FGD Systems
  - – Fluidized Bed Combustion (FBC)

- **FGD By-product Characteristics**
  - – FGD Gypsum vs. “Mixtures” (wet & dry)

- **Production and Use**
  - – Recent and future trends
  - – Effect of SO_2 and Hg regulations

Byproducts from Wet FGD Systems



Lime or Limestone Slurry

Stack Emissions

Boiler

Wet FGD Absorber

Pulverized Coal

Flue Gas

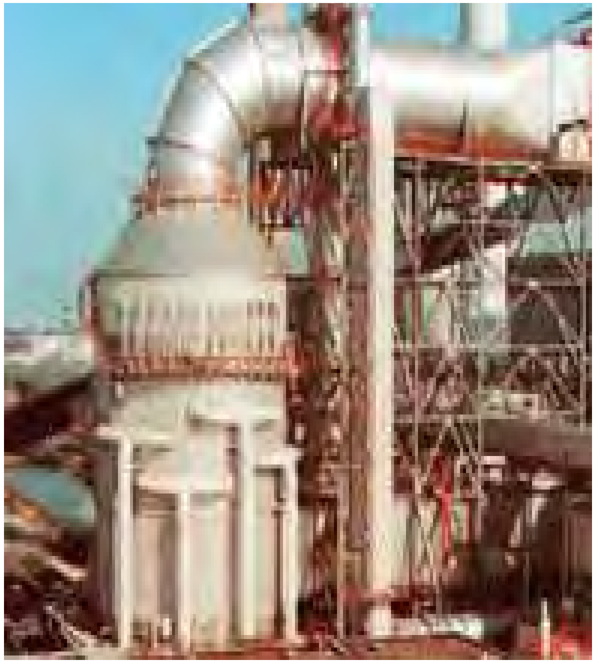
ESP or Fabric Filter

Bottom Ash or Boiler Slag

Fly Ash

Wet FGD By-product

Wet FGD System Alternatives



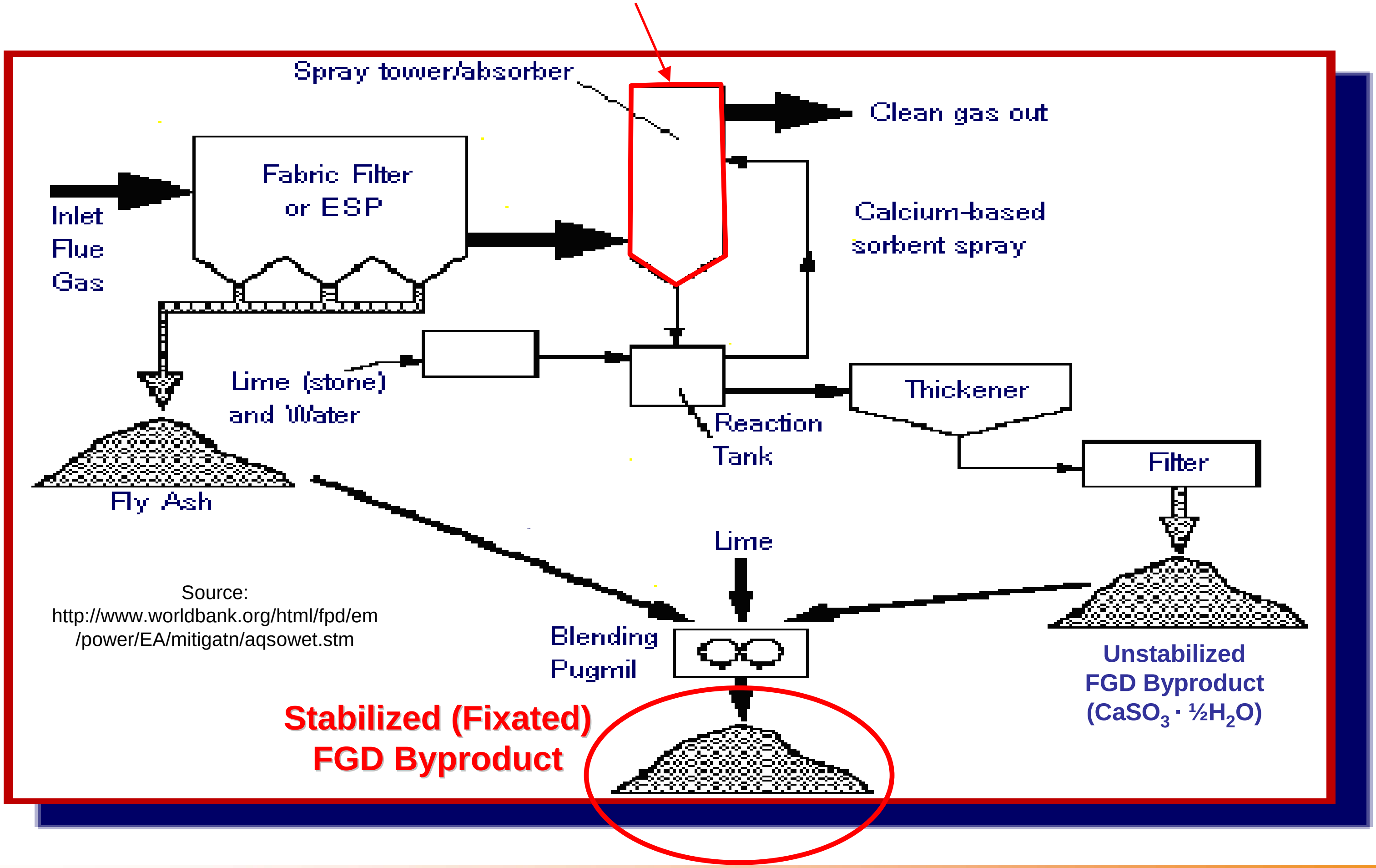
- **Reagent**
  - Limestone or Lime
  - Sodium-based (rare)

- **Oxidation method**
  - Inhibited or Natural
  - In-situ
  - External

- **2 major classes of By-products**
  - Older systems: Sulfite sludge ($CaSO_3 \cdot ½ H_2O$)
    - Must be "stabilized" or "fixated" before disposal or use
  - Newer systems: Gypsum ($CaSO_4 \cdot 2H_20$)
    - No stabilization needed

FGD Byproduct Formation: Sulfite Sludge

- **Basic Chemical Reaction (Limestone Reagent)**
  - $SO_2 + CaCO_3 \rightarrow CaSO_3 \cdot ½ H_2O\ (s) + CO_2\ (g)\uparrow$

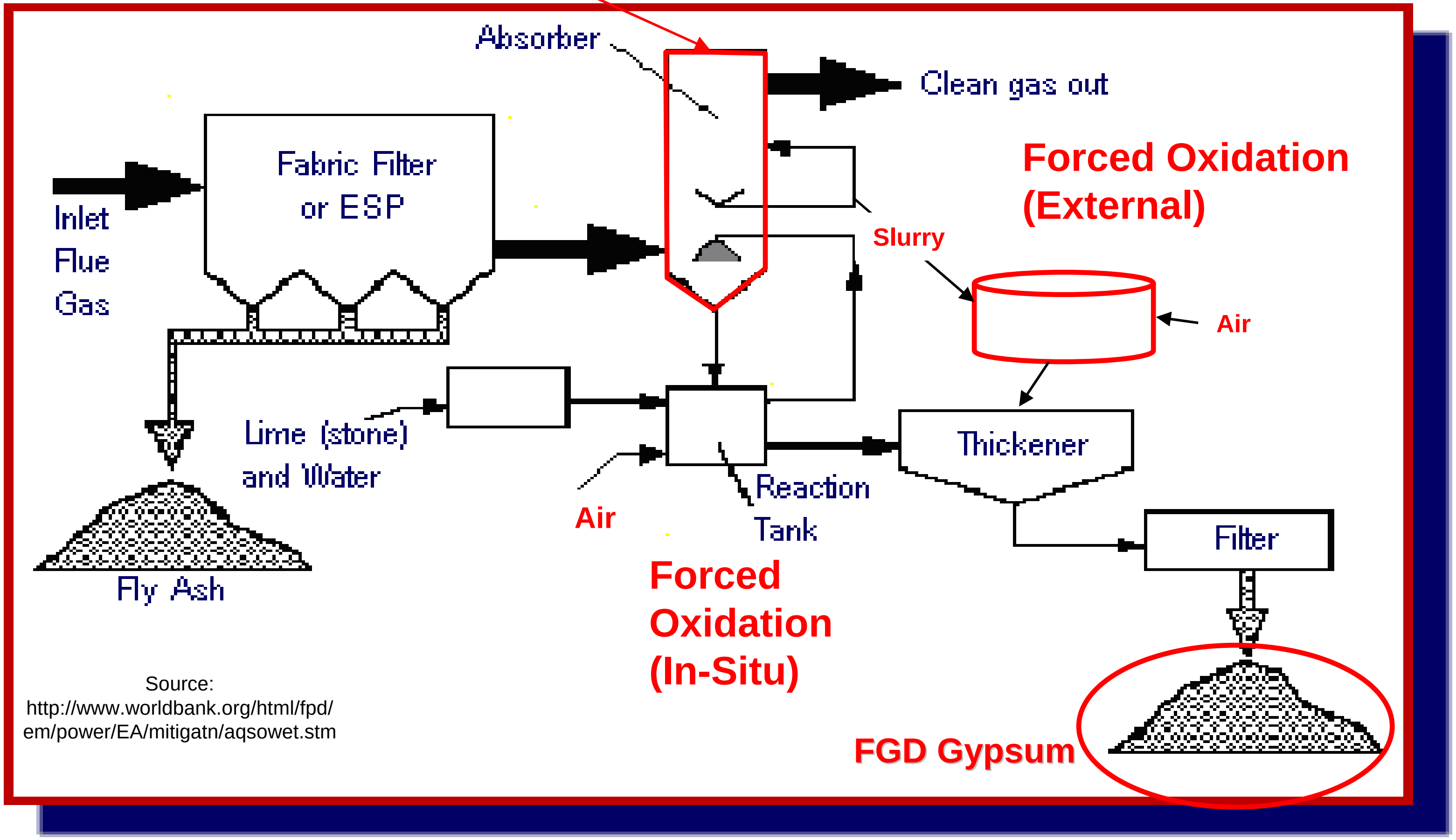


Source: http://www.worldbank.org/html/fpd/em/power/EA/mitigatn/aqsowet.stm

FGD Gypsum Formation

- **Basic Chemical Reaction (Limestone Reagent)**
  - $SO_2 + CaCO_3 \rightarrow CaSO_3 \cdot \frac{1}{2} H_2O + CO_2$ (g)

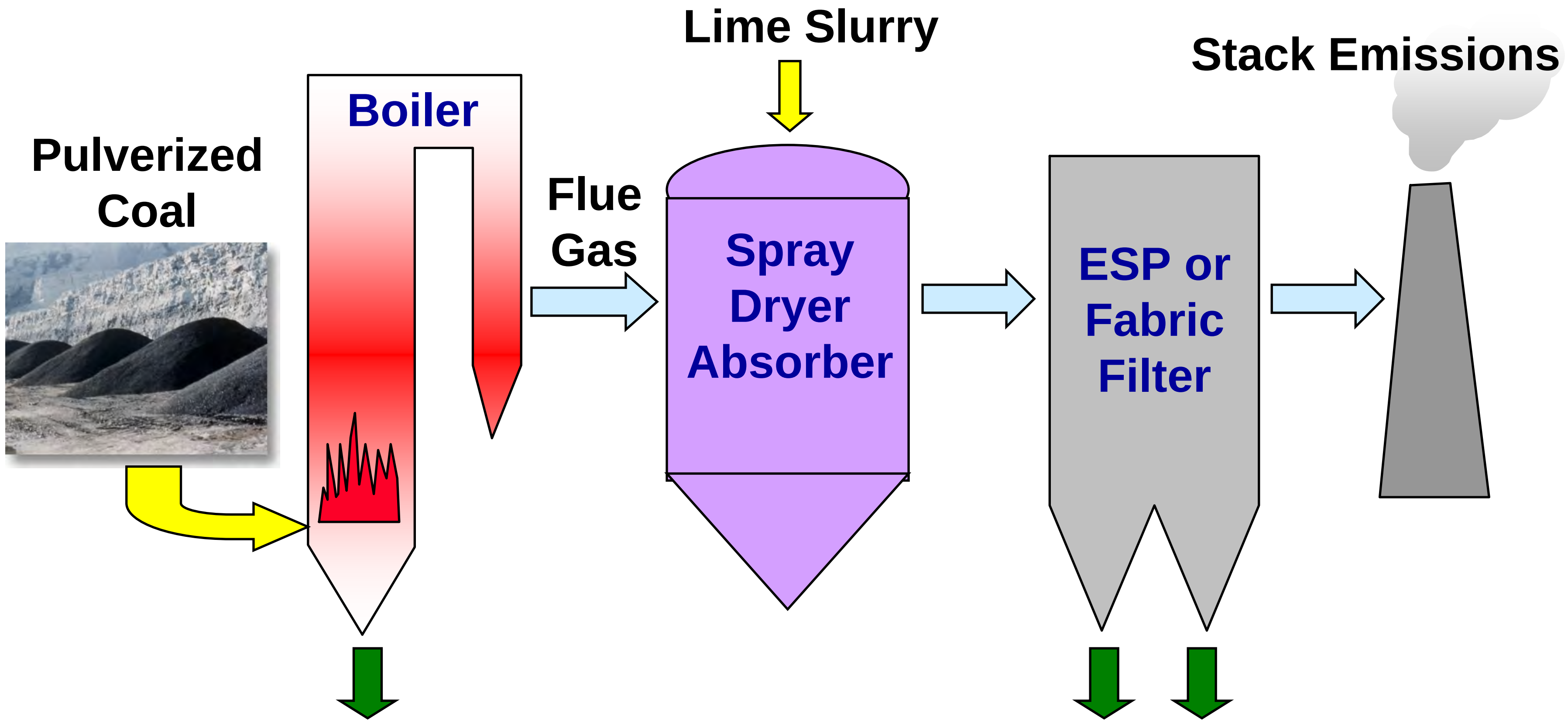
    $+ O_2 \rightarrow CaSO_4 \cdot 2H_20$ (Gypsum)



Source:
http://www.worldbank.org/html/fpd/em/power/EA/mitigatn/aqsowet.stm

Byproducts from Dry FGD Systems

(Spray Dryers)



Lime Slurry

Stack Emissions

Pulverized Coal

Boiler

Flue Gas

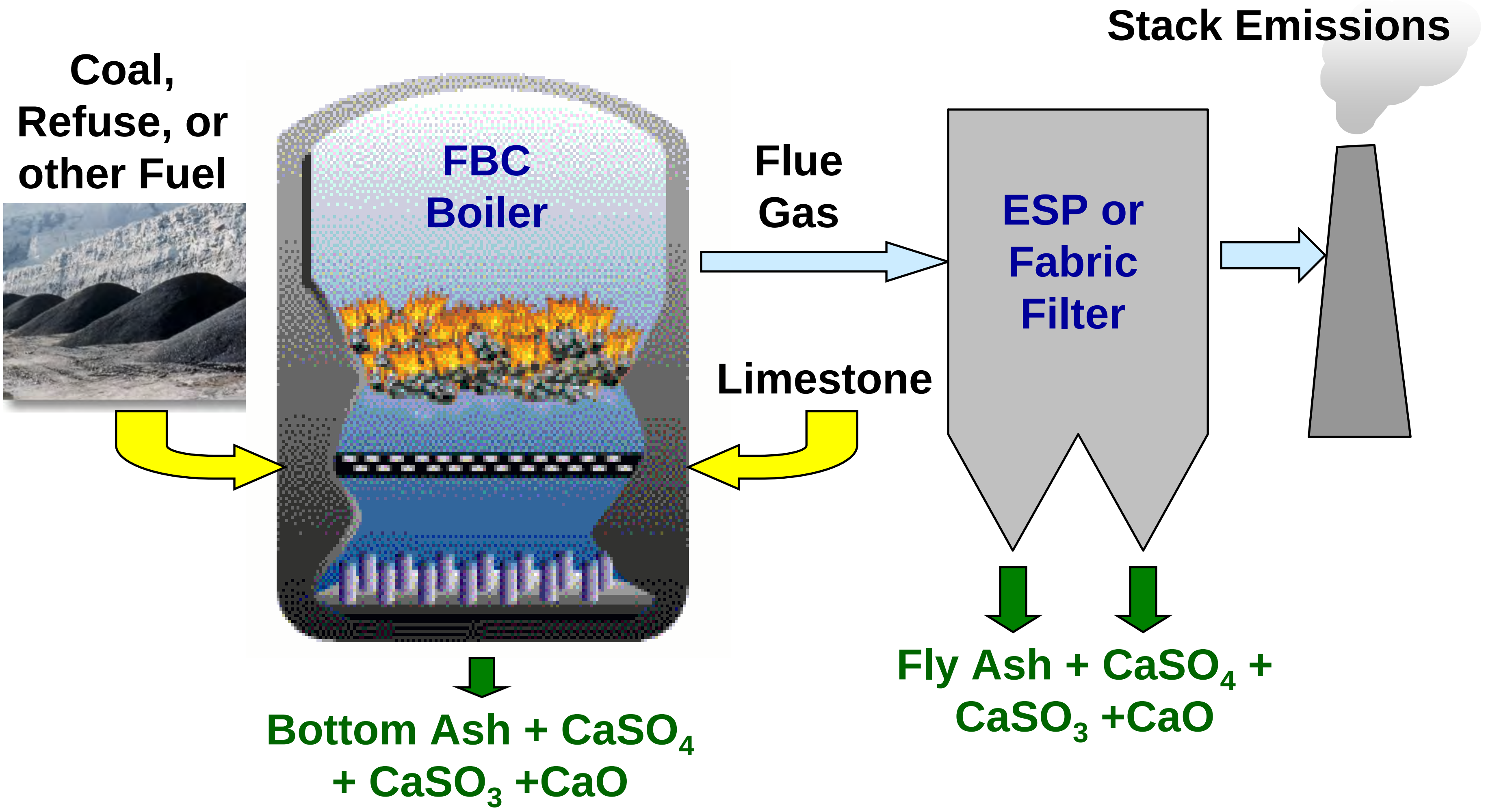
Spray Dryer Absorber

ESP or Fabric Filter

Bottom Ash or Boiler Slag

Dry FGD Byproduct = Fly Ash + $CaSO_3$ + $CaSO_4$ + $Ca(OH)_2$

Byproducts from Fluidized Bed Combustion (FBC)



Coal, Refuse, or other Fuel

FBC Boiler

Flue Gas

Limestone

ESP or Fabric Filter

Stack Emissions

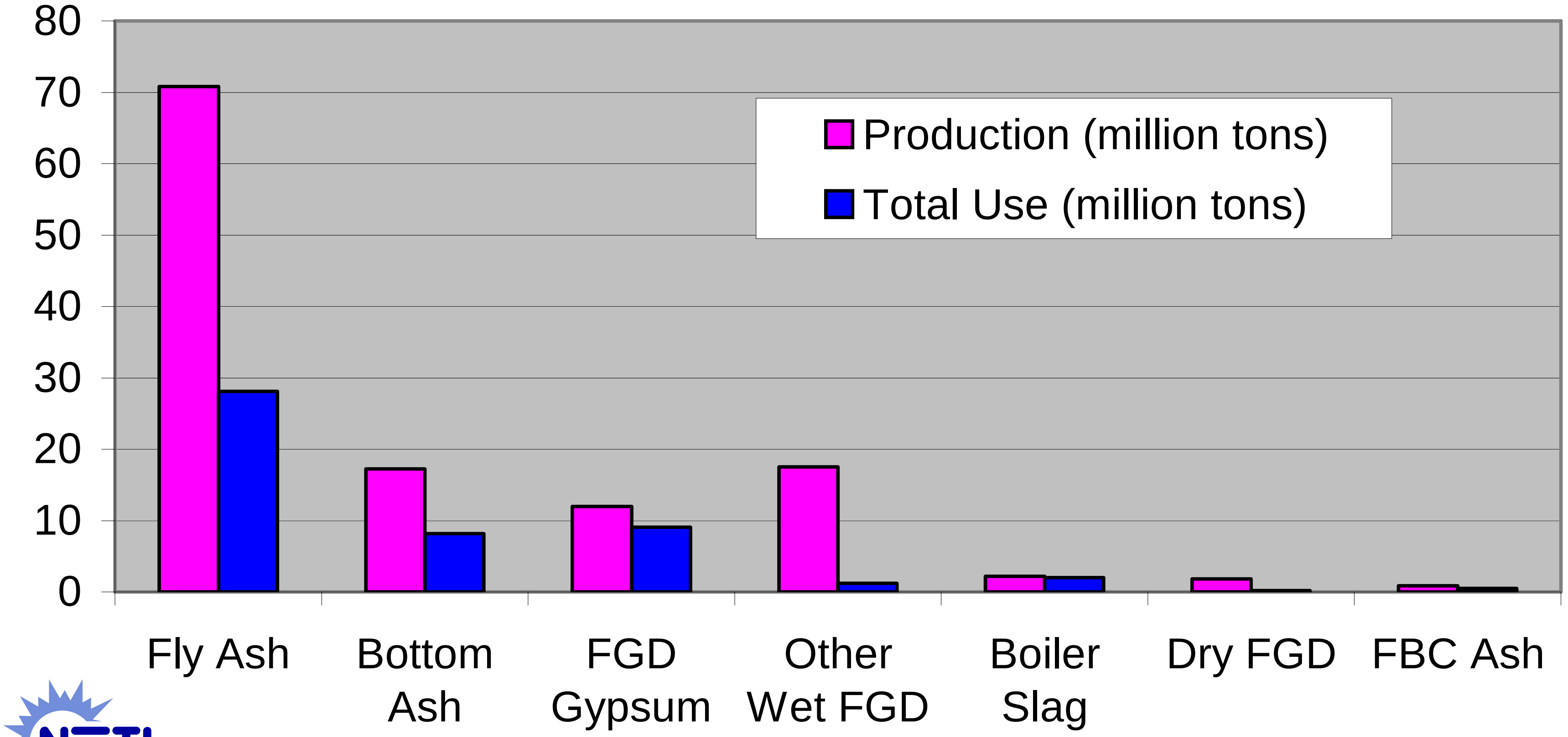
Bottom Ash + $CaSO_4$ + $CaSO_3$ +CaO

Fly Ash + $CaSO_4$ + $CaSO_3$ +CaO

U.S. CUB Production and Use – 2004

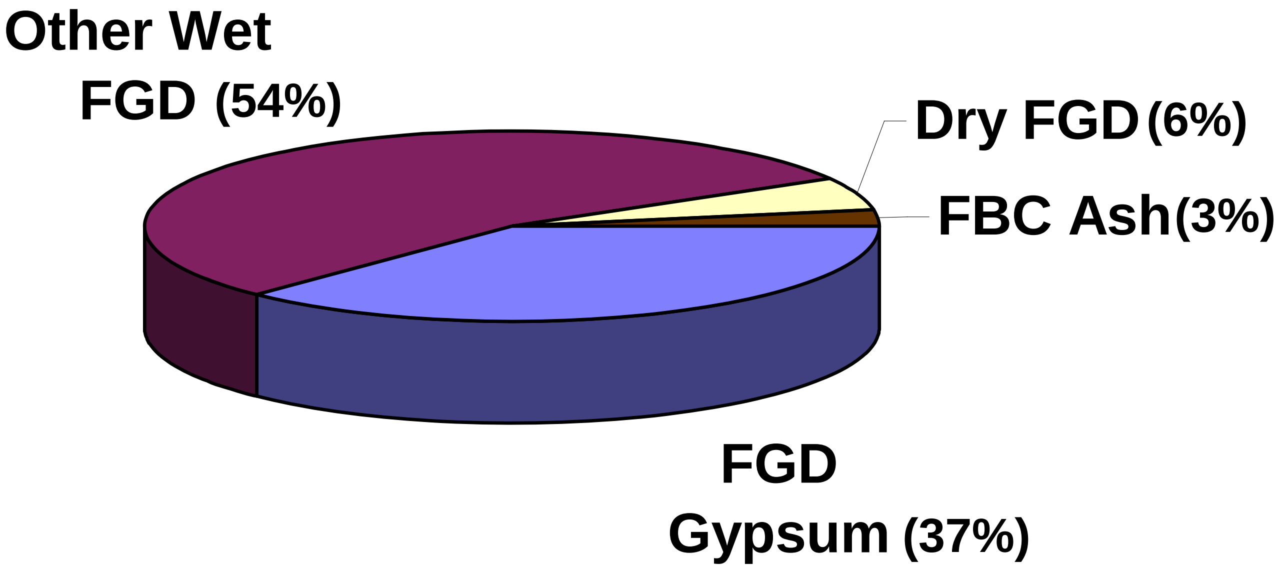
(Data from American Coal Ash Association)

2004	Fly Ash	Bottom Ash	FGD Gypsum	Other Wet FGD	Boiler Slag	Dry FGD	FBC Ash	Total
Production (million tons)	70.8	17.2	12.0	17.5	2.2	1.8	0.9	122.5
Total Use (million tons)	28.1	8.2	9.0	1.2	2.0	0.2	0.5	49.1
Percent of production utilized	39.6%	47.4%	75.7%	6.8%	89.6%	9.7%	54.6%	40.1%



U.S. FGD Byproduct Production and Use – 2004

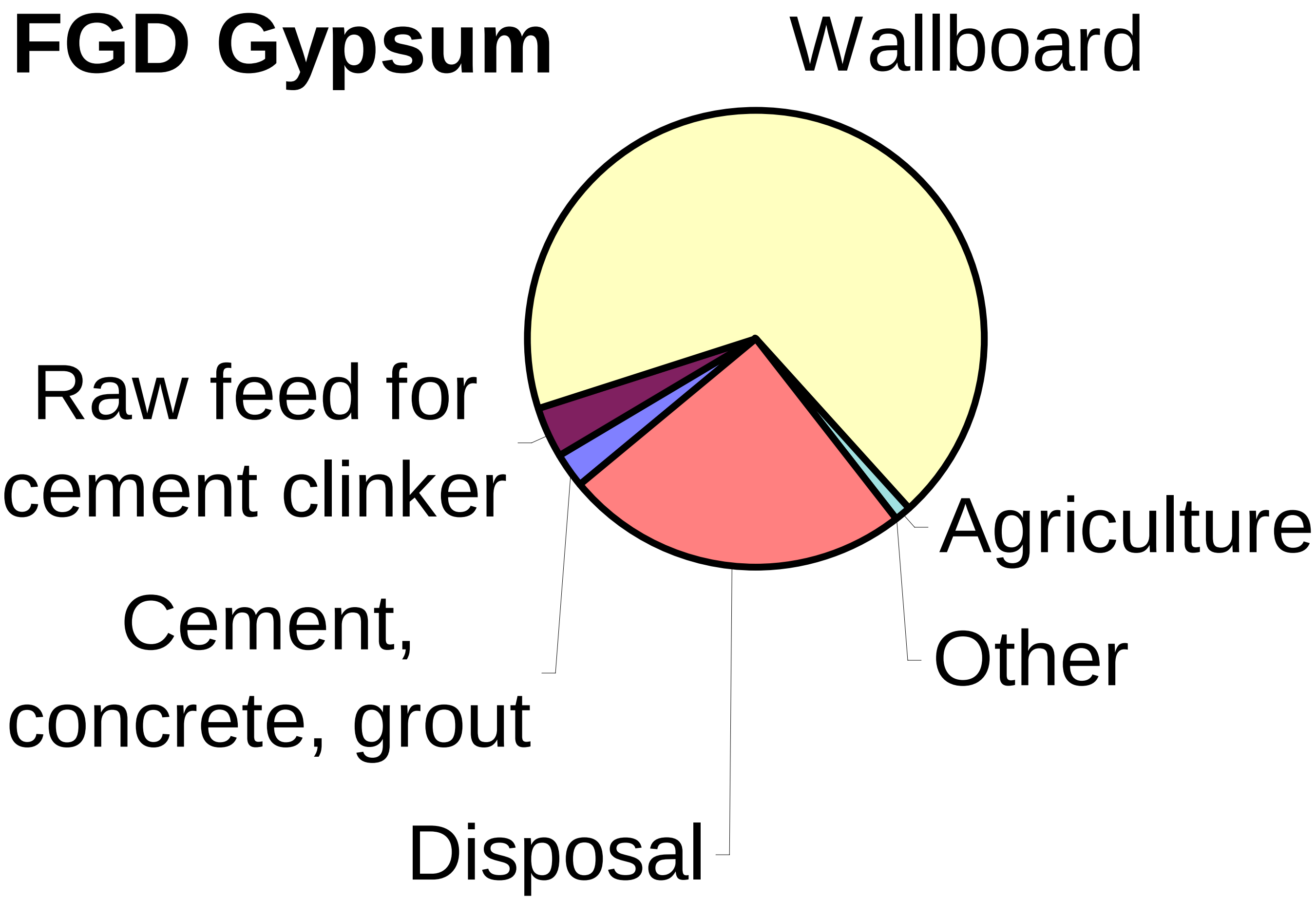
(*Data from American Coal Ash Association)*



2004	FGD Gypsum	Other Wet FGD	Dry FGD	FBC Ash
Production (million tons)	12.0	17.5	1.8	0.9
Total Use (million tons)	9.0	1.2	0.2	0.5
➡ Percent of production utilized	75.7%	6.8%	9.7%	54.6%

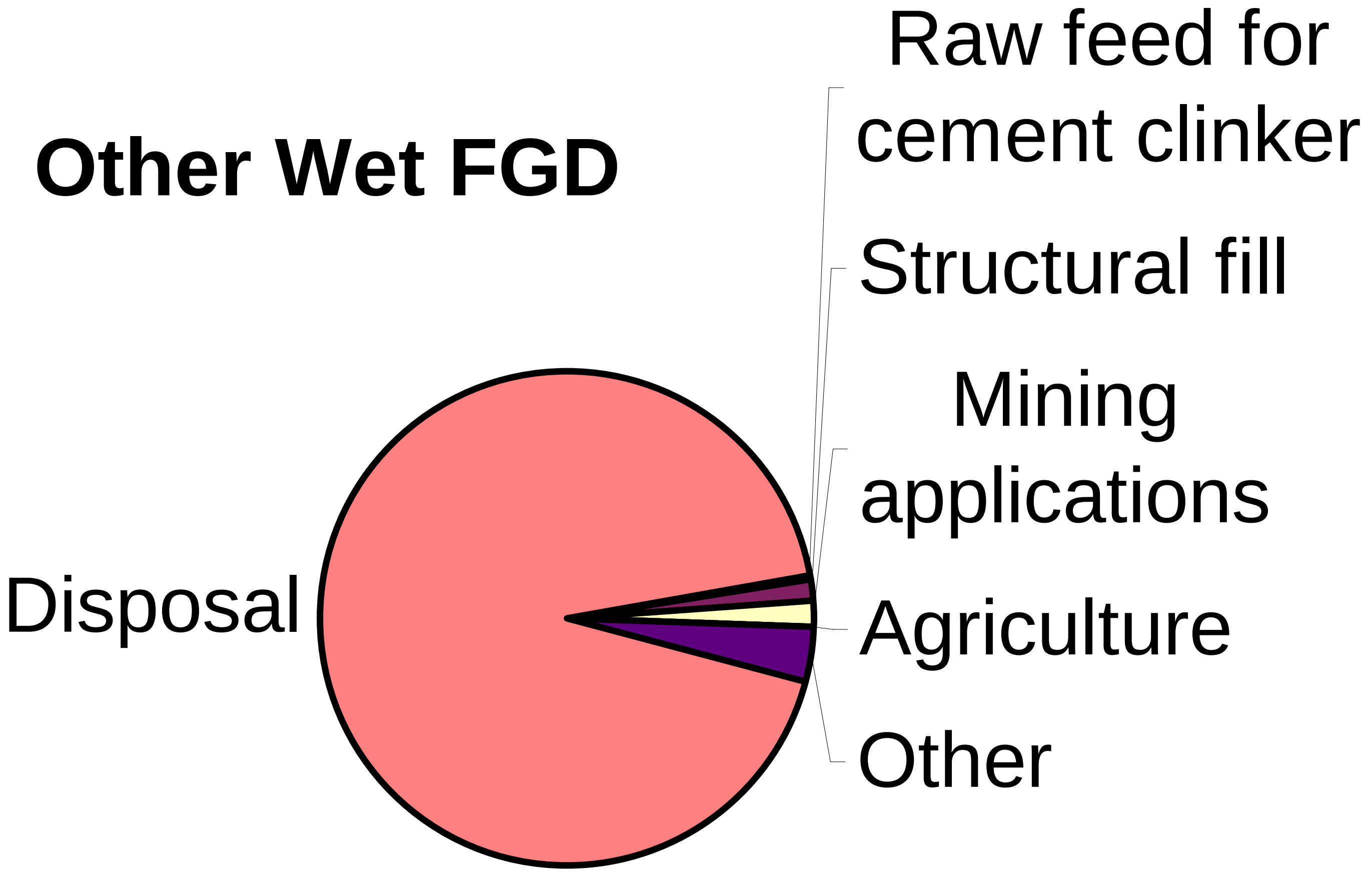
Fate of FGD Gypsum – 2004

(Data from American Coal Ash Association)



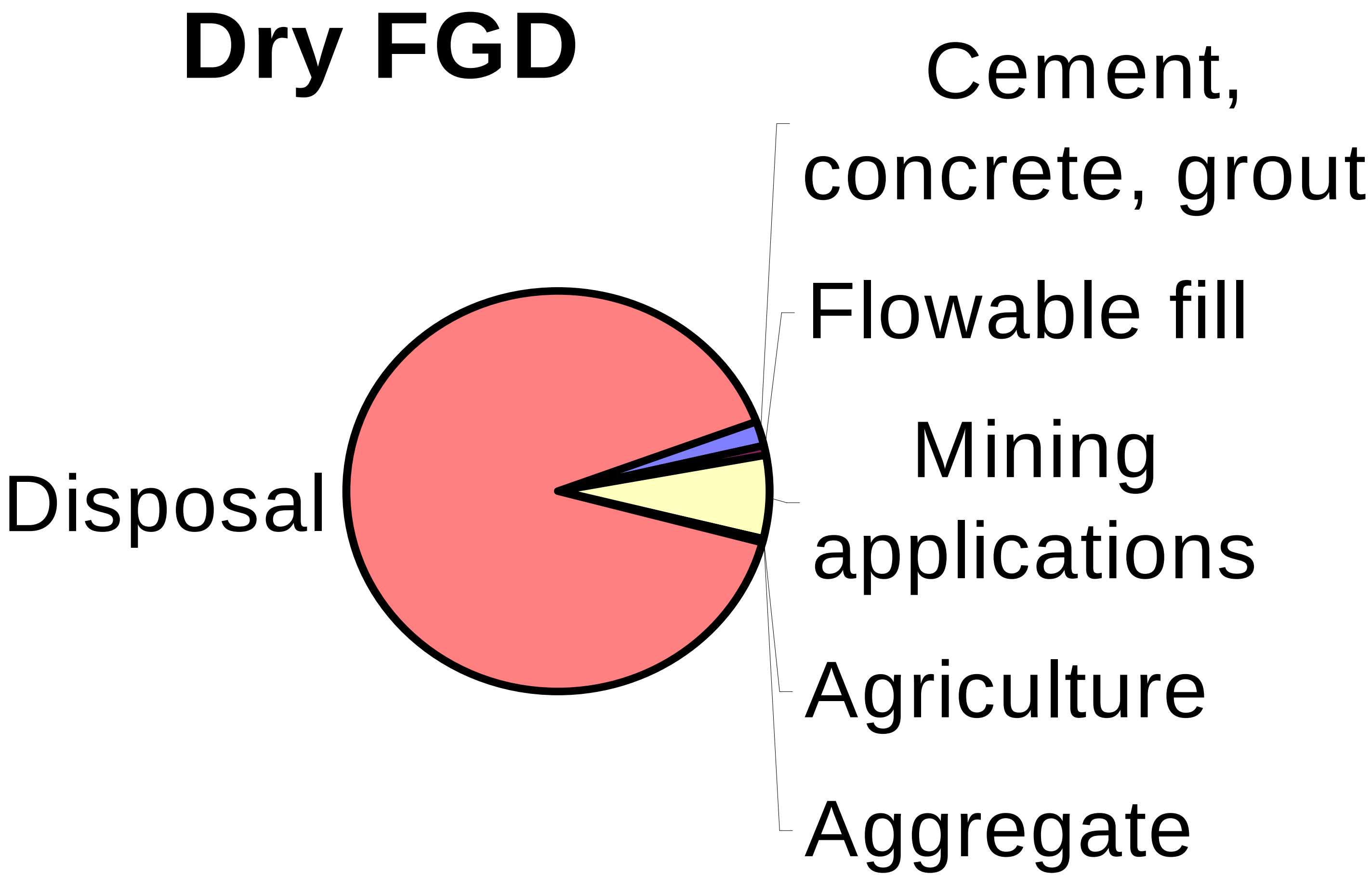
Fate of "Other" (Sulfite) Wet FGD Byproducts – 2004

(*Data from American Coal Ash Association)*



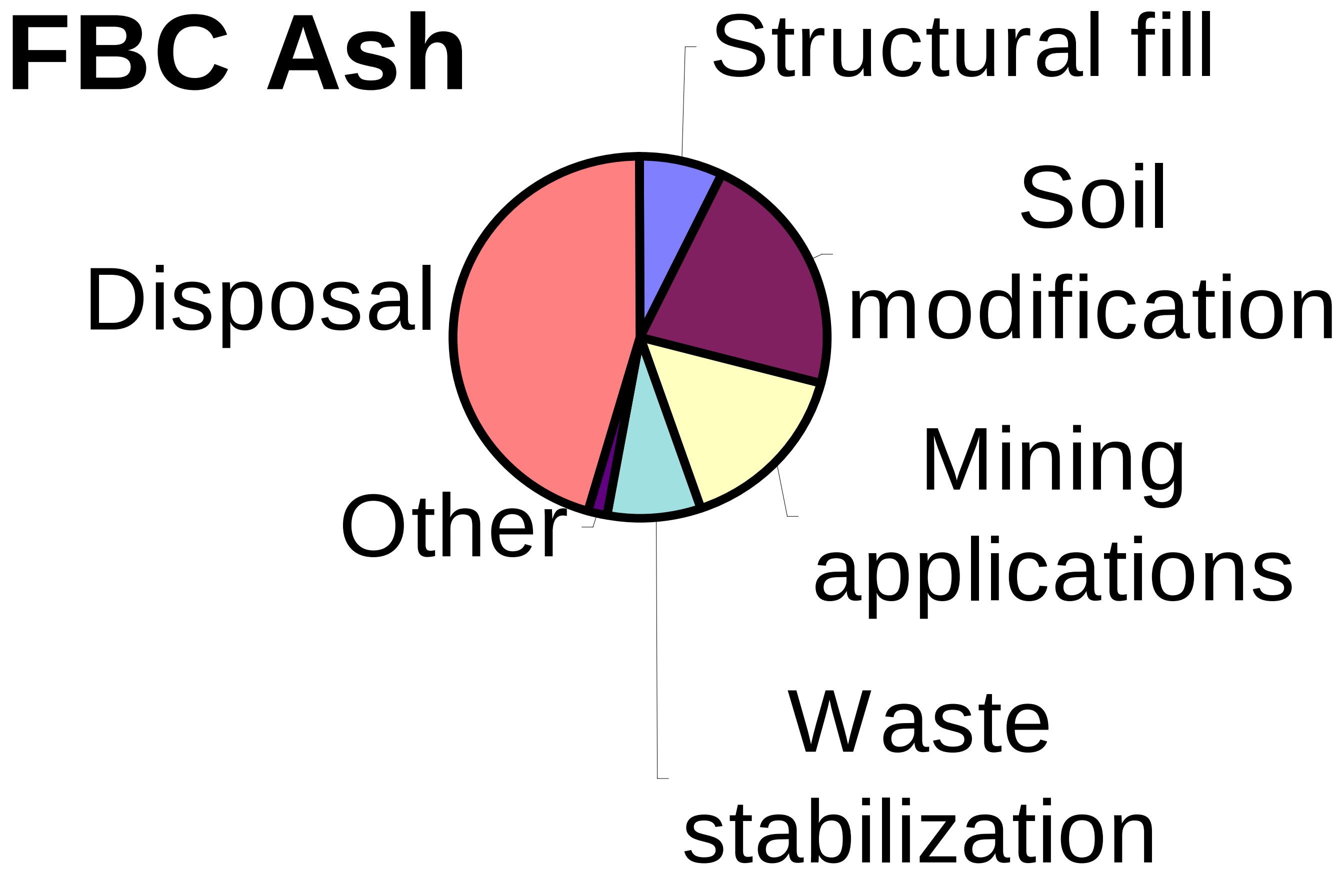
Fate of Dry FGD Byproducts – 2004

(Data from American Coal Ash Association)

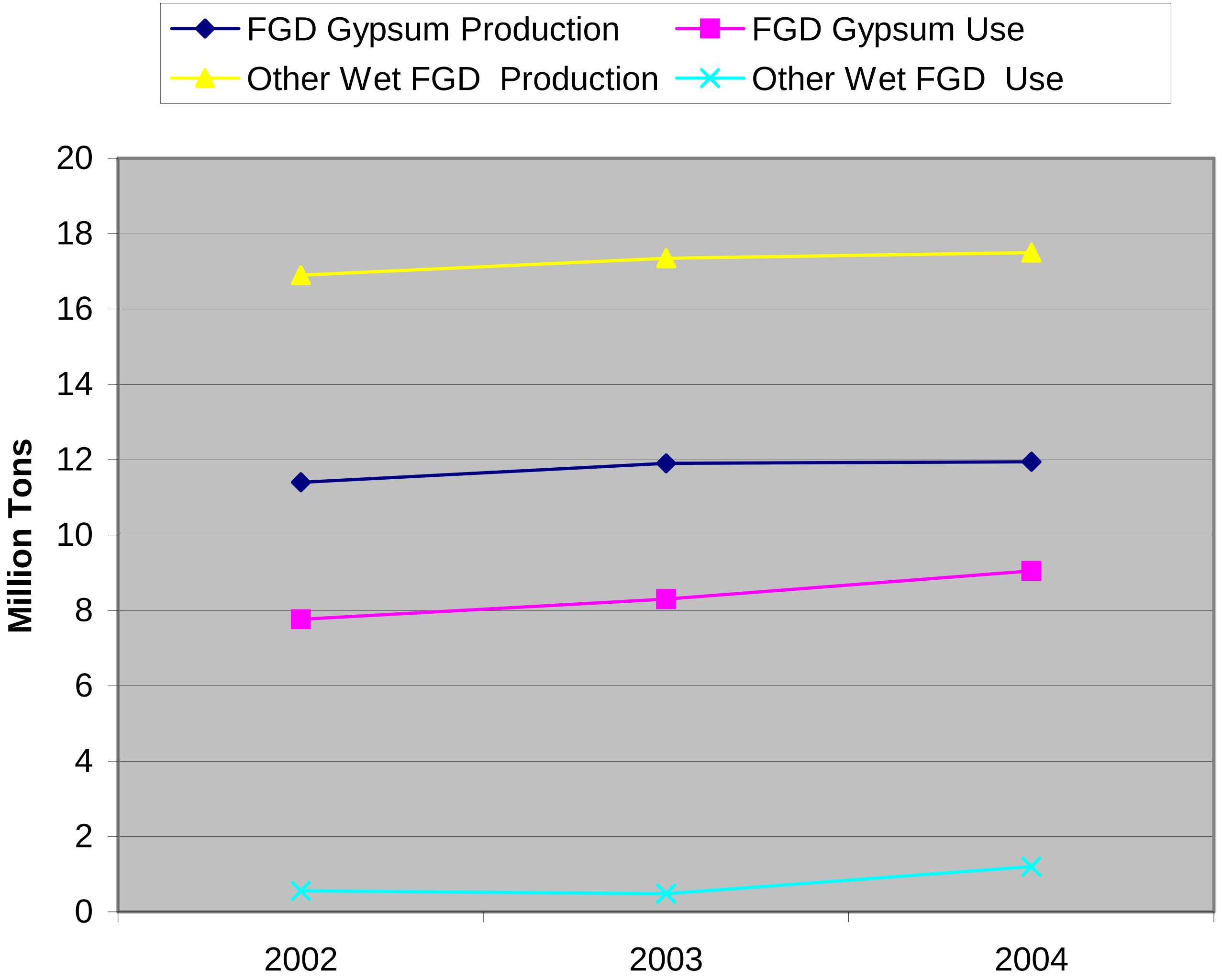


Fate of FBC Byproducts – 2004

(Data from American Coal Ash Association)



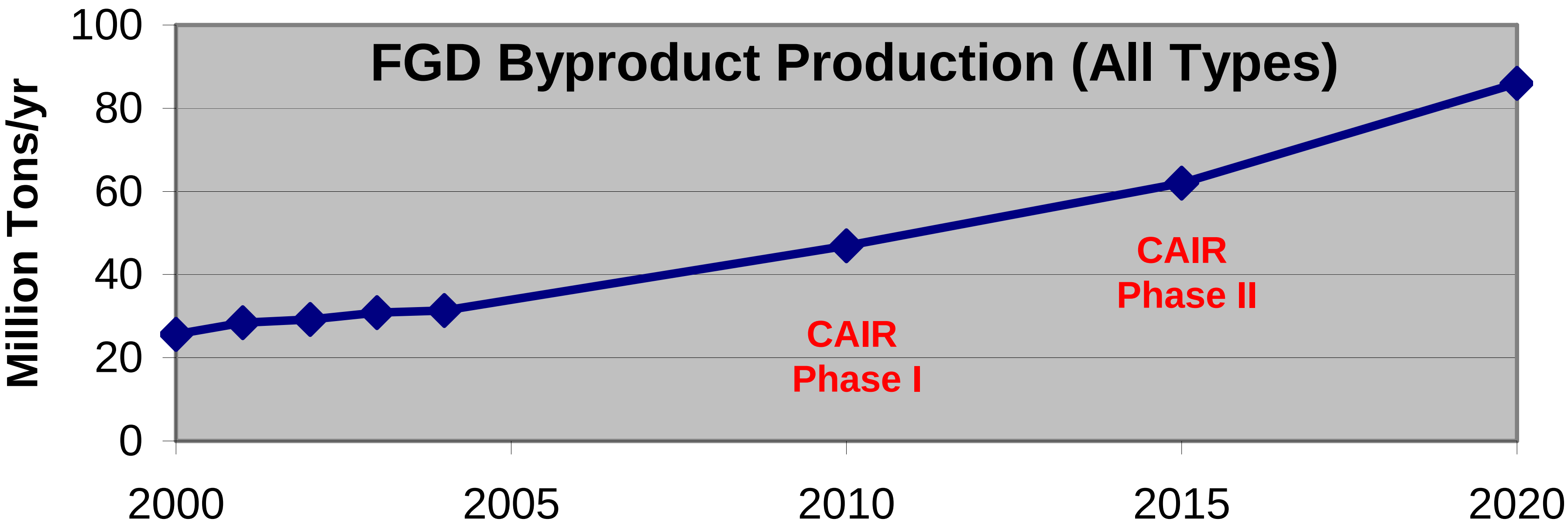
Recent Trends – "Wet" FGD Byproducts



Effect of CAIR on FGD Byproducts

- **CAIR Requirements**
  - 44% reduction in SO_2 emissions by 2010
  - 56% reduction in SO_2 emissions by 2015
- **Total volume of FGD byproducts will increase**
- **Most “new” wet FGD systems will produce gypsum**
  - Many “old” (sulfite) FGD systems will continue to operate
- **More dry FGD systems will be added**
  - Still <10% of Total FGD in 2015
  - Less efficient for SO_2 removal than wet FGD
    - Dry: 70-90%; Wet: 95%+ (BACT considerations)
  - Mostly for low-S coals, where water is scarce

Future Trends in FGD Byproduct Production



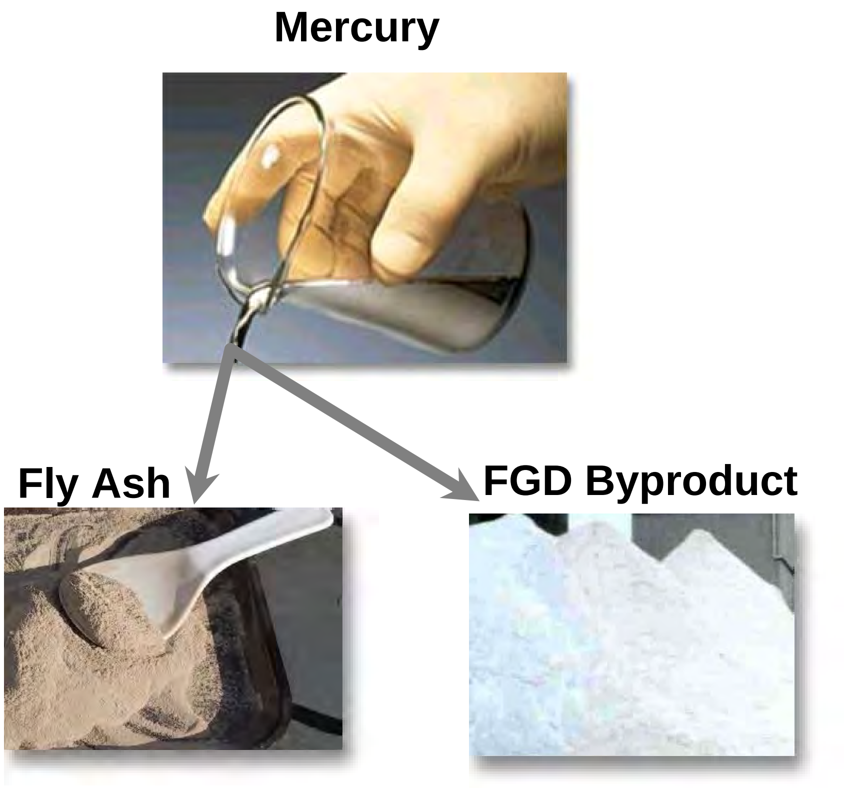
Potential Impact of Power Plant Mercury Emission Regulations (CAMR) on CUBs

Fly Ash

- **Loss of all reuse applications**
  ~ $908 M/yr impact

FGD Solids

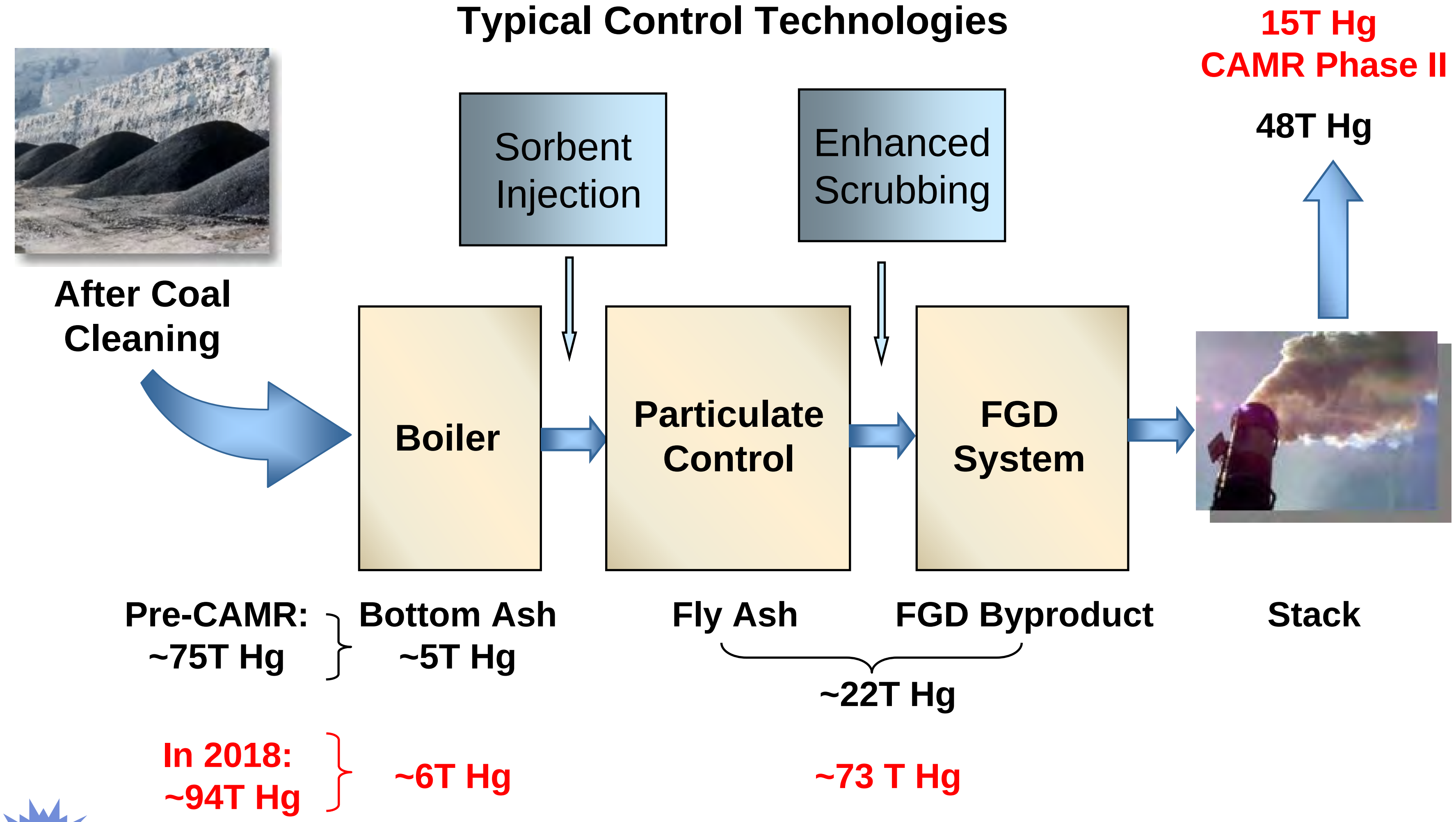
- **Loss of all reuse applications**
  ~ $213 M/yr impact



Hazardous designation of all CUBs could cost more than $11 billion/year

Mercury Partitioning Across Coal Power Plants

(Annual Nationwide Estimates based on 1999 EPA ICR Data)



Typical Control Technologies

Sorbent Injection

Enhanced Scrubbing

15T Hg
CAMR Phase II

48T Hg

After Coal Cleaning

Boiler

Particulate Control

FGD System

Pre-CAMR:
~75T Hg

Bottom Ash
~5T Hg

Fly Ash

FGD Byproduct

~22T Hg

Stack

In 2018:
~94T Hg

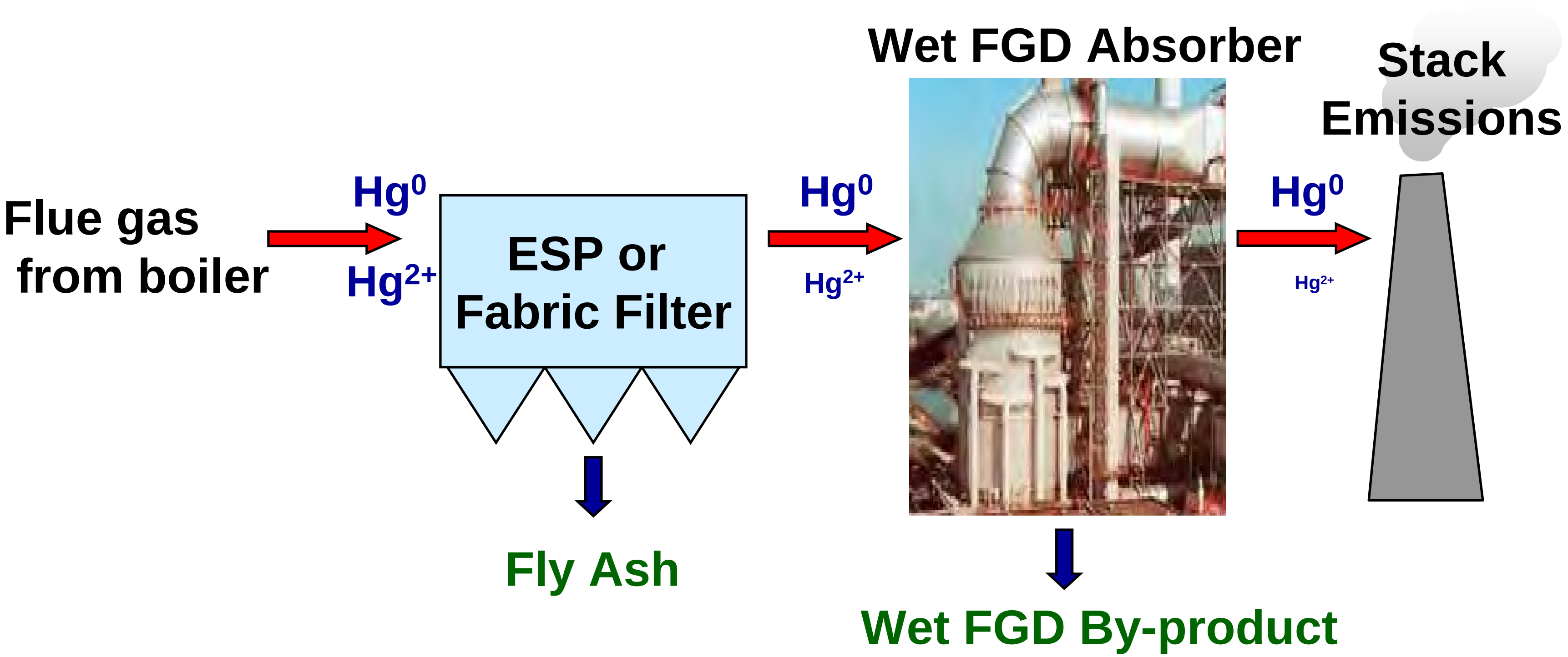
~6T Hg

~73 T Hg

Effects of CAMR on Hg in Wet FGD Byproducts

Points to consider

1. Wet FGD systems <u>already</u> remove oxidized Hg

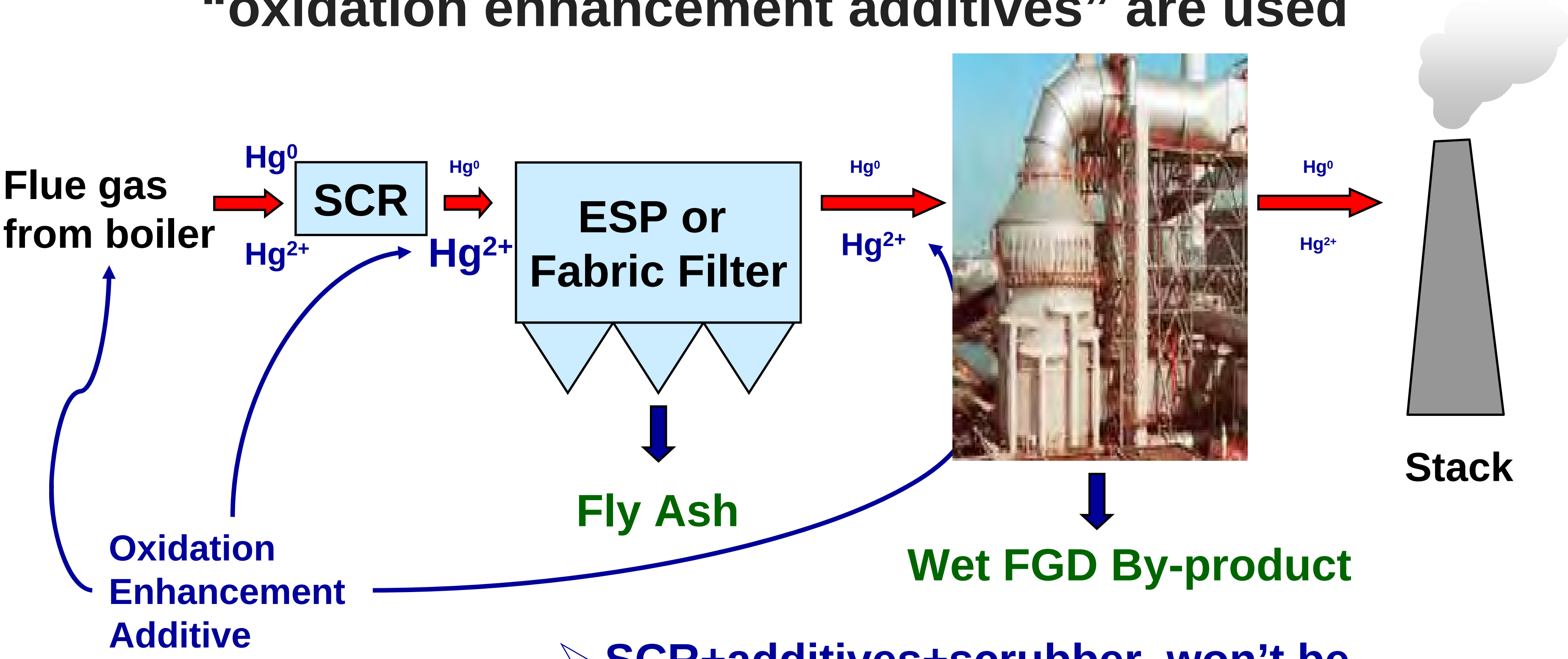


Byproducts already contain 70-90% of initial Hg^{2+}

Effects of CAMR on Hg in Wet FGD Byproducts

Points to consider

2. **Hg concentration in wet FGD byproducts will be <u>slightly</u> higher if SCR is added or if "oxidation enhancement additives" are used**



Flue gas from boiler

Hg^0 Hg^{2+}

SCR

Hg^0 Hg^{2+}

ESP or Fabric Filter

Fly Ash

Hg^0 Hg^{2+}

Wet FGD By-product

Hg^0 Hg^{2+}

Stack

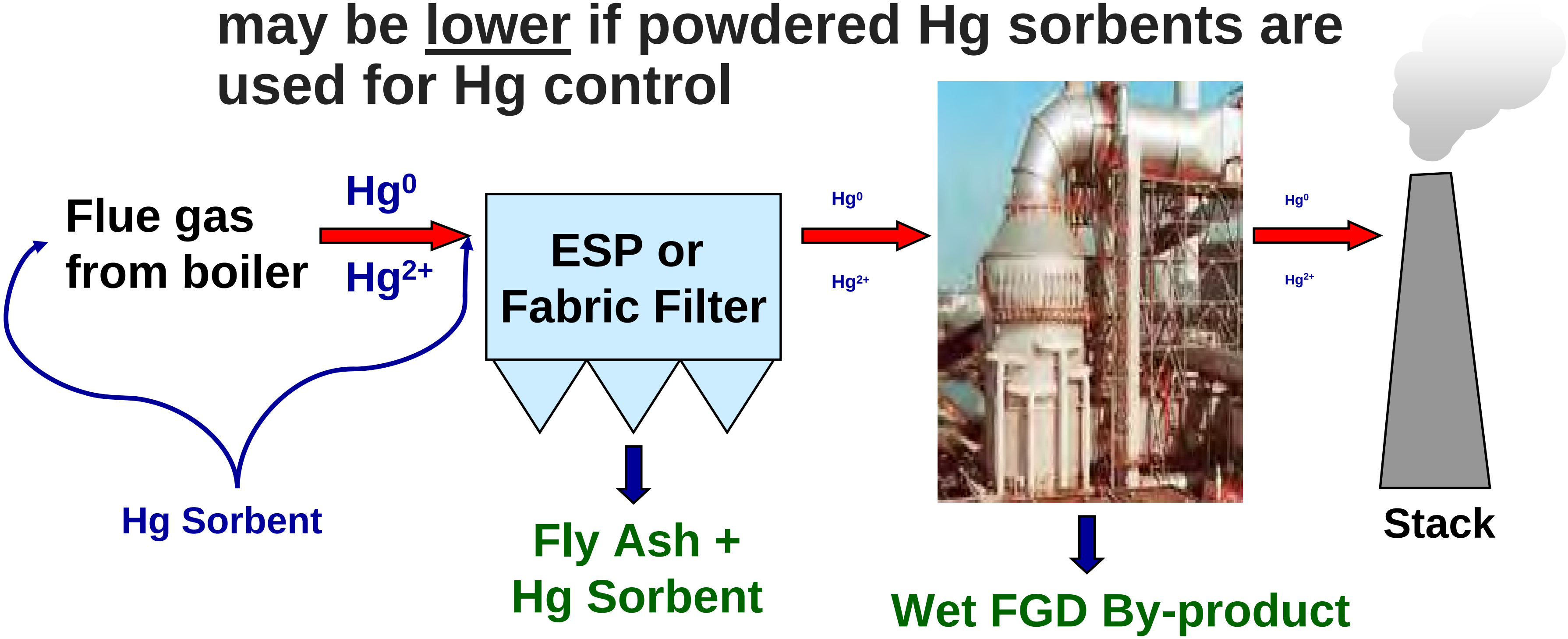
Oxidation Enhancement Additive

- ➢ **SCR+additives+scrubber won't be chosen ($$) if incoming Hg is primarily Hg^0**

Effects of CAMR on Hg in Wet FGD Byproducts

Points to consider

3. Hg concentration in wet FGD byproducts may be <u>lower</u> if powdered Hg sorbents are used for Hg control



Flue gas from boiler

Hg^0

Hg^{2+}

ESP or Fabric Filter

Hg^0

Hg^{2+}

Hg^0

Hg^{2+}

Hg Sorbent

Fly Ash + Hg Sorbent

Wet FGD By-product

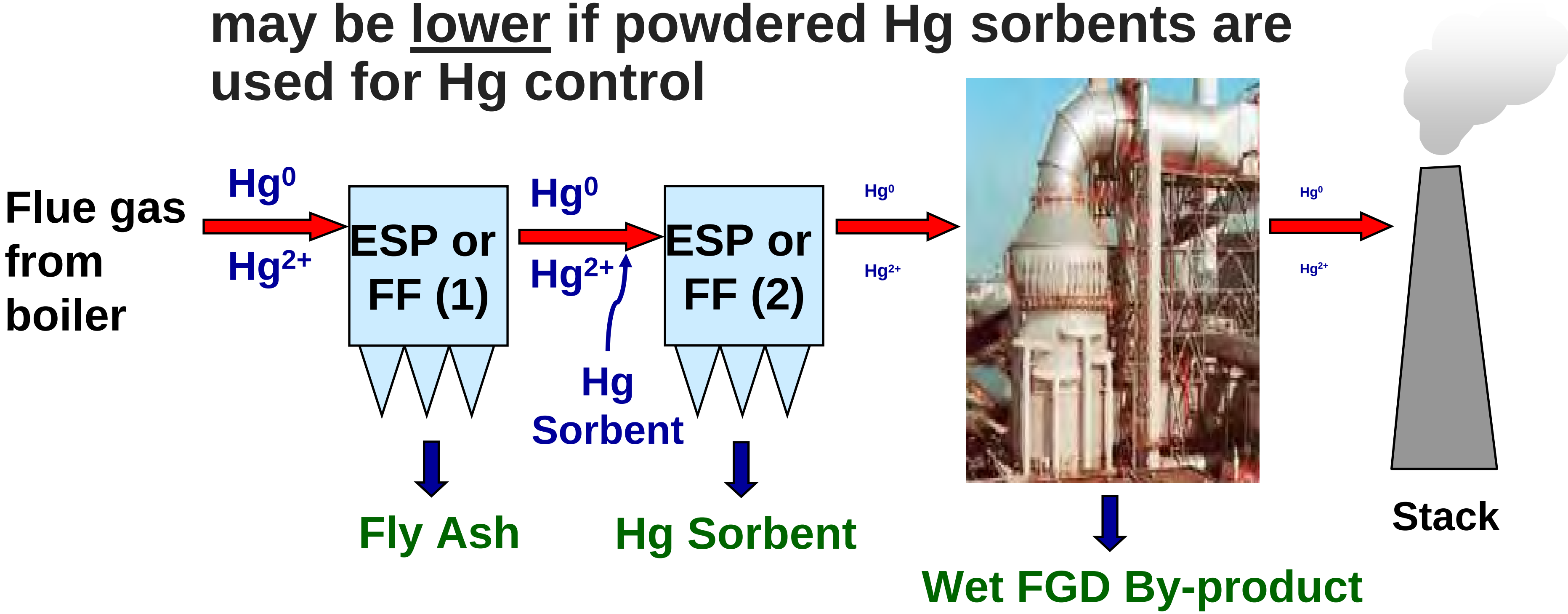
Stack

- ➢ **More Hg in fly ash = less in FGD byproduct**

Effects of CAMR on Hg in Wet FGD Byproducts

Points to consider

3. Hg concentration in wet FGD byproducts may be <u>lower</u> if powdered Hg sorbents are used for Hg control



Flue gas from boiler

Hg^0

Hg^{2+}

ESP or FF (1)

Hg^0

Hg^{2+}

Hg Sorbent

ESP or FF (2)

Hg^0

Hg^{2+}

Hg^0

Hg^{2+}

Fly Ash

Hg Sorbent

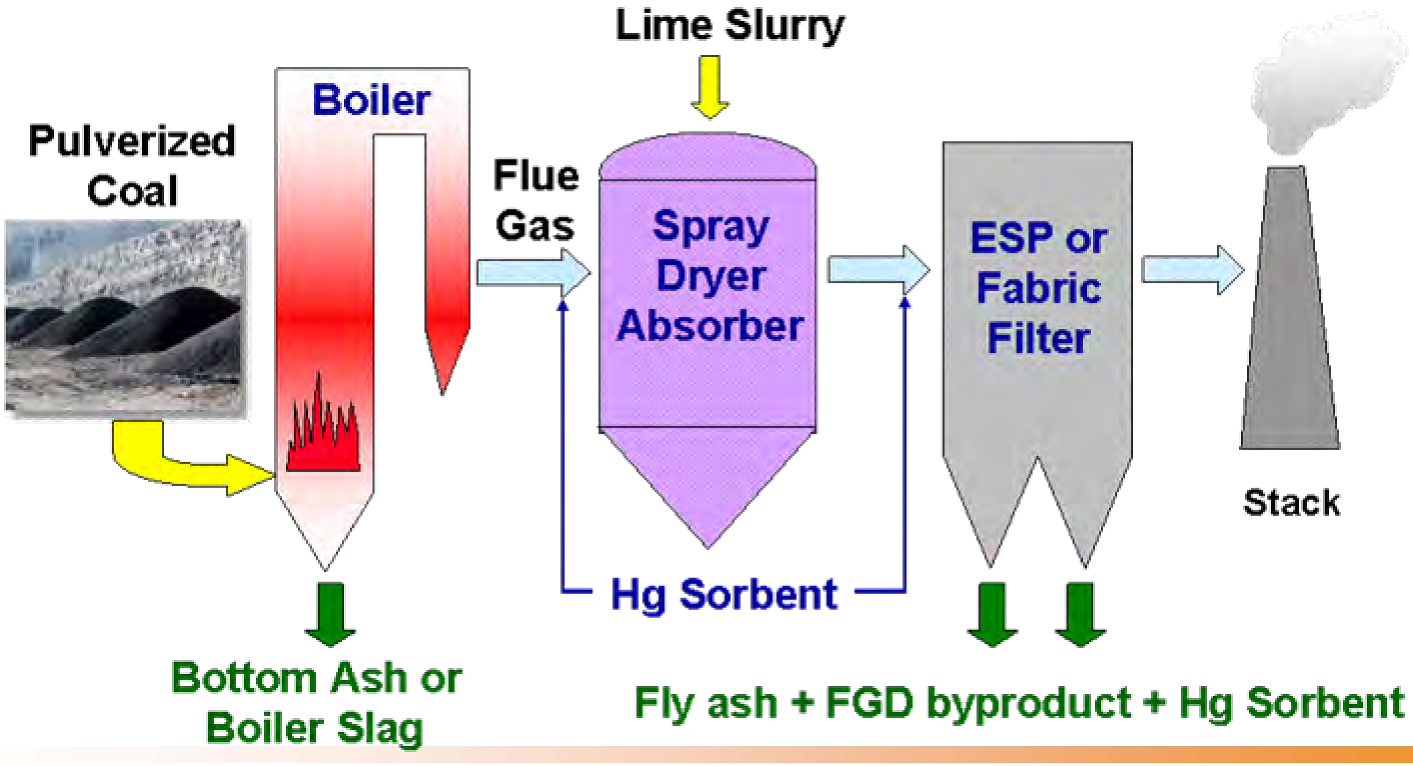
Wet FGD By-product

Stack

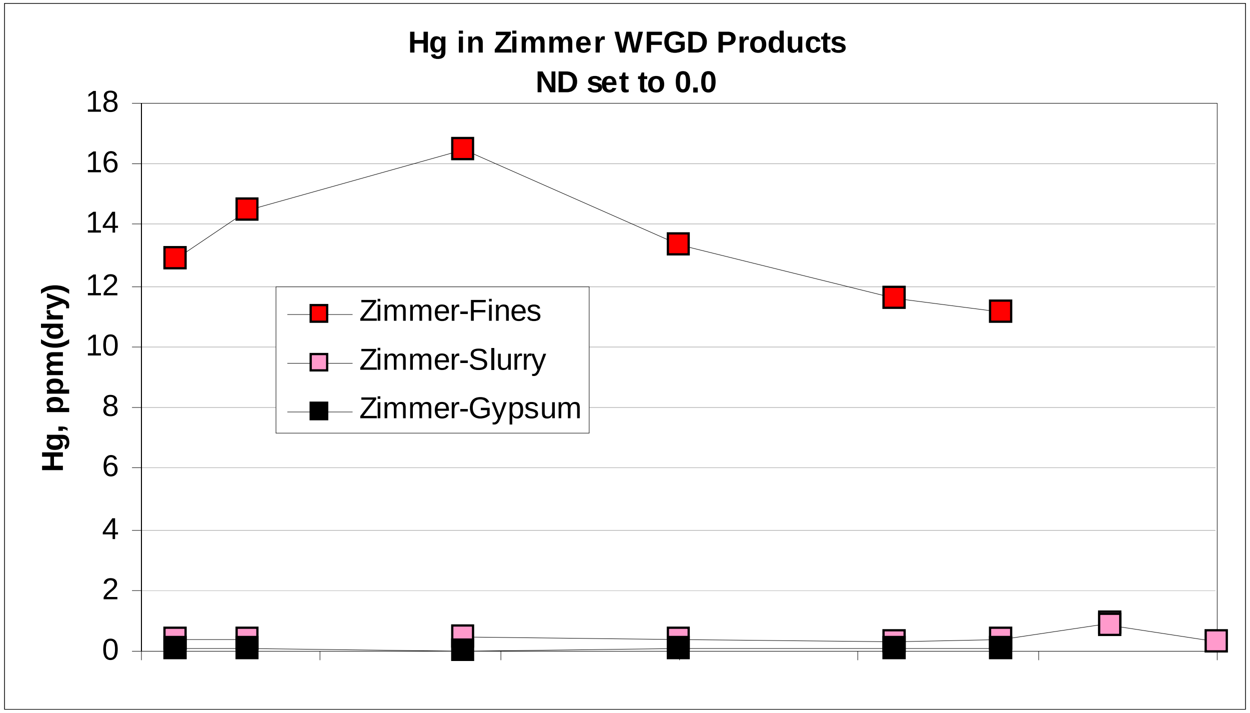
➢ More Hg in fly ash = less in FGD byproduct

Effects of CAMR on Hg in Dry FGD By-products

- **Powdered sorbents will probably be the Hg control method of choice**
- **FGD byproduct will have <u>some more Hg</u> but <u>much more Hg sorbent</u> than before**



Where Does the Hg Go upon Capture ?

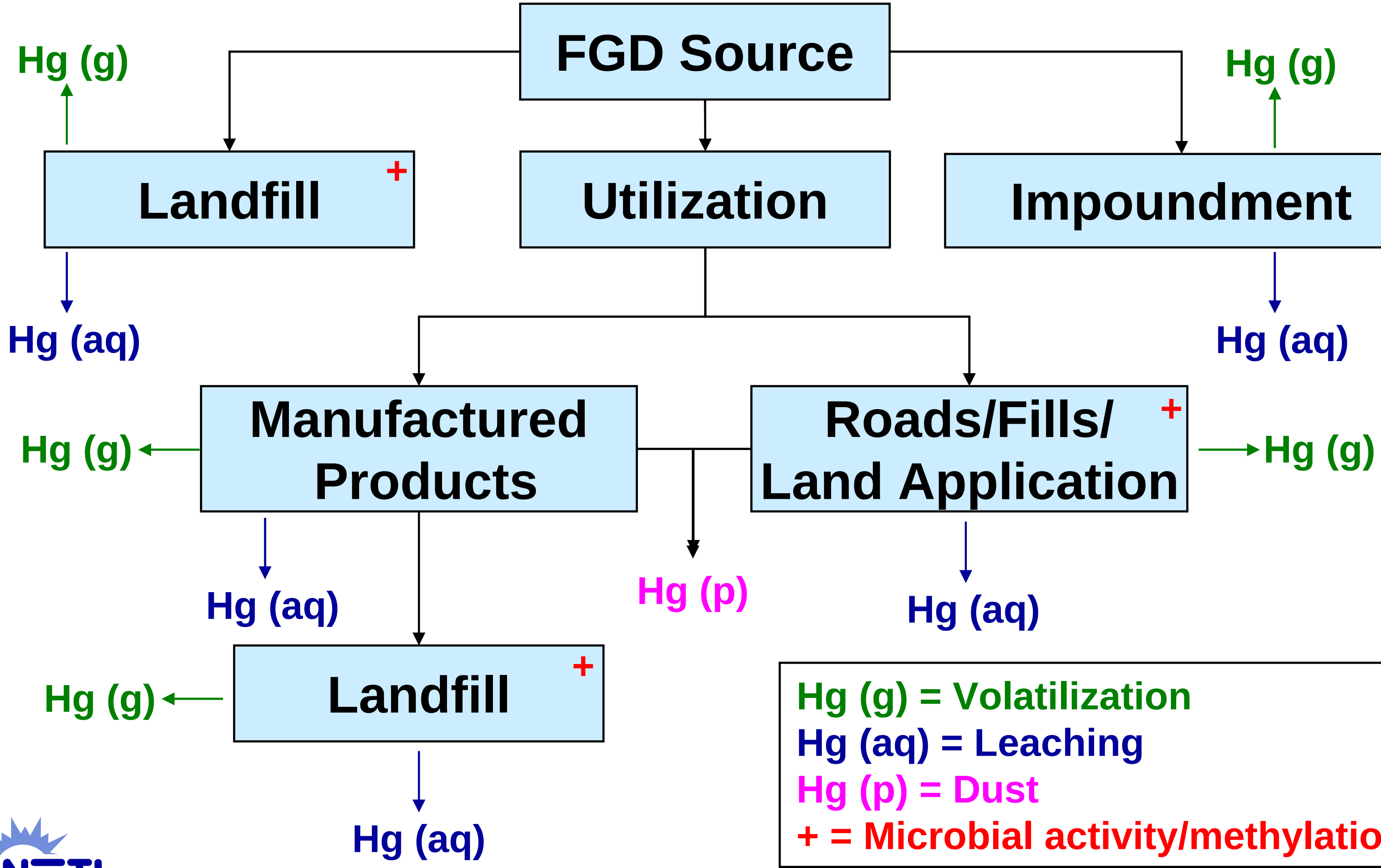


"… the mercury compound formed in the wet scrubber is associated with the fines and is not tied to the larger gypsum crystals."

Source: "FULL-SCALE TESTING OF ENHANCED MERCURY CONTROL TECHNOLOGIES FOR WET FGD SYSTEMS" Final Report, DE-FC26-00NT41006, BABCOCK & WILCOX CO. and McDERMOTT TECHNOLOGY, INC. May 7, 2003

Environmental Release of Hg from FGD Byproducts

R&D Must "Check all the Boxes"



FGD Source

Hg (g)

Landfill +

Utilization

Impoundment +

Hg (g)

Hg (aq)

Hg (aq)

Hg (g)

Manufactured Products

Roads/Fills/ Land Application +

Hg (g)

Hg (aq)

Hg (p)

Hg (aq)

Hg (g)

Landfill +

Hg (aq)

Hg (g) = Volatilization
Hg (aq) = Leaching
Hg (p) = Dust
\+ = Microbial activity/methylation

Near-Term R&D Goals

Hg Release from FGD Byproducts

- **Determine the stability of Hg and other metals under simulated end-use environments**
  - Disposal and re-use

- **Explain the chemistry underlying metal stability**

FGD solids ready for disposal

Drywall ready for landfill

Continuous Stirred Tank Extractor (CSTX)

Near-Total Dissolution of FGD Gypsum and Wallboard Samples

Continuous stirred tank extractor

- **Leachate: ~1% of Hg**
- **Residue:**
  - ~ 99% of Hg
  - ~ 2% of original material
  - Mostly Fe & Al compounds
- **An iron-containing phase, probably introduced with limestone, is responsible for sorption of mercury**
- **Rapid Hg leaching is unlikely in typical disposal and land-application (agricultural) environment**

FGD Byproduct Reuse: Economics 101

- **Producer (Utility) Perspective:**
  - – Recycling occurs when cost of reuse < Cost of disposal
    - In theory: new technology reduces cost of reuse
    - In practice: reuse becomes “economical” when disposal costs rise

- **User Perspective:**
  - – Recycling occurs when cost of reuse < cost of alternative materials
    - Need specifications for reuse (not always available)
    - Need consistent supply and quality of material
    - Need support from material supplier

Characteristics of FGD By-products Determine the Optimum Mine Placement Strategy

- **FGD Gypsum**
  - Highest value: Soil amendment
  - Use care if employed as bulk fill (solution channeling?)

- **Stabilized calcium sulfite**
  - Structural fill, flowable fill, etc.
  - Transportation: May “set up” in trucks

- **Dry FGD and FBC By-products**
  - Highly alkaline; can neutralize acid-producing materials
  - Transportation: May “set up” in trucks

For More Information

- **DOE-NETL CUB Website**
  - http://www.netl.doe.gov/technologies/coalpower/ewr/coal_utilization_byproducts/

Environmental and Water Resources
Coal Utilization By-Products

- Utilization Research
- Environmental Research
- Combustion Byproducts Recycling Consortium (CBRC)
- Regulatory Drivers

The Coal Utilization By-Products (CUB) program is sponsoring research to support the environmentally safe, technically sound handling of CUB material. The program sponsors numerous projects from bench to demonstration scale. The research area includes: 1) Evaluation of potential environmental impacts of CUB disposal or utilization, for example, the photo shows a flowable fill application, 2) Optimization of accepted and novel utilization methods, and 3) Collection and dissemination of data to assist in regulatory decisions related to CUB.

- Recycling and Beneficial Use of Coal Utilization Byproducts, Presented at the AWMA 2006 Waste Management Meeting, Arlington, VA, January 18, 2006.
  - Presentation Slides [PDF-1.07MB]
- The Fate of Mercury in Coal Utilization By-Products - DOE/NETL's Research Program, Presented at the China Workshop on Mercury Control from Coal Combustion, October 31 - November 2, 2005, Beijing, China.
  - Presentation Slides [PDF-1.2MB] Manuscript [PDF-308KB]

DOE-EPA Report on Recent CUB Disposal Practices

- Available at DOE Office of Fossil Energy website:
  - http://www.fossil.energy.gov/programs/powersystems/pollutioncontrols/coal_waste_report.pdf

Coal Combustion Waste Management
at Landfills and Surface Impoundments,
1994–2004

U.S. Department of Energy
Office of Fossil Energy
and the
Office of Policy and International Affairs

U.S. Environmental
Protection Agency
Office of Solid Waste

FGD AS AN IMPERMEABLE CAP FOR COAL WASTE

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View Presentation

Abstract

This paper describes the pre- and post-reclamation hydrologic study of the Rock Run valley-fill coal-refuse pile. Our one-year pre-reclamation study in 1995-96 resulted in a pile water budget used to plan water management, namely stream diversion and capping the pile with FGD by-product. The water budget indicated that significant groundwater seepage would continue, so additional passive treatment was installed in the 1999 reclamation, namely open-limestone channels and a Successive Alkalinity-Producing System (SAPS). We conducted a nine-month study of the hydrology in 2000-2001, after reclamation. This paper focuses on the hydrologic regime before and after capping and diversion and does not discuss the passive treatment. We invoke 2004 results of our study of a second pile, the Flint Run pile, to discuss the possible role of the FGD cap in limiting airflow. A future post-reclamation study at Rock Run would test the long-term efficacy of the reclamation, including the limitation of both water- and air-flow. Published papers emphasize three hydrologically important variables, namely: 1) waste permeability; 2) surface infiltration into the pile; and 3) the hydrogeology of the surrounding terrain. The pre-reclamation study therefore attempts to quantify or constrain these variables via a year of data collection on surface discharges and hydraulic heads and vertical gradients within the pile. A numerical steady-state flow model of the pile further constrains the inherently uncertain variables. A comparison of pre- and post-reclamation discharges and hydraulic heads shows an estimated 60% reduction in the pile recharge, the water table lowered by as much as 7m (average 3.4m decrease), and continued high gradients indicating upward flow at the toe. Stream diversion accounts for 98% of the recharge decrease; capping only accounts for 2%. Pre-reclamation water quality in Rock Run downstream of the pile was pH 2.9-3.5; acidity 105-360 mg/l; total iron 46-180 mg/l (40% ferrous), and acidity load 290-2700 lbs/day. Post-reclamation water quality was pH 4.1-6.3; acidity 46-100 mg/l; and total iron 9 mg/l (no ferrous) to 80 mg/l (48% ferrous), with the higher iron concentrations measured soon after reclamation. Acidity loading decreased to 16-122 lbs/day. Improvements are due to the combined effects of the capping, stream diversion, and passive treatment. Control of air flow by the FGD cap may have played a role, as indicated by observations at the Flint Run pile.

Introduction

The Rock Run pile was formed when raw coal mined in the surrounding area was sorted, first by hand and later by crushing and washing to float light coal from heavier shale and pyrite impurities. As much as 40% of mined coal became waste material in the earlier operations (modern operations have a much higher efficiency), so old waste piles are a significant factor in poor water quality in previously mined areas. The Middle Kittanning (No. 6) Coal mined in Perry County, Ohio has average sulfur content of 4.2% (Ver Steeg 1944) and waste piles are enriched in sulfur relative to the coal.

Acid mine drainage (AMD) forms when sulfide minerals, mainly pyrite, are exposed to surface or ground waters and oxygen (Sengupta 1993). The reactions are summarized below (Stumm and Morgan 1981, Banks *et al.* 1997):

$$FeS_2 + 7/2O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$
$$Fe^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O$$
$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$$
$$FeS_2 + 14\,Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

The reactions show the key role of oxygen and water in generation of mine drainage, and the characteristic AMD products, namely protons (acid), sulfate, iron, and Fe $(OH)_3$ or “yellow boy.” In addition, the low pH frees metal ions from a variety of minerals. The reactions also suggest, as approaches to AMD control, limiting air and/or water contact with the refuse.

The most important factor controlling the rate of AMD production in surface-mining wastes is the availability of oxygen, which is the primary oxidizing agent for pyrite and a key component in sustaining biological respiration (Watzlaf & Hammack 1989; Guo et al. 1994; Rose & Cravotta 1998). The partial pressure of oxygen must be extremely low, however, to suppress pyrite oxidation. Lab column studies found reaction rates to be independent of oxygen partial pressures down to 1% (Hammack & Watzlaf 1990). For this reason, sub-aqueous disposal of tailings is widely favored (Broman & Göransson 1994; Amyot & Vézina 1997). The solubility of oxygen in water is low so that its concentration in groundwater is 0.0001 times that of air, limiting redox reactions under water-saturated conditions. In experiments with inundation, a 96% reduction in pyrite oxidation was achieved. Under unsaturated conditions, the major physical processes that control the availability of oxygen include the permeability of the waste material and the transfer of gas by advection and/or diffusion mechanisms (Prein & Mull 1998; Lefebvre et al. 2001; Guo et al. 1994; Rose & Cravotta 1998). The oxidation front or zone of maximum pyrite oxidation in surface mining wastes will take place at some depth in the unsaturated zone. Column leaching experiments show that oxidation fronts will migrate deeper with time as iron pyrite is depleted, requiring the oxidant to diffuse farther into the waste material to reach new pyrite oxidation sites (Watzlaf & Hammack 1989; Guo et al. 1994; Hecht & Kolling 2002).

In coarse, permeable mining wastes, advective transport of oxygen is believed to dominate diffusion because the permeability allows convective airflow circulation driven by exothermic pyrite oxidation (Lefebvre et al. 2001). As pore gas is heated, the air becomes less dense and moves upward through the waste. Cold dense outside air is drawn into the pile along thermal gradients (Watzlaf & Hammack 1989; Guo et al. 1994). Once sufficient oxygen is supplied to the reaction zones, bacteria catalyze the reactions, liberating more heat and driving air circulation in a self-sustaining cycle.

Infiltrating precipitation can disrupt thermal gradients by transferring heat from the hotter reactive zones to the cooler, deeper regions of the pile (Smith et al. 1995; Lefebvre et al. 2001). Continuous monitoring at the Myra Falls waste rock dump in British Columbia found significant cooling of pile temperatures by infiltrating precipitation to depths of 10-15 m over a matter of hours (Smith et al. 1995). Both advective airflow and disruption of this airflow by infiltration depend upon the temperature and depth of the reactive zone, rainfall intensity, and waste permeability (including surface infiltration capacity).

Clearly, the permeability of the waste is important. Studies of mine spoils provide insight into the nature of the Rock Run waste pile. Spoil is an extremely heterogeneous and anisotropic material due to handling and disposal during mining and reclamation (Hawkins 1998). Spoil hydraulic conductivity (K) has been shown to exhibit a 95% confidence-interval range of six orders of magnitude around a mean of 1.7×10^{-5} m/sec (Hawkins 2004). Slug-test estimates of K were seen to range over four orders of magnitude (10^{-6} to 10^{-2} m/s), displaying two prominent statistical modes ascribed to fine matrix and coarse rubble zones, respectively (Maher and Donovan 1997). Coarse material (boulders to cobbles) is often "spoiled" together with finer material (silt, clay, and/or coal fines). A natural sorting takes place during the process of spoiling and grading the waste rock. The coarse material has a tendency to roll to the base of the spoil pile while smaller fragments tend to remain near the top and sides of the spoil ridge (Hawkins 1998). This buildup of coarse material can create zones of higher hydraulic conductivity parallel to the contour of the spoil ridge. Haul roads and mine spoil can become highly compacted from the use of heavy equipment. Most spoil aquifers drain freely under the influence of gravity. In the case of valley-fill material, water will drain along the underlying topography of the valley floor. Spoil aquifers usually have a single water table that mimics the overlying topography, though they can exhibit multiple water tables under transient conditions (Hawkins & Aljoe 1991). Spring or seep discharges at the toe of the spoil will commonly form along structural low points in the pit floor or along the toe of the spoil near the valley floor interface (Hawkins 1998).

Monitoring and testing indicate that groundwater is stored in and flows through large voids or conduits in the spoil. Under steady-state conditions, spoil behaves mainly as a porous medium, but during transient conditions macropore flow becomes more pronounced (Hawkins 1998). However, diffuse groundwater flow through the interstices of the fine-grained material between the voids may exert significant control, because macropore networks may not be well connected across a mine site (Hawkins 1998). During a rainfall event, runoff is captured and fills macropores connected to the surface. The infiltrating water fills the macropore conduit and may move either from the macropore to the matrix or the opposite if the matrix is saturated (Beven & Germann 1982). Initiation of flow in the macropore requires a supply of water exceeding all losses to the matrix (Beven & Germann 1982). Water fluxes may vary several orders of magnitude over a distance of only a few centimeters. Any flow concept based on average hydraulic gradients can be expected to fail due to a departure from predictions based on Darcian principles (Beven & Germann 1982). In porous media with strongly variable K, water follows preferred flow paths or channels having hydraulic properties that are different from those of the global porous medium (Moreno and Tsang 1994). Macropores also increase the storage volume that must be filled before surface runoff occurs. Macropore networks increase the surface area for matrix infiltration and thereby allow rainfall to penetrate deeper than is predicted by a uniform wetting front (Guebert & Gardner 2001). Macropore development is a common theme in engineering and is referred to as piping. Piping or subsurface erosion begins at springs near the downstream toe and proceeds upstream along the base of a structure or a bedding plane.

Decreasing recharge to a pile can increase the size of the unsaturated oxidation zone in the pile (Lin & Qvarfort 1996). If a pile is capped, however, concentrations in pile discharge are not expected to increase in proportion to the thickness of the oxidation zone. Keeping wastes “high and dry” (through capping, drainage, or water diversion) minimizes flushing of oxidation products (Gabr et al. 1994). Capping is likely to be fully effective only if precipitation is the primary source of recharge; that is, there is little interaction between the waste pile and the regional bedrock aquifer (Durham 1989). Capping will be less effective where there is significant groundwater recharge of the waste (Gabr et al. 1994, Hawkins & Aljoe 1991, Bullock 1997, Wunsch et al. 1999). In such cases, subsurface diversion by a grout curtain, for example, may be effective (e.g., Gabr et al. 1994).

Site Description

The Rock Run coal refuse pile (Figure 1 and 2) was created at a coal-washing plant in Perry County, Ohio that processed and shipped strip-mined coal trucked in from the surrounding area in 1944 and 1945. Coarse dry wastes from crushing and screening appear to have been dumped directly on natural valley soils, forming a permeable dam. Behind the dam, coal-washing slurry was discharged from a pipe moved around to disperse the slurry (Thompson 1988). The dam was raised as needed to accommodate the growing pile, which by 1995 was as much as 15m thick. Surface water flowing from the two major tributaries formed ephemeral ponds on or beside the pile (Ponds 1 and 2, Figure 1). Some of this surface water flowed across the pile into Rock run; and some infiltrated into the pile. A mine opening near the head of the stream in Region 4 discharged acid mine drainage into Pond 1. Groundwater recharged the pile from the sides and bottom and discharged the pile through seeps in the face of the coarse dam to the west and as groundwater seepage into the bed of Rock Run.

Bedrock at the site includes units from the top of the Pennsylvanian Pottsville Series and units from the bottom of the Pennsylvanian Allegheny Series (Flint 1951), including (from oldest to youngest) the Tionesta shale, the Tionesta clay, the Homewood sandstone, and the Homewood sandy shale (Figure **3**). A weathered zone between the coal waste and the bedrock reflects the character of the parent rock, with sandy material over sandstone and clayey material over shale. Except where sandy parent material exists, the pile lies on a low-permeability brown clay, believed to be the original soil. The Upper Freeport (No. 7) coal (and later, its underclay) was mined starting around 1900 (ODNR 1921). Based on measurements of two persistent rock units, the Ames Limestone and Middle Kittanning Coal, the Pennsylvanian rocks in the area strike N 17.5° E and dip 0.33° SE. Prominent conjugate tectonic joint sets trend NW-SE and NE-SW (Ver Steeg 1944).

Bedrock fracturing is expected to play a hydrologically important role in pile recharge. Uplift and erosion of rocks formed under compression causes differential removal of stress. Erosion of valleys causes stress-relief opening of joints along steep valley walls (Hobba 1981) and of bedding planes under valley floors, creating a characteristic fractured aquifer (Figure 4) (Wyrick & Borchers 1981). Ground-water flow occurs as vertical infiltration along valley walls via the stress-relief fractures, and lateral movement along the bedding-plane fractures. The primary permeability of sandstone in the region generally is low due to cementation and compaction, but secondary permeability due to fractures may cause an increase in hydraulic conductivity of one to three orders of magnitude (Brown & Parizek 1971). Sandstone and coal are the most permeable of the Pennsylvanian rocks because they can support fractures (Peffer 1991). The massive Homewood sandstone is notable because it crops out over 20% of the original valley beneath the waste, and is believed to discharge water into the pile. It acts as the primary conduit of groundwater because it is sandwiched by less permeable clay, shale, and sandy shale. Joints in shale and claystone are tighter so permeability is less than that of other units (Peffer 1991). Moreover, shale tends to self-heal fractures that develop at depth (Hawkins et al. 1996).

Reclamation of the Rock Run pile in 1999 included regrading the pile to minimize erosion and to drain ponds, diverting surface runoff through geotextile-lined limestone channels, and capping the refuse with 60cm of compacted FGD by-product, 60cm of a 50/50 mixture of FGD and refuse, and 20cm artificial resoil (Figure 5). A passive wetland treatment (SAPS) system was installed to treat the mine water, which was diverted into the lined channel (Figure 6).

Methods

Studies were conducted for a one-year period (Nov.1995-Nov.1996) prior to reclamation (Bullock 1997) and for a 9-month period (Sept. 2000-June 2001) after reclamation (Pereira 2001). The pre-reclamation study was designed to estimate the benefit of the reclamation in terms of acid mine drainage control. The post-reclamation study was designed to compare actual performance to the predictions of the pre-reclamation study. For the pre-reclamation, a conceptual model of the pile was constructed, including an annual water budget, and based on site and regional geology, measured surface flows, and published values for precipitation and evapotranspiration. A numerical flow model was used to refine the conceptual model and constrain estimates of groundwater recharge and discharge using measured groundwater levels, hydraulic gradients, and hydraulic conductivity. The conceptual model was then modified to account for post-reclamation changes in the water budget.

The pile watershed was divided into seven hydrologically distinct runoff regions (Figure 1), and a water budget was calculated for each region. This approach was taken because precipitation onto the pile is small compared to infiltration of runoff from precipitation on the pile's watershed. Rainfall data from a rain gauge 10km north of the site was used, for the period October 1, 1995 to September 30, 1996. Precipitation for the 1995-96 water year (126 cm) exceeded mean annual precipitation by 24% (Harstine 1991). Precipitation volumes were calculated by multiplying regional areas by 126cm; evapotranspiration, runoff and infiltration were estimated to be 60%, 35% and 5% of precipitation, respectively, based on regional ratios (Harstine 1991). Runoff rates are high due to the clay soils and moderate to steep slopes of the surrounding watershed (USDA 1988). Evaporation from Ponds 1 and 2 was calculated from their surface areas and the annual 81 cm/yr open-water evaporation for the region (Harstine 1991). Evaporation from Pond 1 was apportioned to its three contributing regions' water budgets by area. "Maximum pile recharge" for each region was calculated as the sum of infiltration and runoff, minus pond evaporation where applicable. Surface runoff from Regions 1, 6 and 7 was captured in drainage channels and conveyed to Rock Run with negligible loss to the waste pile, so runoff from those areas did not contribute to pile recharge. Because the waste pile intercepts natural surface drainage and baseflow, a significant portion of the "maximum recharge" is expected to enter the pile and eventually exit the pile toe into Rock Run.

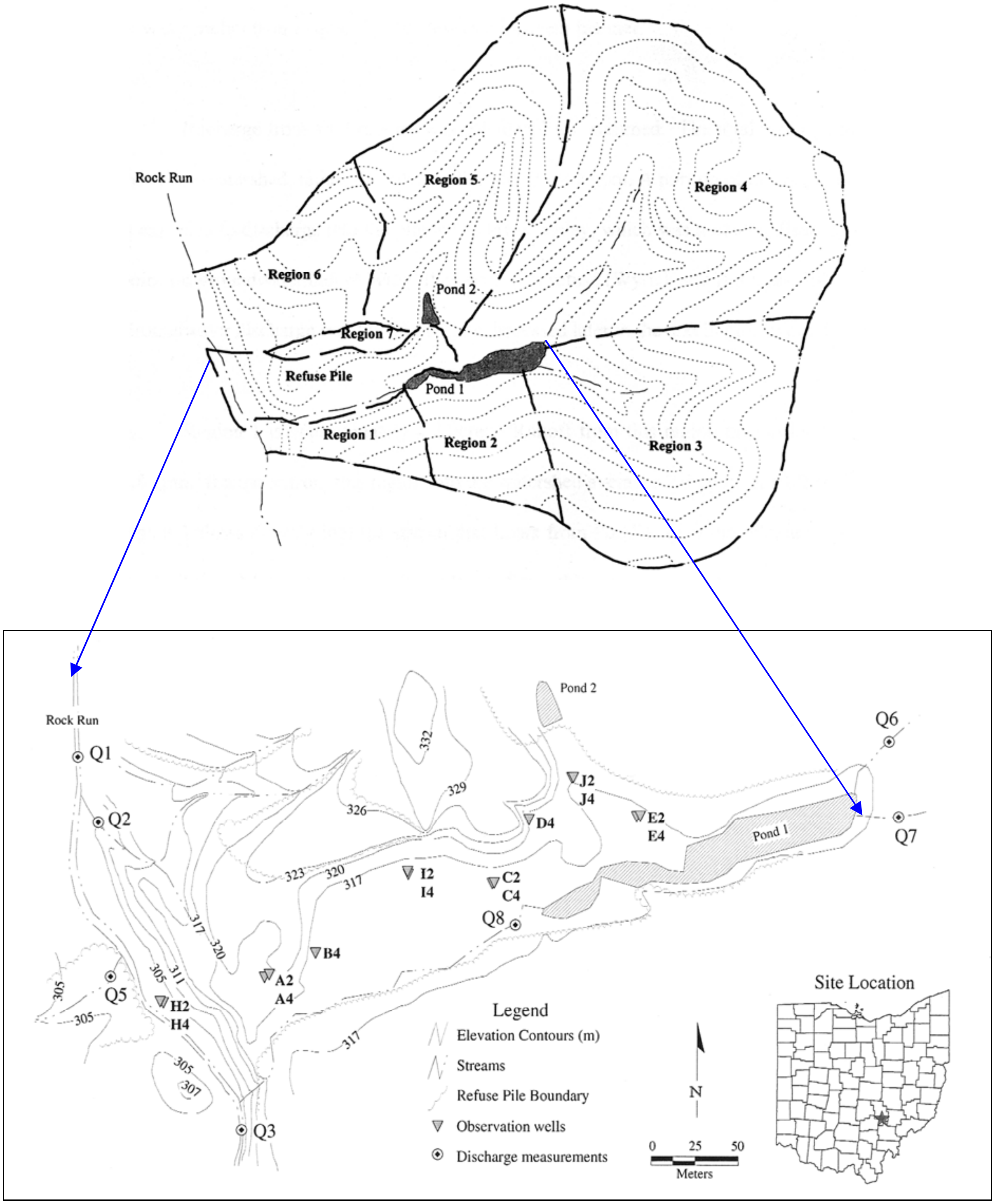

Figure 1. Location, watershed and topography of the coal-refuse pile. Note observation-well locations and discharge-measurement sites. (Contour interval in upper map is 6m.)

Figure 2. View of the Rock Run refuse pile prior to reclamation. Note Pond 1 in right background.

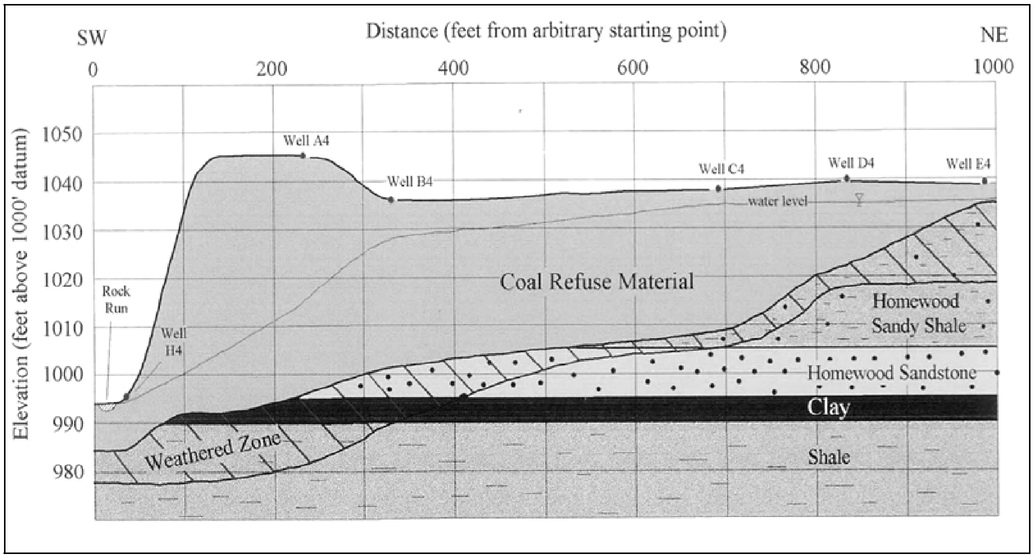

Figure 3. Cross section of the Rock Run coal refuse pile, constructed from borehole logs drilled to bedrock refusal and local stratigraphy (Flint 1951). Water level is based on heads measured in monitoring wells (tops of casings shown as small circles).

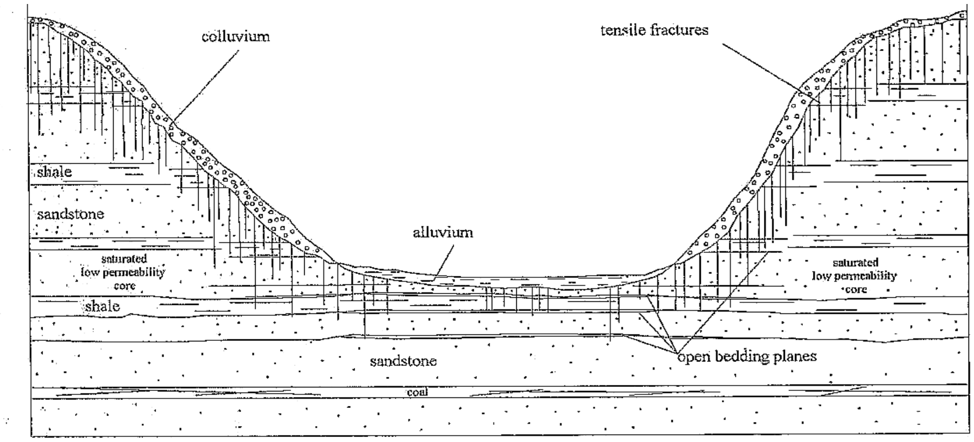

Figure 4. Valleys formed in the Appalachian Plateau have predictable, interconnected fracture systems formed in response to stress relief (Wyrick & Borchers 1981).

Figure 5. Spreading of 60 cm of FGD by-product on the regarded pile surface (top); construction of diversion channel using a geotextile liner and limestone (bottom).

Figure 6. The lined passive treatment system (SAPS) treated the mine discharge at the pile head and discharged the treated water into the diversion channel. In 2006, the system continues to require maintenance.

Not all precipitation entering the fracture system discharges into the Homewood sandstone. At least 30% of recharge to the aquifer is expected to discharge as seeps in the surrounding watershed, enter the regional aquifer system, or remain in the fracture system and be transported further down-gradient. However, some of the recharge clearly discharges into the pile. In constraining the model discussed below, recharge into the base of the pile is assumed, using symmetry arguments, to fall between 20 and 50% of the available water. This high rate reflects the focused discharge of large volumes of water from the surrounding watershed. Other studies have found similarly high rates where a stream intersected a massive, horizontally fractured sandstone bedrock unit (Wyrick & Borchers 1981).

Surface discharges were measured at eight points (Q1 to Q8; Figure 1). Moderate discharges (5-20 L/sec) were measured using a Baski collapsible 20-cm cutthroat flume; small discharges (<5 L/sec) were measured with a bucket and stopwatch; and larger discharges (>20 L/sec) were measured with a pygmy meter and wading rod. Seepage from the pile toe into the streambed of Rock Run was estimated as a residual of other discharges (Q1-(Q2+Q5+Q8+Q3)). It is intrinsically uncertain due to uncertainty in measurements of the other discharges. Seepage into the streambed from the west side of Rock Run may occur and is assumed to constitute less than one third of the baseflow. It may be negligible because of the far steeper topography and strong hydraulic gradients on the east side. Also, some drainage from the western side is accounted for by Q5.

To constrain toe seepage for the steady-state model, the residuals were averaged excluding December (missing data), March, May, and June, when high surface discharges propagated potentially high errors into the residual baseflow. (The May 4, 1996 discharge at Q1 exceeded 0.3 m^3/sec in Rock Run.)

Hydraulic head was measured monthly in 14 observation wells or piezometers (Figure 1). Wells were installed prior to reclamation as six pairs or nests, screened to different depths to measure vertical gradients. Deep wells were drilled to refusal using hollow stem augers. Shallow wells were cased with 2” PVC and the remaining wells with 4” PVC casings. All wells used 1.5m screens, completed at depths from 4 to 15m in deep nested wells, and at depths of 1.5 to 6.7m in all other wells. Water levels in the 14 wells were measured relative to sea level on eight dates before reclamation. An average water-level map was constructed by averaging heads on three days of moderate water level (April 10, July 26, and September 29, 1996). Some of the wells were removed during reclamation and re-drilled afterwards for the post-reclamation monitoring. Hydraulic conductivity was measured in 12 of the 14 monitoring wells using slug tests (Bouwer & Rice 1976) and specific capacity tests (Bradbury and Rothschild 1985). A specific capacity test was performed in the only well capable of prolonged pumping (well D4; Q = 0.6 l/s for 132 min).

Wells were removed during reclamation and re-installed afterwards in approximately the same locations. Slug tests were again performed in the wells.

A steady-state areal two-dimensional hydrologic model was constructed using MODFLOW (McDonald & Harbaugh 1988), discretizing the problem domain into a 77x38 grid, with 934 active cells with dimensions 4-6m. A steady-state model is justified because the purpose of modeling is to determine relative and average source contributions, rather than complex aquifer responses to individual events. Spoil piles have been observed to exhibit what is described as "pseudokarst" flow during transient conditions (Aljoe 1994) with subsurface conduits connecting stream sinks and resurgent springs (Hawkins & Aljoe 1990). Flow can be rapid; in a large waste pile in British Columbia, water penetrated 45 m in 12 to 36 hours (Morin et al. 1994). Hydraulic conductivity (K) values consistent with models may be 1-2 orders of magnitude greater than field-measured K because of pseudokarst conditions that lower heads. In some waste piles, however, the model-calibrated K is close to values measured in the field (Durham 1989). Flow in waste piles is not always rapid. They may store and slowly release water (Kemp 1990) and may have annual head fluctuations less than 1 m (Durham 1989). In any case, even pseudokarstic mine spoils have been successfully simulated under steady conditions (Hawkins 1994).

Ponds 1 and 2 were treated as constant-head boundaries. Lateral no-flow boundaries occurred where refuse contacts natural valley clay soil. A surficial recharge rate based on regional averages for infiltration as a percentage of precipitation (Harstine 1991) was assumed initially. After early runs failed to simulate observed heads, the conceptual model was revised to include a new significant source of water. Literature review revealed a likely mechanism, namely infiltration of watershed runoff into stress-relief fractures along the valley walls, as described earlier. This upward flow from bedrock was modeled as additional recharge at the Homewood Sandstone outcrop underlying 5800 m^2 (20%) of the pile, because the two-dimensional model does not discriminate between recharge from above and from below. To calibrate the model, hydraulic conductivity and recharge were adjusted within their expected ranges, with the criteria being a match of simulated heads to observed heads, and a match of simulated pile discharge to the estimated range of discharge.

Results and Conclusions

The pre-reclamation water budget is summarized in Figure 7. The post-reclamation water budget differs in having no infiltration through the cap, no infiltration from Pond-1 discharge, and a 22% decrease in the bedrock recharge. Vertical hydraulic gradients (Table 1) are consistent with the conceptual model, reinforcing the importance of the Homewood sandstone. Flow is horizontal in the eastern part of the waste pile (Nest E), downward near Pond 2 where impounded water enters fractures (vertical gradient as high as 0.05 at Nest J, screened in natural material), downward into the sandstone at the eastern extent of its outcrop during the dry season, but horizontal or even slightly upward during the wet season (Nest C), upward near the middle of the Homewood outcrop (gradient as high as -0.04 at Nest I), and upward into Rock Run (gradient as high as -0.09 at Nest H). Well A2, just beyond the western extent of the Homewood outcrop, shows much higher heads than A4, suggesting water perched on fines within the coarse dam materials.

Table 1. Gradients in the pile prior to reclamation.

Well Nest	11/16/95	4/10/96	4/21/96	6/15/96	6/23/96	7/26/96	9/29/96	11/19/96	Flow direction
A	-	0.623	0.613	0.558	0.581	0.584	0.552	0.542	DOWN into Rock Run
C	0.027	0.000	0.020	-0.007	0.007	0.013	0.013	0.013	down into Homewood
E	-	-0.030	-0.007	0.007	0.000	0.000	-0.007	-0.007	flat
H	-0.035	-0.087	-0.043	-0.070	-0.043	-0.009	-	-	up into Rock Run
I	0.256	-0.040	-0.040	-0.032	-0.032	0.000	0.000	-	up from Homewood
J	-	0.000	0.011	0.042	0.053	0.000	0.000	0.032	down from Pond 2

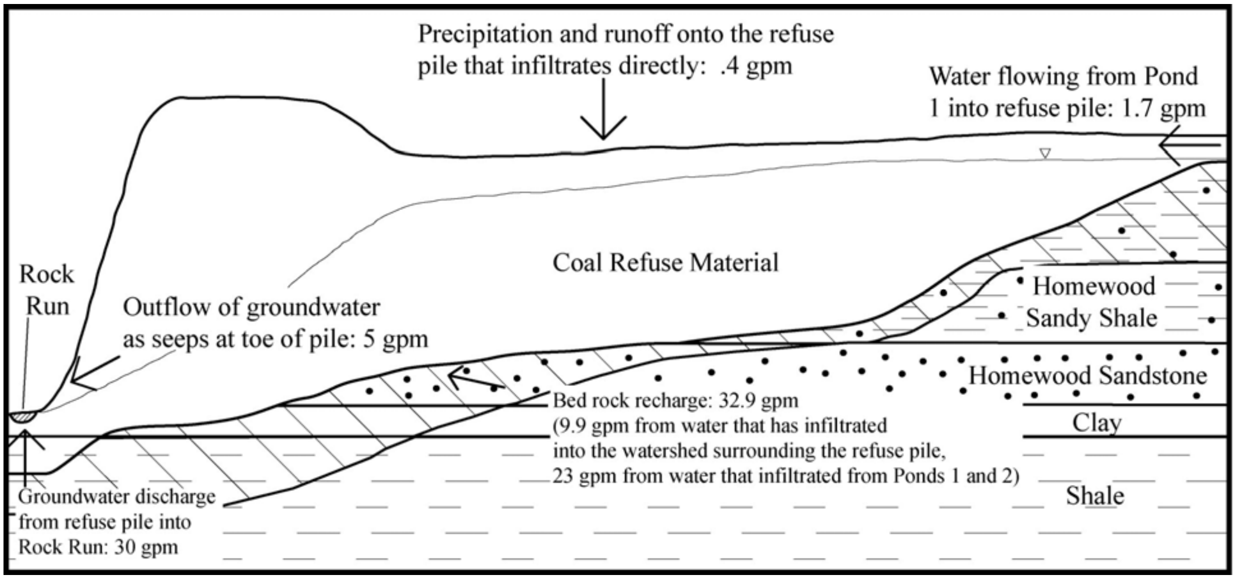

Figure 7. Water budget for the waste pile. Groundwater discharge from the Homewood sandstone recharges the pile from below. Capping the pile and diverting surface flow intercepted an estimated 60% of pile recharge. Capping accounted for an estimated 2% of the total decrease; stream diversion accounted for 98%.

In modeling the pile, hydraulic conductivity (K) measurements are needed. K of the coal waste is lognormally distributed, ranging from 2.6×10^{-7} to 2×10^{-3} m/sec, with a modal value of 5×10^{-5} m/sec. The specific capacity test yielded the highest value because it was done on the one well capable of pumping for an extended period. Values after reclamation are similar, changing by less than an order of magnitude. However, neither hydraulic conductivity nor recharge uniquely determines the hydraulic head distribution, so it is critical to constrain the numerical solution with fluxes. In matching modeled and measured heads as a calibration criterion, the solution to the governing equation will be inexact because of modeling simplifications, so there are many parameter choices yielding approximately the same head fit. The difficulty is that either hydraulic conductivity (K) or recharge (R) can be varied to achieve a similar head distribution. It is therefore critical to constrain the model with Cauchy (flux) data. The parameters K and R were varied over their probable ranges (discussed earlier) and solutions that achieved an acceptable head fit are graphed (Figure 8). The outflow from the refuse pile into Rock Run is the dependent variable. The measured and modeled water tables match well ($r^2 = 0.99$).

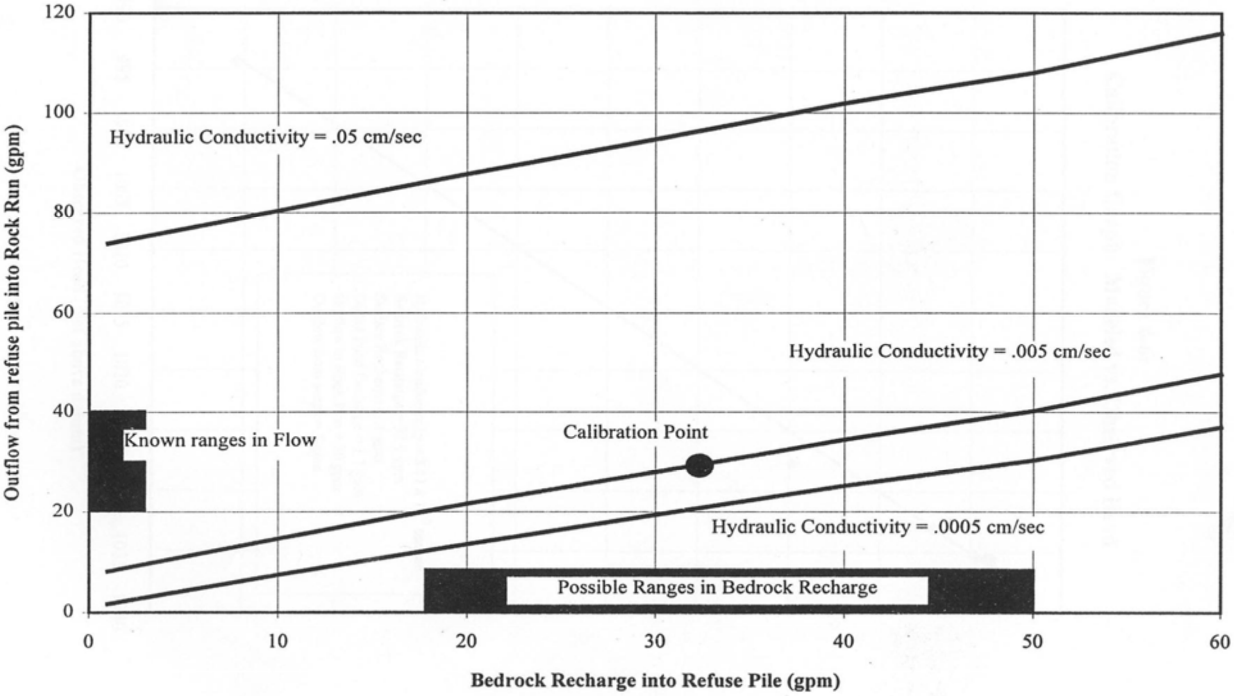

Figure 8. Model calibration and sensitivity analysis. Varying recharge input varies pile discharge output, depending on K (heavy lines). The calibrated model used K = 8×10^{-3} cm/sec, bedrock recharge = 33 gpm, and pile discharge is found to be about 30 gpm.

Discussion of the validity of the conceptual model is warranted, because evidence of flow exploiting a fracture system and recharging the waste pile is indirect. Measured heads and groundwater flow from the pile into Rock Run require a significant flow of water into the pile, an amount which cannot be supplied solely by precipitation onto the pile. The natural process of infiltration into earth materials, entering a stress-relief fracture system and discharging down-gradient in stream valleys has been well documented in the Appalachian plateau. This site differs primarily in the obstruction of the natural system by the waste pile. Water has been observed to collect in both ponds following storms, then to gradually dissipate. The occurrence of acidophilic bacteria in the stream bed substantiates suspected upwelling of low-pH water. The water budget for the watershed shows a significant volume of water produced by the region, with little outflow. Because the pile interrupts the pre-mining drainage, it is likely that the pile will be involved in the post-mining drainage system.

A comparison of pre- and post-reclamation heads shows a decrease in the water-table elevation of 0.2 to 7.4m (average 3.7m), except at the stream so no change was expected. Diversion of surface water at Pond 1 and capping the pile was predicted to reduce pile recharge (and therefore, toe discharge) by <60%. The water table decrease since reclamation is attributed primarily (98%) to stream diversion. Most water is expected, based on the geology, to enter the refuse pile as groundwater discharge from interconnected stress-relief fractures in bedrock in contact with the pile base.

Pre-reclamation water quality in Rock Run downstream of the pile was pH 2.9-3.5; acidity 105-360 mg/l; total iron 46-180 mg/l (40% ferrous), and acidity load 290-2700 lbs/day (Bullock 1997). Post-reclamation water quality was pH 4.1-6.3; acidity 46-100 mg/l; and total iron 9 mg/l (no ferrous) to 80 mg/l (48% ferrous), with the higher iron concentrations measured soon after reclamation (Pereira 2001). Acidity loading decreased to 16-122 lbs/day in the post-reclamation study period. The SAPS removed an average of 31 lbs/day acidity (Christensen 2001), mainly treating the AMD from the mine in Region 4 and releasing about 100 mg/l net alkalinity. Clearly, the large acidity load decrease is attributable only in part to the passive treatment. Improvements are due to the combined effects of the capping, stream diversion, and passive treatment.

Capping eliminated only an estimated 2% of pile recharge. Limiting water infiltration may not be the FGD cap's most important function, however. Observations of the Flint Run pile in Vinton County (Laverty, 2004) suggest that the cap may decrease advective airflow, so that oxygen transfer to the reactive zone is by diffusion. Evidence of piping macropores was seen in 1995 in an eroded gully on the pile's face (Figure 9, left). Holes were seen in another study at the Flint Run refuse pile (Figure 9, right), and were watched during a rain event when they began to flow (Figure 10, left). Excavation of one of the piping holes (Figure 10, right) shows its depth and nature. In that same pile, continuous monitoring of head, DO and pH (Figure 11) shows that increasing heads are concurrent with an abrupt decrease in DO and increase in pH. Although we have not proven causality, we speculate that rising head interrupts the airflow cycle that depends on macropores, causing a rapid depletion of oxygen and a rise in pH.

To test the airflow-interrupting role of the cap, we recommend monthly sampling the seepage from the flowing artesian well at the pile toe (H4). Redox conditions in the pile can be inferred from concentrations of sulfate vs. hydrogen sulfide, and ferric vs. ferrous iron. Redox potential in the H4 water can be measured directly with an eH probe. In addition, gases in the cap can be sampled by soil-gas probes. Another possibility to explore is thermal infrared imaging for escape of hot gases. We also recommend a post-audit of the passive system to monitor long-term performance.

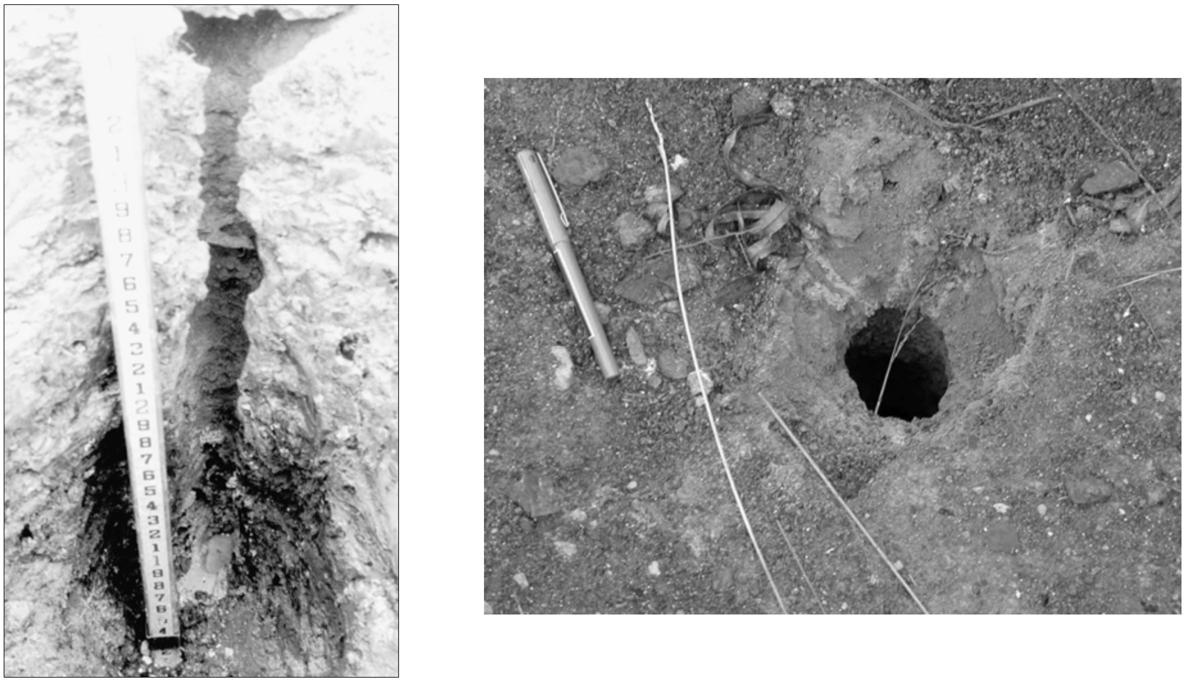

Figure 9. Possible piping macropore exposed in a gully at Rock Run pile (left) resembled piping seen later at Flint Pile Run (right).

Figure 10. The Flint Run pipe discharging water (left) within 48 hours of a recharge event; excavation of the Flint Run pipe (right).

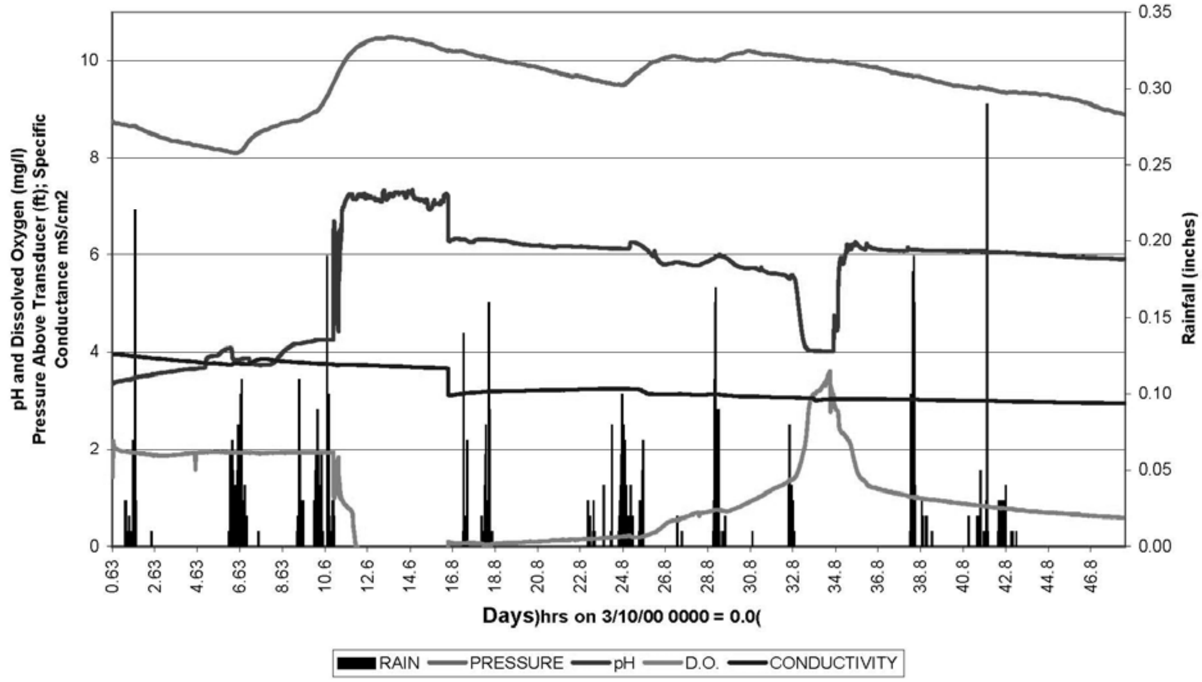

Fig 11. Head increase in response to rainfall at the Flint Run pile is associated with flowing pipes, decreased DO, and increased pH. Interruption of air circulation is a possible explanation.

Acknowledgements

Ohio Department of Natural Resources, Division of Mineral Resources Management provided major support of this project. Rural Action provided project management and field assistance, and Jay Hawkins of the U.S. Office of Surface Mining helped train students and provided some pre-reclamation sample analysis. Damariscotta, Inc. designed the reclamation.

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Editor's note:
Mary Wilder Stoertz, 49, passed away on February 26th, 2007. Dr. Stoertz was an associate Professor of Hydrogeology in the Department of Geological Sciences at Ohio University, where she had worked since 1994. She was also the director of the interdisciplinary Appalachian Watershed Research Group at OU's Voinovich Center of Leadership and Public Affairs. Her efforts focused on restoration of rivers damaged by acid mine drainage from coal mines and coal refuse. Among her recent honors were: the Interstate Mining Compact Commission's "Mining Awareness Education"' award (2006); Ohio Department of Natural Resources' "Minerals Education Award" (2005) and her status as the "AEP Professor of Watershed Science." Mary received her M.S. (1985) and PhD (1990) from the University of Wisconsin, and a B.S. from the University of Washington (1980). For more information about Dr. Stoertz's life and contributions to science and her community please see p. xv of this publication.

FGD as an impermeable cap for coal waste

Mary Stoertz, OU
Mitch Farley, ODNR DMRM
Brian Bullock
Pearl Pereira
Brett Laverty

Student Researchers

Brian
Bullock

Pearl
Pereira

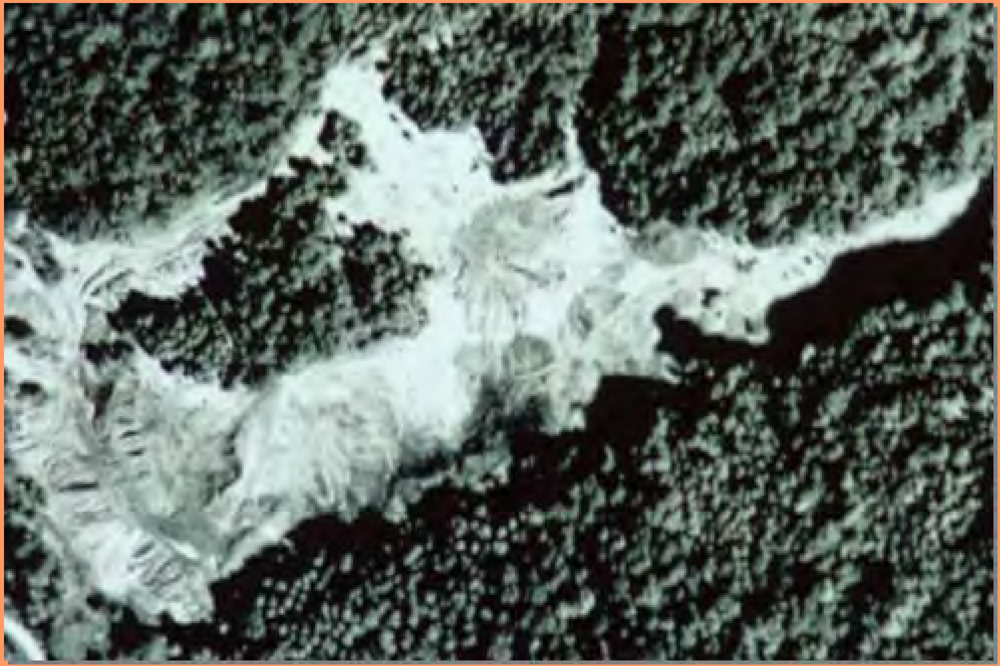
Brett
Laverty

Overview of talk

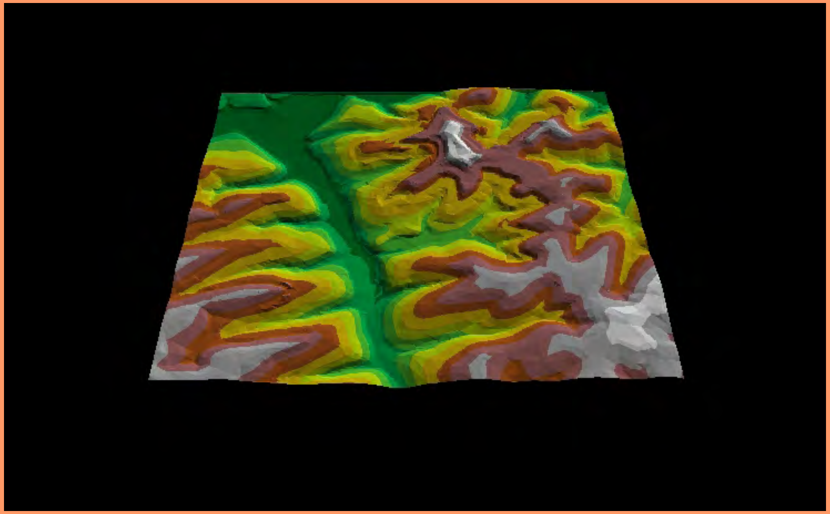
- Site characterization
- Rationale for water control
- Performance of cap for water control
- Implications of cap for airflow

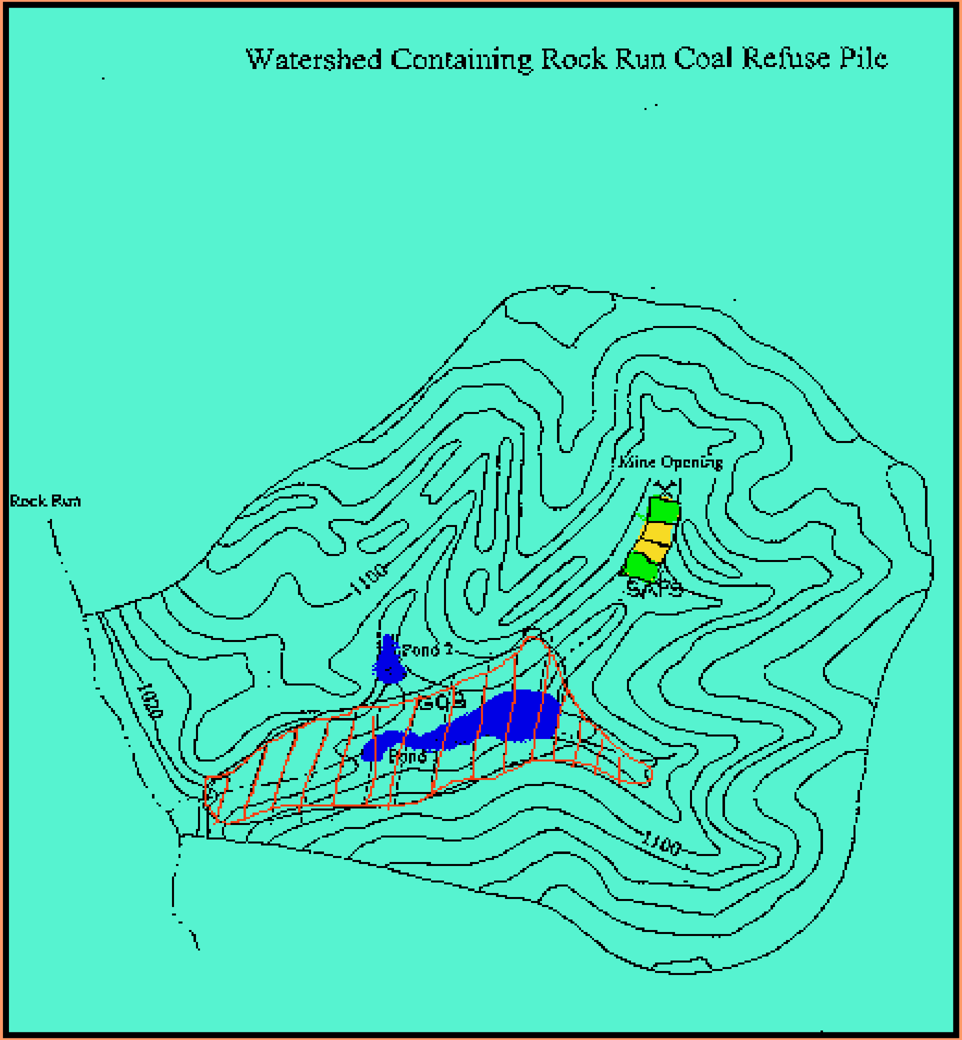
Mining history

Figure 1: [illegible] LICK RUN COAL CO [illegible]
[illegible]
(Atlas of Athens County, 1875)

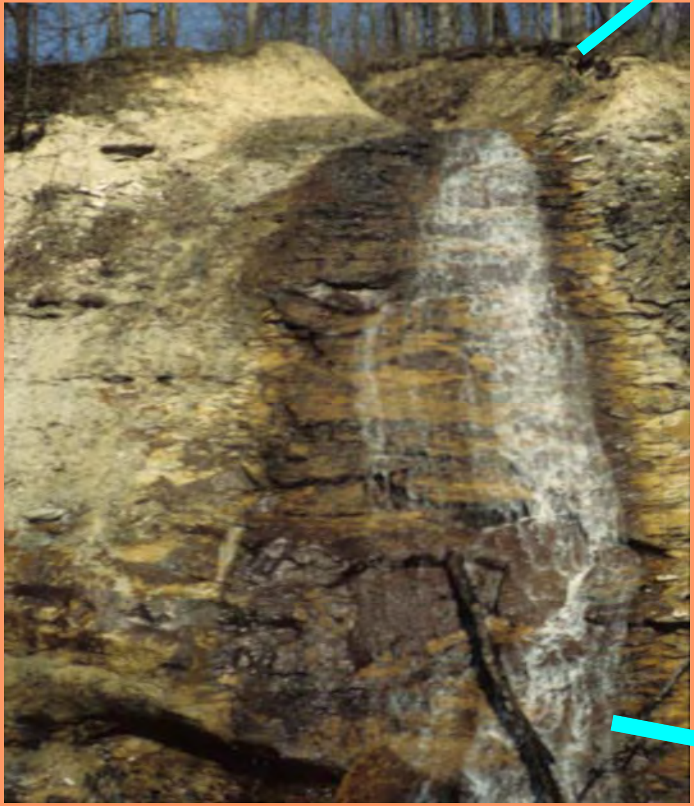


Watershed approach





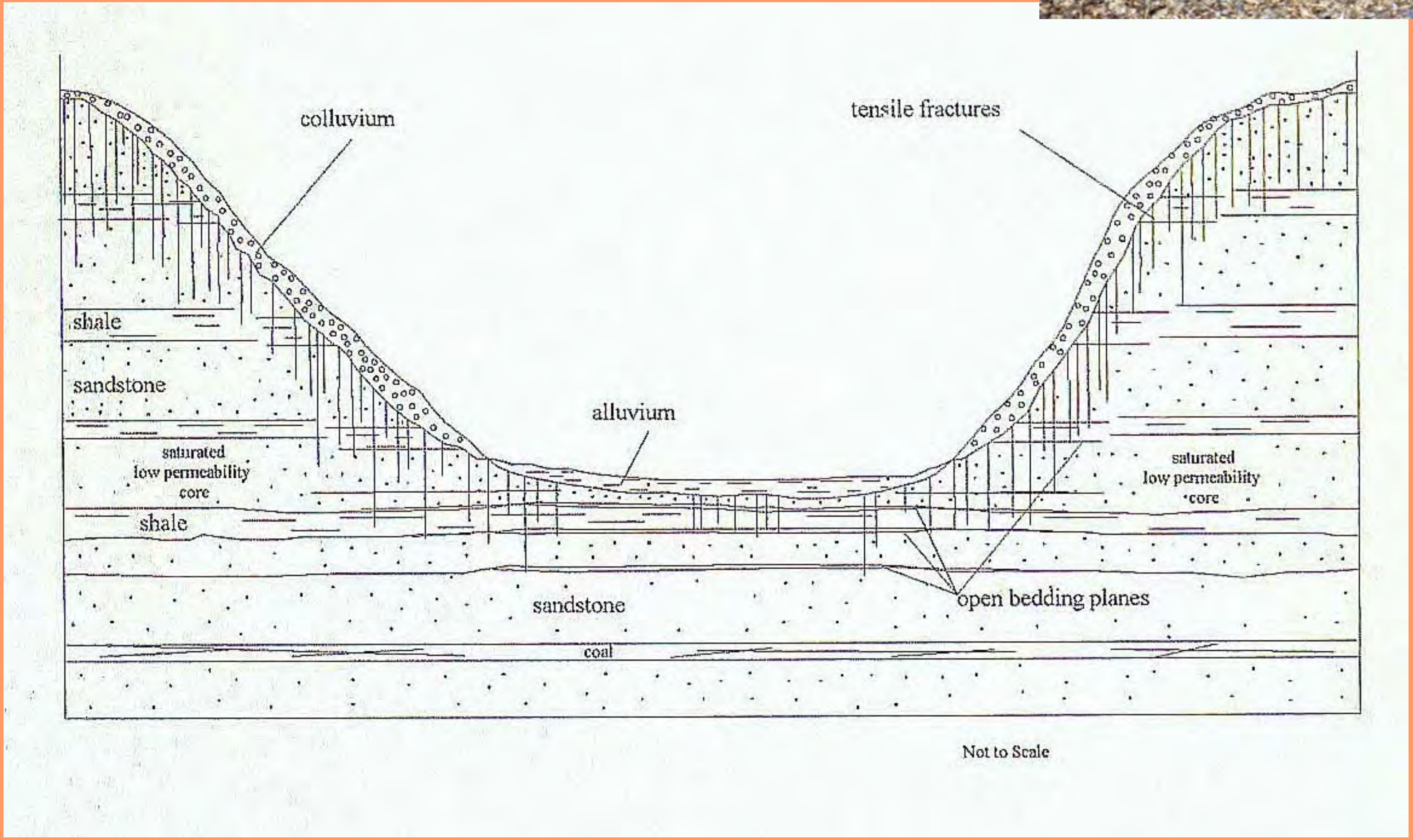
Geologic characterization



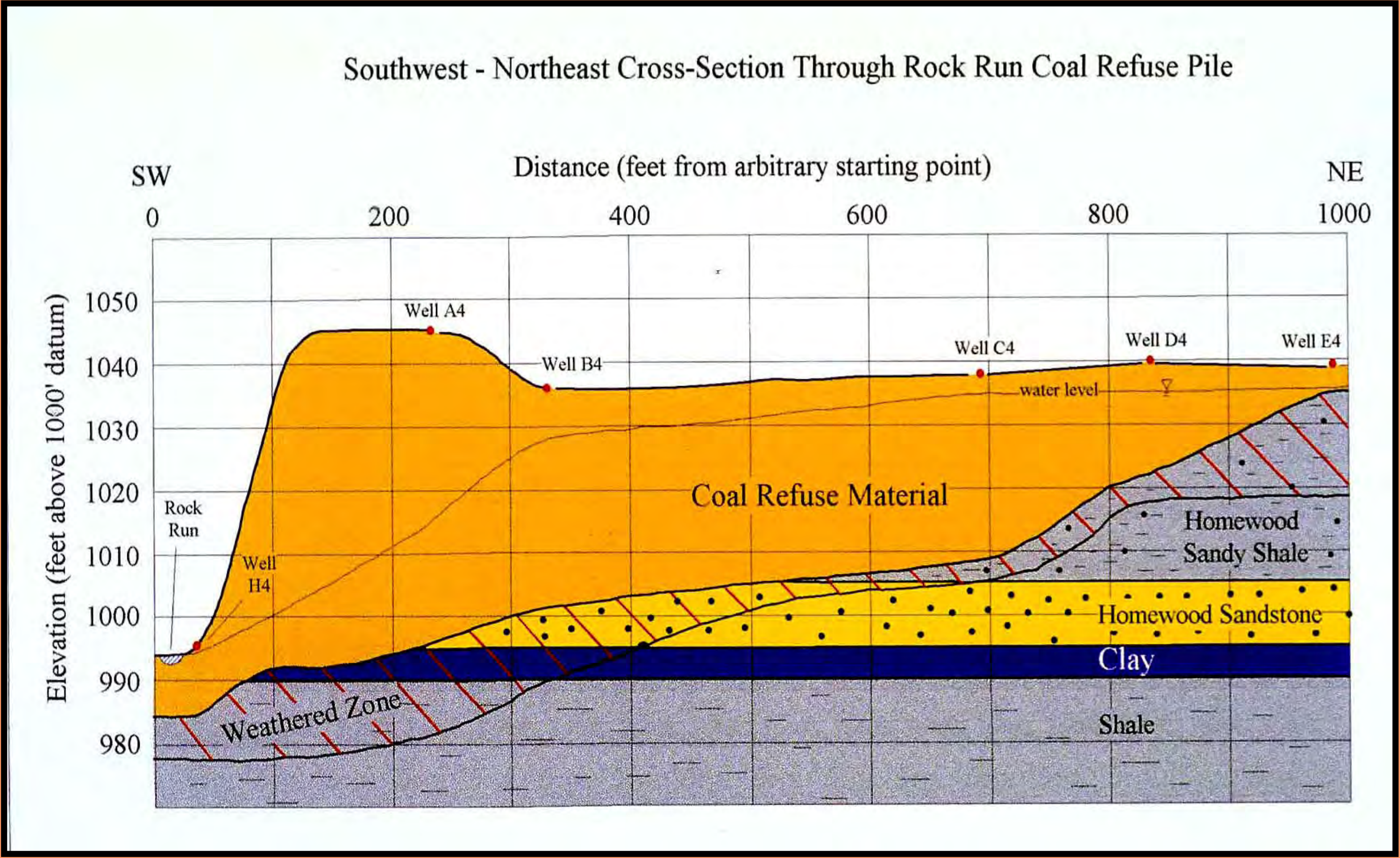
Weathered bedrock

Fractured bedrock

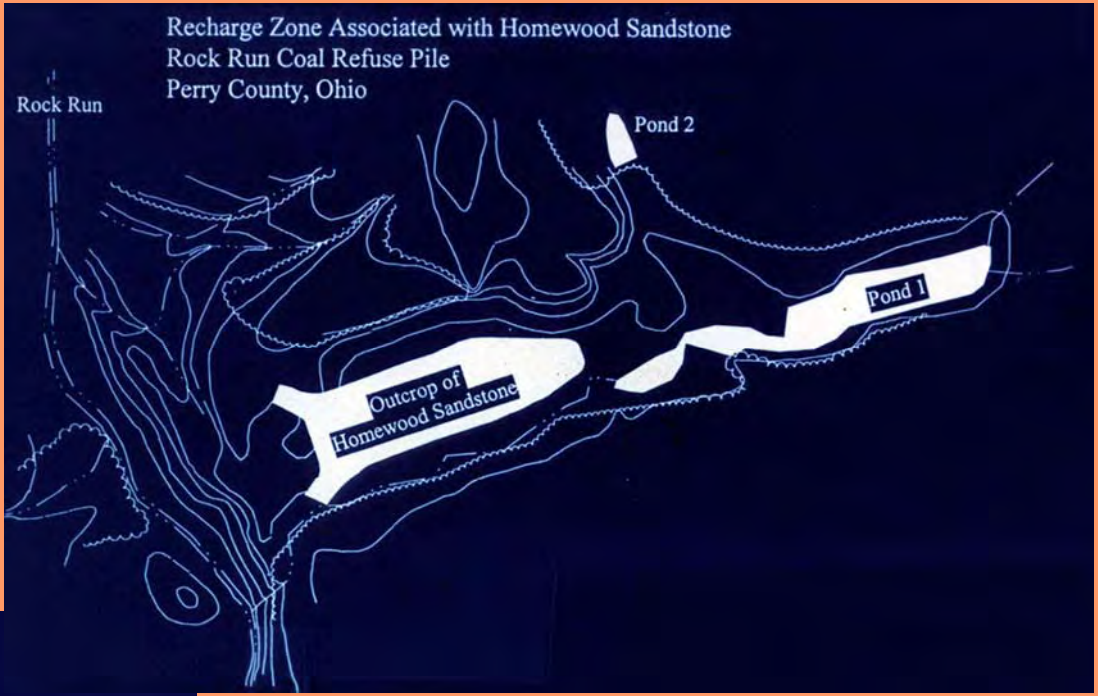
Geology - fracturing

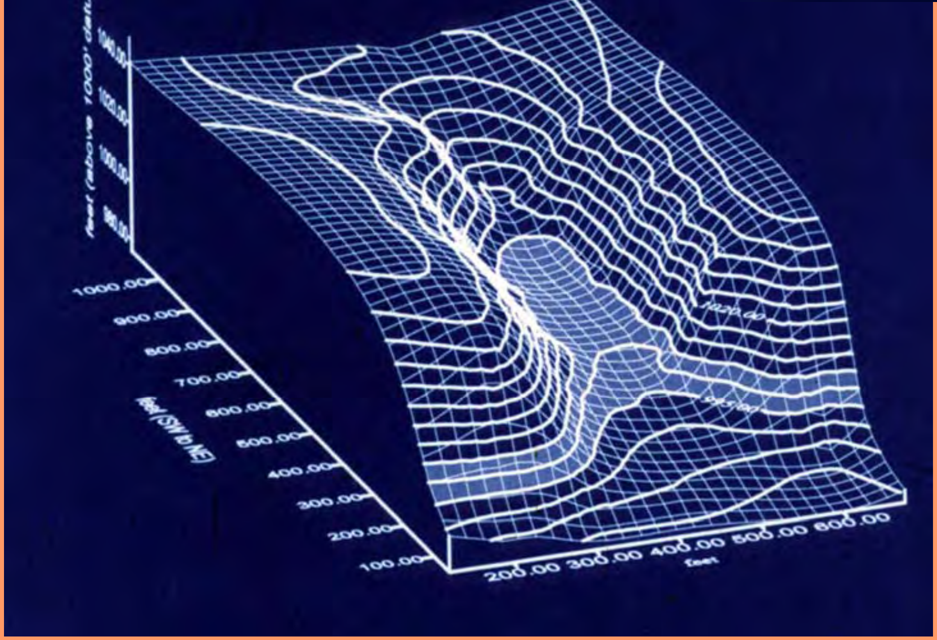


Geologic cross-section

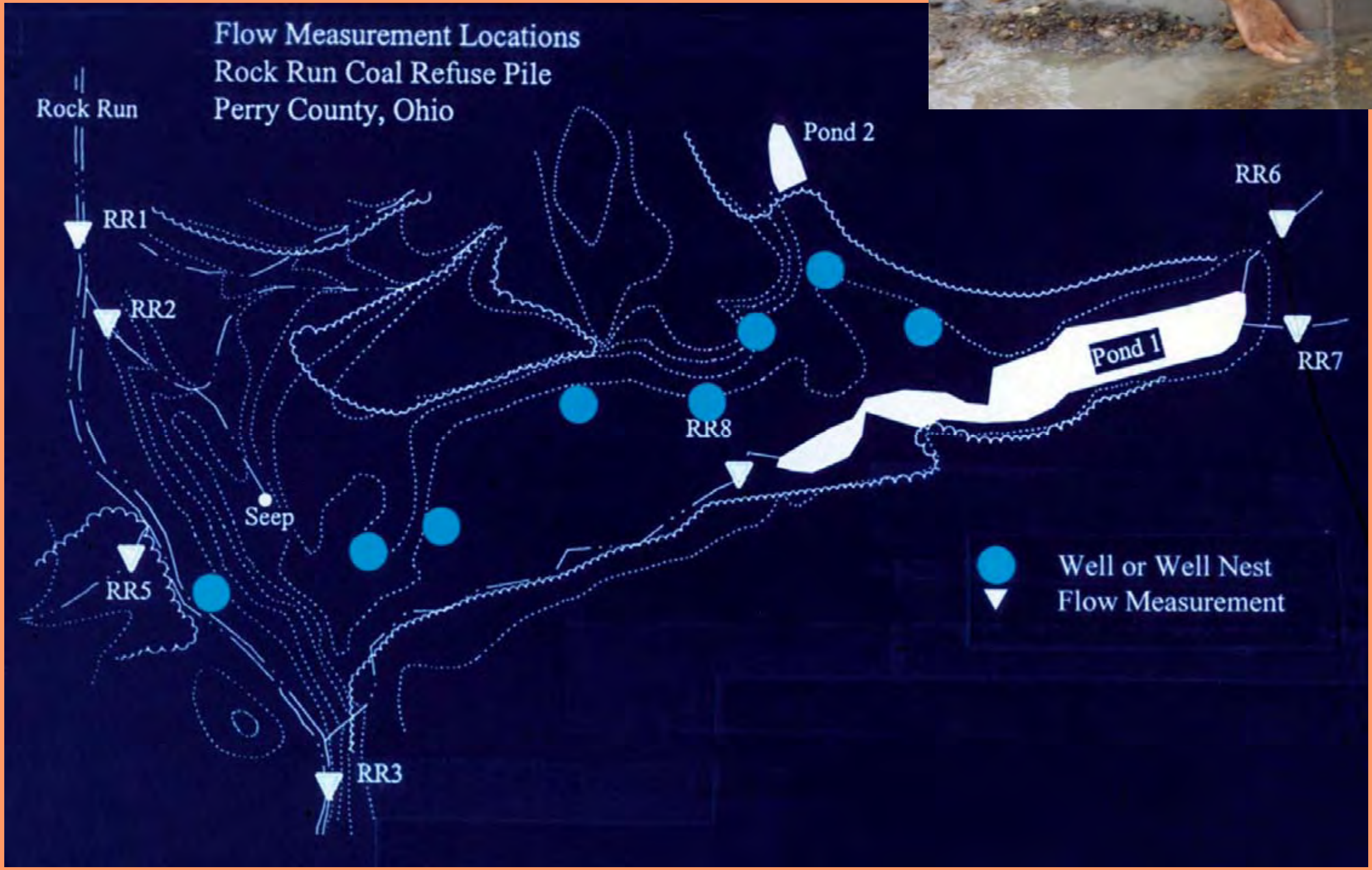


Geology – extent of sandstone outcrop


Recharge Zone Associated with Homewood Sandstone
Rock Run Coal Refuse Pile
Perry County, Ohio



Surface water measurement

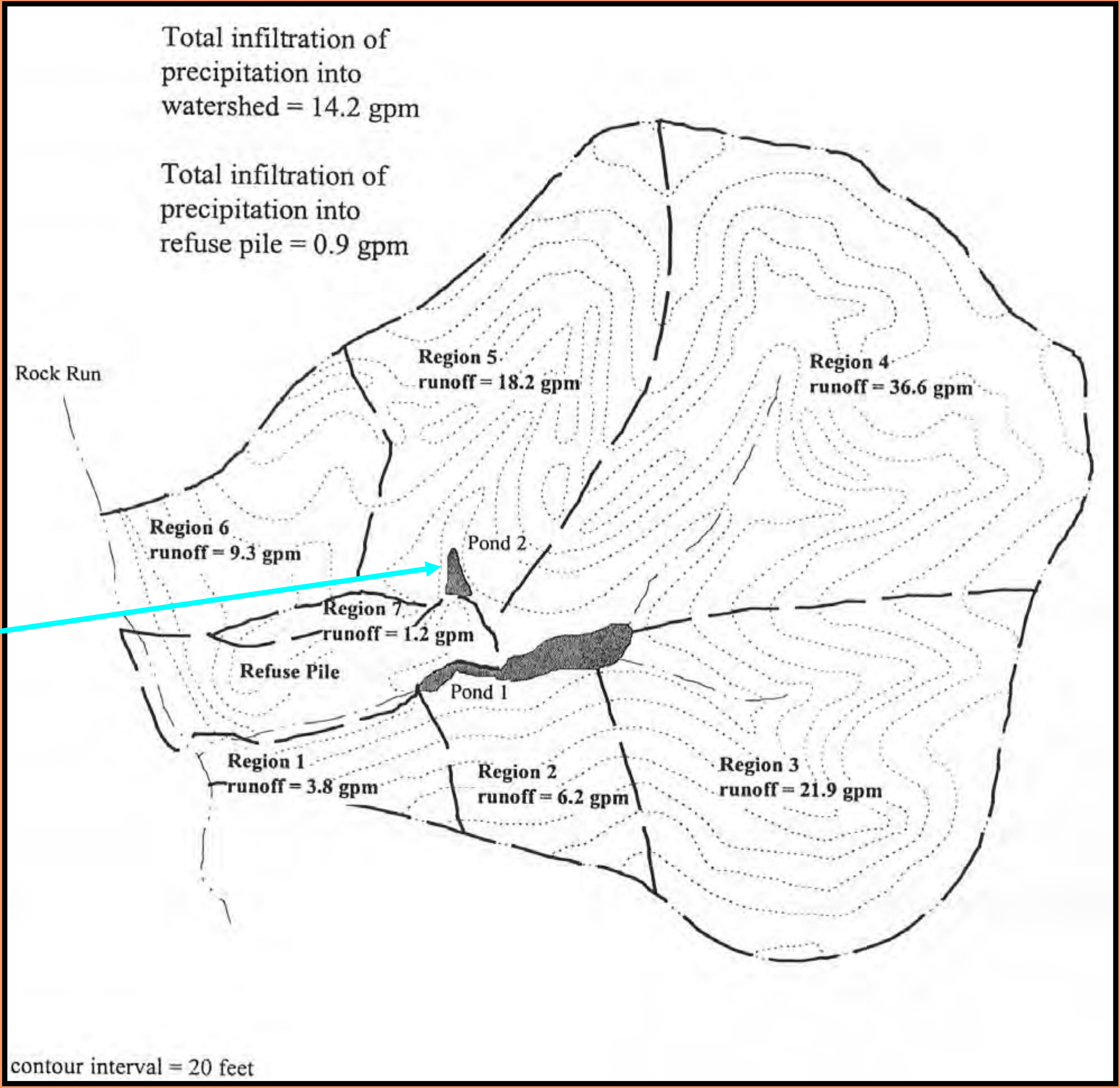


Flow Measurement Locations
Rock Run Coal Refuse Pile
Perry County, Ohio

Surface infiltration, Pond 1

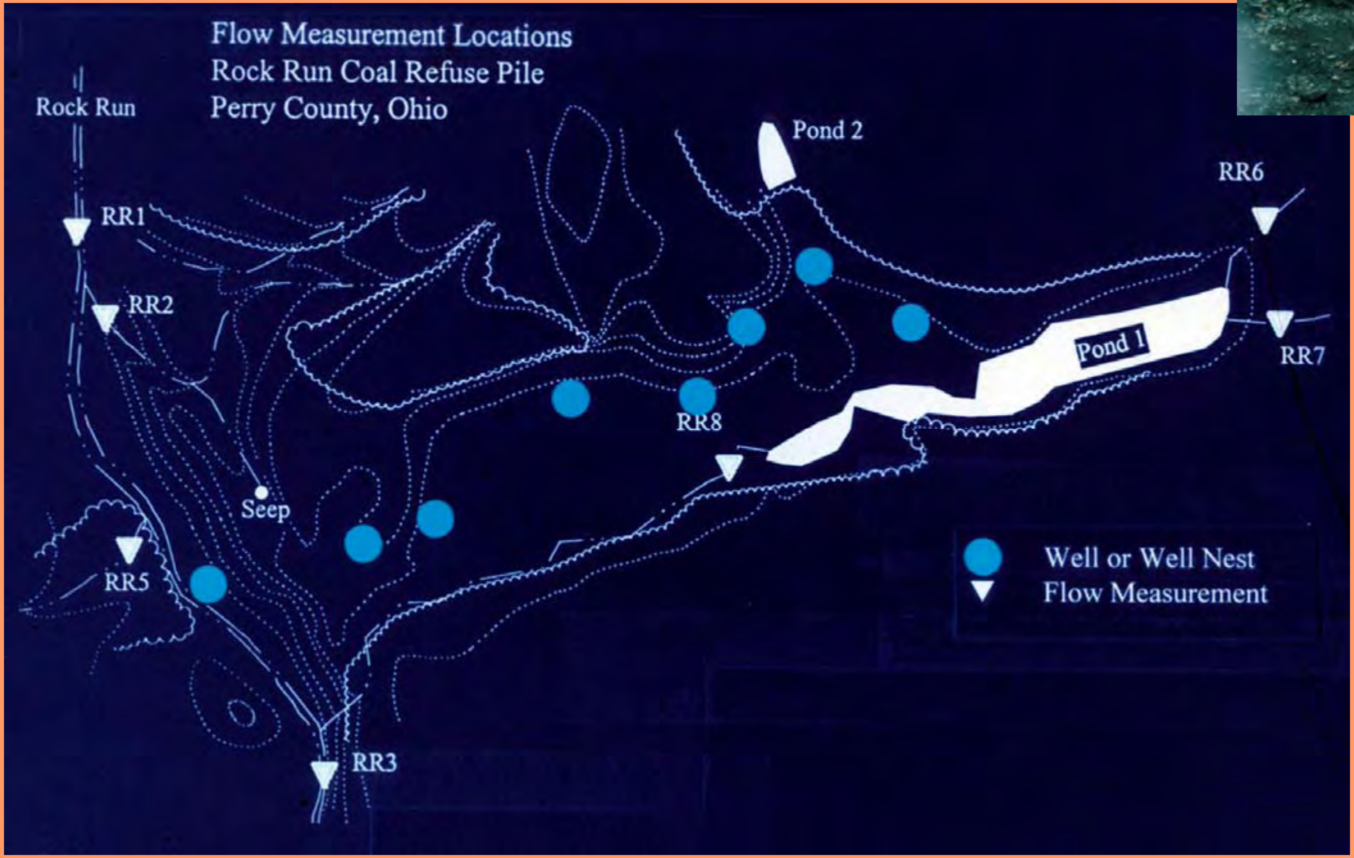
Infiltration estimation

Pond 2



Mine discharge to head of pile

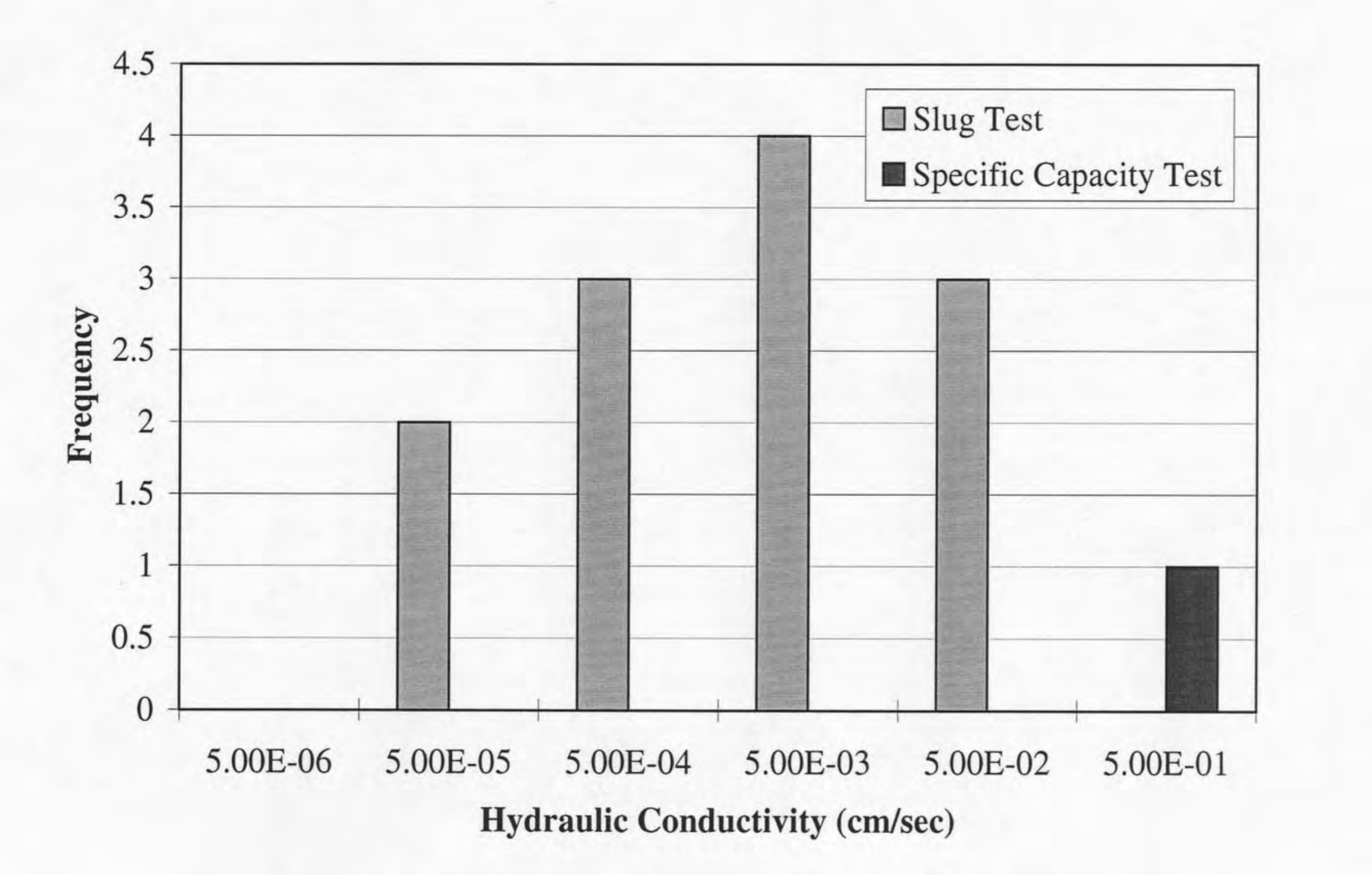
Groundwater investigation



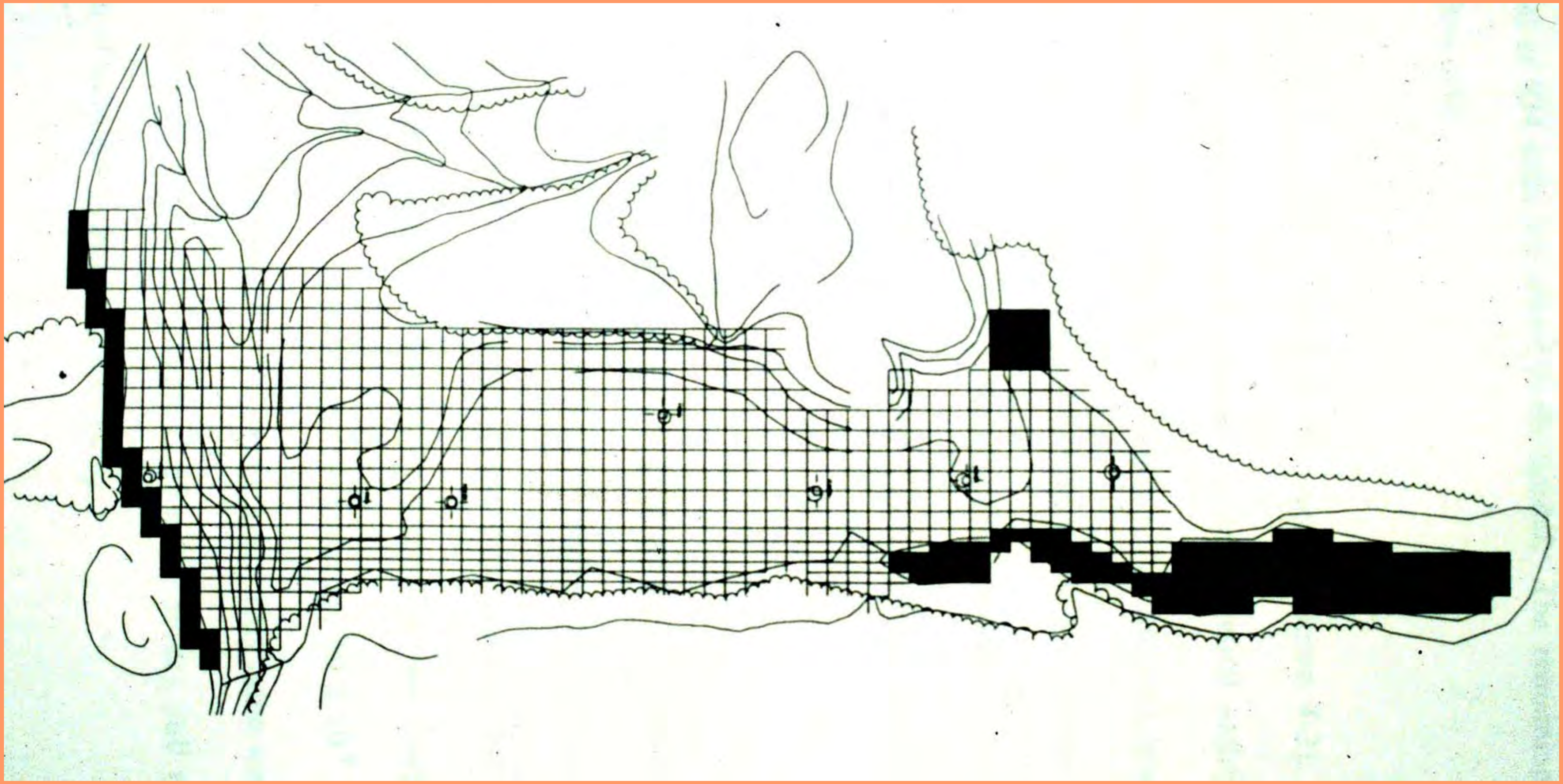
Flow Measurement Locations
Rock Run Coal Refuse Pile
Perry County, Ohio

Groundwater investigation

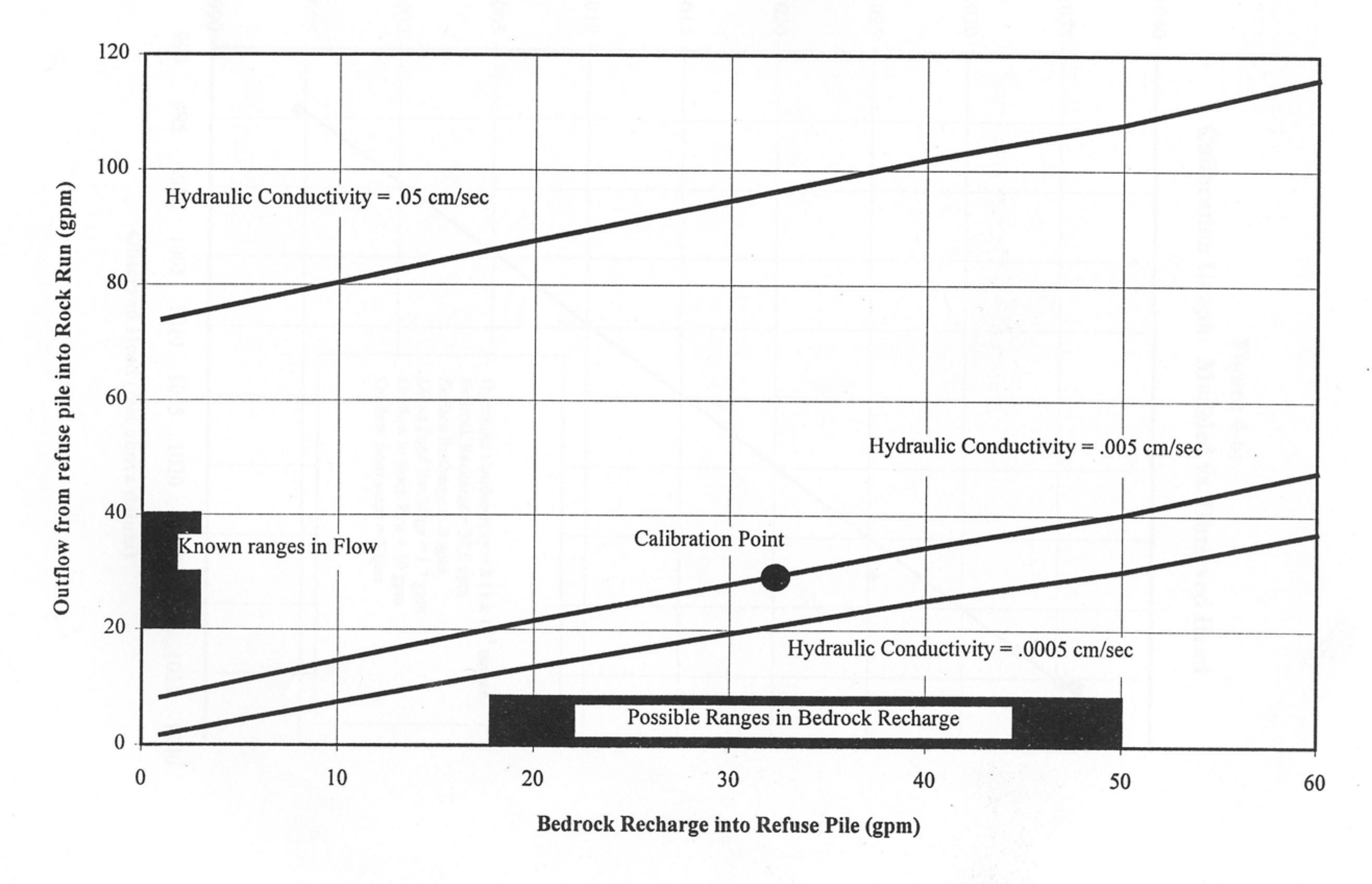
Groundwater investigation



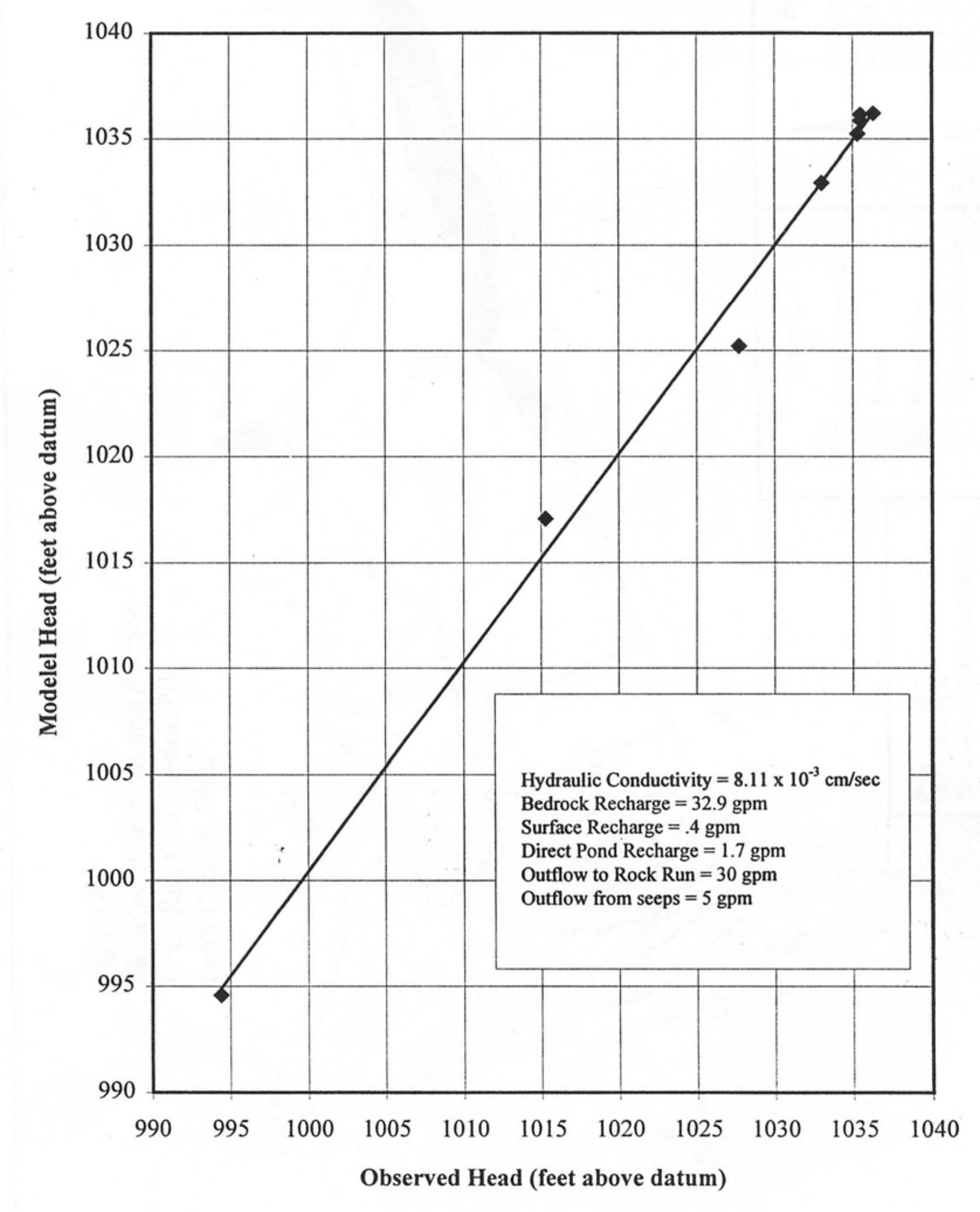
Groundwater modeling



Calibration:
bedrock inflow, toe seepage and K.

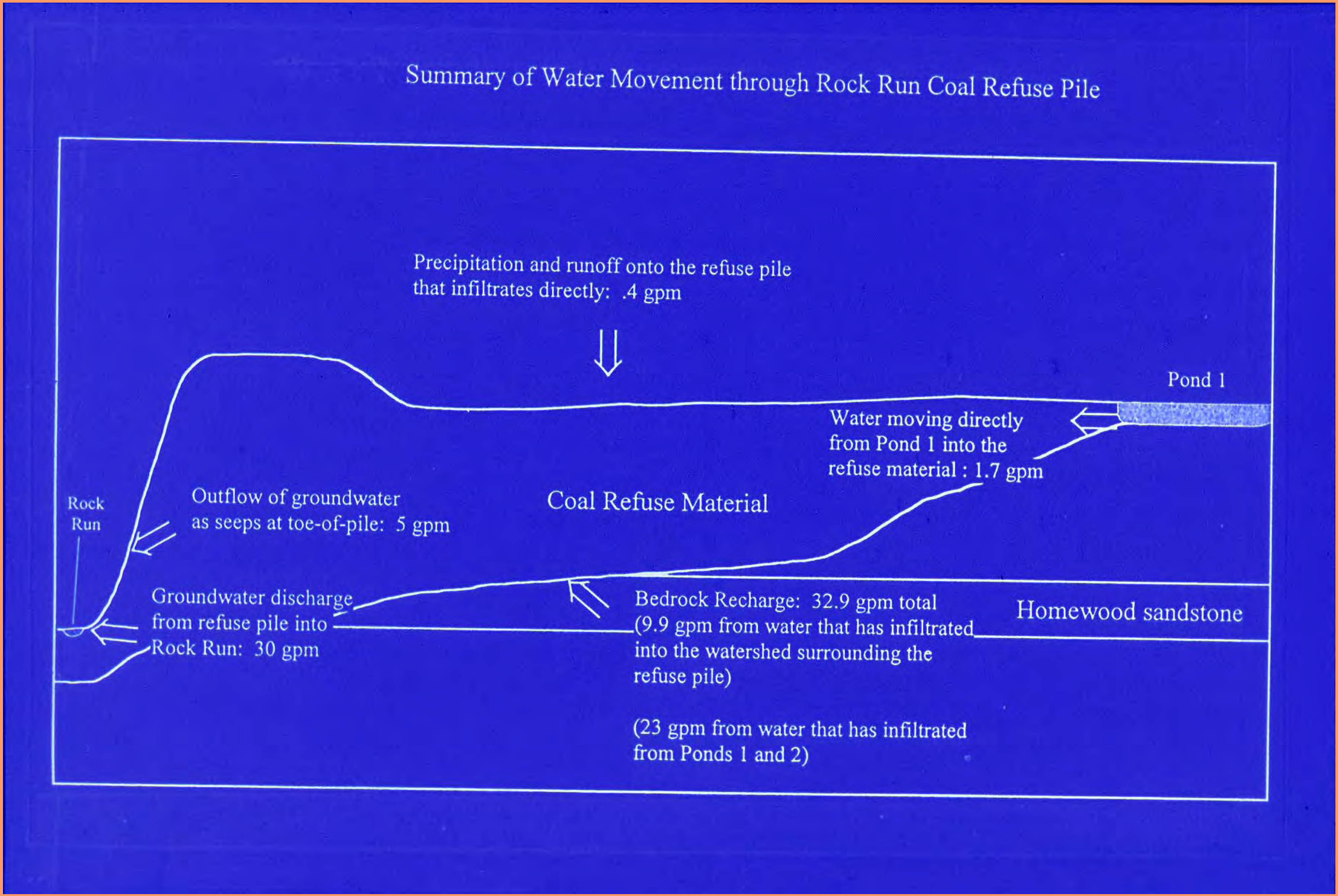


Calibration of modeled to observed heads



Hydraulic Conductivity = 8.11 x 10^{-3} cm/sec
Bedrock Recharge = 32.9 gpm
Surface Recharge = .4 gpm
Direct Pond Recharge = 1.7 gpm
Outflow to Rock Run = 30 gpm
Outflow from seeps = 5 gpm

Overall water budget



Summary of Water Movement through Rock Run Coal Refuse Pile

Precipitation and runoff onto the refuse pile that infiltrates directly: .4 gpm

Water moving directly from Pond 1 into the refuse material : 1.7 gpm

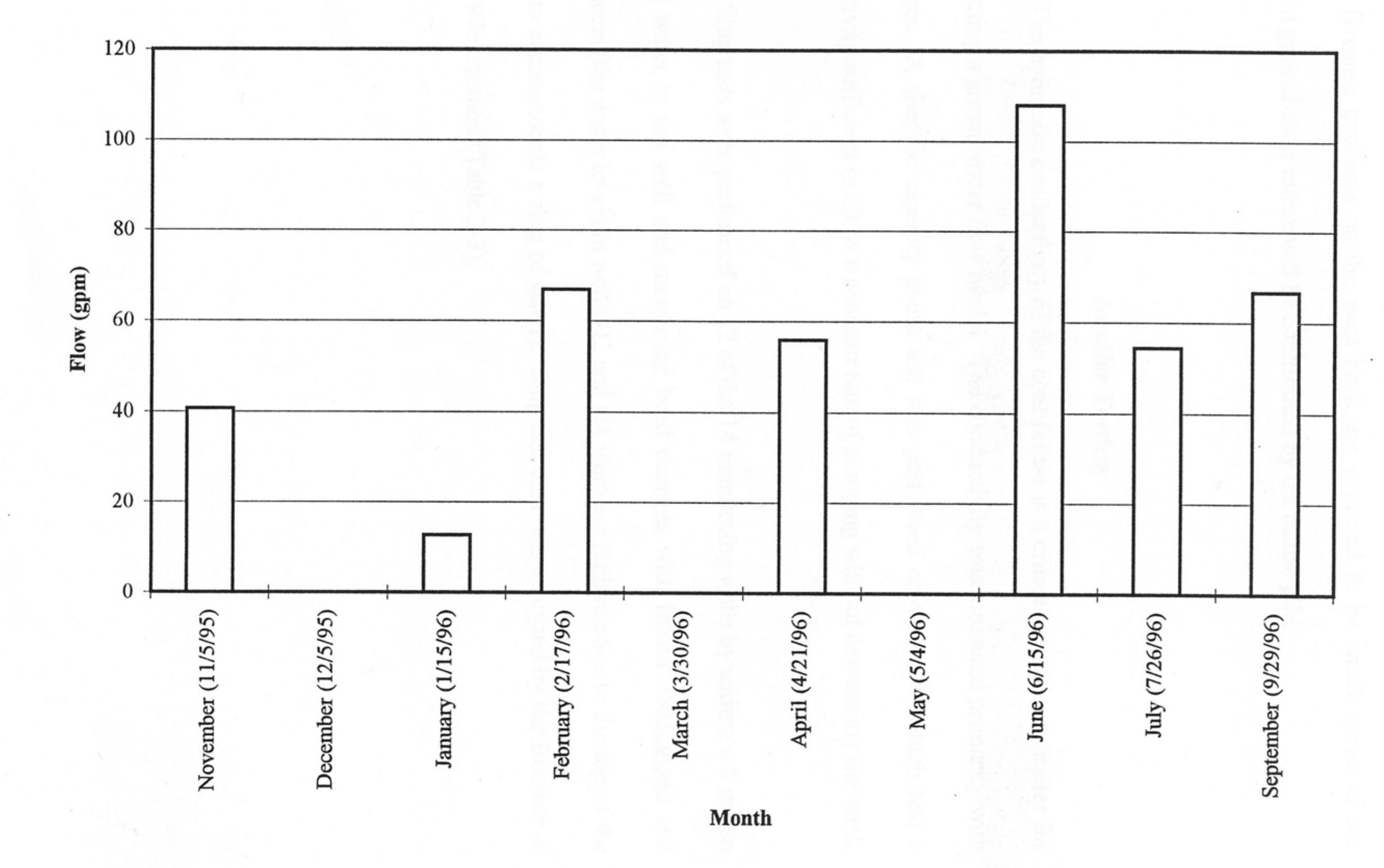
Outflow of groundwater as seeps at toe-of-pile: 5 gpm

Groundwater discharge from refuse pile into Rock Run: 30 gpm

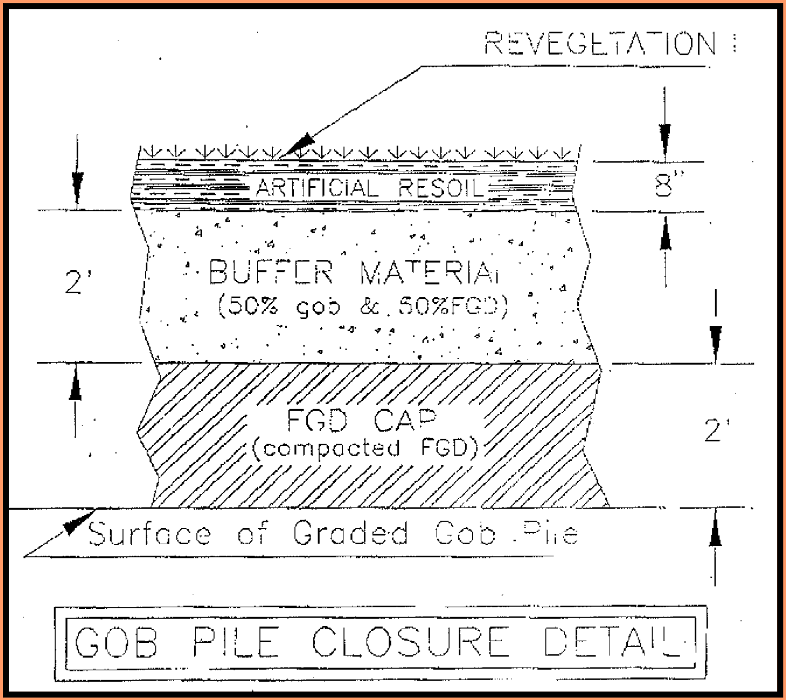
Bedrock Recharge: 32.9 gpm total (9.9 gpm from water that has infiltrated into the watershed surrounding the refuse pile)

(23 gpm from water that has infiltrated from Ponds 1 and 2)

Groundwater seepage from pile



FGD Capping

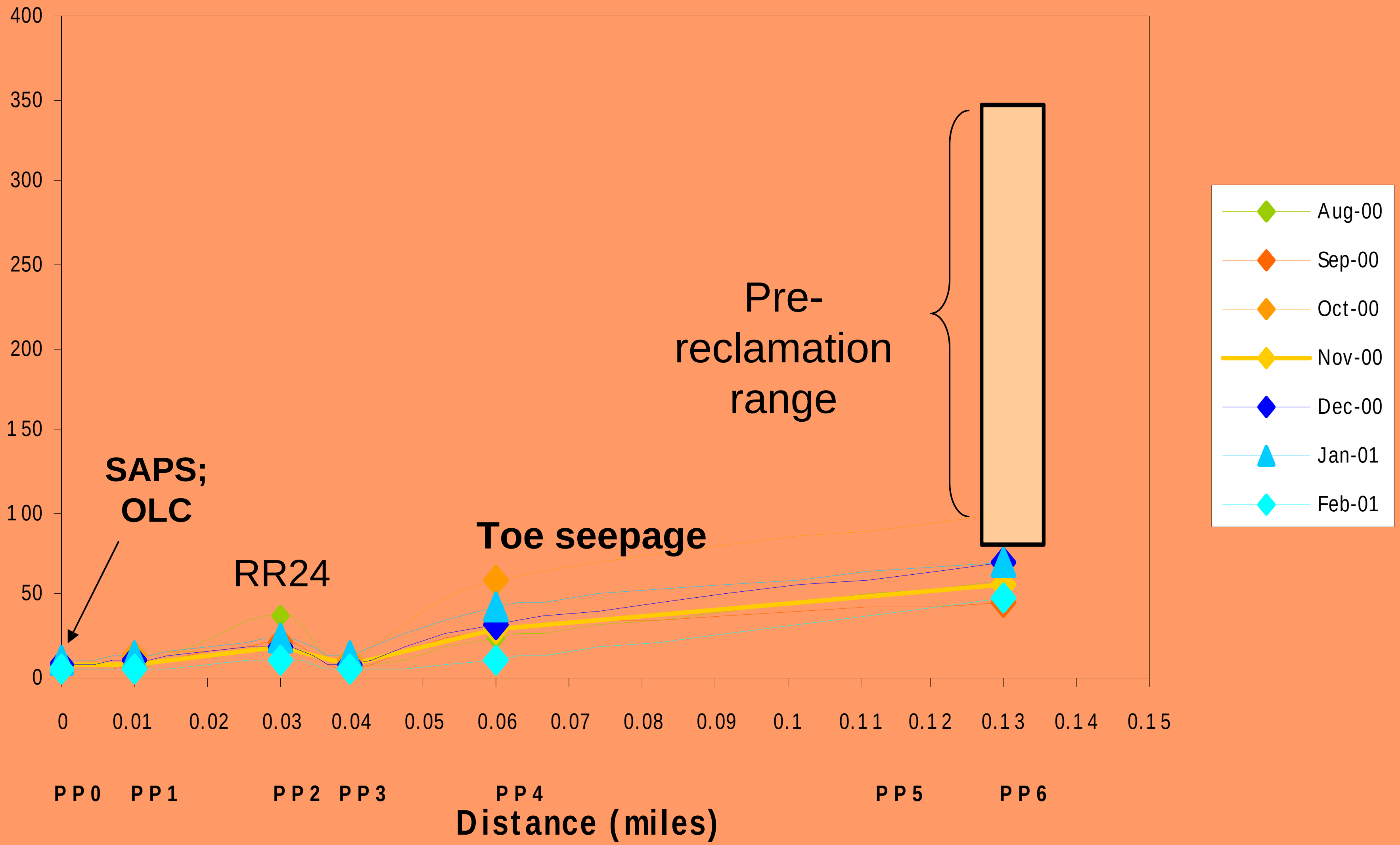

REVEGETATION
ARTIFICIAL RESOIL
8"
2'
BUFFER MATERIAL
(50% gob & 50%FGD)
FGD CAP
(compacted FGD)
2'
Surface of Graded Gob Pile
GOB PILE CLOSURE DETAIL

Surface-water diversion, passive systems

pH 8 water from top of pile…

…but residual pile toe seepage degrades it

Residual seepage affects acidity



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Residual groundwater seepage

Flowing artesian well in creek

Microbe *Euglena* at low-pH groundwater/surface-water interface

Evidence of conduits

Rock Run pile (Bullock, 1998)

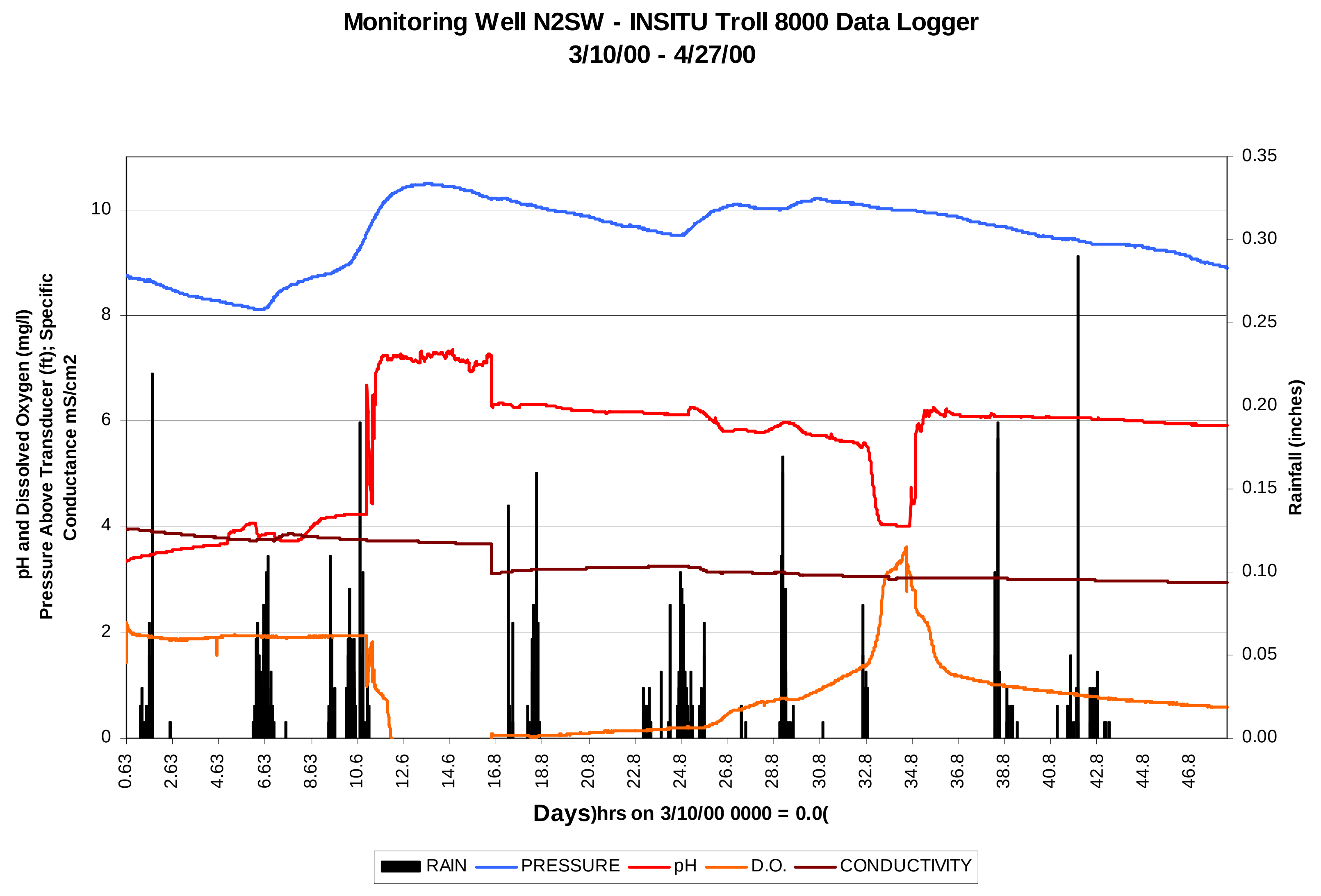
Flint Run pile (Laverty, 2003)

Role of conduits

Conduit at Flint Run flows within 48 hours of recharge event (Laverty, 2003)

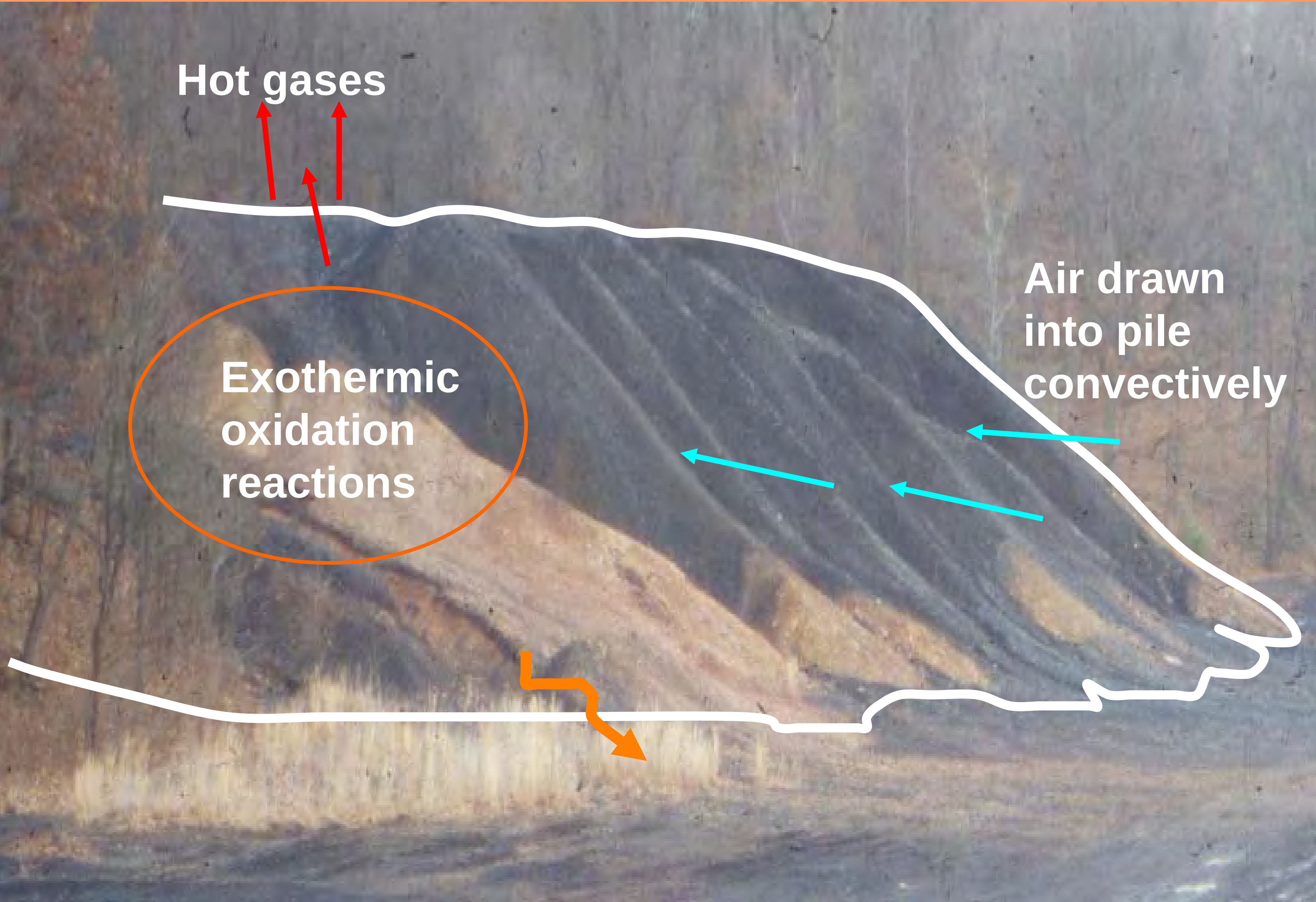
Excavated conduit at Flint Run (Laverty, 2003)

Implications of airflow at Flint Run pile



Laverty, 2003

Chemical and airflow role of conduits



Hot gases

Exothermic oxidation reactions

Air drawn into pile convectively

How is cap holding up after 7 years?

Good vegetation cover; some erosion from recreational use

Slumping, burnout areas

Passive systems functioning, need regular maintenance


MOBILE DRI

FGD AS AN ALKALINE AMENDMENT FOR COAL WASTE

Dennis Noll
Earthtech, Inc.
Johnstown, PA

View Presentation

Abstract

The coal combustion waste byproduct, identified as Flue Gas Desulfurization Material (FGD), is derived from a process typically used for reducing sulfur dioxide emissions from the exhaust gas systems of pulverized coal-fired boilers. This material is typically a wet sludge, produced by a limestone-based reagent wet scrubbing process and is predominantly calcium sulfite, unless it has been exposed to forced oxidation to change it to calcium sulfate (gypsum). The sulfite-rich FGD material has been used primarily as a low permeability embankment and road base material, but has also been experimented with as an alkaline amendment at active coal waste landfills. Discussed here is one site in Pennsylvania where 16 million cubic yards of FGD-sulfite-dominated material has been authorized for placement as a final cap on a 300-acre, 40 million ton abandoned coal refuse site and as a stabilizer for a failing embankment at that site that impounds fine coal refuse and water. The purpose of this approach is to contribute to the environmental data-base that exists for sites where FGD-sulfite has been placed in direct contact with coal refuse in the hope that the empirical results at this site will be used to evaluate future uses of that coal combustion by-product elsewhere.

Introduction

Research has been conducted into the use and environmental impacts of FGD-sulfite material and the treatment of coal refuse. FGD-sulfite material is the by-product of wet scrubbing the exhaust from coal boilers by adding calcium-based sorbents without forced oxidation. The mixture results in a high moisture ash that is physically dewatered and mixed with quick (dehydrated) lime and fly or bottom ash to stabilize it for transportation and/or placement. Its chemical composition and use is different than that of FGD-sulfate, which is gypsum. Gypsum is a primary component of wallboard, the most common end-product of that material.

Treatment of coal refuse in this context is defined as the addition of FGD-sulfite to the waste stream of active coal preparation plants, via selective placement at the coal refuse landfills or addition of this by-product to abandoned coal refuse piles. The object of this placement is to utilize the available alkalinity of this by-product to buffer the acid production of the coal refuse. Very little information for this particular use appears to exist outside of Ohio, Illinois, and Pennsylvania. In Pennsylvania, no authorizations have been issued to date for this purpose and only two examples have been found to have been reported in Ohio [1]. In Illinois, one demonstration project [2] has been reported.

This paper discusses one site in Pennsylvania where 16 million cubic yards of FGD-sulfite has been authorized for placement as a final cap on a 300-acre, 40 million ton abandoned coal refuse site and as a stabilizer for a failing embankment at that site that impounds fine refuse and water. The purpose of this approach is to contribute to the environmental database that exists for sites where FGD-sulfite has been placed in direct contact with coal refuse in the hope that the empirical results at this site will be used to evaluate future uses of coal combustion by-products elsewhere.

Site Development History

The Labelle coal refuse landfill was created by Jones and Laughlin Steel Company to receive the rejected coal and non-coal waste from a coal preparation plant, located on an adjacent tract which also served as a transloading facility for rail, barge, and truck transport. Coarse and fine coal refuse was deposited at the site for an unknown number of years until operations ceased in 1994. By that time, approximately 40 million tons of this material had been delivered and placed at the site over a 300 acre area at depths approaching 150 feet in some places. The fine coal refuse was deposited in two large impoundments that are contained by massive embankments of coarse coal refuse. When operations ceased, the site was left in an abandoned, partially reclaimed condition with stability problems concerning one of the fine coal refuse impoundments. Water discharging from the site from the underdrain and other sites provided a continuous supply of metals and sulfate contamination to the Monongahela River. Water seeping through the refuse and captured by the underlying Pittsburgh seam underground coal mine pool provided similar contamination to surface and groundwater resources to the south and southeast.

The impoundment of concern has a footprint of approximately 24 acres and a contributing drainage area of approximately 87 acres. Comparison of pre-landfill mapping, post-1994 aerial photography, and drilling at various dates results in an impoundment depth range from 60 to 100 feet, averaging 74 feet. Several feet of standing water, contributed by precipitation falling on the surface of the drainage area, are present at all times in the impoundment and this water is loading the fine coal refuse and the laterally-confining coarse refuse. As early as 1984, the eastern slope of the coarse refuse embankment began to show signs of movement and various engineering plans were designed and implemented to some degree before the site was abandoned in 1994. Among these plans were: (1) regrade the out-slope with drainage ditches to discourage infiltration; (2) construction of additional underdrain laterals near the toe of the embankment; and (3) construction of a breach channel to drain the water in the impoundment. Implementation of the regrading and underdrain installation was developed to a much larger degree than the development of the breach channel when all operations ceased. Subsequent to the abandonment of the site, concerns by the Pennsylvania Department of Environmental Resources (now the Department of Environmental Protection) and the area residents for the stability of this impoundment did not abate.

With respect to the water contamination associated with the site, six sampling points were evaluated and found to have an average cumulative flow rate of 627 gallons per minute and a total loading in pounds per day for iron of 6.6, manganese 9.9, aluminum 0.7, and sulfates 19,282. The underdrain discharge, located below the coarse refuse embankment discussed above, is responsible for much of this contamination.

In 1996, Matt Canestrale of Matt Canestrale Contracting, Inc. purchased the LaBelle coal refuse landfill and associated transloading facility. At the time of purchase or shortly thereafter, it was decided to explore the idea of providing a location at this site for the placement of coal combustion by-products. In order to avoid the permitting and operational costs of a residual waste landfill, it was decided to import those by-products that had a beneficial use designation for low permeability cementicious (LPC) material for the purpose of stabilizing the impoundment and capping the entire refuse site in order to minimize the contribution of precipitation to the existing water contamination.

Reclamation Plan

A reclamation plan was developed to address the concerns of the PA DEP, regarding the slope stability issue, and to have a significant impact upon the water contamination issues. It was known that Allegheny Power's Mitchell Power Plant was interested in exploring the idea of finding alternate areas to receive its fluidized gas desulfurization sludge (FGD). At the Mitchell plant, the FGD is not exposed to forced oxidation and, as a result, FGD-sulfite (calcium sulfite hemihydrate) is primarily produced by the scrubbing. This material, according to officials at Mitchell, is combined with fly-ash and dehydrated (quick) lime in the proportions 75% FGD-sulfite, 24% fly ash, and 1% quick-lime. This material, when applied as a low permeability cementicious (LPC) substance[3], has exhibited strengths averaging 200 psi and permeabilities averaging 1×10^{-7} cm/sec. Testing of samples, collected by Earthtech and analyzed by L. Robert Kimball Associates, indicated permeabilities ranging from 2.1×10^{-6} to 3.3×10^{-8} cm/sec.

Based upon the reclamation needs of this site, it was determined that a buttress, keyed into original ground, should be built with this LPC material to secure the failing portion of the eastern outslope of the impoundment and that the entire site should be capped with this material as well. The design created a post-reclamation configuration that modified all outslopes to an overall 4:1 slope and raised the elevation of the site, ranging from five to fifty feet, creating a gently sloping, “flat” area of approximately 170 acres. The eastern out-slope area of the impoundment was to be thickened by approximately 50 feet and anchored into original ground.

A permit to conduct these activities was applied for in 1997 and Mining Activity Permit #26970702 was issued for coal refuse disposal. General Permit #WMGR052 was issued for use of the Mitchell FGD as a component of the LPC material to be placed in the buttress area as well as being utilized as structural fill and the final cap. In July 2001, the mining Activity Permit was amended to allow additional coal combustion by-products that qualify for beneficial use under Pennsylvania’s residual waste regulations (i.e. fly and bottom ash from Allegheny Power’s Hatfield Power Station). This material was approved for structural fill use only at this site. In 2002, FGD as a component of LPC from Reliant Energy’s Elrama Power Station was approved for structural fill at the site under General Permit #WMGR052. In April 2006, the Mining Activity Permit was renewed for an additional 2+ years to June 2008 with only the materials listed above approved for application at the site and only the Mitchell LPC material approved for placement at the buttress area, monitored by underdrain sampling point GW-5.

Placement of the Mitchell LPC began in October 1998 in the key-cut excavated in original ground at the toe of the existing coarse refuse embankment. Placement has continued to the present with final slopes achieved over 10 of the 24 acres of designated buttress area and an additional 9 acres nearly to design grade. The following schedule of material placement has been documented:

YEAR(S)	TONS OF MITCHELL LPC
1998-99	85,146
2000	133,894
2001	276,259
2002	207,097
2003	230,000
2004	223,200
2005	296,827
1Q 2006	96,880
2Q 2006	64,286

TOTAL 1,613,589

Placement of this material in the buttress area was preceded by extending the underdrain in 1998 to avoid burial and blockage as well as installation of additional shallow laterals to sufficiently drain the buttress area as it was being built. Approximately 1000 feet of channel, comprised of rip-rap, wrapped in filter cloth, has been installed at the interface of the LPC and original ground or the coarse refuse.

Environmental Impact

When the LaBelle coal refuse facility was abandoned in 1994, it was contributing a net negative environmental impact for the following reasons:

- Polluted runoff and shallow groundwater flow was impacting the Monongahela River.
- Polluted groundwater was seeping into the underlying Pittsburgh coal seam underground mine pool.
- A huge potential existed for additional surface water contamination due to the instability of sections of the refuse pile outslopes.
- Airborne fugitive emissions were escaping from the site due to the several hundred acres of unreclaimed, exposed coal refuse.

Completion of the project, involving the approved coal combustion by-products, dominated by the FGD-sulfite from the Mitchell Plant, will eliminate these problems, hopefully resulting in a net positive environmental impact. Authorization to apply this material requires rigorous laboratory analysis and, upon approval, semi-yearly certification by testing to maintain that authorization. In order to acquire authorization as an LPC material under General Permit #WMGR052, the following levels may not be exceeded:

Constituent	Total (mg/kg)*	Leachable (mg/l)**
Aluminum		5.0
Antimony	30	0.15
Arsenic	41	1.25
Barium	5000	50
Boron	7000	3.15
Cadmium	20	0.125
Chromium	1000	1.25
Chloride		2500
Copper	700	32.5
Iron		7.5
Lead	200	1.25
Manganese	400	0.5
Mercury	20	0.05
Molybdenum		4.38
Nickel	200	2.5
pH	12.5	
Selenium	60	1.0
Sulfate		2500
Zinc	1000	125

* May be based on 90% upper confidence level, using *Test Methods for Evaluating Solid Waste* (EPA SW-846) as guidance for the statistical treatment of data.

** The *toxicity characteristic leaching procedure* (EPA Method 1311) or the *synthetic precipitation leaching procedure* (EPA Method 1312) or other leaching procedure approved by the Department (PA DEP) shall be used for all leaching analyses.

In addition to these chemical limits the following requirements must also be met:

- Shall not be hazardous waste or be mixed with same
- Shall not be stored or placed in direct contact with ground water
- Runoff shall not cause surface water pollution or groundwater degradation and shall be managed in accordance with the Clean Streams Law.
- Shall not be stored or placed within these minimum isolation distances, unless variances are granted:
    - 100 feet of an intermittent or perennial stream
    - 300 feet of a groundwater source

    - 50 feet of a property line
    - 300 feet of an occupied private dwelling
    - 100 feet of a sinkhole or area draining to a sinkhole
    - 1000 feet upgradient of a surface water source
    - 25 feet of the perimeter of an undrained depression
    - 300 feet of an exceptional value wetland
    - 100 feet from the 100-year flood plain
    - 25 feet of a bedrock outcrop
- The slope of any project using LPC material as a construction material shall not be greater than 2.5 horizontal to 1.0 vertical without written authorization from the Department.
- After placement and compaction, the LPC material must be covered with 12 inches of soil, unless infiltration is prevented by another cover material.
- LPC material must be spread and compacted in layers (lifts) not exceeding two feet in thickness.

The LPC material utilized at this site and its placement meets the criteria listed above and its affect upon surface and groundwater will ultimately be measured at several points on and around the site, but the activity to date is measurable only at the underdrain (GW-5) and sediment pond SP-1. The underdrain system, described above, has provided an uninterrupted flow that has been sampled prior to and during placement of the FGD-sulfite material over a period of nine years. Sediment Pond SP-1 was constructed at or about the time placement of the Mitchell material began and it receives all the surface runoff from the placement area as well as some from the coarse refuse above the placement area. Both sites are in an excellent position to receive water that has been in contact with the LPC material in all of its states of solubility, throughout the project.

The underdrain sample point, GW-5, was sampled monthly for six months in 1996, during the permit application process, and has been sampled quarterly for standard inorganic mining parameters from December, 1998 through September, 2006. The parameters required to be tested quarterly are pH, total acidity, total alkalinity, total iron, total manganese, total aluminum, total sulfates, specific conductance, and total suspended solids. The effluent from the underdrain is also tested annually for total arsenic, total cadmium, total chloride, total calcium, total chromium, total copper, total lead, total magnesium, total mercury, total nickel, total potassium, total selenium, total sodium, total zinc, and total dissolved solids. The sediment pond is required to be sampled monthly, if discharging and the effluent is tested for pH, total acidity, total alkalinity, total iron, total manganese, total aluminum, total sulfates, specific conductance, and total suspended solids.

Table 1 lists the results of the quarterly sampling at the underdrain sampling point GW-5 for the period 8/29/1996 to 9/26/2006. Sampling dates 8/29/96 through 9/19/98 represent conditions prior to placement of the Mitchell LPC material. Figure 1 illustrates the differences in concentrations for the tested parameters for the pre-placement and during-placement periods. Figure 2 illustrates the differences in loading for the same parameters over the same periods. Figures 3A and 3B illustrate the results for the annual sampling at GW-5 for selected trace elements and indicator parameters, respectively. Figure 4 illustrates the concentrations for selected parameters for the sampling conducted from 2/9/1999 to 9/27/2006.

The following is observed about the quarterly results recorded at the underdrain (GW-5) during the period 8/29/1996 to 6/26/2006 (Table 1 and Figures 1 and 2):

- Flow rates have dropped significantly from an average of 110 GPM in 1996 to an average of 14 gallons per minute over the period 2003 to 2006, reducing loading for all parameters. For the same periods, average sulfate loading has dropped with time from 3,534 to 364 pounds per day with no single result for the period 12/17/1998 through 9/26/2006 exceeding the range established pre-placement in 1996. Also for the same periods, average iron loading has dropped from four to two pounds per day and manganese loading has dropped from four to one pound per day with no single result for the period 9/19/1998 through 9/26/2006 exceeding the range established pre-placement in 1996. Aluminum loading has also dropped from an average of 0.06 pounds per day, pre-placement to 0.03 pounds per day, during placement.

- Some of the typical signs of coal combustion waste dissolution are absent in that alkalinity concentrations are slightly lower in the period 2003 to 2006 (average = 333 mg/l) than they were in 1996 (421 mg/l) with only one result (473 mg/l) exceeding the highest value recorded in 1996 (457 mg/l). Average sulfate concentrations dropped from 2678 to 2264 mg/l over the same period with only two results (2942 and 3100 mg/l) for the period 9/19/1998 through 9/26/2006 exceeding the highest value recorded in 1996 (2917 mg/l). This lack of dissolution may be attributable to the generally alkaline environment associated with the site, the source of which is unknown. Abandoned coal refuse piles, comprised of rejects from the same coal seam that is the source for the refuse at LaBelle, generally produce highly acidic water.
- Average aluminum concentrations increased from an average of 0.06 mg/l in 1996 to 0.20 mg/l over the period 9/19/1998 through 9/26/2006, a not unexpected trend for coal ash, but not suggestive of significant dissolution.

The following is also observed about the annual sampling at GW-5 (Figure 3a and 3b):

- Arsenic, cadmium, chromium, mercury, and selenium concentrations for all sampling dates are below the drinking water MCL's and lead concentrations are below the action limit established for treatment at some public drinking water authorities.
- The average chloride concentration at GW-5 for the period 3/8/1999 through 9/26/2006 (189 mg/l) is slightly higher than the one pre-placement result (168 mg/l), recorded on 9/19/98. The highest spike recorded during the period 3/8/1999 through 9/26/2006 was 206 mg/l, recorded on 9/26/2006.
- The average calcium concentration at GW-5 for the period 3/8/1999 through 9/26/2006 (329 mg/l) is slightly higher than the one pre-placement result (279 mg/l), recorded on 9/19/98. The highest spike recorded during the period 3/8/1999 through 9/26/2006 was 442 mg/l, sampled on 9/23/2003.
- The average potassium concentration at GW-5 for the period 3/8/1999 through 9/26/2006 (16.1 mg/l) is slightly higher than the one pre-placement result (13.6 mg/l), recorded on 9/19/98. The highest spike recorded during the period 3/8/1999 through 9/26/2006 was 19.6 mg/l, sampled on 6/28/1999.

The following is observed about the quarterly results recorded at Sediment Pond SP-1 during the period 8/29/1996 to 6/26/2006 (Figure 4):

- The average sulfate concentration for the period 2/9/1999 through 9/27/2006 is 1570 mg/l with 25 out of 46 samples exceeding the average, the highest of which (2392 mg/l) was sampled on 6/29/2004. These results are significantly lower than those recorded during placement at the underdrain.
- The average alkalinity concentration for the period 2/9/1999 through 9/27/2006 is 147 mg/l with 23 out of 46 samples exceeding the average, the highest of which (428 mg/l) was sampled on 9/30/1999. These results are significantly lower than those recorded during placement at the underdrain.
- The average aluminum concentration for the period 2/9/1999 through 9/27/2006 is 0.25 mg/l with 9 out of 46 samples exceeding the average, the highest of which (3.38 mg/l) was sampled on 12/31/2002. The average during placement results are comparable to those recorded during placement at the underdrain.
- The average iron concentration for the period 2/9/1999 through 9/27/2006 is 0.19 mg/l with 15 out of 46 samples exceeding the average, the highest of which (0.89 mg/l) was sampled on 3/26/2005. These results are significantly lower than those recorded during placement at the underdrain.

Conclusions

1. The use of FGD-sulfite as a component of LPC material at the LaBelle site, where that material has been in direct contact with coal refuse over a period of nearly eight years, appears to not be adversely affecting water quality with respect to general mining parameters, trace elements, and selected indicator parameters. Testing at the underdrain indicates significant improvement of loading values for iron, manganese, aluminum, and sulfates.
2. Comparison at the underdrain of pre-placement with during-placement concentrations of selected trace elements, plus alkalinity, sulfates, aluminum, chlorides, calcium, and potassium does not suggest that significant dissolution of the FGD material is occurring. Monitoring of the sediment pond that receives direct

runoff from the FGD placement area as well as the coarse coal refuse confirms this observation. The generally alkaline environment of the site, perhaps attributable to the properties of the coal refuse itself, may be contributing to the lack of dissolution of the FGD-sulfite placed there to date.

3. The continued use of this material as a slope stabilizer and final cap at the 300 acre, 40 million ton coal refuse site should result in a net positive environmental benefit with respect to surface and groundwater quality, fugitive emissions, and public safety.
4. The use of FGD-sulfite in applications where it will come into direct contact with coal refuse, should be considered more seriously. Such uses would include alkaline amendment for coal refuse and capping of coal refuse deposits.

Literature Cited

1. Interviews with PA DEP officials, American Electric Power employees, and personnel at The Ohio State University.
2. "Final Technical Report, Monitoring Mines Reclaimed with Mixtures of Spoil and Coal Combustion Residues", ICCI Project No. 96-1/7.1A-3, Dr. Stephen P. Esling, Dr. Bradley C. Paul, Dr. Daniel Banerjee, Southern Illinois University, 1997.

3 "Stabilized FGD Compositions Yield Environmentally Positive Mine Reclamation", Charles L. Smith, Conversion Systems, Inc., year unknown.

Dennis Noll is a Registered Professional Geologist in Pennsylvania and has practiced for a total of 35 years in the field of environmental geology. In 1980, he co-founded Earthtech, a firm largely dedicated to dealing with the environmental requirements of mining companies and energy producers. He has managed numerous projects for Earthtech that involve the environmental aspects of coal combustion by-products and coal waste. Many of these projects have dealt with the beneficial use of those by-products generated by conventional and circulating fluidized bed boilers. Earthtech, under Noll's guidance, currently provides environmental oversight at numerous coal combustion by-product and coal waste placement sites.

TABLE 1

Operator: **Canestrale Contracting**
Operation Name: **LaBelle**
Permit No:
Township: **Luzerne**
County: **Fayette**

Monitoring Point I.D.: **GW-5**
Latitude: N and
Longitude: W
Grid Coordinate:
Surface Elevation:

Description of Sample Point**:
Underdrain

Date Sampled	Method of Flow Measurement	Flow (GPM) or Static Water Elevation	Field pH	Lab pH	Specific Conductance (micromhos/cm) @ 25° C	Field Temp. °C	Alkalinity mg/l	Acidity mg/l	Fe mg/l	Mn mg/l	Al mg/l	Sulfate mg/l	Suspended Solids mg/l	Total Dissolved Solids mg/l	Laboratory and Name of Sampler
08/29/96		117					451		4.1	3.6	0.0	2700			
09/27/96		117					426		6.7	3.5	0.1	2917			
10/31/1996		113					386		0.6	2.4	0.1	2625			
11/21/1996		112					457		3.6	3.1	0.1	2400			
12/31/1996		90					384		1.5	2.9	0.0	2750			
1/31/1997	-----						387		1.1	1.9	0.2	2700			
9/19/98		8					266		4.03	0.001	0.1	2472			
12/17/98		2					379		8.9	0.001	0.1	2451			
3/8/99		3					318		1.05	0.001	0.86	2365			
6/28/99		1.5					457		0.07	0.001	0.1	3100			
9/30/99		0.5					400		0.24	0.001	0.1	2817			
12/30/99		1					413		0.12	0.001	0.1	2933			
9/28/00		5					473		2.57	0.001	0.1	2590			
12/30/00		8					452		3.93	0.001	0.1	1527			
3/2/01		25					354		14.5	0.001	0.1	2404			
6/28/01		12					381		1.63	0.001	0.1	2609			
12/26/01		15					429		12.1	0.001	0.1	2702			
3/25/02		30					370		6.1	0.001	0.1	2694			
6/29/02		8					404		16.4	0.001	0.5	2376			
9/30/02		6					453		20.3	0.001	0.26	2942			
12/31/02		10					359		18.4	0.001	0.1	2462			
12/31/02		10					359		18.4	0.001	0.1	2462			
3/22/03		20					297		18.2	0.001	0.1	2252			
6/24/03		35					318		16.48	0.001	0.36	2732			
9/24/03		25					386		17.84	0.001	0.29	2552			
12/29/2003		20					287		11.4	3.5	0.3	1928			
3/27/2004		15					348		12.9	4.1	0.3	2052			
6/29/2004		23					349		22.3	4.7	0.4	2532			
9/29/2004		8					332		17.1	5.0	0.3	2786			
12/24/2004		10					312		19.8	4.4	0.2	1892			
3/26/2005		15					250		15.9	3.9	0.4	2072			
6/25/2005		8					370		16.8	4.5	0.1	2212			
9/26/2005		10					331		4.0	3.2	0.0	2072			
12/27/2005		20					359		15.5	4.2	0.1	2232			
3/30/2006		11					333		7.3	4.1	0.1	2352			
6/26/2006		12					386		8.9	3.2	0.3	2032			

CHART 1 CONCENTRATIONS: MCC UNDERDRAIN GW-5

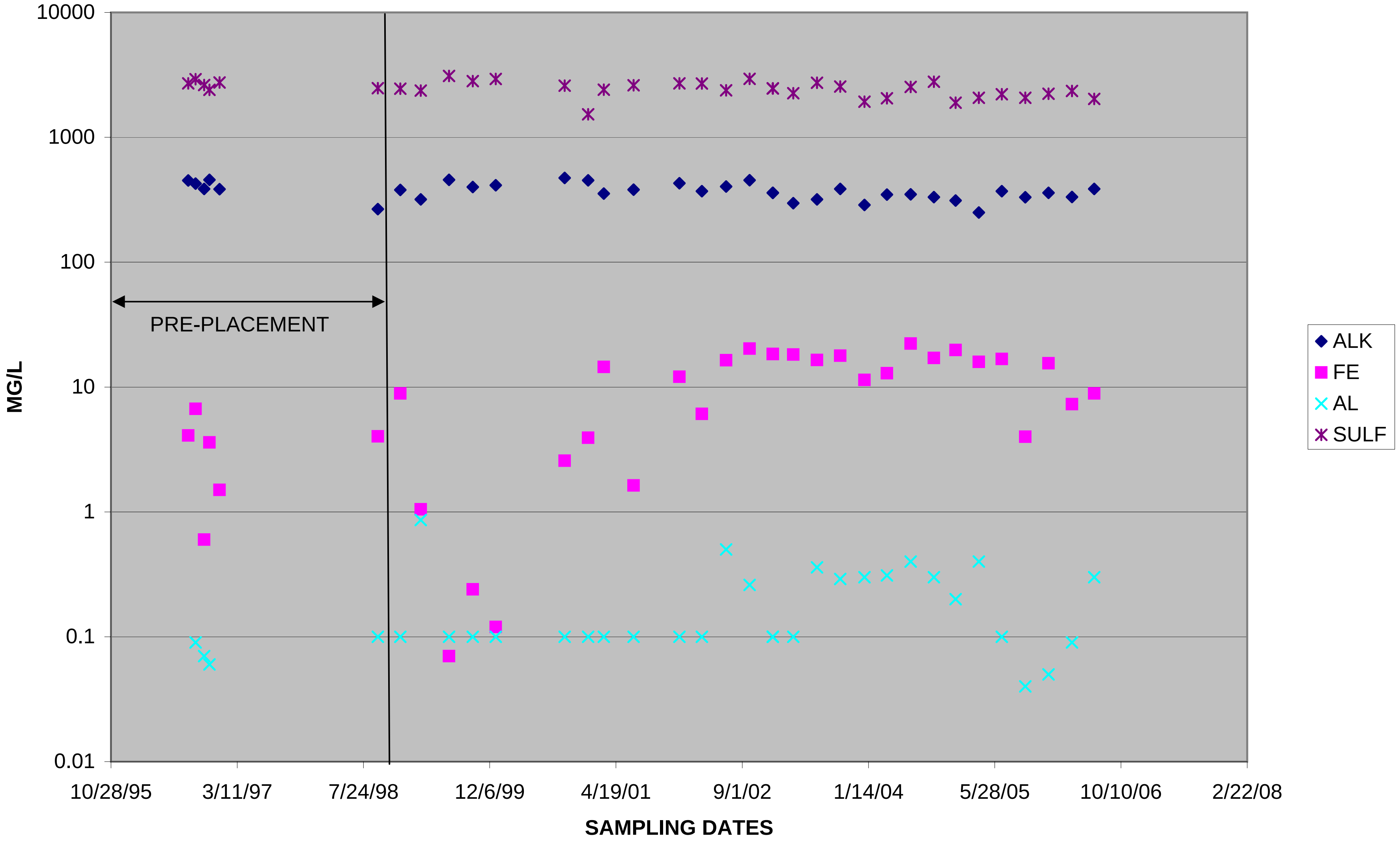


CHART 2 LOADING: MCC UNDERDRAIN GW-5

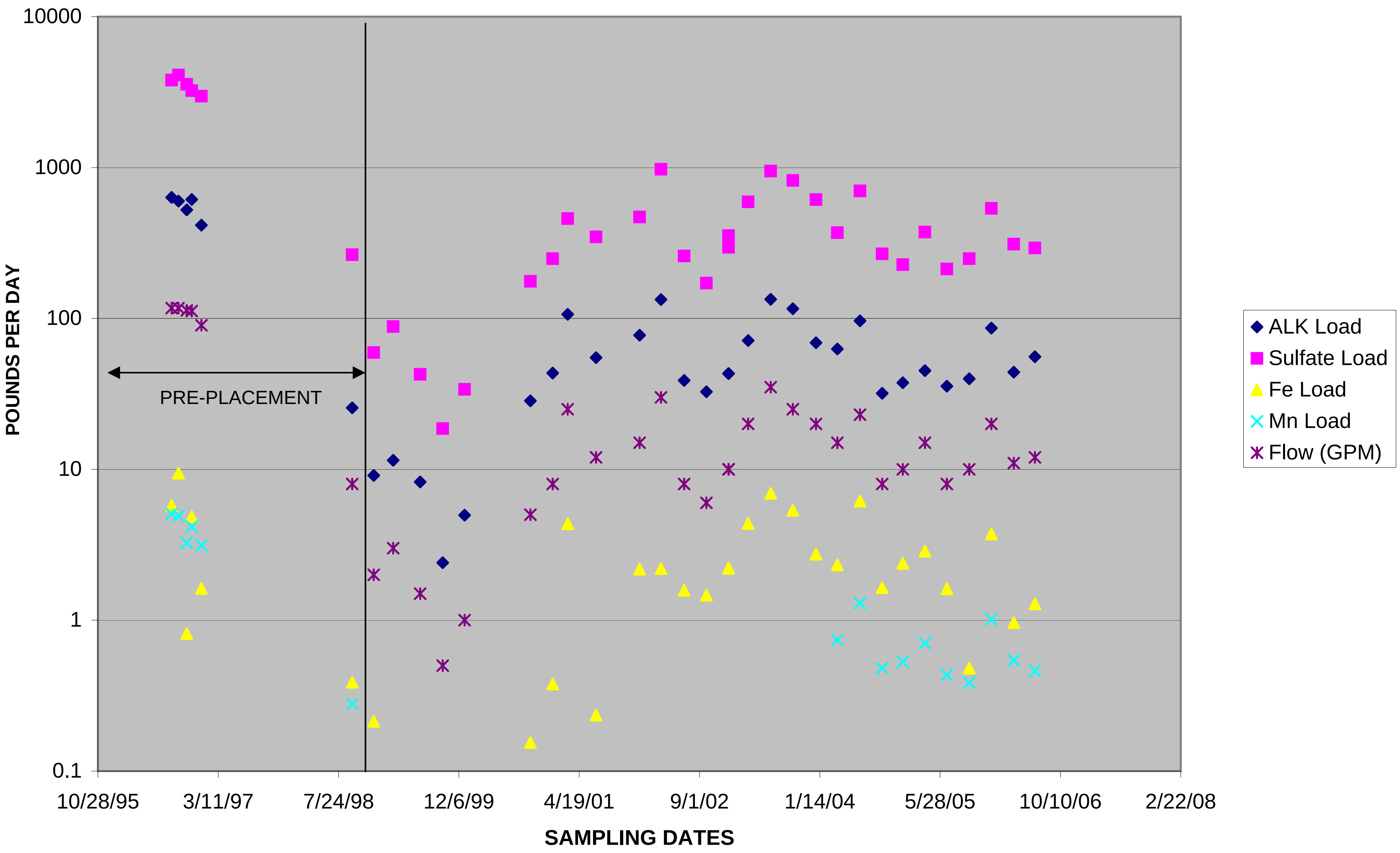


CHART 3A GW- 5 TRACE ELEMENT CONCENTRATIONS

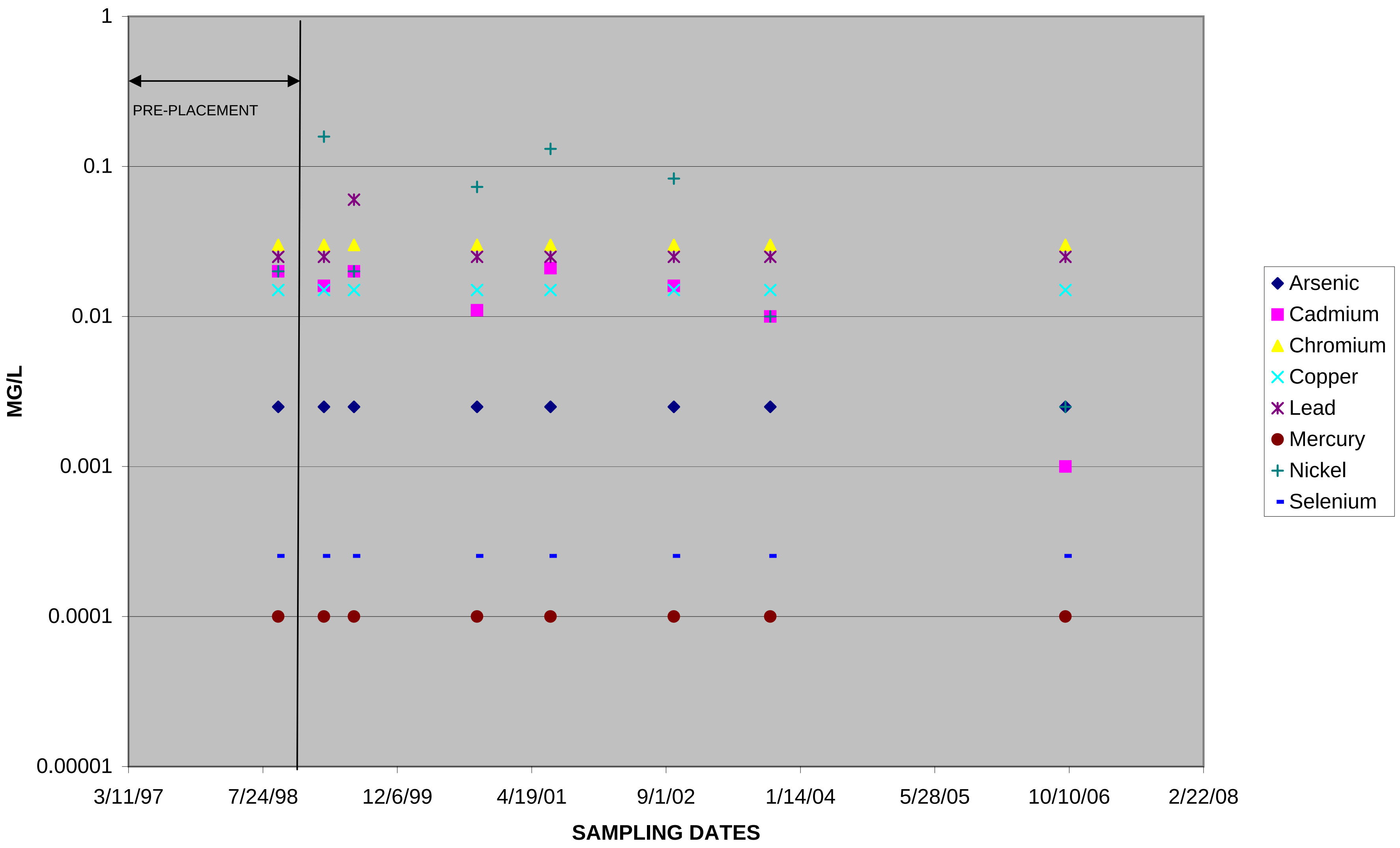


CHART 3B   GW- 5 INDICATOR PARAMETER CONCENTRATIONS

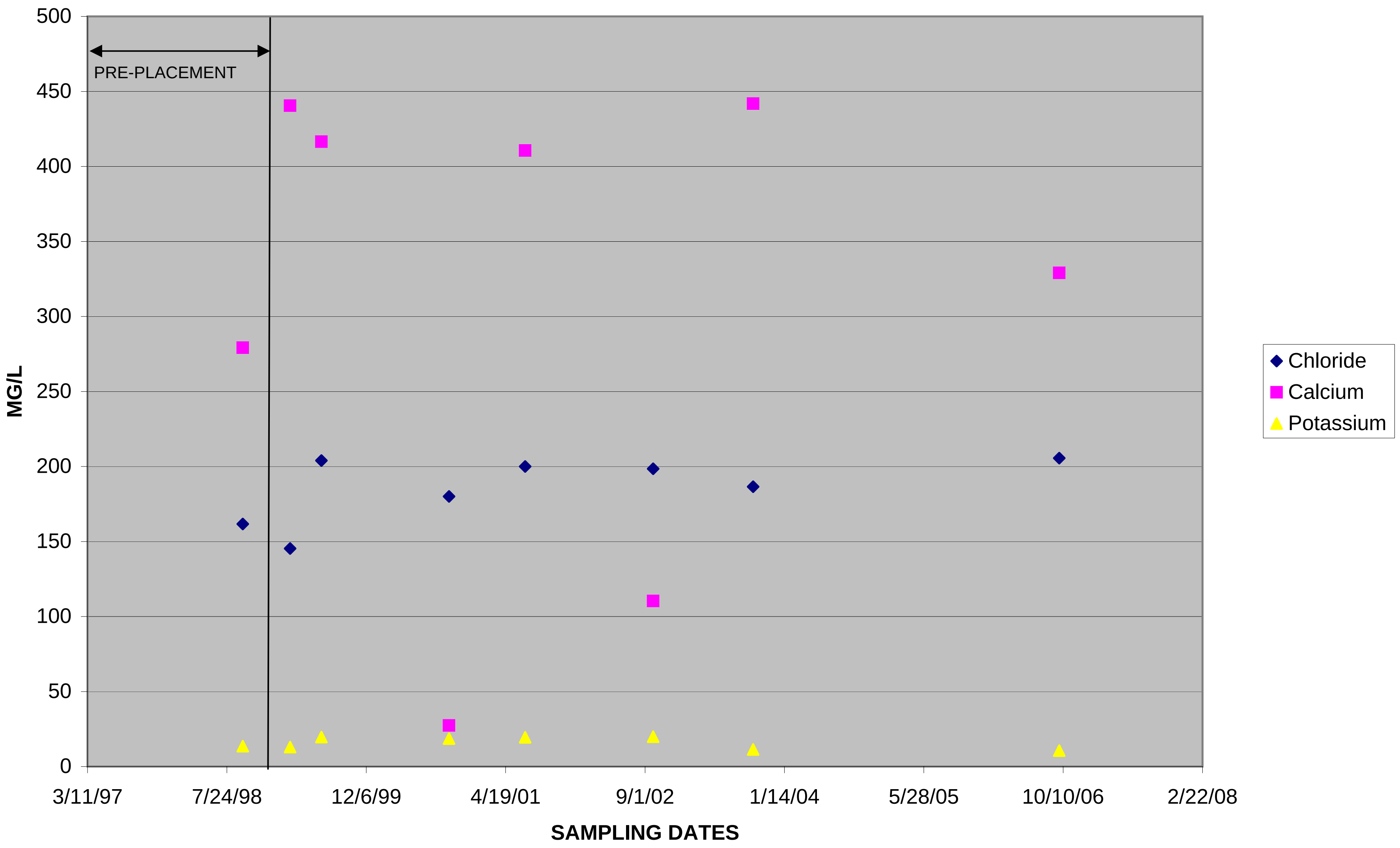
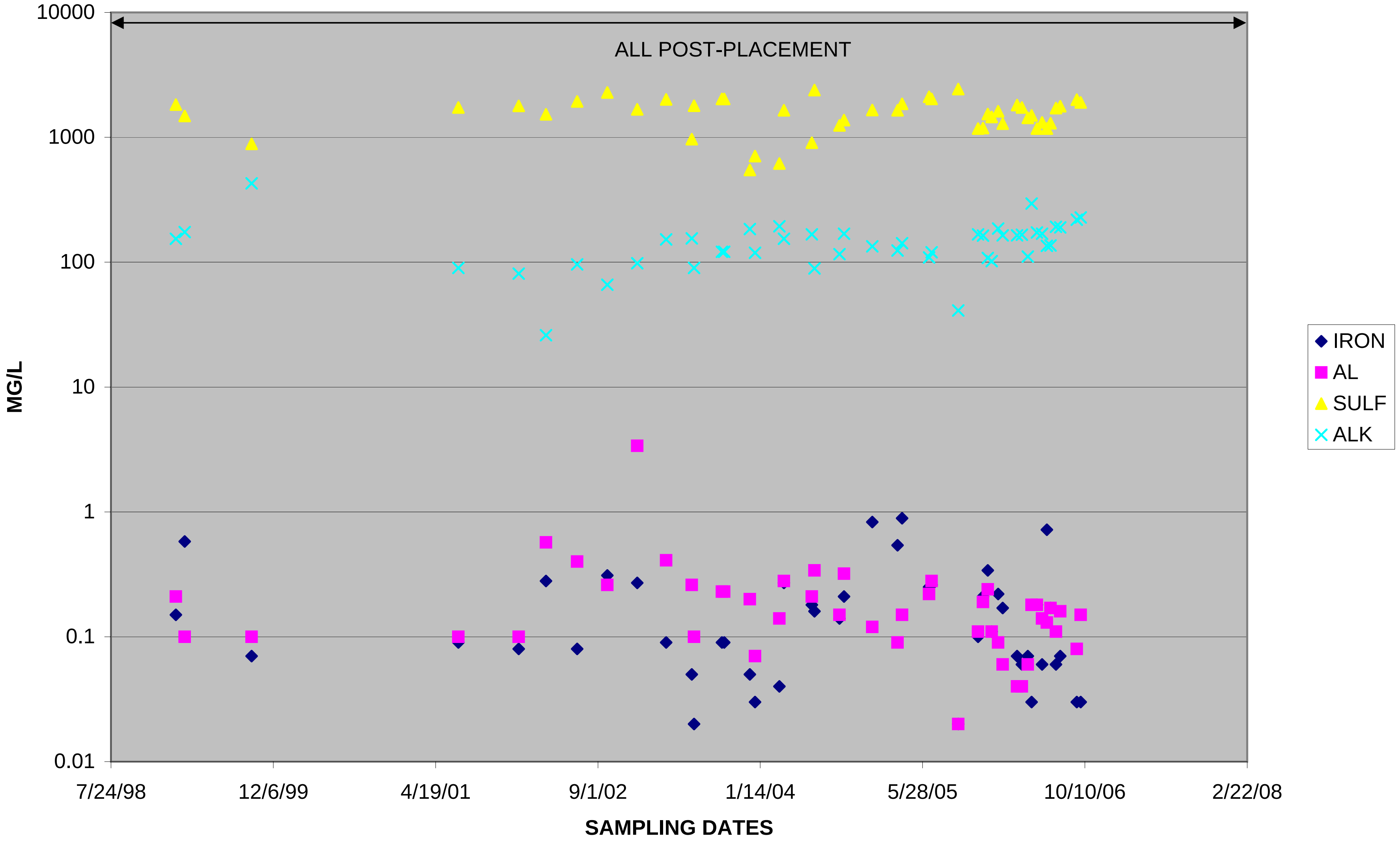


CHART 4 CONCENTRATIONS AT MCC SED POND #1



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Township: **Luzerne**
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Latitude: N and
Longitude: W
Grid Coordinate:
Surface Elevation:

Description of Sample Point**:
Underdrain

Date Sampled	Method of Flow Measurement	Flow (GPM) or Static Water Elevation	Field pH	Lab pH	Specific Conductance (micromhos/cm) @ 25° C	Field Temp. °C	Alkalinity mg/l	Acidity mg/l	Fe mg/l	Mn mg/l	Al mg/l	Sulfate mg/l	Suspended Solids mg/l	Total Dissolved Solids mg/l	Laboratory and Name of Sampler
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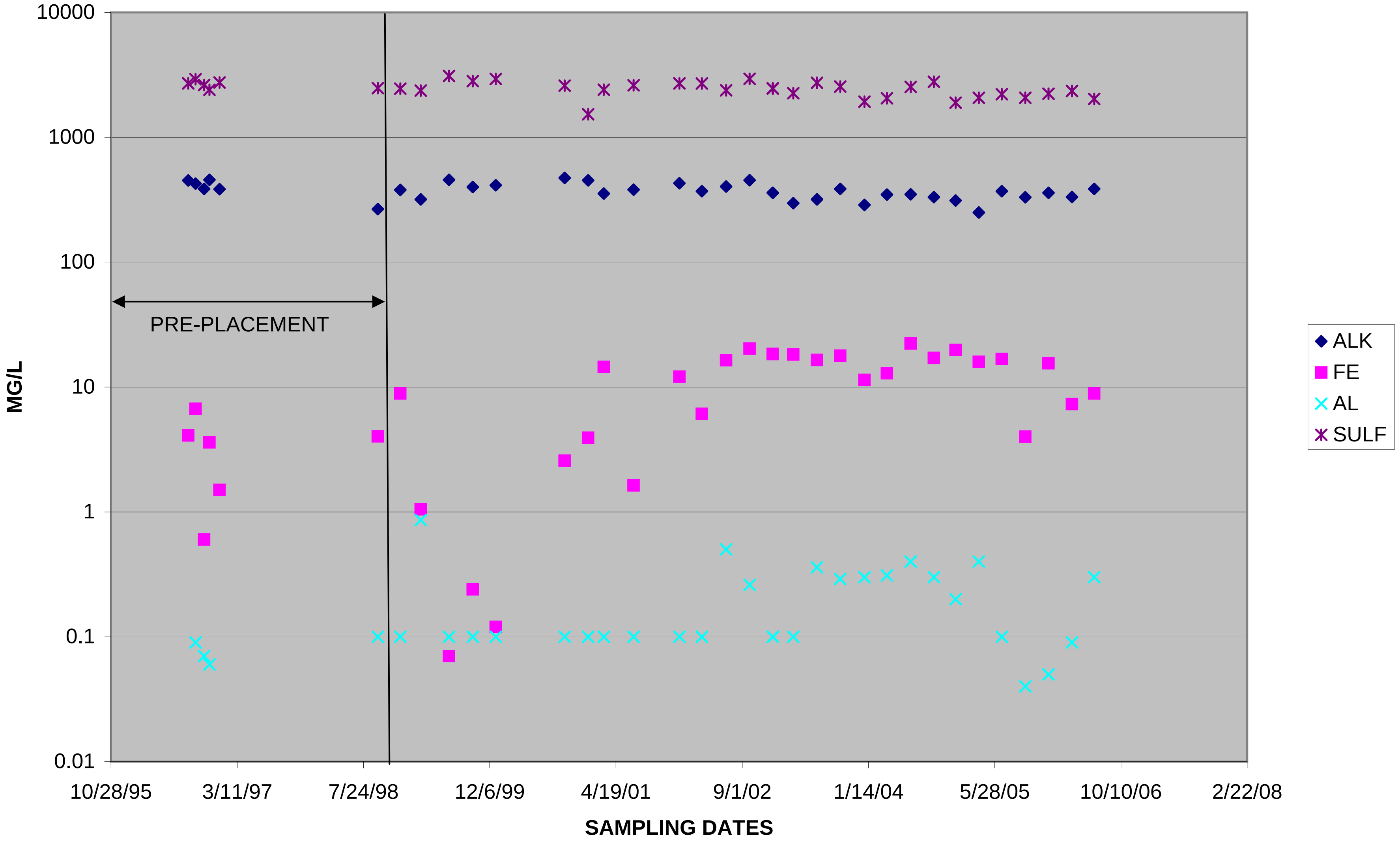
CHART 1 CONCENTRATIONS: MCC UNDERDRAIN GW-5



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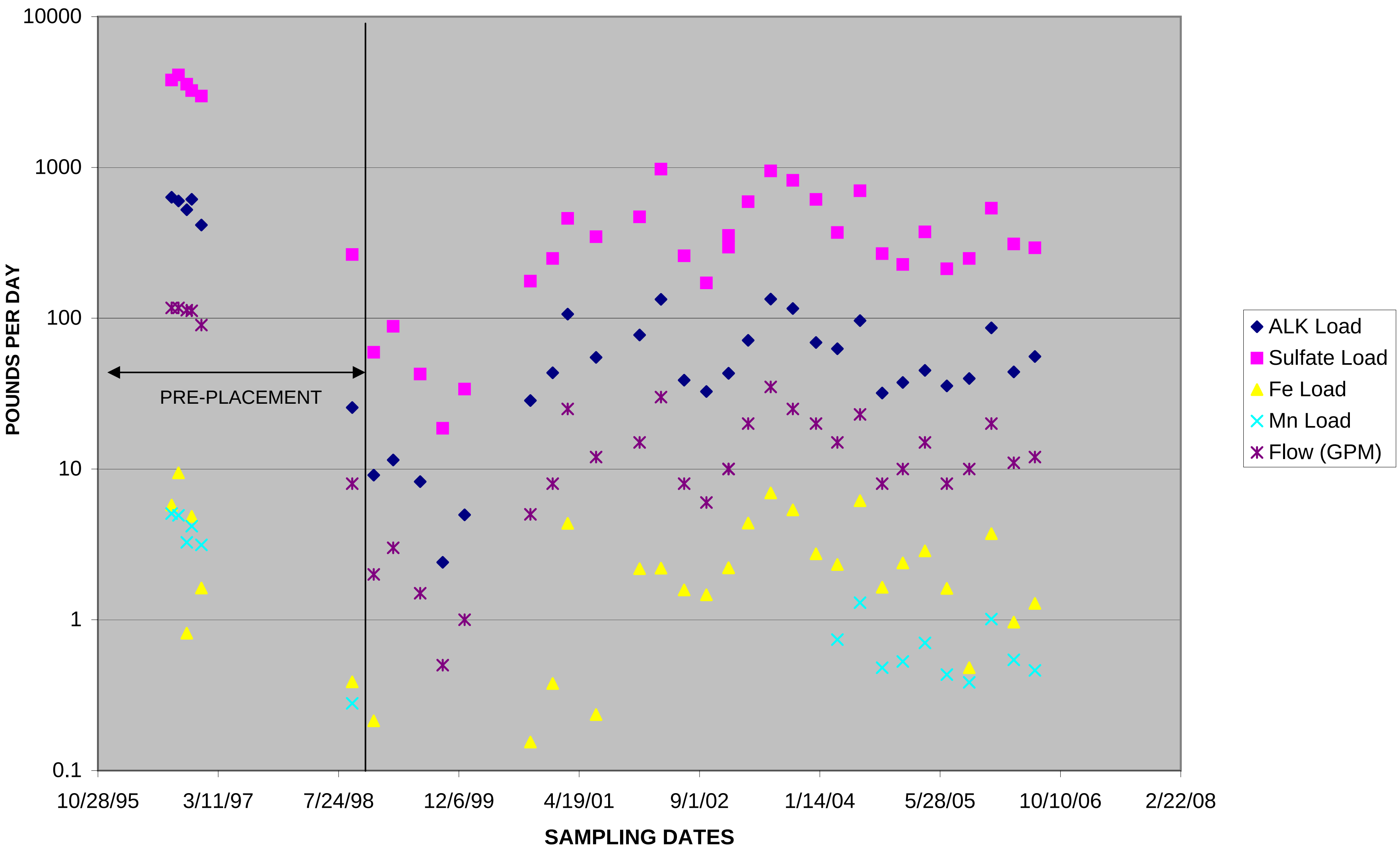


CHART 3A GW- 5 TRACE ELEMENT CONCENTRATIONS

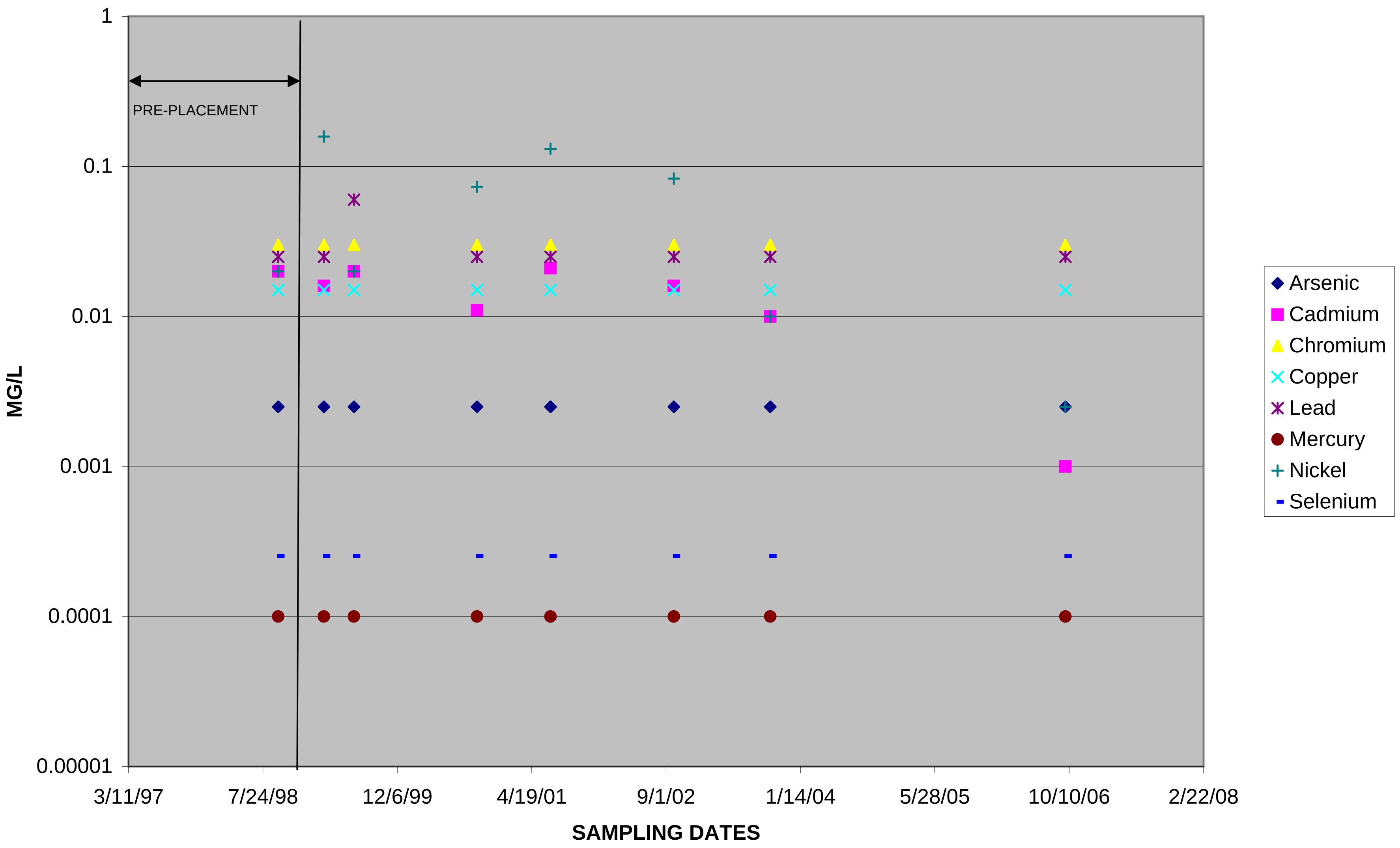


CHART 3B GW- 5 INDICATOR PARAMETER CONCENTRATIONS

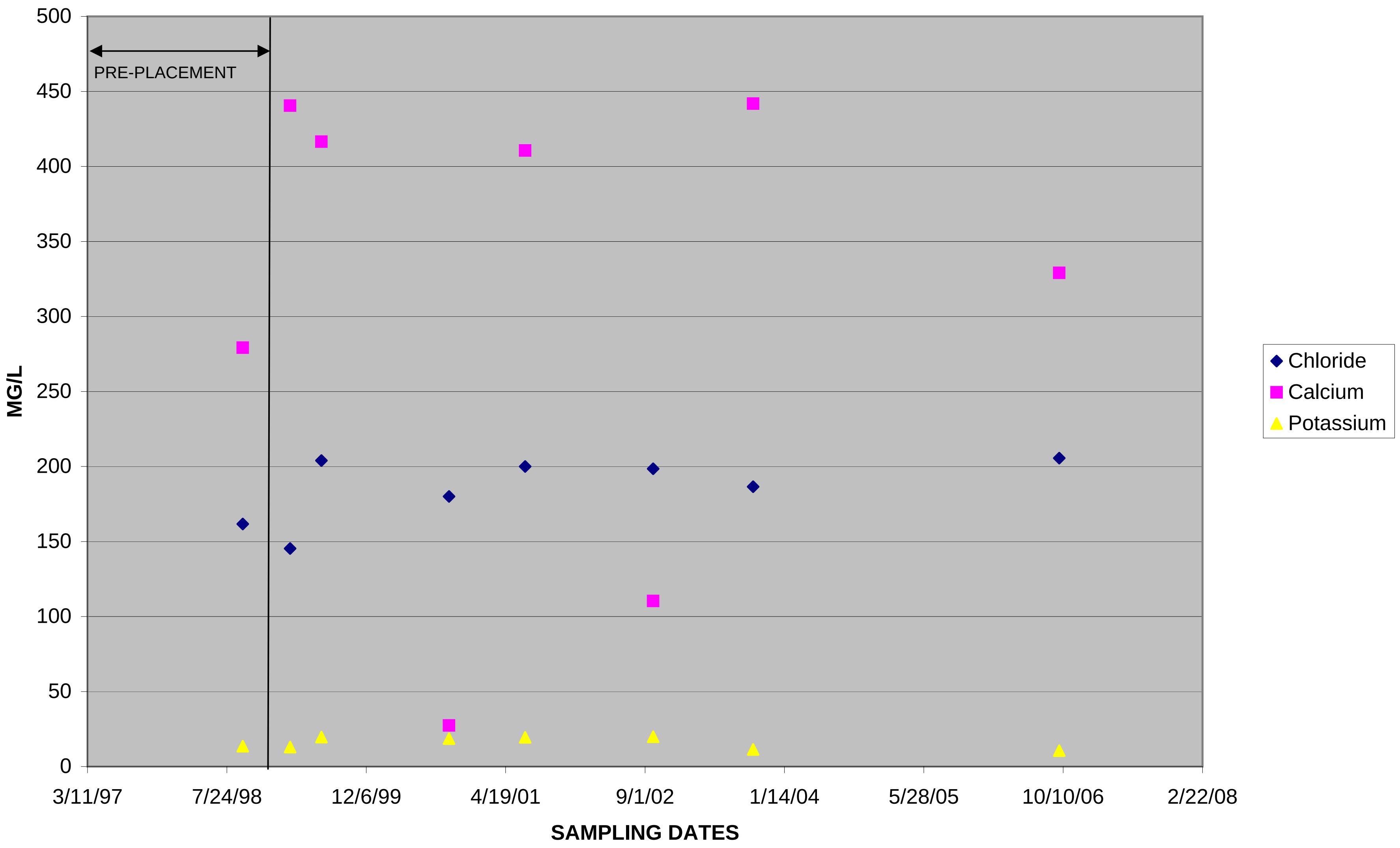
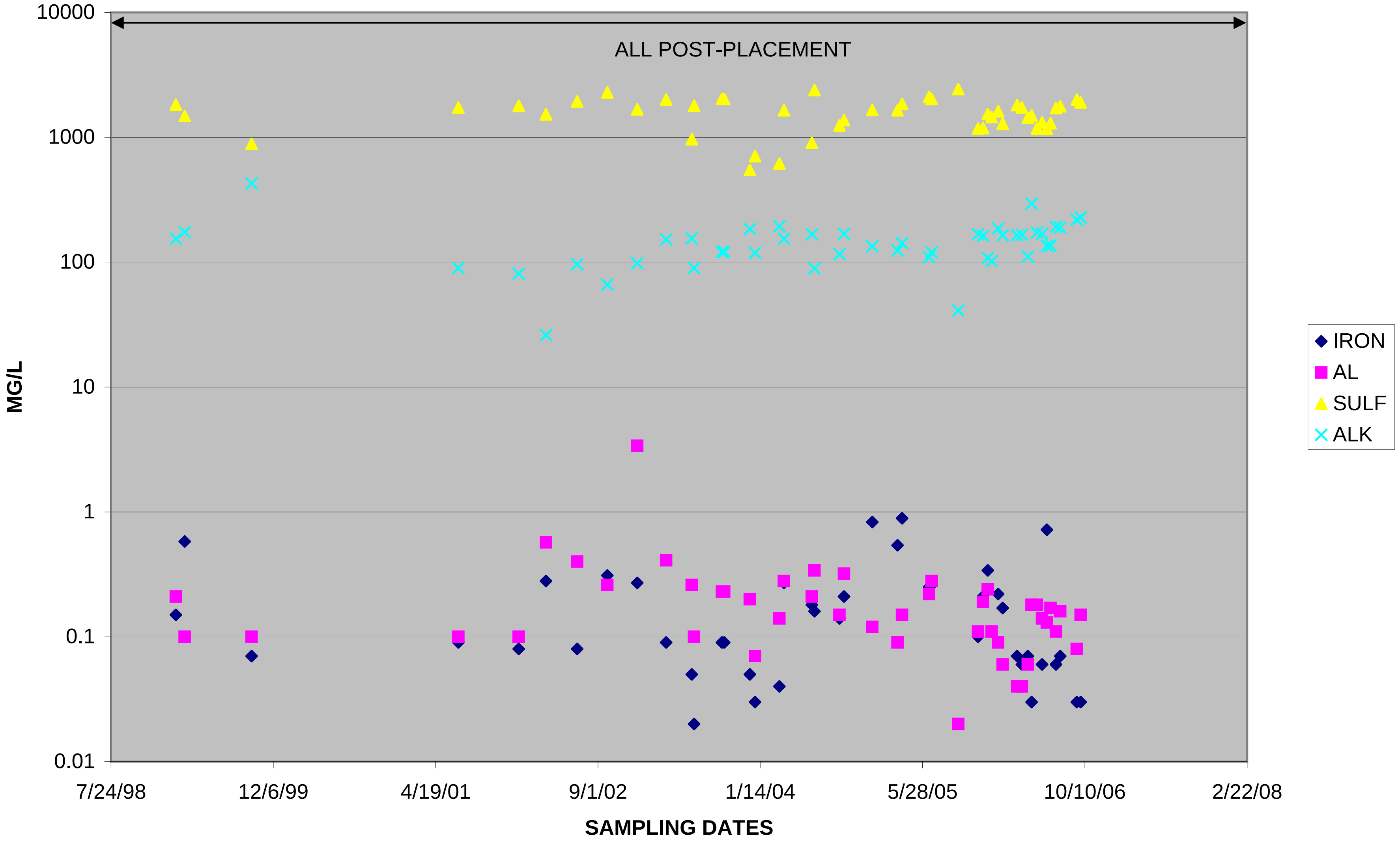
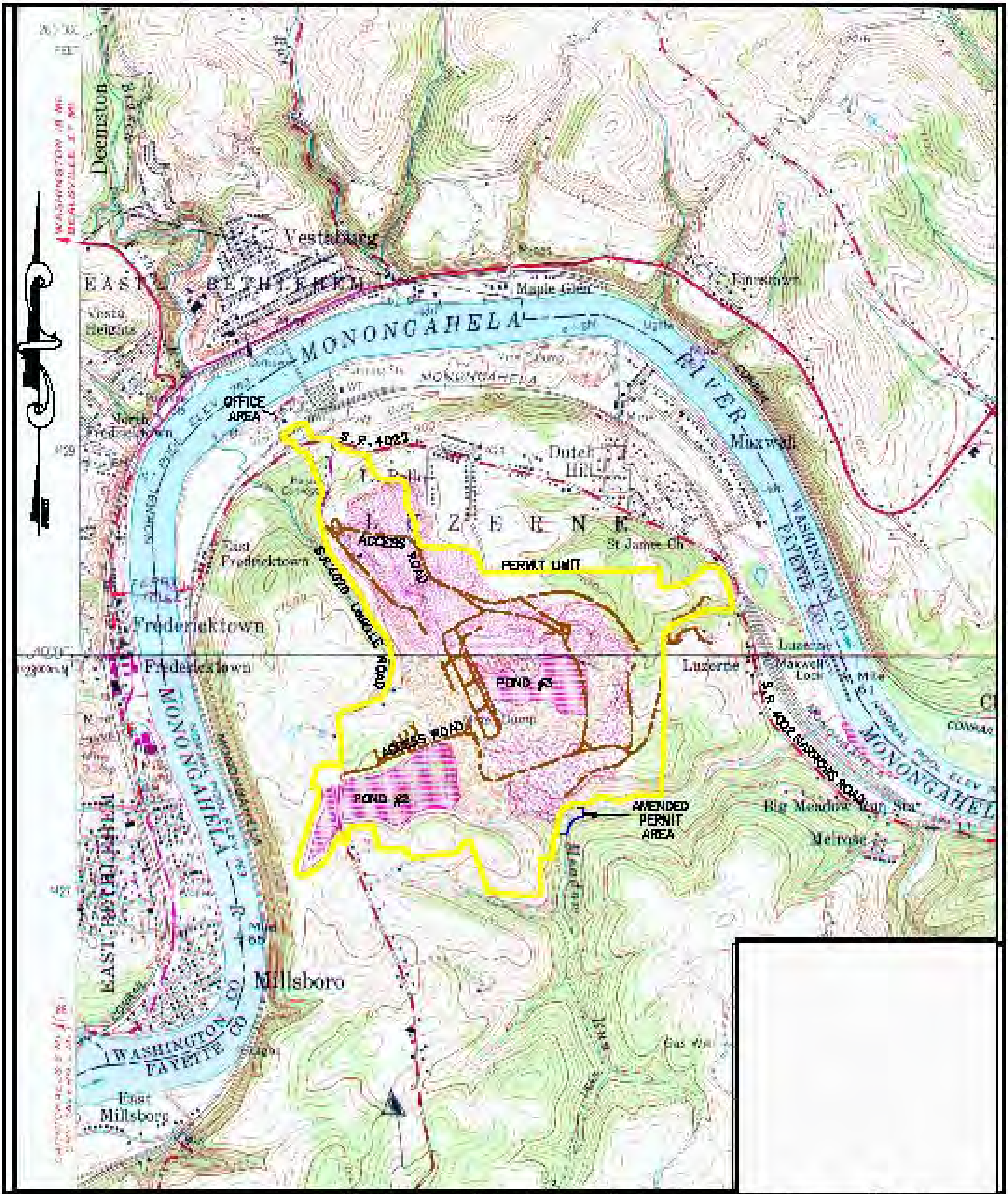


CHART 4 CONCENTRATIONS AT MCC SED POND #1



FGD AS AN ALKALINE AMENDMENT FOR COAL WASTE

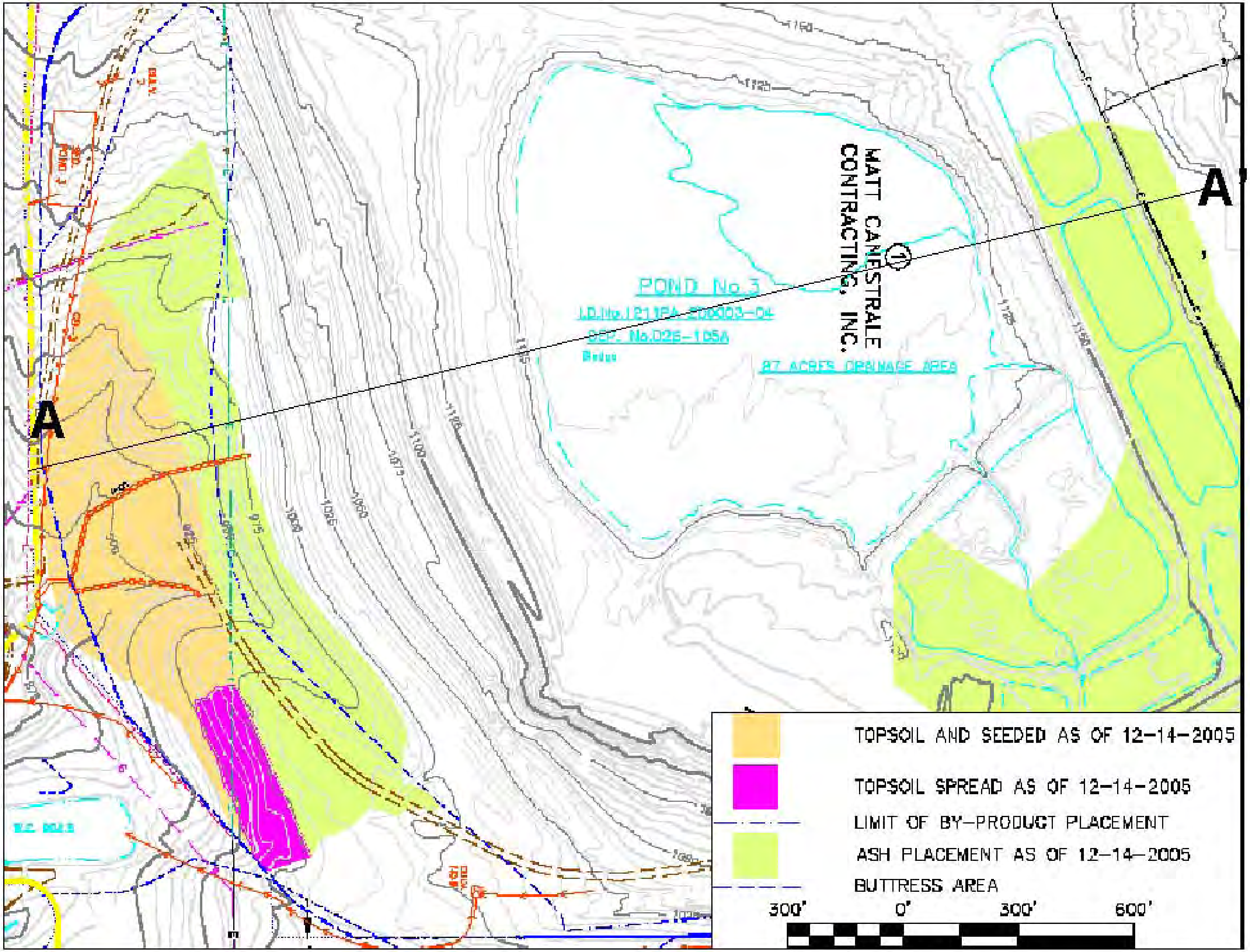
Dennis Noll, P.G.
Earthtech, Inc.
October 2006



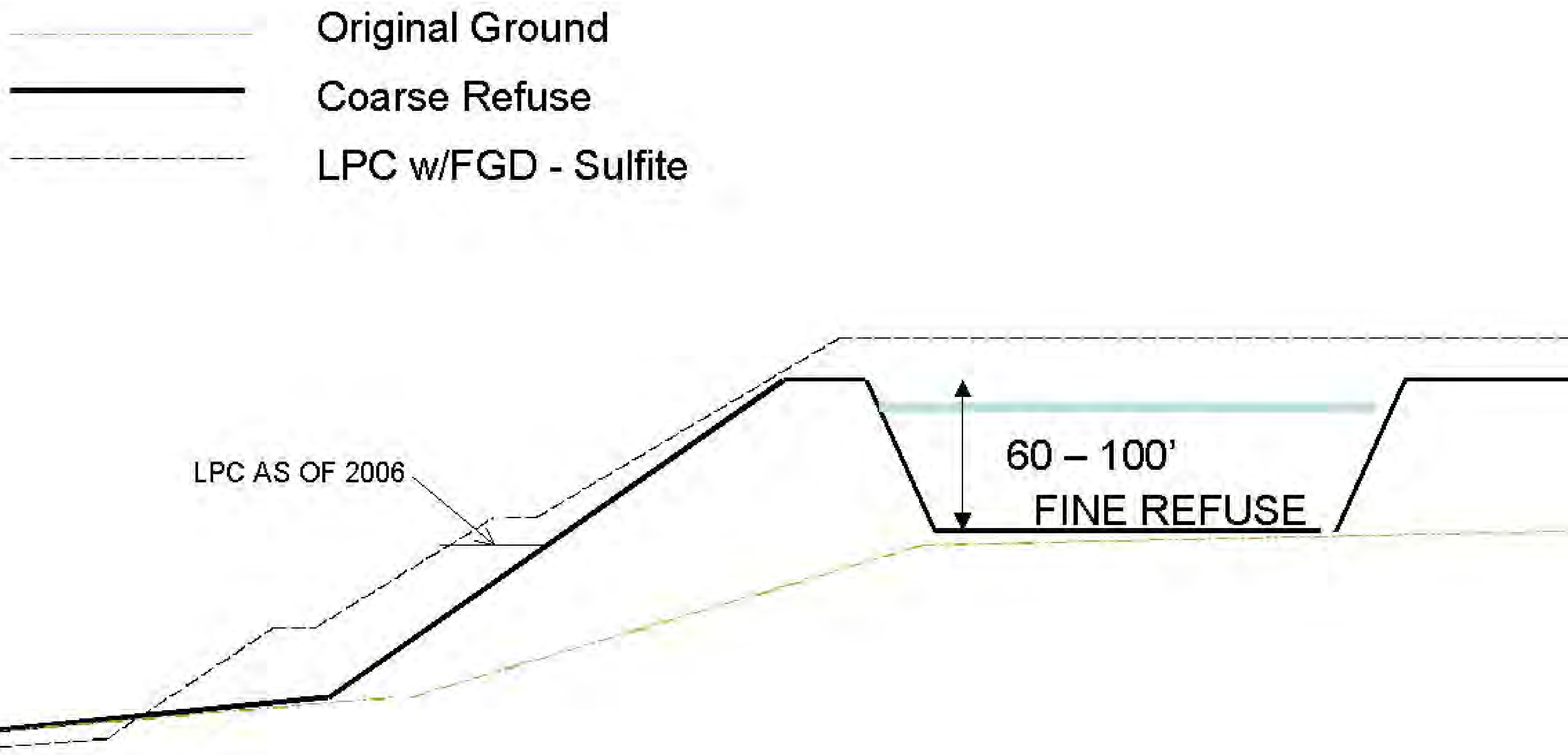
MATT CANESTRALE CONTRACTING, INC.	FILE NAME: MCC-EX6-1.DWG	SCALE: 1" = 7000'	DATE: 5-13-2005	DWN. BY: GMB	CHK. BY: HCR

LaBELLE SITE
EXHIBIT 6.1 – LOCATION MAP
LUZERNE TWP., FAYETTE CO., PA

Earthtech, Inc.
334 Bloomfield Street, Suite 201 Johnstown, PA 15904
Telephone: (814) 266-6402 Fax: (814) 266-6330


A
A'
MATT CANESTRALE CONTRACTING, INC.
1
POND No.3
I.D.No.1211PA 200003-04
DEP. No.026-105A
87 ACRES DRAINAGE AREA
1150
1125
1100
1075
1050
1025
1000
975
TOPSOIL AND SEEDED AS OF 12-14-2005
TOPSOIL SPREAD AS OF 12-14-2005
LIMIT OF BY-PRODUCT PLACEMENT
ASH PLACEMENT AS OF 12-14-2005
BUTTRESS AREA
300'
0'
300'
600'

TYPICAL SECTION A – A’


Original Ground
Coarse Refuse
LPC w/FGD - Sulfite

LOADING: MCC - LABELLE SITE UNDERDRAIN (GW-5)

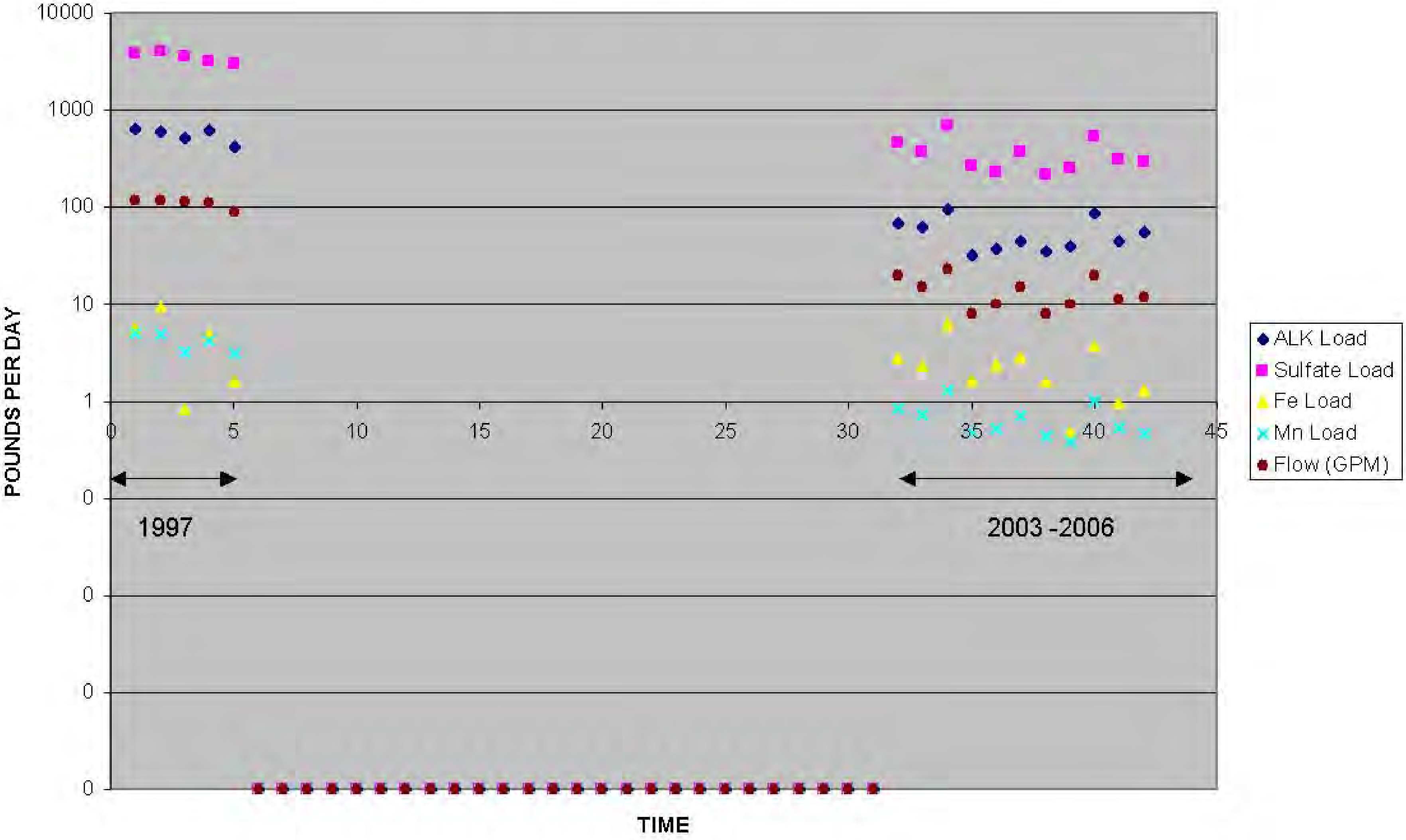


CHART 3A SW- 3 TRACE ELEMENT CONCENTRATIONS

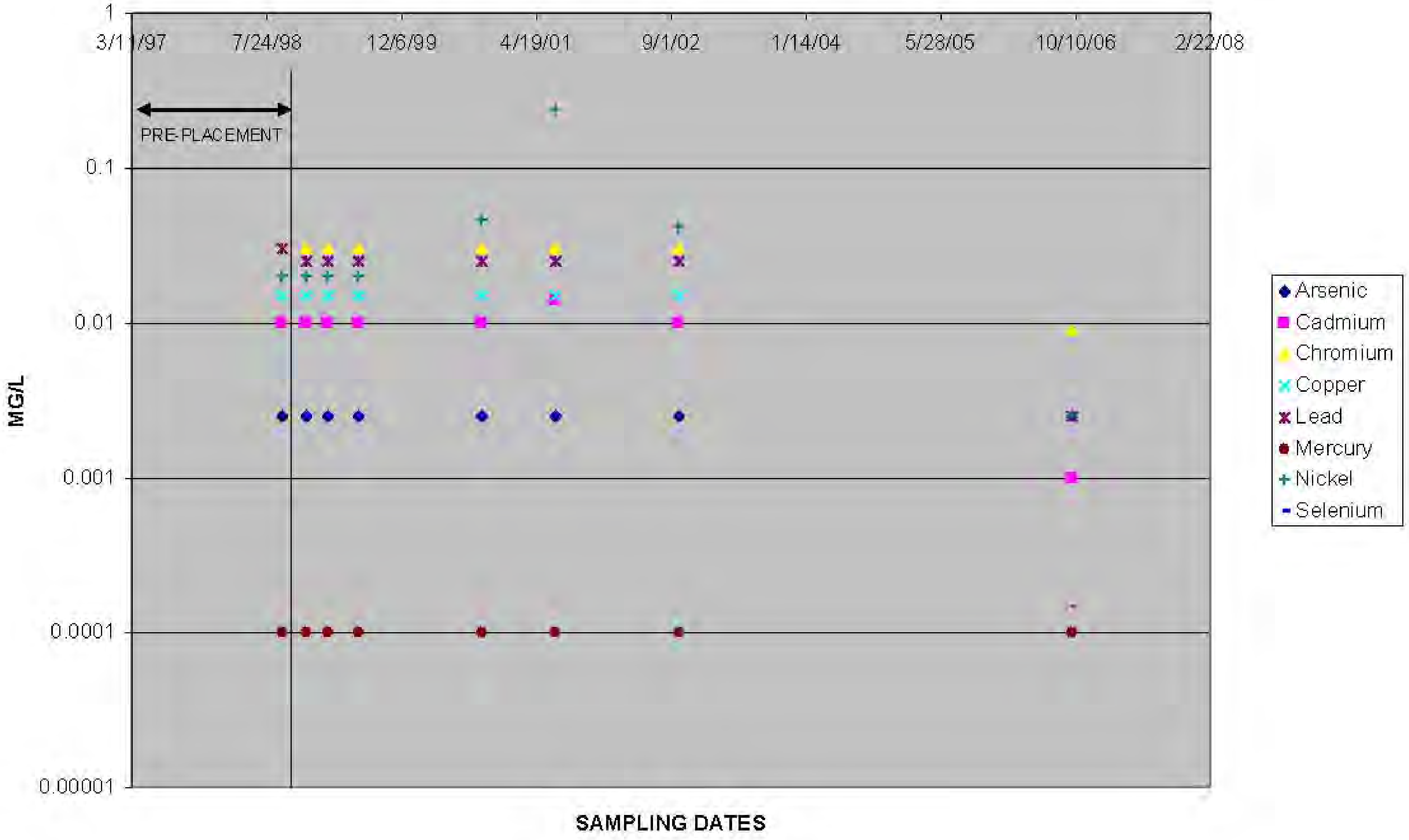


CHART 3B SW- 3 INDICATOR PARAMETER CONCENTRATIONS

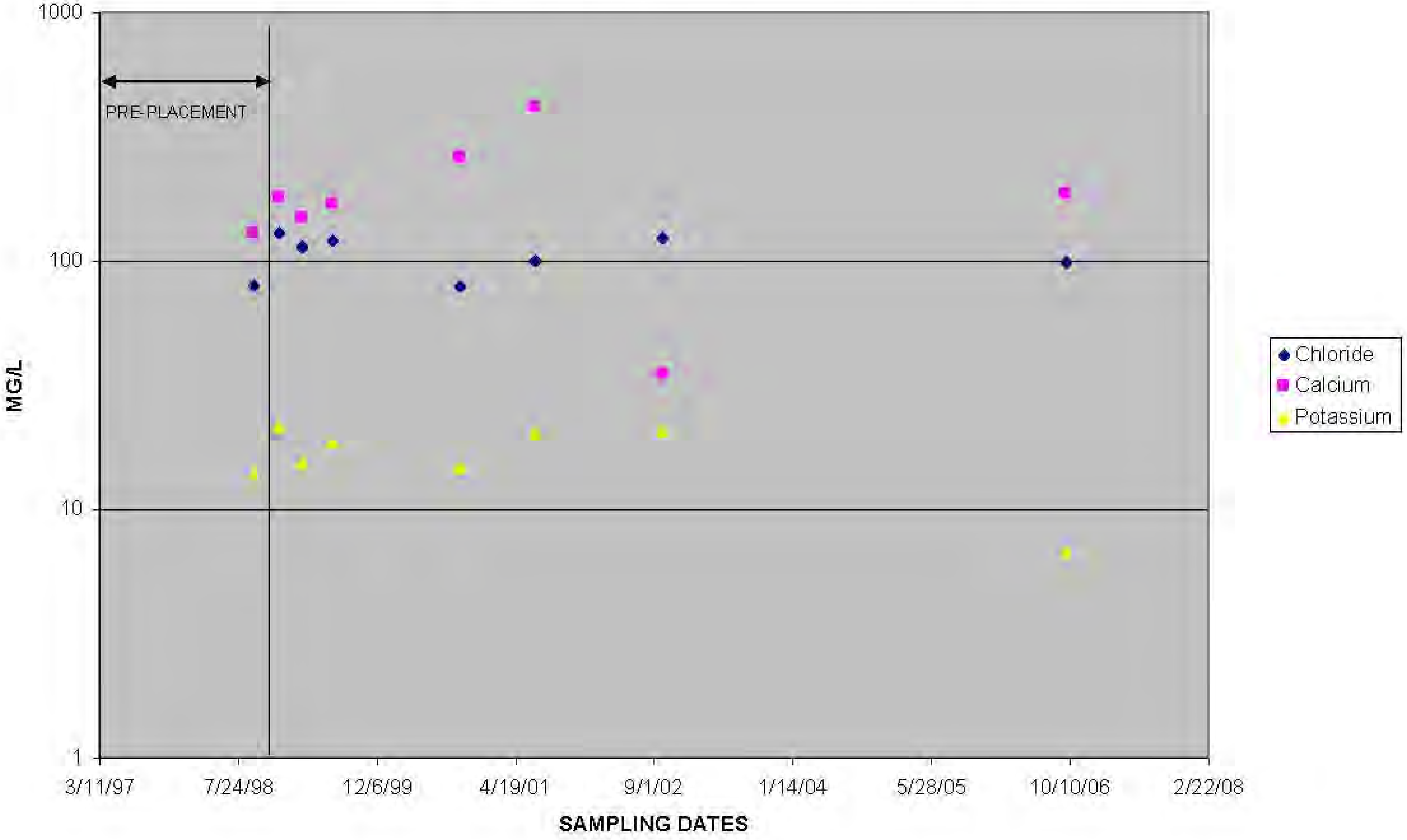


CHART 4A GW- 5 TRACE ELEMENT CONCENTRATIONS

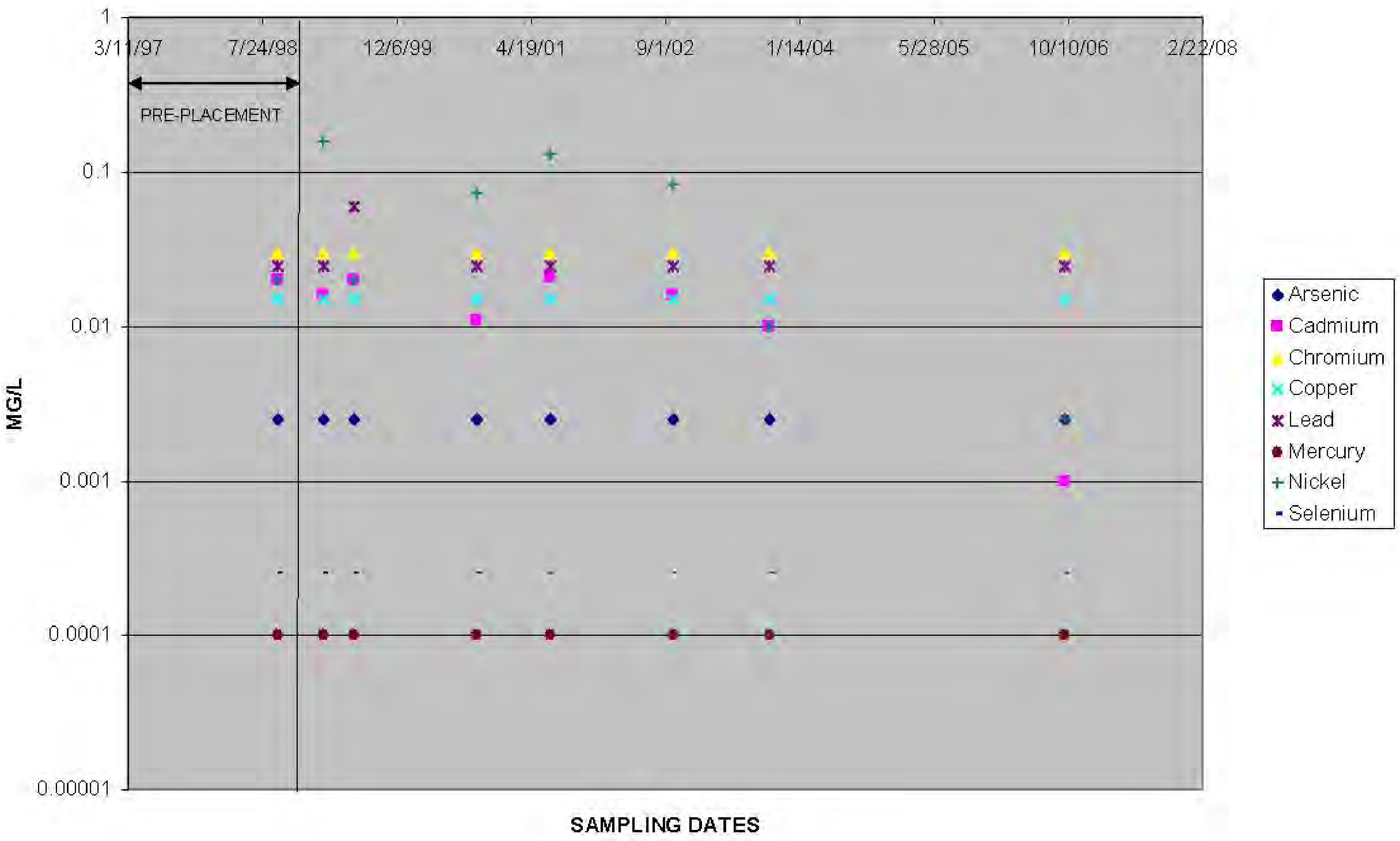


CHART 4B GW- 5 INDICATOR PARAMETER CONCENTRATIONS

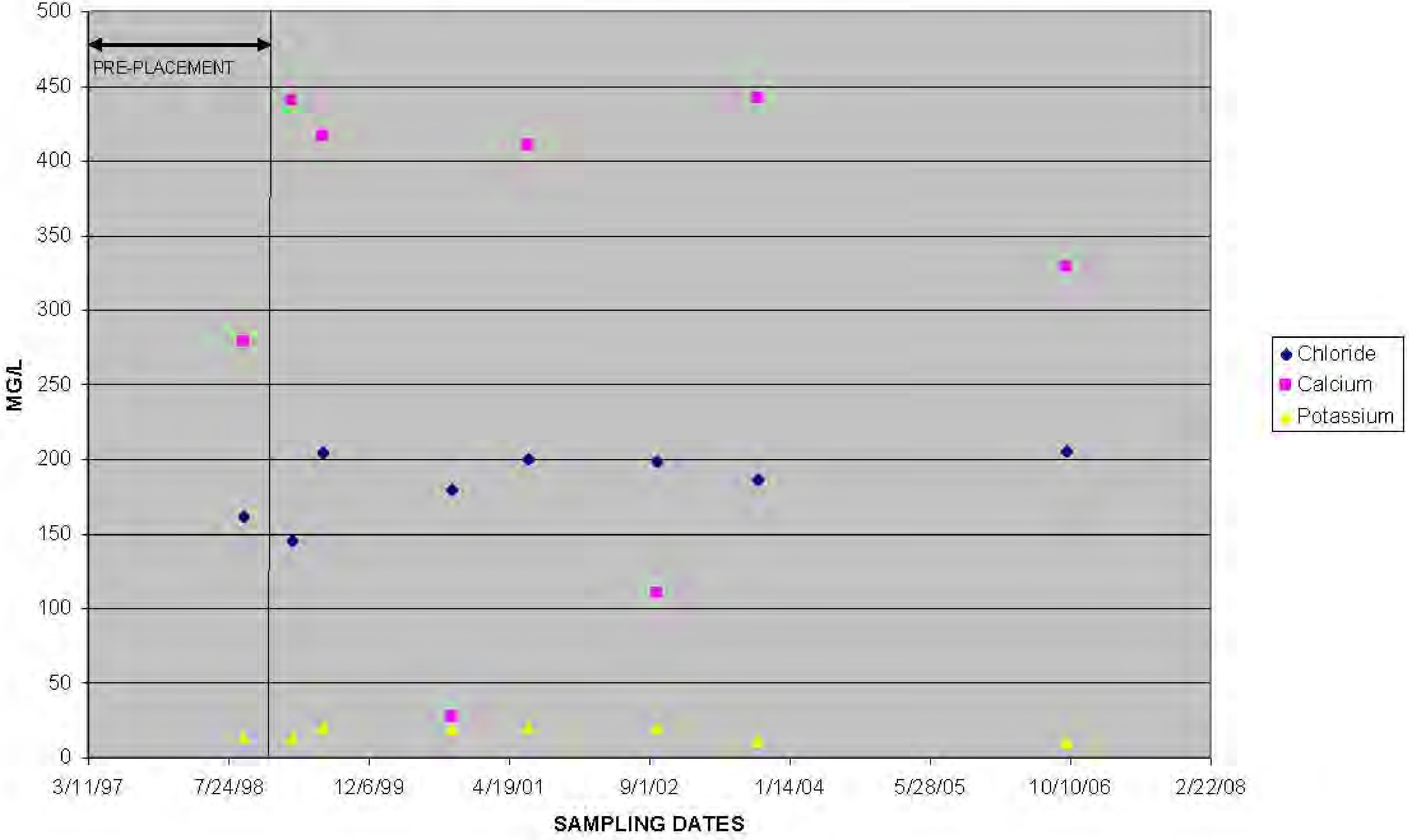


CHART 5A GW- 6 TRACE ELEMENT CONCENTRATIONS

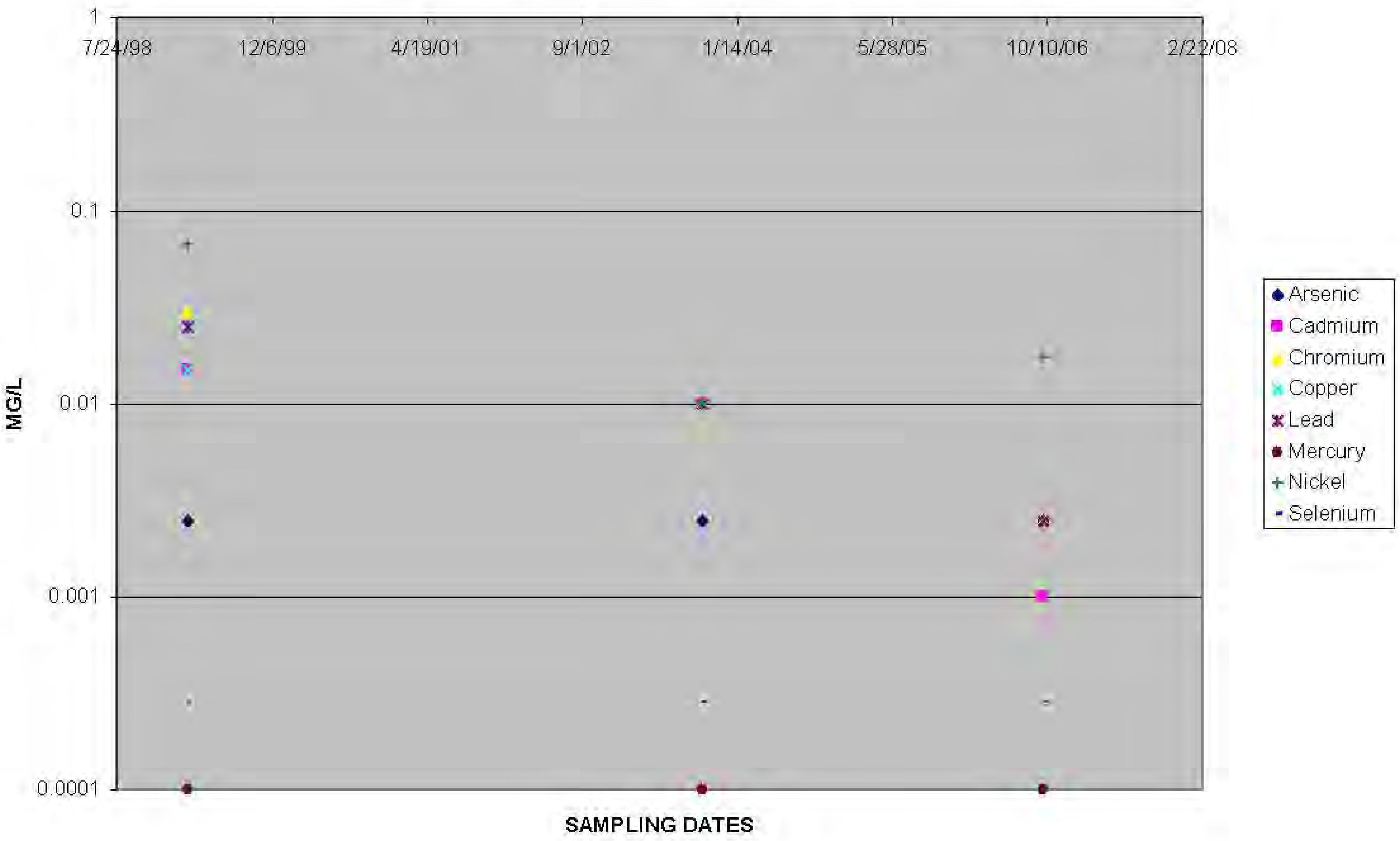
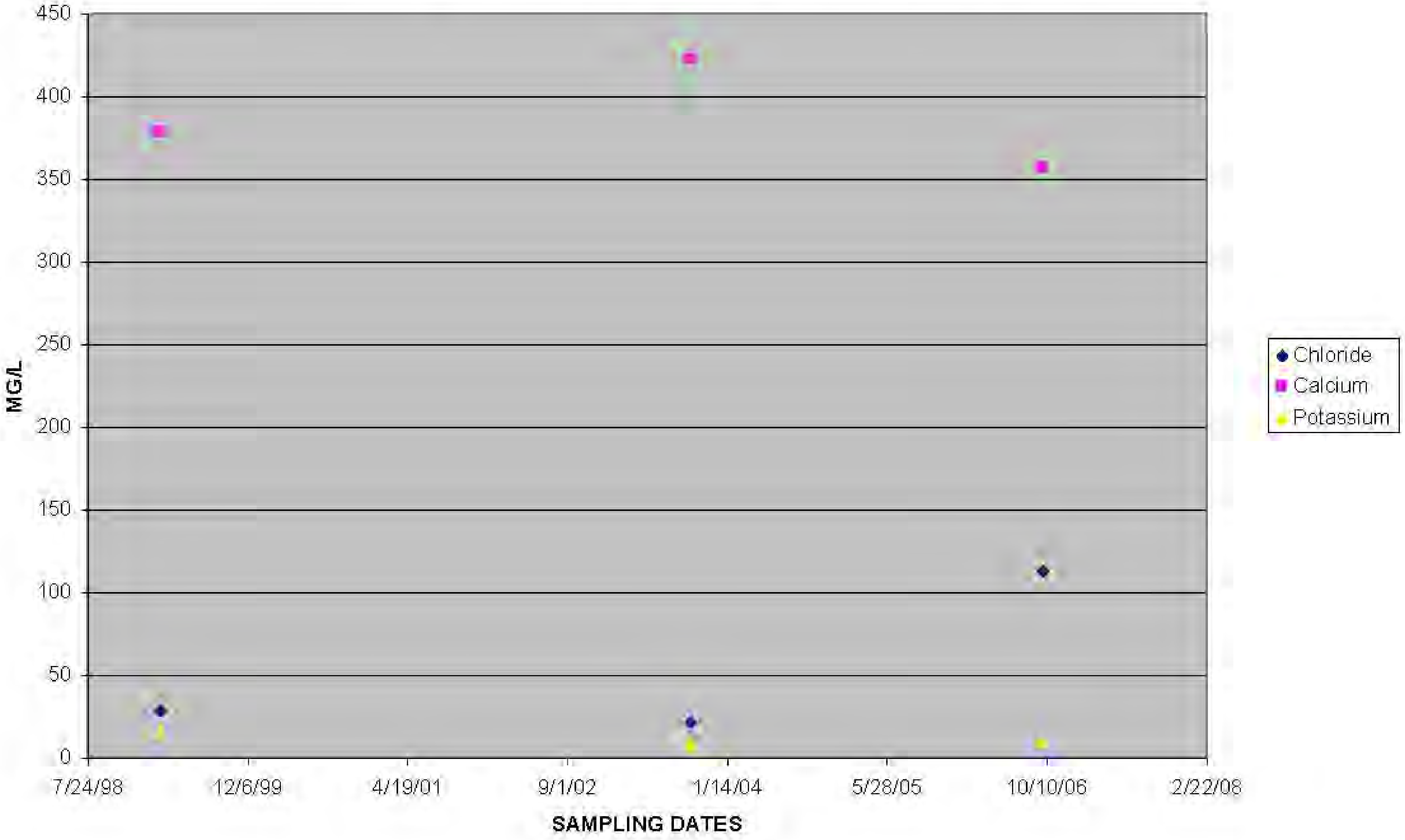


CHART 5B GW- 6 INDICATOR PARAMETER CONCENTRATIONS



FLUE GAS DESULFURIZATION (FGD) PRODUCT AS A SOIL AMENDMENT FOR MINE RECLAMATION

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View Presentation

Abstract

Acid and toxic abandoned mine land sites provide opportunities whereby flue gas desulfurization (FGD) product can be beneficially used as a reclamation amendment material. However, there are few field studies with replicated treatments that compare reclamation using FGD with standard practices. We conducted initial studies to determine the chemical and physical properties of the FGD product and how to transport and blend the FGD product with yard waste compost. Greenhouse studies indicated that FGD could provide benefit for reclamation of acid and toxic spoil contained at the Fleming abandoned mine land (AML) site located in Tuscarawas County, eastern Ohio. Before reclamation activities could actually begin, considerable effort was required to educate and gain acceptance by the public concerning the merits of reclaiming the Fleming AML site using FGD product. Education efforts must continue if FGD products are to achieve general acceptance as a reclamation alternative in cases where resoil is of scarce supply. Three treatments were established including FGD alone (125 dry tons/acre), FGD (125 tons/acre) plus yard waste compost (50 tons/acre), and standard resoil reclamation (8 inches of resoil plus lime). Problems in evenly spreading the FGD or FGD+compost treatments were anticipated but were not realized as standard lime spreading equipment provided a uniform application on the spoil surface. Our results indicated that heavy metal loading rates were generally much lower using the FGD+compost mixture than using resoil material. Dioxin in the mixture was also less than the 5 parts per trillion (ppt) level considered as normal background. Plant growth was initially higher with resoil, but adequate plant cover was achieved by all treatments to provide good erosion control. Surface water quality was immediately improved, as was the interstitial soil water. However, the impact of the mining activities that originally caused degradation of ground water quality was still evident after seven years, but overall improvement was predicted. In conclusion, FGD product has been effective in stabilizing the Fleming AML site and in remediating surface water quality and plant growth.

***Keywords*:** Abandoned mine lands, ground water, fluidized bed combustion products, surface mine land reclamation, surface water, trace metals, water quality.

Introduction

The 1990 amendments to the Federal Clean Air Act have led to the development of various clean coal technologies. Several of these technologies produce alkaline FGD products that have been successfully used as amendments to remediate toxic surface coal mine spoil under greenhouse conditions (Stehouwer et al., 1995a; 1995b; Dick et al., 2000). The ultimate test, however, of the effectiveness of a proposed amendment for reclamation of an acid and toxic spoil is to conduct studies in the field under naturally occurring climatic conditions. Results obtained under laboratory or greenhouse conditions do not always transfer to the field as expected. This paper reports on the steps that must be taken when formulating plans to conduct a field scale reclamation study utilizing FGD product and on the results obtained when such a field study of an abandoned surface mine site is conducted.

Approximately 3.5 million acres of land have been disturbed in the United States by surface mining for minerals and require some level of reclamation. Included in these statistics are many abandoned coal mines in Ohio and throughout the Appalachian coal region that are characterized by acid mine drainage (AMD). These mines typically require alkaline amendments such as crushed limestone or agricultural lime to raise the pH of soil so that vegetation can be reestablished. Abandoned mine sites also commonly have very little topsoil that is of poor quality.

Because of the acidity commonly found at abandoned mine sites in the Appalachian coal region, concentrations of many metals are often naturally elevated compared to nearby, unmined areas. Addition of alkalinity as FGD product will raise the soil and water pH and generally reduce metal concentrations in surface and ground waters. However, questions still arise concerning the transport and fate of major elements such as sulfur and of trace elements such as arsenic, lead, selenium, and boron that may be derived from the FGD product.

In late 1994, an abandoned surface coal mine in eastern Ohio (hereafter referred to as the “Fleming site”) was reclaimed with fluidized bed combustion (FBC) products. Although the FBC products used in this study are not strictly FGD products, because the reaction of sulfur with calcium does not typically take place in the flue gas, they are chemically and physically comparable to other dry FGD products. This paper presents the processes involved in planning the reclamation activity, the preparation and application of FGD product during reclamation, and the post reclamation monitoring of the site. Post reclamation monitoring included site instrumentation to document the chemical character of the surface water, unsaturated-zone water (hereafter referred to as “interstitial water”), ground water, and spring water. This process began soon after reclamation to determine the mobility and fate of elements derived from the FBC products.

Background to Field Study

Field studies were planned to take place at an abandoned surface coal mine site in Ohio. Criteria considered during the site selection process included: (1) timing and extent of reclamation that matched project objectives; (2) cooperation from the land owner(s), mining company, and/or state regulatory agencies; (3) requirement of alkaline amendments to ameliorate predicted acid mine drainage; (4) acquisition of a representative site based on hydrogeology and soils so that transferability of results to similar sites in the region could be accomplished; (5) drainage-basin morphology and site accessibility; (6) premining land use; and (7) distance to FGD product source. After considering several sites, the Fleming AML project area was selected. It is located in Franklin Township, west of Dover in Tuscarawas County, Ohio. The site consisted of approximately 25 acres of exposed, highly erodible underclay bordered on two sides by about 45 acres of unreclaimed spoil and coal refuse.

The Fleming site is located within the Pottsville and Allegheny system of Pennsylvanian-age sedimentary rocks of eastern Ohio. The Lower Kittanning (No. 5) coal was mined from the site by surface operations over a 20-year period approximately corresponding to 1950 through 1970. The mine site was abandoned after depletion of the coal and clay reserves in the early 1970s. Soon thereafter, local residents lodged complaints regarding flooding and sedimentation along a nearby road. Springs were discharging AMD with pH less than 4 and high concentrations of dissolved solids, including iron and sulfate. Some baseline data of the Fleming AML site, compiled by the Ohio Department of Natural Resources and The Ohio State University, revealed the following. The site was characterized by high erosion rates (450 tons/acre/year based on a 2-year, 24 hour storm) and discharge of acid mine drainage. The acid mine drainage was due to the oxidation of pyrite contained in the mining overburden associated with the coal. The pH of the spoil and underclay was 3.1 and surface drainage water samples exhibited pH values of 2.5 to 3.9 with high concentrations of total acidity and soluble aluminum, iron, sulfate, and manganese. The ability of this material to support plant growth was extremely low. Site visits prior to reclamation clearly indicated vegetation was sparse or nonexistent on much of the site. Total clay content was high suggesting water infiltration and availability was limiting plant growth. Equilibrium water infiltration measured at eight different locations on the exposed underclay revealed values from 1.2×10^{-6} cm/s to 8.3×10^{-6} cm/s.

Reclamation and Monitoring Activities

Reclamation plans were developed for the site and a site map is provided (Figure 1). A total of six 1-acre watersheds were developed to provide replication of three different treatments. Larger areas, reclaimed using either FGD+compost or resoil+lime, surrounded these small watersheds.

The sources of the FGD for the six watersheds and for the surrounding areas treated with FGD+compost were different. For the watersheds, the FGD material was from an atmospheric fluidized bed combustion (AFBC) burner located at a General Motors plant in Pontiac, MI. FGD product produced by the PFBC process was obtained from American Electric Power's Tidd Demonstration Plant in Brilliant, OH and used in areas surrounding the watersheds.

Both materials were highly alkaline with the AFBC having a calcium carbononate equivalency of approximately 10% and the PFBC of approximately 30%. A complete analysis of these two materials has been previously reported (Dick et al. 1999). The yard waste composts was obtained from Earth-N-Wood, a company located in North Canton, OH that collects grass clippings, leaves, and chipped branches and brushes and then composts them in windrows.

A greenhouse study was conducted to evaluate the effectiveness of applying PFBC product to acid mine spoil obtained from the Fleming site. The spoil had a pH (1:1 in water) of 3.1; particle size distribution of 17% sand, 35% silt and 48% clay; S content of 1.0% and low nutrient status. The Fleming site spoil was amended with PFBC product at rates of 0, 30, 60, 120 and 240 g/kg by weight (roughly equivalent of 0 to 240 tons/acre) alone or with 60 g/kg (60 tons/acre) biosolids. Supplemental fertilizer was added and fescue planted. Following an initial 3-month growth period, fescue was harvested once each month for a total of six harvests. Pots were leached with water immediately after treatment of the spoil and then again after the sixth and last harvest.

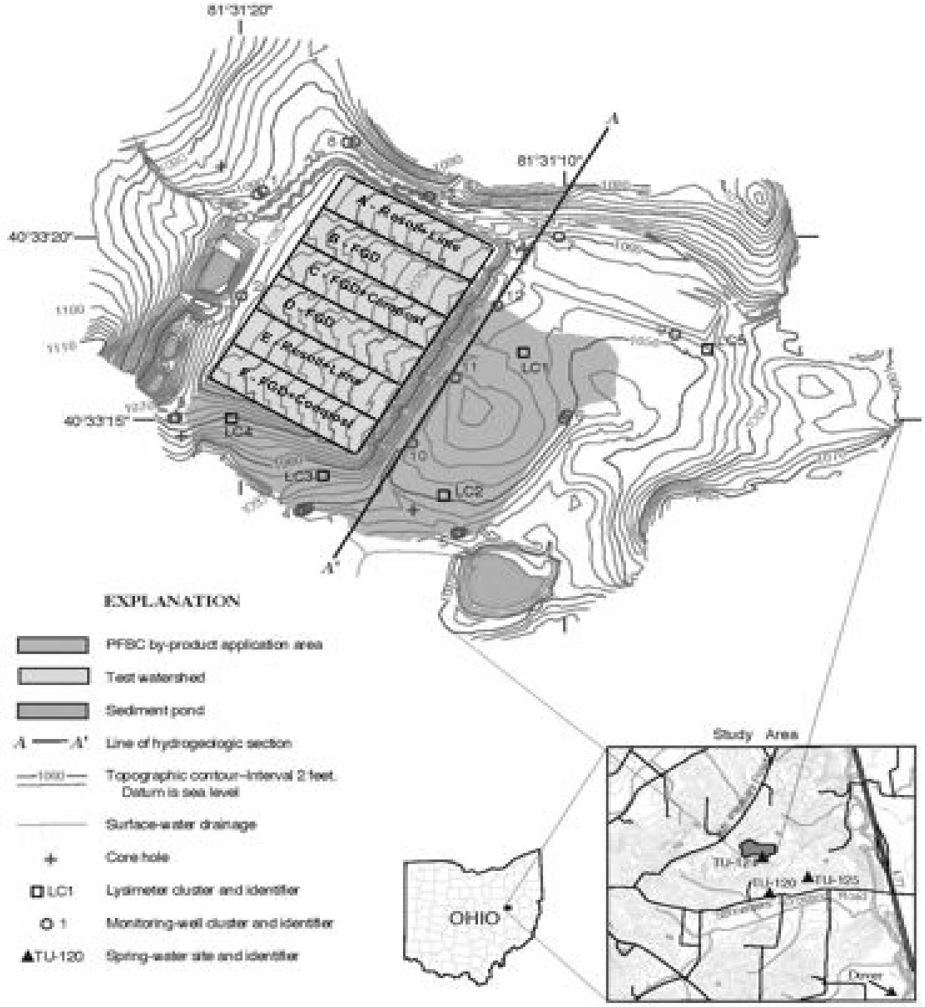

Figure 1. Site map showing treated areas, location of the six 1-acre watersheds, lysimeter clusters, monitoring wells and other relevant information at the Fleming abandoned mine land site in Ohio.

Actual reclamation materials and rates used to develop treatments were based on the quality (i.e. toxicity and acidity) of the spoil material and the results obtained from the greenhouse experiment. The three treatments developed were: (1) 125 tons/acre of FGD product only—treatments B and D of Figure 1; (2) 125 tons/acre of FGD plus 50 tons/acre of yard waste compost—treatments C and F; and (3) 50 tons/acre of limestone followed by placement of 8 inches of borrow resoil and then an additional 20 tons/acre of limestone mixed into the final spoil cover—treatments A and E.

Reclamation of the site was completed in the late summer and fall of 1994 by regrading the spoil to the approximate pre-mining topographic contour and applying treatments to the watersheds. The areas surrounding the watersheds were reclaimed at the same time. The site was instrumented after reclamation so that changes in both surface and ground water quality could be assessed through time. Soil suction lysimeters were also installed in the PFBC product application area, outside of the watersheds, and in a control area reclaimed using resoil methods. Figure 1 shows the location of the six 1-acre watersheds, lysimeters, the ground water monitoring wells and other relevant information. Surface water samples were collected starting in the spring of 1995 and water samples from the lysimeters, monitoring wells, and springs were collected in June 1995 (sampling round 1), January 1996 (round 2), June 1996 (round 3), June 1997 (round 4), June 1998 (round 5), June 2000 (round 6), and June 2001 (round 7). Water samples were analyzed by methods described in Stehouwer et al. (1998), Haefner (1998), and Dick et al. (1999). The USGS Isotope Laboratory in Reston, Virginia analyzed water samples for sulfur-isotope ratios.

Results of Preliminary Greenhouse Experiment

Fescue did not grow unless the spoil was amended with PFBC product or sewage sludge. At the 120 g/kg PFBC rate, fescue growth for the six harvests totaled 42.7 g/kg treated spoil. Nothing could be harvested from the untreated control. In general, the combination of an organic amendment, in this experiment biosolids, with the PFBC product provided a better combination of physical, chemical and biological properties required for initial plant growth, than PFBC alone. The amendments were also very effective in raising the pH of the mine spoil leachate. Leachate concentrations of Al and Mn, elements that are frequently toxic to plants, decreased substantially when the spoil was amended with PFBC product and biosolids. pH was the most important variable controlling the concentrations of most elements. Concentration of elements of environmental concern was near or below drinking water standard levels. The greenhouse results indicated that PFBC product, applied at rates equivalent to spoil neutralization needs, creates a medium that can support plant growth with little potential for introduction of toxic concentrations of elements in leachate water or the food chain. Based upon these greenhouse results a full-scale field reclamation test, using FGD product, was planned for the Fleming site.

Citizen Involvement

Initially our reclamation plans called for the use of biosolids, some from out of state, with the FGD product. A local citizen's group reacted negatively because of previous experiences with out-of-state biosolids being used at excessive rates in a reclamation project. The plans were, therefore, revised to use advanced, alkaline stabilized sewage sludge from in-state. Mixing FGD product, or other highly alkaline material, with biosolids provides a pasteurized and stabilized soil substitute with high neutralization potential and organic matter content. Strong opposition against the use of biosolids continued.

Our project was to demonstrate beneficial uses of FGD products and not to become embroiled in the issue of land application of biosolids. The reclamation plan was revised a second time to include composted yard waste as the organic component of the amendment material. This time opposition became focused on the use of the FGD product itself. After an initial meeting to allow local opinions to be voiced and emotions to be spent, a series of further meetings were held to provide accurate information about the questions related to the potential exposure risks of heavy metals and dioxin. Meetings were held with the county health board, county commissioners, township trustees, mayor of a nearby town, Soil Conservation Service, Tricounty Solid Waste Board, concerned citizen groups, regulatory agencies, and other interested parties. In our meetings, we openly shared all of our data. Background data on heavy metal concentrations at the AML reclamation site and heavy metal and dioxin concentrations in the FGD and FGD+compost were shared to counteract scare tactics being circulated that reclamation of the acid and toxic spoil would contaminate private and city wells that were located within a four mile radius of the site. One important observation was that loading rates of some heavy metals are actually higher if an 8-inch depth of resoil is used for reclamation than if the FGD+compost mixture is used (Table 1). Dioxin levels for the FGD+compost mix were also less than 4 ppt (parts per trillion) or below the 5 ppt level commonly considered as a background level in untreated environments (Table 2). This education effort paid off in eliminating much of the opposition and reclamation activities commenced. However, follow-up activities such as sharing of reports and post-reclamation field days also were conducted and provided further public education.

Table 1. Estimated trace element concentrations and loading rates for various materials used to reclaim the Fleming abandoned mine land site (adopted from Dick et al. 1994).

	Concentrations			Loading Rate		
Element	FGD[2]	Mix	Resoil	FGD[3]	Mix[4]	Resoil[5]
	---------------- mg/kg	-------------		------------- lbs/acre	-------------	
Arsenic	71.5	54.4	5.5	17.9	19.1	14.3
Cadmium	1.5	1.1	3.3	0.40	0.40	8.6
Chromium	42.2	111	95.6	10.6	38.9	249
Copper	49.5	55.1	62.8	12.4	19.3	163
Lead	17.4	19.9	15.9	4.4	6.9	41.3
Mercury	1.0	1.0	ND[1]	0.30	0.40	ND
Molybdenum	22.4	23.9	0.2	5.6	8.4	0.50
Nickel	78.8	166	44.8	19.7	57.9	117
Selenium	8.6	6.2	0.7	2.2	2.2	1.8
Zinc	112	111	138	28.0	38.8	358

[1] ND = not determined.
[2] Mean of four FGD [i.e. atmospheric fluidized bed combustion (AFBC) material] samples from Pontiac, MI.
[3] Based on application rate of 125 tons per acre of FGD (i.e. AFBC material).
[4] Based on application rate of 125 tons per acre of FGD (i.e. AFBC material) + 50 tons per acre of yard waste compost.
[5] Based on application rate of 1300 tons per acre that is approximately equivalent to 8 inches of resoil.

Table 2. Dioxin concentrations in FGD, yard waste compost, and FGD+compost mixes applied to the Fleming site and of the spoil at the Fleming site prior to reclamation (Dick et al., 1999).

Sample	Dioxin toxicity equivalents[1] (parts per trillion, ppt)
PFBC[2]	0.53
AFBC[3]	0.48
Yard Waste Compost[4]	4.33
PFB+ Compost	2.83
AFBC+ Compost	3.08
Minespoil[5]	0.57

[1] Calcaulated based upon a full scan of various dioxin congeners according to a worksheet procedure prescribed by the Ohio Environmental Protection Agency (Columbus, OH).
[2] PFBC, pressurized fluidized bed combustion FGD product.
[3] AFBC, atmospheric fluidized bed combustion FGD product.
[4] Yard waste compost obtained from Earth-N-Wood (North Canton, OH).
[5] Representative minespoil as obtained from the surface of the Fleming site located in Tuscarawus, Count, OH.

Vegetation Establishment

Aboveground biomass plant production was greatest for the resoil+lime treatment in the first year after completion of the reclamation (Figure 2). However, for all treatments there was always sufficient plant cover of the soil surface to prevent soil erosion. The increased biomass associated with the resoil+lime continued for the next three years but the differences among the treatments became less with time. An inspection of the site in the summer of 2006 showed no visible differences among the three treatments in terms of vegetative growth. If anything, the FGD+compost treatment seemed to have the best growth and this was probably due to more of the legumes in the seed mixture surviving on this treated site compared to the resoil+lime treated site. The lush grass growth in the first year after reclamation, which occurred for the resoil+lime treatment, crowded out the legumes. However, legumes can provide long-term vegetative cover stability because they provide nitrogen input on an annual basis whereas the resoil+lime treatment eventually become depleted of nitrogen.

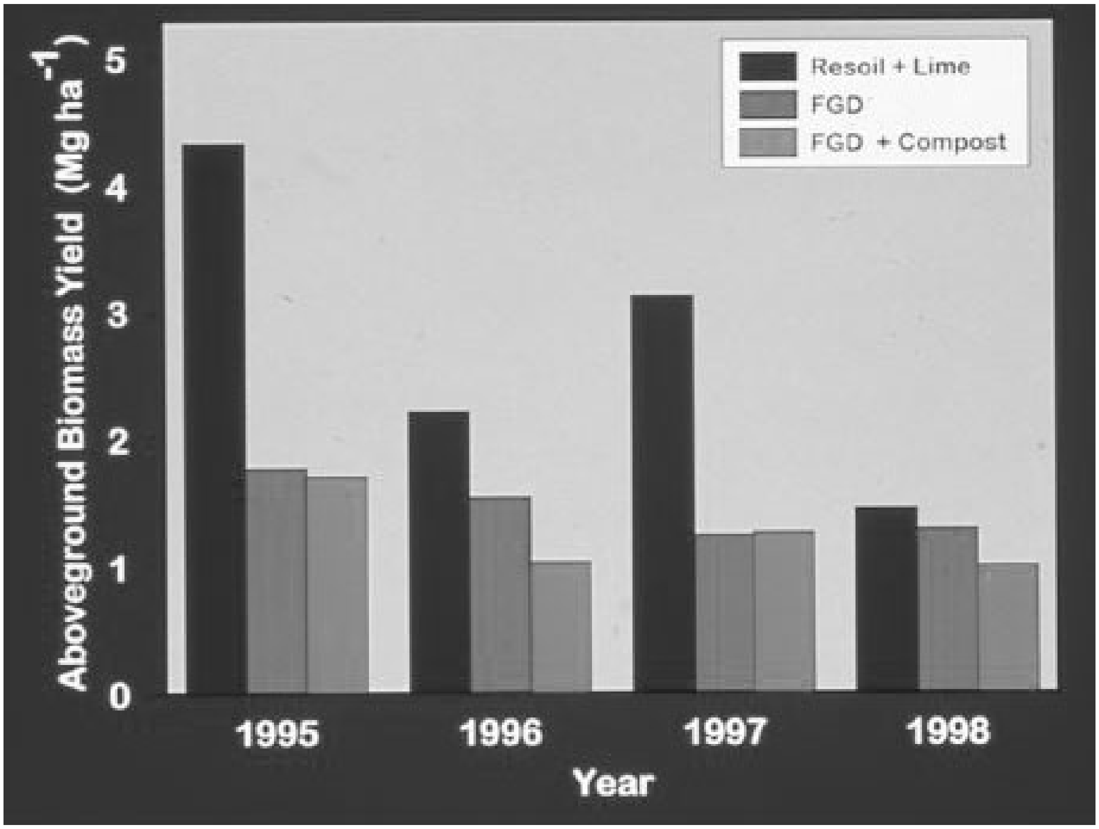

Figure 2. Aboveground biomass (i.e. vegetative) yields at the Fleming abandoned mine land site for the years 1995-1998. Seeding of the site occurred in the autumn of 1994.

Surface Water Quality

The surface water quality was measured before, during and after reclamation in the areas of the six small watersheds. Figure 3 summarizes the results observed for three variables as affected by reclamation treatment. pH was consistently below 3.0 prior to reclamation but rose rapidly during reclamation and reached a new equilibrium pH of approximately 7.0. The treatment with the highest pH was the FGD product alone and the resoil treatment was always the lowest. However, the differences were not considered to be enough to have much impact on the surface water chemistry. Once pH is raised, the concentration of many metals is reduced because of precipitation reactions. Aluminum is highly toxic to plants and ranged from 40-120 mg/L during the pre-reclamation period. During and after reclamation, the level of Al in the surface runoff water decreased to near zero for all treatments. Sulfur initially remained unchanged when the abandoned mine site was reclaimed. This is not surprising as FGD materials contain high amounts of sulfur. However, with time the levels of sulfur decreased substantially and became equal to or less than that found before reclamation. Work conducted by the USGS using sulfur tracers found that up to 75 percent of the sulfate in interstitial waters (i.e. water samples collected from the lysimeters) was derived from the FGD product (Haefner 2001, 2002). However, this sulfur leached out only slowly as the same tracer results also indicated only very small amounts, if any, of the dissolved sulfate in surface water were derived from the PFBC product.

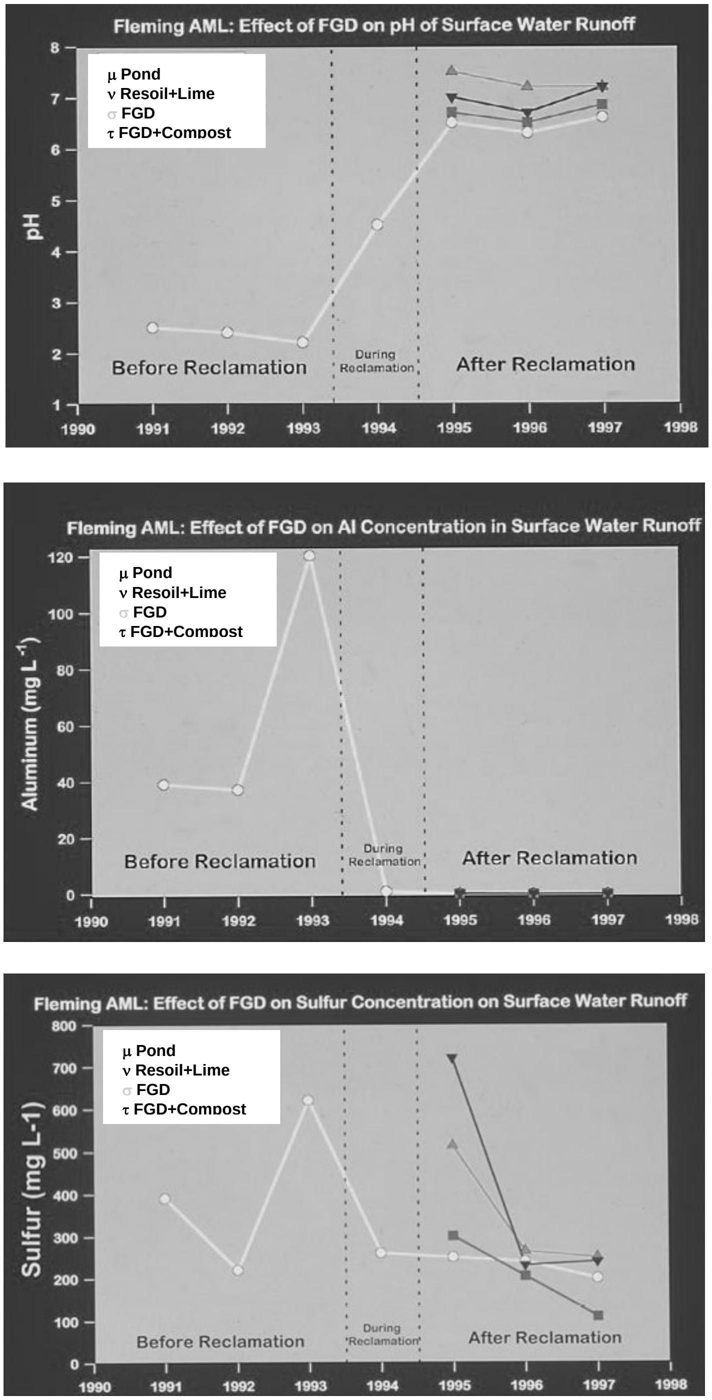

Figure 3. pH, aluminum and sulfur concentration changes in surface water samples collected from areas reclaimed using FGD (AFBC), FGD (AFBC)+compost or resoil+lime (topsoil) occurred from before reclamation to during and then after reclamation.

Other elements measured in surface and tile water were arsenic, boron, barium, beryllium, cadmium, cobalt, chromium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, and zinc. With the exception of boron, concentrations remained very low and unaffected by the reclamation treatments. Mean concentration of arsenic, barium, cadmium, chromium, copper, mercury, and selenium were often below detection limits or below primary drinking water standards. Occasional samples had higher concentrations, but these could not be ascribed to the FGD or compost as all three reclamation treatments gave values in the same concentration ranges. Boron was the only trace element that was clearly increased in surface water runoff and tile drainage by the addition of FGD. Boron is associated with the coal ash component of the FGD and is a function of the coal being combusted during FGD production. The boron concentration in this study was not high enough to cause phytotoxicity. Furthermore, the most phytotoxic boron species are highly water-soluble and are rapidly leached from the soil of the treated watersheds. The leached boron is not considered to be of concern because it poses no threat to vertebrate or invertebrate organisms.

Ground Water Quality

Waters influenced by leachate from the areas outside the six watersheds treated with PFBC product could be distinguished from other waters at the site because the feed coal and sorbent originated from a different mine (and a different geologic environment) than the reclamation site (Haefner 2002). Thus, the isotope signatures and geochemistry of the PFBC product as compared to spoil and rocks found at the site were distinctly different. Ground water monitoring at the study site concluded in September 2001. The results provided in Table 3 are mostly taken from Haefner (2002).

Properties and constituents of water derived from the PFBC product that can serve as environmental tracers include boron concentrations, magnesium-to-calcium (Mg:Ca) mole ratios, and sulfur-isotope ratios (δ34S). An environmental tracer is defined as any conservative constituent or characteristic of a sample that can be used to indicate something about the source of the sample. For example, boron was used as a tracer of PFBC product because it is present as an uncharged, and thus conservative, species. Boron was found in elevated concentrations (median of 690 µg/L) in interstitial-water samples from the PFBC product application area, but was found in significantly lower concentrations outside the application area (median of 70 µg/L). Similarly, Mg:Ca mole ratios and δ34S of interstitial water from within the PFBC product application area were elevated as compared to those in interstitial-water samples from outside the application area. Because dolostone was used as the sorbent in the PFBC process, water samples that contain PFBC product leachate had Mg:Ca ratios greater than 1, whereas all other water samples had Mg:Ca ratios less than 1. Mixing diagrams that include sulfur-isotope ratios and other conservative tracers provide estimates of the relative contribution of sulfate derived from the PFBC product. Sulfur-isotope ratios of sulfate from the PFBC product (maximum of +4.8 per mil) and solid-phase sulfide in pyrite from the mine site (minimum of -26.3 per mil) were used to determine source of sulfur in ground water. Only very small amounts, if any, of the dissolved sulfate was derived from the PFBC product. No deleterious concentrations of toxic trace elements from the PFBC product, including arsenic and selenium, were observed in any ground water samples obtained at the site.

Although it is not likely that the water at the Fleming site will ever be used as a drinking-water source, comparisons of water-quality data obtained at the Fleming site to the U.S. Environmental Protection Agency Maximum Contaminant Levels (MCLs) were made (Table 3). Many exceedances of the MCLs were observed and of all the MCLs that were exceeded, only fluoride and sulfate were found in higher concentrations in the application-area interstitial waters than in control-area waters. This indicates that the pre-reclamation conditions were much more important than the use of FGD for treatment of the site during reclamation in regards to affecting ground water quality. There were no exceedances of MCLs for elements of concern such as arsenic, lead, or selenium.

Table 3. Comparison of maximum Contaminate Levels for drinking water established by the U.S. Environmental Protection Agency with analyses of all water samples obtained from the Fleming abandoned mine land site, Tuscarawas, County, Ohio (Haefner 2002).

[mg/L, milligrams per liter; na, not applicable; TDS, total dissolved solids; min, minimum; max, maximum; MCL, Maximum Contaminant Level]

Constituent	Maximum Contaminant Level (mg/L)	Detection limit(s)[a] (mg/L)	Total number of samples	Number of detections above detection limit (percent given in parentheses)	Number of samples that exceed MCL (percent given in parentheses)	Maximum value (mg/L)
National Primary Drinking-Water Regulations						
Antimony	0.006	0.106	160	8 (5)	unknown[b]	0.16
Arsenic	0.05	0.001 - 0.002	185	37 (20)	0 (0)	0.010
Barium	2	0.001	160	160 (100)	0 (0)	0.075
Beryllium	0.004	0.0001 - 0.002	160	79 (49)	30 (19)	0.037
Cadmium	0.005	0.001 - 0.08	206	90 (44)	61 (30)	0.17
Chromium	0.1	0.002 - 0.1	206	118 (57)	0 (0)	0.026
Copper	1.3	0.002 - 0.05	206	66 (32)	0 (0)	0.31
Fluoride	4.0	0.1 - 1.0	216	105 (49)	36 (17)	15.0
Lead	0.015	0.001 - 0.01	196	9 (5)	1 (<1)	0.058
Mercury	0.002	0.0001	61	0 (0)	0 (0)	na
Nitrate	10	0.01 - 0.05	163	34 (21)	0 (0)	4.4
Selenium	0.05	0.001 - 0.005	178	38 (21)	0 (0)	0.006
National Secondary Drinking-Water Regulations						
Aluminum	0.2	0.015 - 0.045	206	188 (91)	104 (50)	29.6
Chloride	250	0.1 - 1.0	216	188 (87)	1 (<1)	261
Copper	1.0	0.002 - 0.05	206	73 (35)	0 (0)	0.31
Fluoride	2.0	0.1 - 1.0	216	124 (57)	0 (0)	0.015
Iron	0.3	0.010	228	219 (96)	164 (72)	920
Manganese	0.05	0.0016	228	228 (100)	224 (98)	150
pH	6.5-8.5	na	267	na	192 (72[c])	min 3.2 max 7.9
Silver	0.10	0.003 - 0.046	206	183 (89)	0 (0)	0.063
Sulfate	250	0.11	216	216 (100)	212 (98)	13500
TDS	500	computed[d]	164	na	157 (96)	20850
Zinc	5	0.001 - 0.06	206	188 (91)	0 (0)	3.8

a. Detection limits varied depending on which laboratory performed the analysis, the dilution ratio, and the sample matrix.

b. The MCL was below the detection limit.

c. Seventy-two percent of the pH measurements were below the minimum accepted value of 6.5. No samples exceeded the maximum accepted value of 8.5.

d. Total dissolved solids is computed as the sum of all dissolved constituents.

Three plausible hypotheses were developed to explain the fate and transport of elements in the PFBC product and the apparently minor influence of the product on water quality (Haefner 2002). The hypotheses are: (1) the sampling schedule missed the highest concentrations of PFBC product leachate; (2) the mass of PFBC product applied at the site was so small that dilution by rainwater and the overwhelming influence of AMD obscured detection by the methods used in this study; and (3) elements derived from the PFBC product leachate have precipitated as secondary minerals in the unsaturated zone. Graphical analysis of median concentrations of elements associated with the PFBC product show that the concentrations of elements seemed to have peaked at or around the time of interstitial-water sampling round 3 (January 1996--about 15 months after reclamation). Therefore, changes in water quality (if any) should have been detected during this timeframe. Results from geochemical models indicate that down-gradient ground water may have mixed with a small amount of PFBC leachate and that thermodynamic conditions are favorable for secondary minerals to precipitate in the unsaturated zone and in aquifers at the site. Because the amount of PFBC product applied was small compared to the mass of other elements already in solution at the site, it is likely that dilution caused difficulty in distinguishing constituents from the PFBC product in down-gradient ground waters.

Conclusions

Reclamation of the site was successful in that vegetation was reestablished and erosion was reduced. It also was successful in the sense that water quality in the PFBC product application area shows higher pH and reduced concentrations of dissolved iron, nickel, and zinc. Except for potentially phytotoxic concentrations of boron, concentrations of elements of concern were only at or near the detection limits. The ground water part of the study revealed that pH in the interstitial waters from the FGD product application area was higher than the pH in traditionally reclaimed areas. There was also no evidence that FGD product leachate had adversely affected the chemistry of ground water beneath the application area. Visual inspection of the site 12 years after reclamation also revealed that vegetation was still growing well and erosion was controlled. Samples included water from soil-suction lysimeters (interstitial water), wells, and spring sites established down-gradient of the application area seven years after reclamation revealed the FGD product treated areas still showed a raised pH, thus promoting the precipitation of potentially toxic elements. Because of low application rates and sorption onto iron and aluminum hydroxides, it is improbable that any of the toxic elements of concern (arsenic, lead, or selenium) will cause water-quality problems at this site or other sites where similar application rates are used. However, the impact of the mining activities that originally caused degradation of ground water are not easily reversed and the quality of ground water after seven years remained poor but with indications that improvement would occur. Overall, the site has become stabilized and improved surface water quality and plant growth has been achieved.

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Dr. Warren A. Dick is a Professor of Soil Science in the School of Environment and Natural Resources at The Ohio State University, Wooster, OH. He grew up on a farm in North Dakota and has both a practical knowledge of soils and agriculture as well as solid scientific training and experience. Since 1990, he has worked extensively on characterizing flue gas desulfurization (FGD) products and developing land application uses of these products. The goal of his research efforts is to develop uses that make sense both economically and environmentally. The use of FGD as a soil amendment for mine reclamation was one of Warren's first research projects and this led to numerous other FGD-related projects. Warren was recently involved (September, 2006) in hosting a workshop in St. Louis, MO on "Research and Demonstration of Agricultural Uses of Gypsum and Other FGD Materials" and in writing a major review on this topic for the Electric Power Research Institute (EPRI). Warren has been very active professionally and teaches a graduate level course on soil and environmental biochemistry at The Ohio State University. He has served as Editor of the Journal of Environmental Quality and Editor-in-Chief of the Soil Science Society of America.

FGD as a Soil Amendment for Mine Reclamation

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FGD Properties of Value for Mineland Reclamation

- $CaCO_3$ equivalency
- Presence of plant nutrients
- Particle size
- Presence of gypsum*
- Presence of calcium sulfite

FGD Properties That Reduce Their Value for Mineland Reclamation

- Material handling properties
- Boron and heavy metals
- Salt concentrations
- Easily eroded after application
- Variability of material
- Bulky nature of material
- Regulatory issues

History of Gypsum as a Soil Amendment

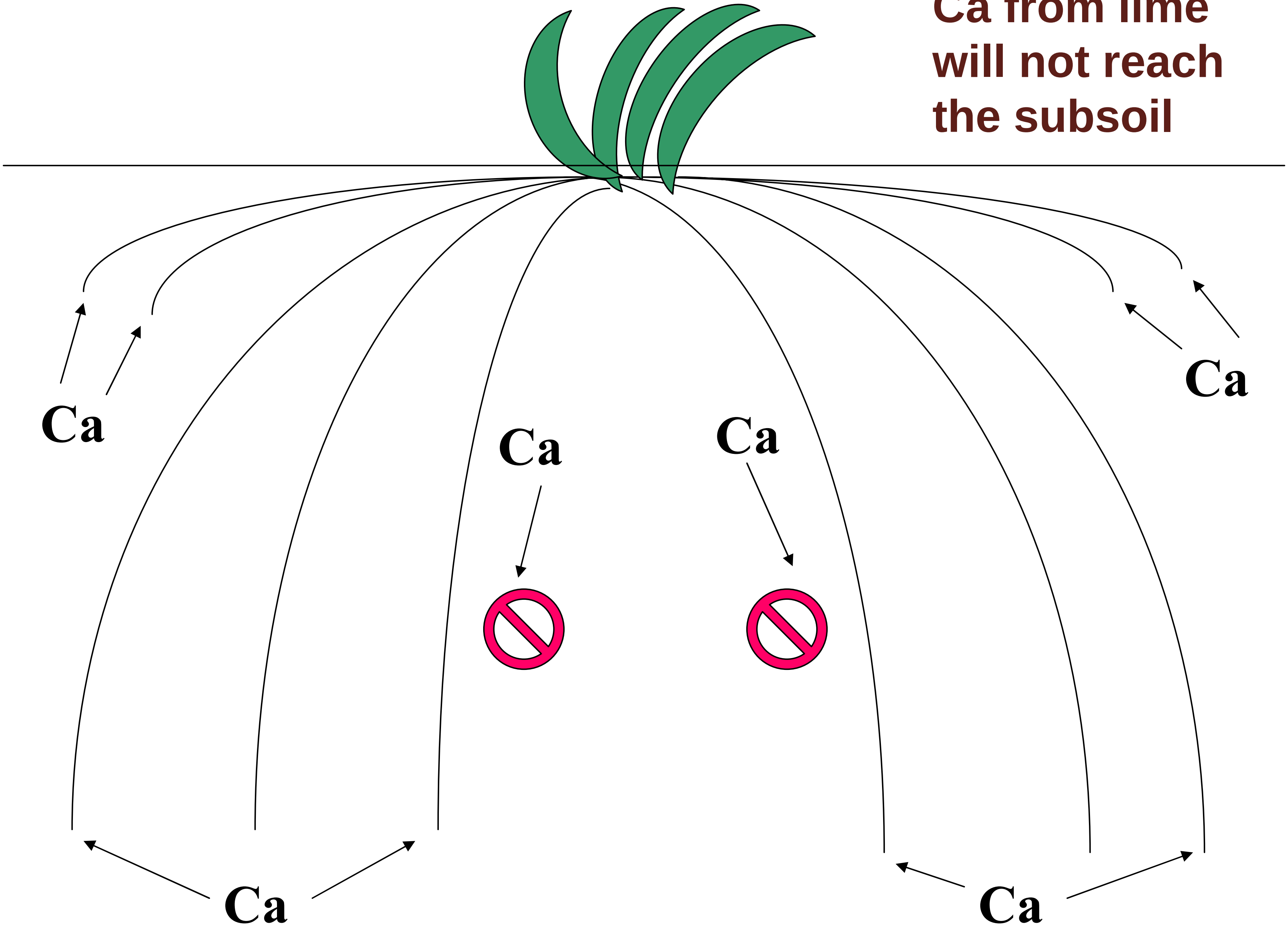
- Early Greek and Roman times
- Fertilizer value discovered in Europe in last half of 18th century
  - Germany (1768) – Reverend A. Meyer
  - France (date?) – Men working with alabaster (plaster of paris) noted better grass growth in areas they shook dust from clothing
- Extensive use in Europe in 18th century

History of Gypsum as a Soil Amendment

- Widespread use in America (Pennsylvania region) in late 1700’s
  - Benjamin Franklin demonstration – “This land has been plastered”
  - Richard Peters book – gypsum came from Nova Scotia

Summary of Gypsum Benefits for Mineland Reclamation

- Ca and S source for plant nutrition
- Source of exchangeable Ca
  - Ameliorate subsoil acidity and Al^{3+} toxicity
  - Reclaim sodic soils
- Flocculate clays to improve soil structure
- Solubility
  - 2.5 g/L or 15 mM (approximately 200 times moer than ag lime)

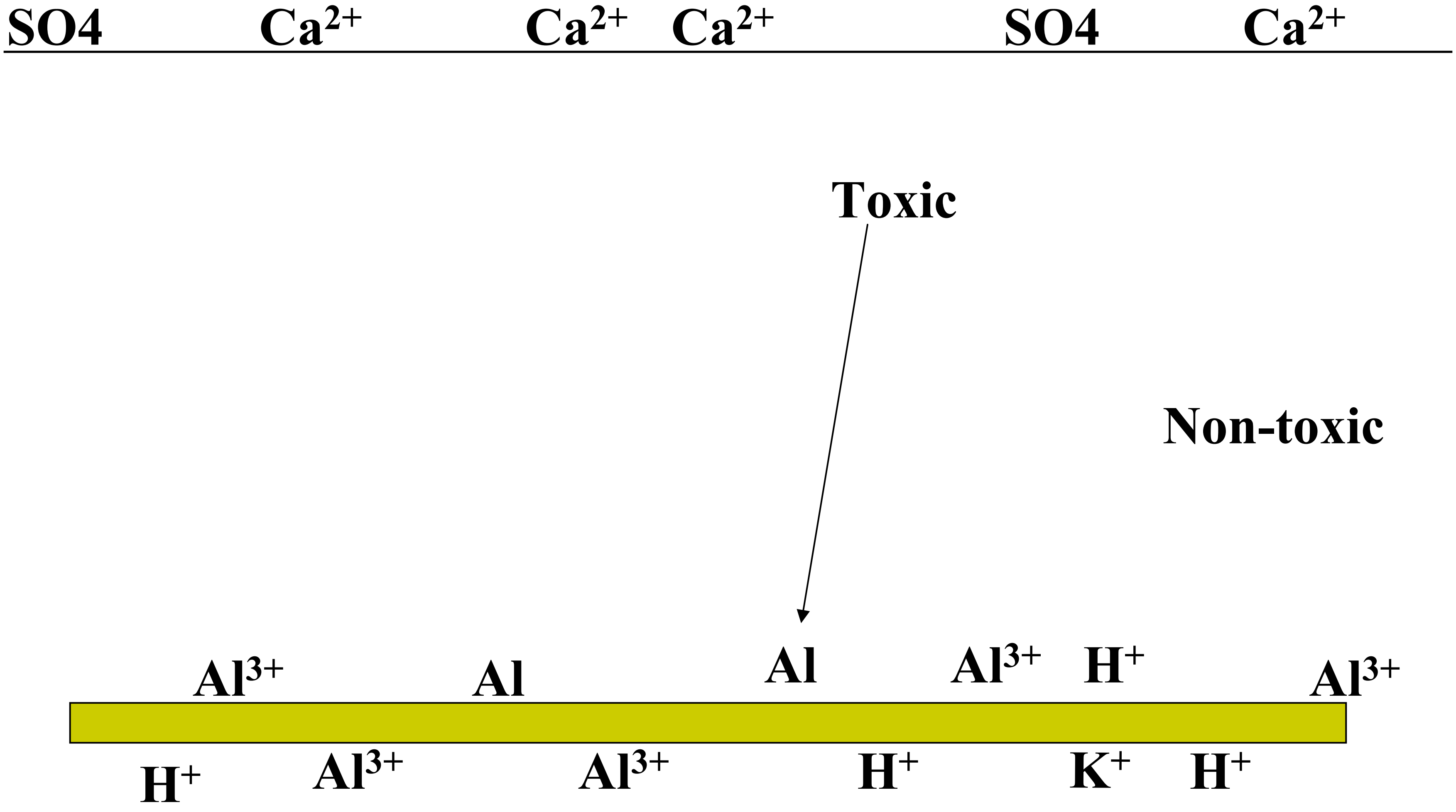


Ca from lime will not reach the subsoil

Amelioration of Subsoil Acidity and Al^{3+} Toxicity

- Surface-applied gypsum leaches down to subsoil
- Ca^{2+} exchanges with Al^{3+}
- SO_4^{2-} forms complex ion $AlSO_4^+$ with Al^{3+}
- $AlSO_4^+$ is not toxic to plant roots
- Results in increased root growth in the subsoil

Gypsum applied to surface of soil with acidic subsoil



SO4 Ca^{2+} Ca^{2+} Ca^{2+} SO4 Ca^{2+}

Toxic

Non-toxic

Al^{3+} Al Al Al^{3+} H^{+} Al^{3+}

H^{+} Al^{3+} Al^{3+} H^{+} K^{+} H^{+}

Clay platelet in subsoil

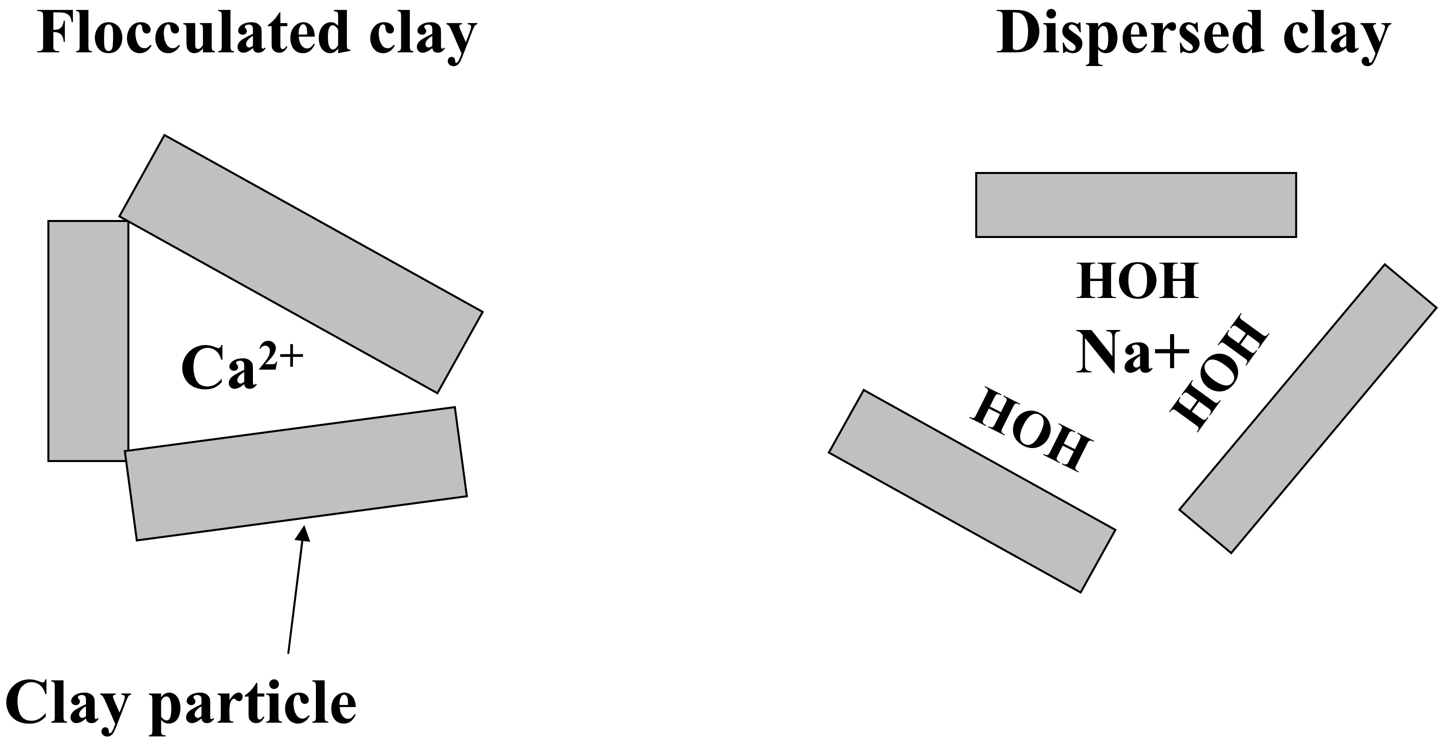
Increased Root Growth into Subsoil

- Increased water absorption
- Increased recovery of nutrients from subsoil
  - Demonstrated in Ohio and Brazilian soils
  - Improved N-use efficiency

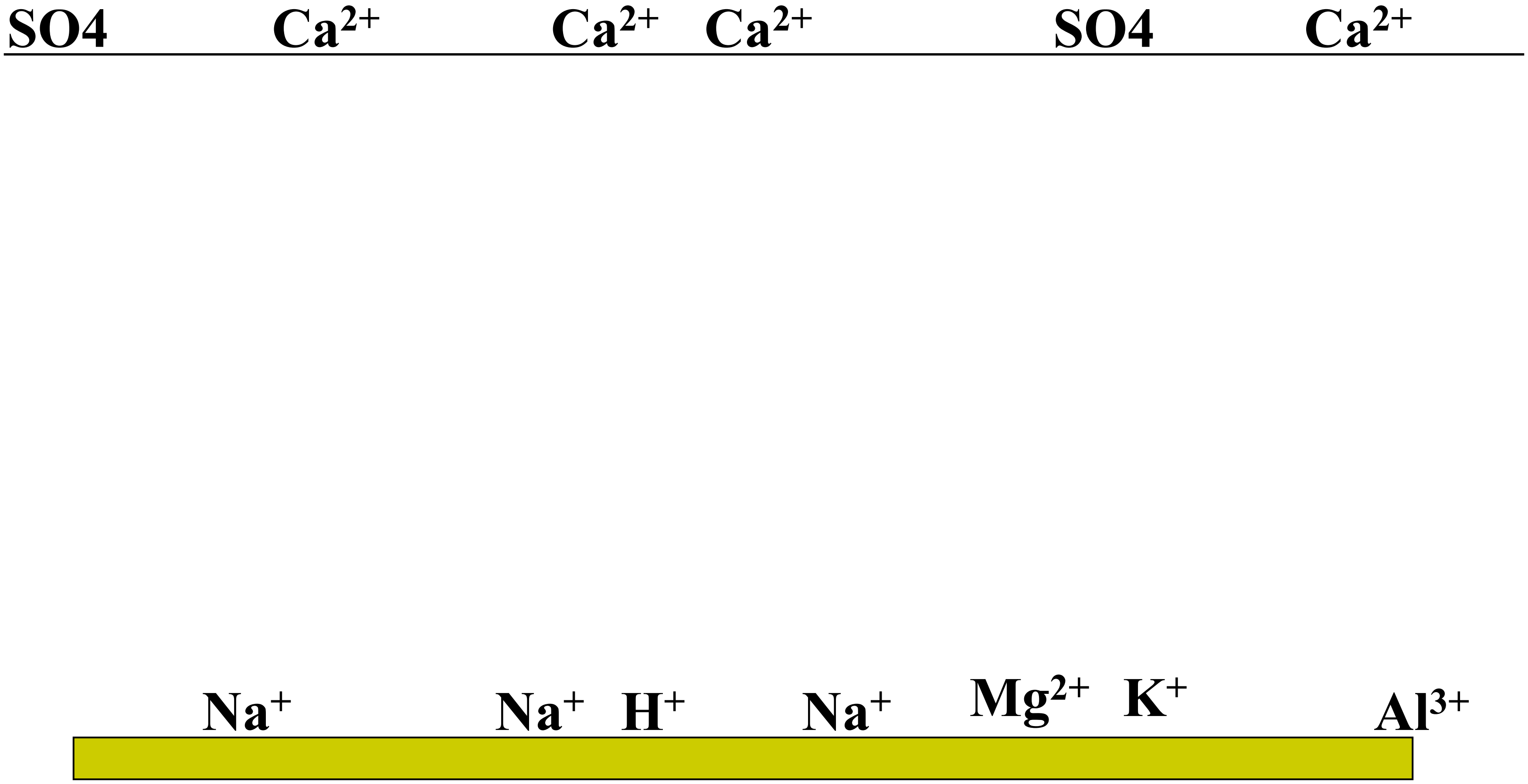
Gypsum and Clay Flocculation

- Reduces soil crusting
- Improves water infiltration
- Improves water transmission (conductivity)

Flocculation and Dispersion



Gypsum applied to surface of sodic soil



SO4 Ca^{2+} Ca^{2+} Ca^{2+} SO4 Ca^{2+}

Na^+ Na^+ H^+ Na^+ Mg^{2+} K^+ Al^{3+}

Clay platelet in sodic soil

Fleming AML Site (east central Ohio)

1. Located within the Pottsville and Allegheny system of Pennsylvanian-age sedimentary rocks of eastern Ohio.
2. The Lower Kittanning (No. 5) coal was mined from the site by surface operations over a 20-year period approximately corresponding to 1950 through 1970.
3. The mine site was abandoned after depletion of the coal and clay reserves in the early 1970s. Soon thereafter, local residents lodged complaints regarding flooding and sedimentation along a nearby road. Springs were discharging AMD with pH less than 4 and high concentrations of dissolved solids, including iron and sulfate.

Fleming AML Site (east central Ohio)

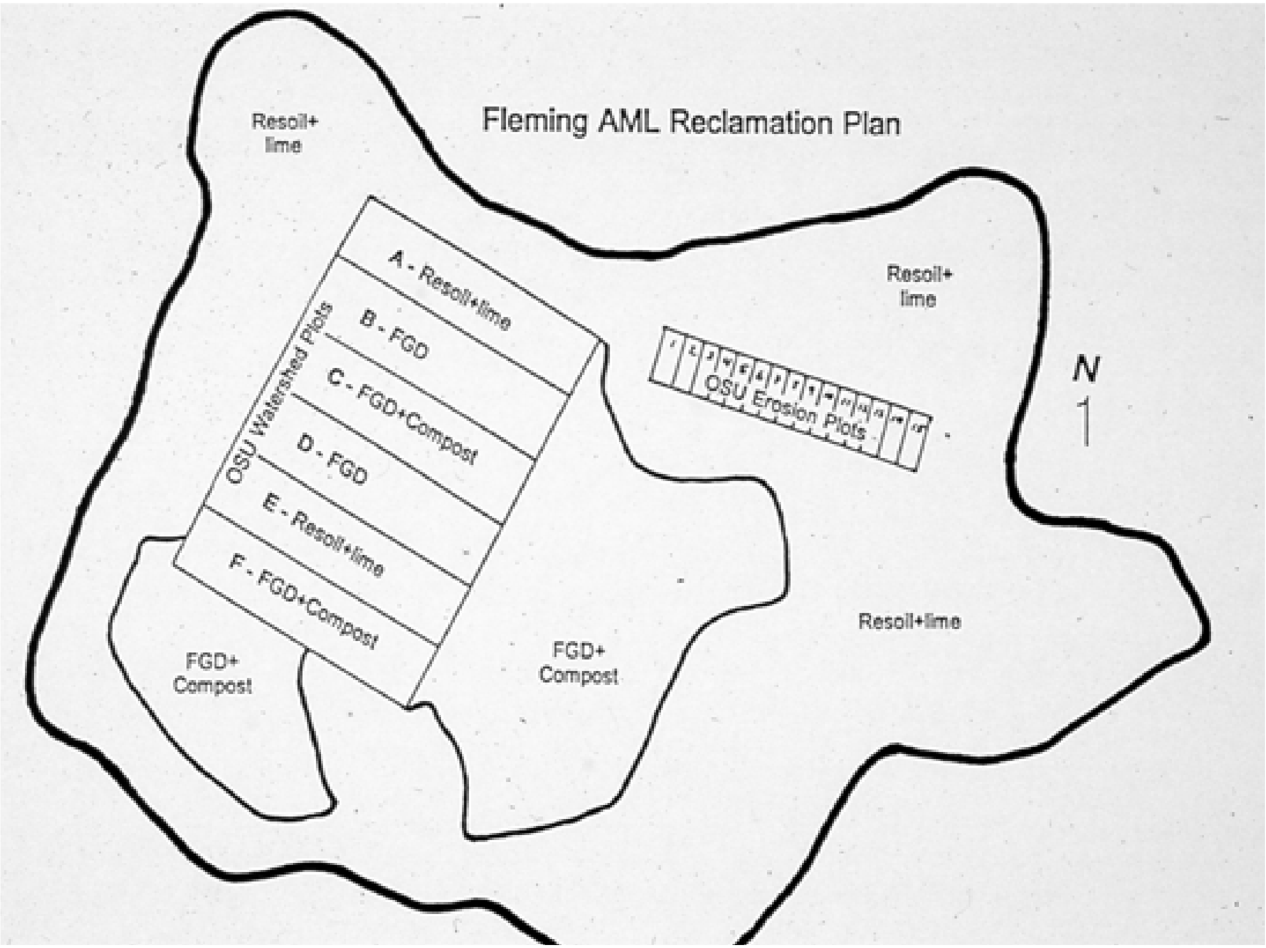
- Highly eroded underclay (25 acres)
- Unreclaimed spoil (45 acres)
- Coal refuse (5 acres)

Fleming Site

Fleming Site (Prereclamation)

Fleming Site (Prereclamation)

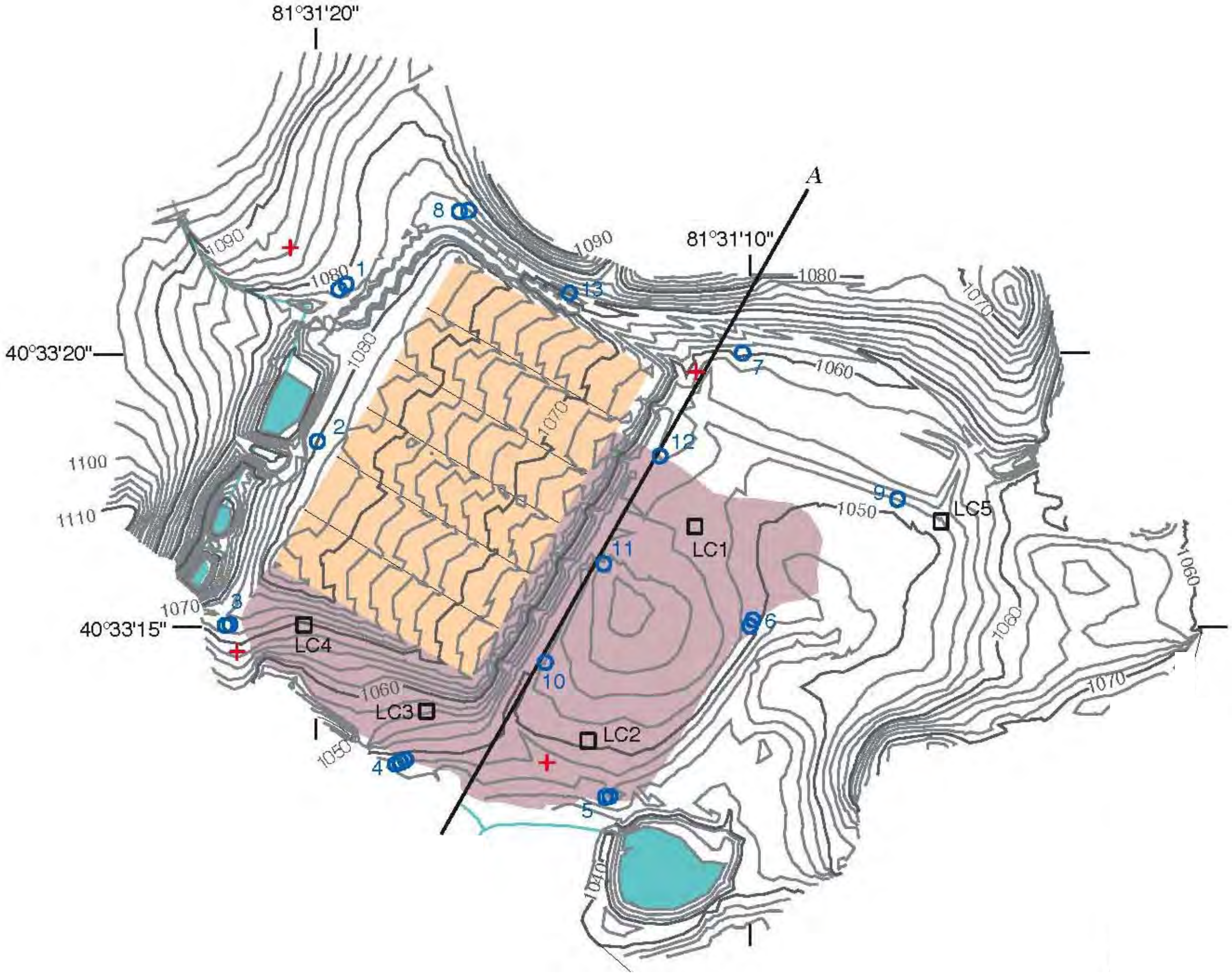
Fleming Site (Reclamation Plan)



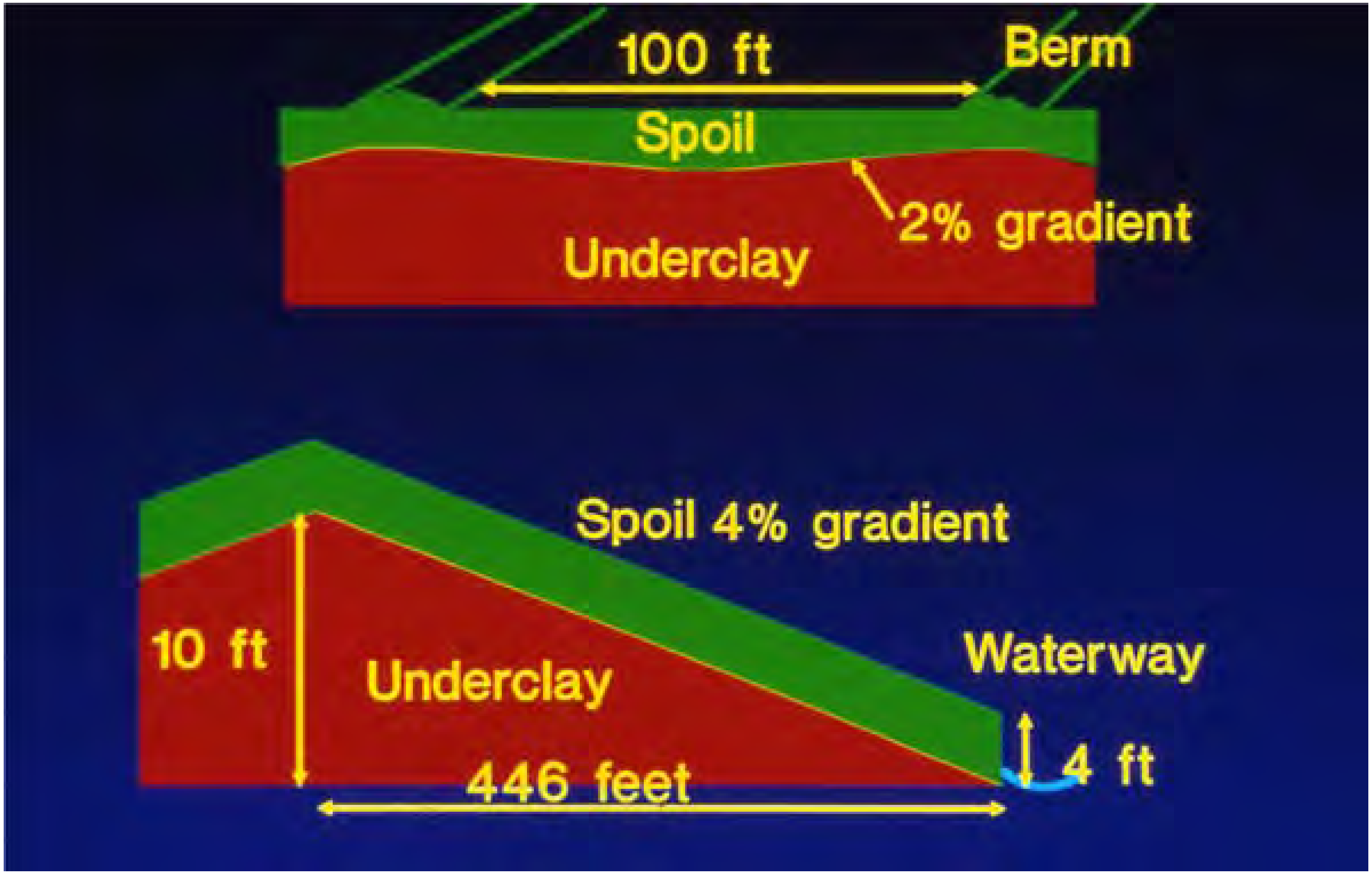
Fleming Site (Reclamation Plan) Treatments Applied in 1994

1. 125 dry tons/acre of FGD product
2. 125 dry tons/acre of FGD product plus 50 dry tons/acre of yard waste compost
3. 50 dry tons/acre of limestone plus 8 inches of resoil treated with an additional 20 tons/acre of limestone

Fleming Site (Reclamation Plan)



Fleming Site (Reclamation Plan)



Fleming Site (Reclamation Activities)

Fleming Site (Reclamation Activities)

Fleming Site (Reclamation Activities)

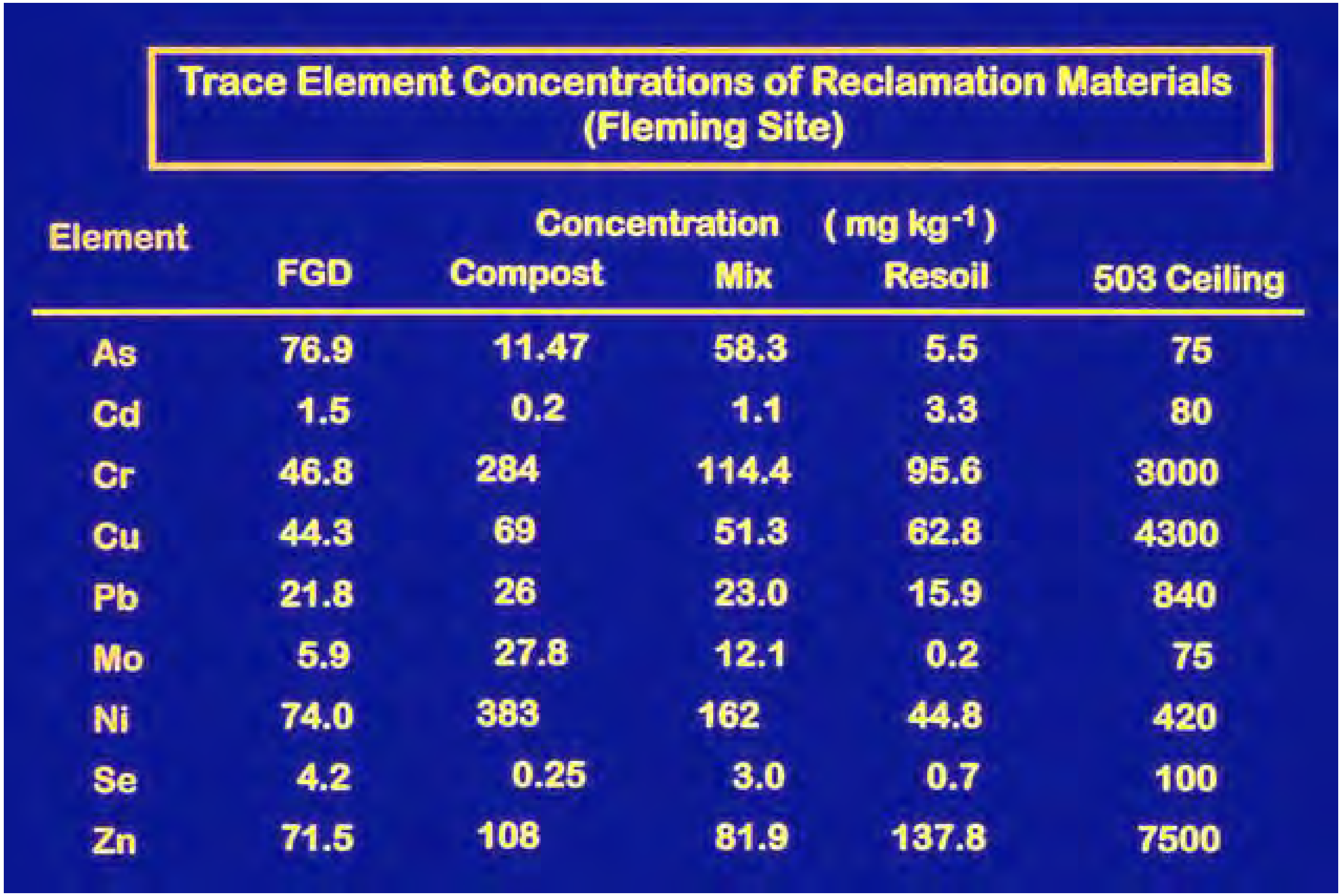
Fleming Site (Reclamation Activities)

Constituent	**FGD Product**	**Yard-Waste Compost**
	Major Elements (weight percent)	
Aluminum	3.3	3.8
Calcium	18	3.6
Iron	4.4	3.3
Potassium	0.59	1.5
Magnesium	9.5	0.93
Manganese	0.01	2.1
Sodium	0.10	0.52
Sulfate-S	4.9	<0.05
Total Carbon	4.5	13
Organic Carbon	0.73	13
Calcium Carbonate Equivalency (CCE)	38.3	3.5

Fleming Site (Reclamation Activities)

Constituent	FGD Product	Yard-Waste Compost	Maximum Concentration in Spoil and Aquifer Material
		Trace Elements (parts per million)	
Arsenic	75	11	91
Boron	190	92	120
Beryllium	3	1	9
Barium	150	400	730
Cadmium	<2	<2	<2
Chromium	37	290	210
Nickel	23	37	100
Lead	15	110	110
Selenium	1.3	6	21.5
Strontium	160	130	720

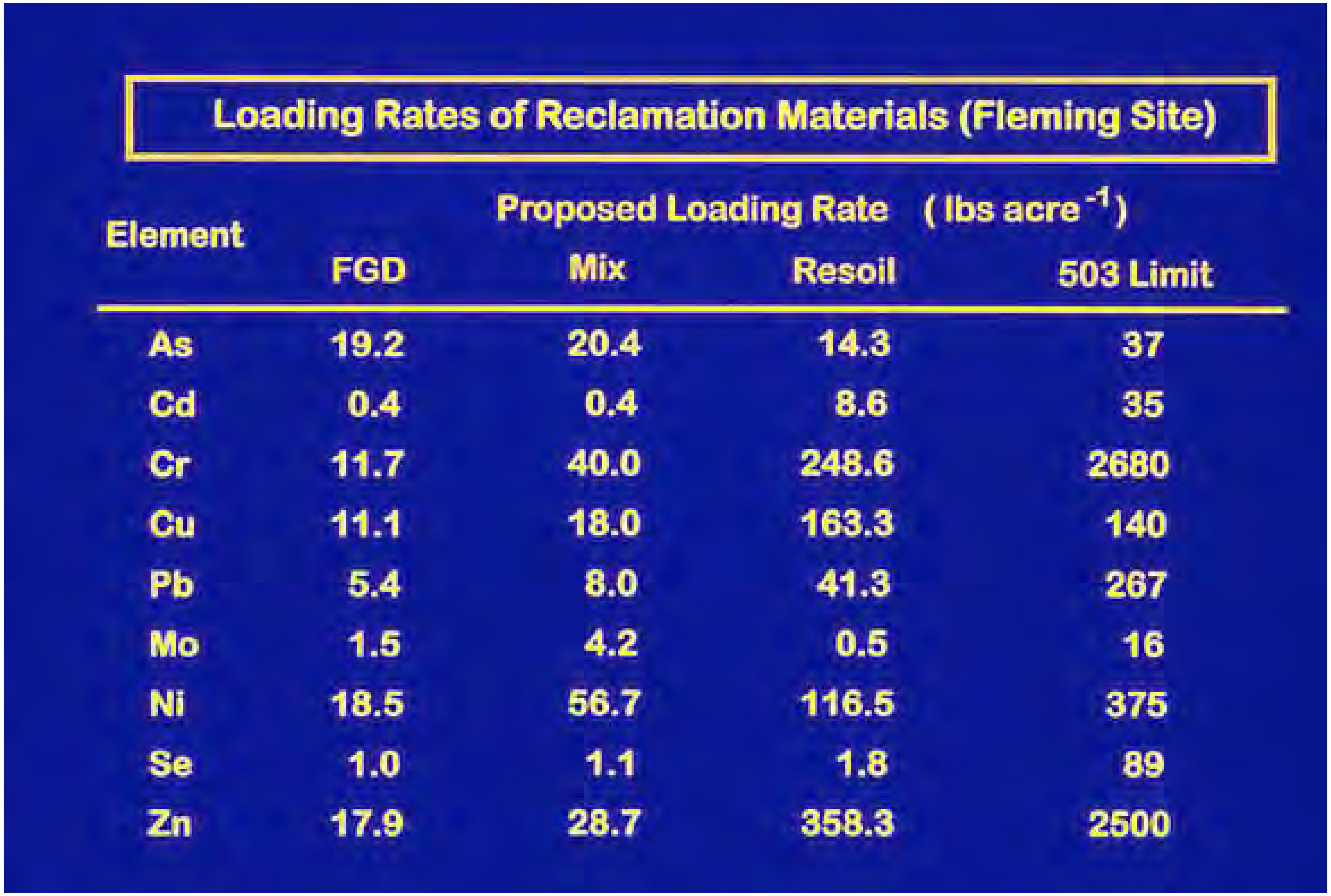
Fleming Site (Reclamation Activities) Metals Concentrations



Trace Element Concentrations of Reclamation Materials (Fleming Site)

Element	Concentration (mg kg^{-1}) FGD	Compost	Mix	Resoil	503 Ceiling
As	76.9	11.47	58.3	5.5	75
Cd	1.5	0.2	1.1	3.3	80
Cr	46.8	284	114.4	95.6	3000
Cu	44.3	69	51.3	62.8	4300
Pb	21.8	26	23.0	15.9	840
Mo	5.9	27.8	12.1	0.2	75
Ni	74.0	383	162	44.8	420
Se	4.2	0.25	3.0	0.7	100
Zn	71.5	108	81.9	137.8	7500

Fleming Site (Reclamation Activities) Metals Loading



Loading Rates of Reclamation Materials (Fleming Site)

Element	Proposed Loading Rate	(lbs acre $^{-1}$)		
	FGD	Mix	Resoil	503 Limit
As	19.2	20.4	14.3	37
Cd	0.4	0.4	8.6	35
Cr	11.7	40.0	248.6	2680
Cu	11.1	18.0	163.3	140
Pb	5.4	8.0	41.3	267
Mo	1.5	4.2	0.5	16
Ni	18.5	56.7	116.5	375
Se	1.0	1.1	1.8	89
Zn	17.9	28.7	358.3	2500

Fleming Site (Reclamation Activities) Dioxin Concentrations

DIOXIN CONCENTRATIONS (TTE'S)

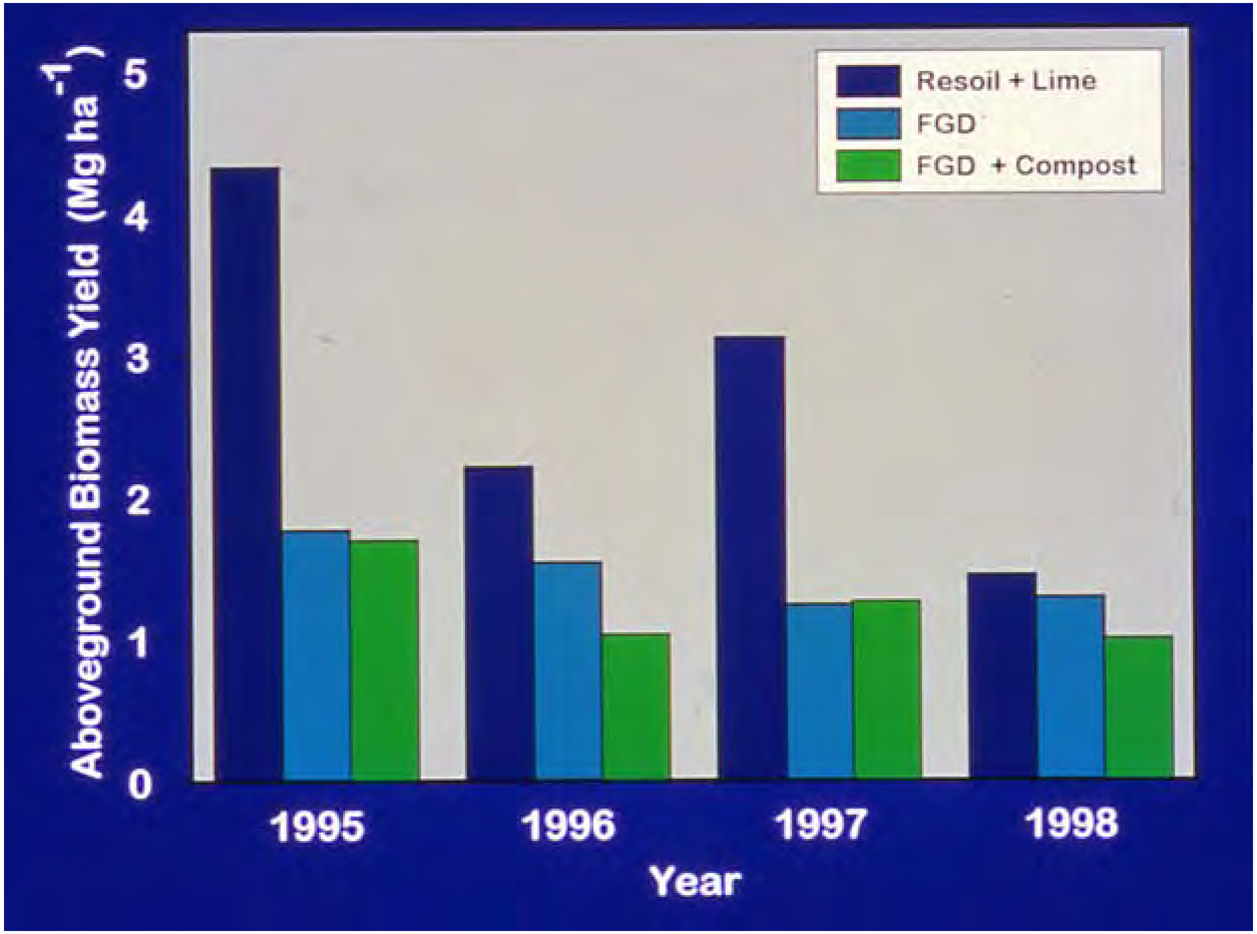
SAMPLE	CONCENTRATION (ppt)
PFBC / Compost Mix	2.83
AFBC / Compost Mix	3.08
PFBC Ash	0.53
AFBC Ash	0.48
Compost	4.33
Minespoil	0.57

Fleming Site (Reclamation Activities)

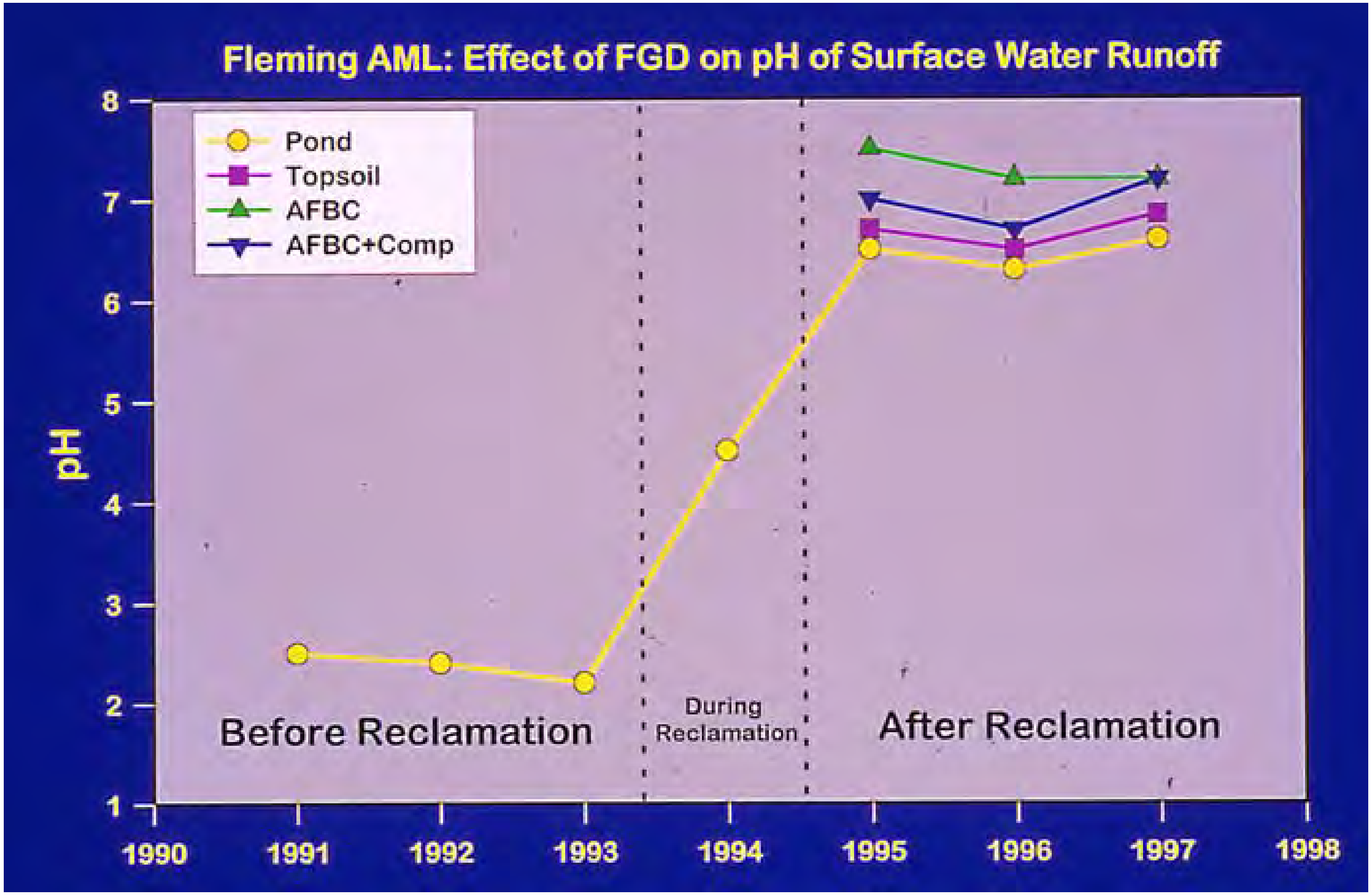
Fleming Site (Reclamation Activities)

Fleming Site (Reclamation Activities)

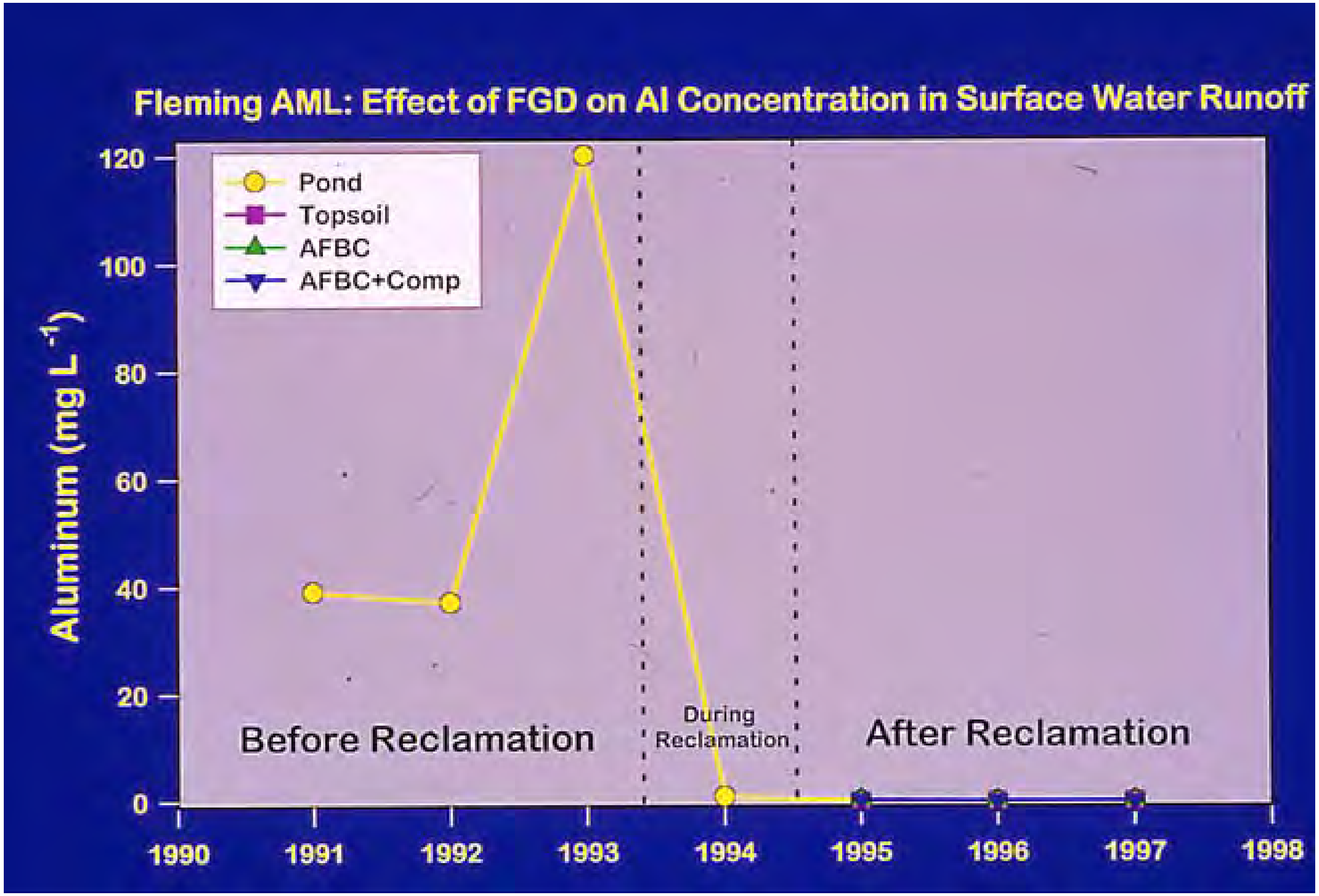
Fleming Site (Reclamation Results) Biomass Production



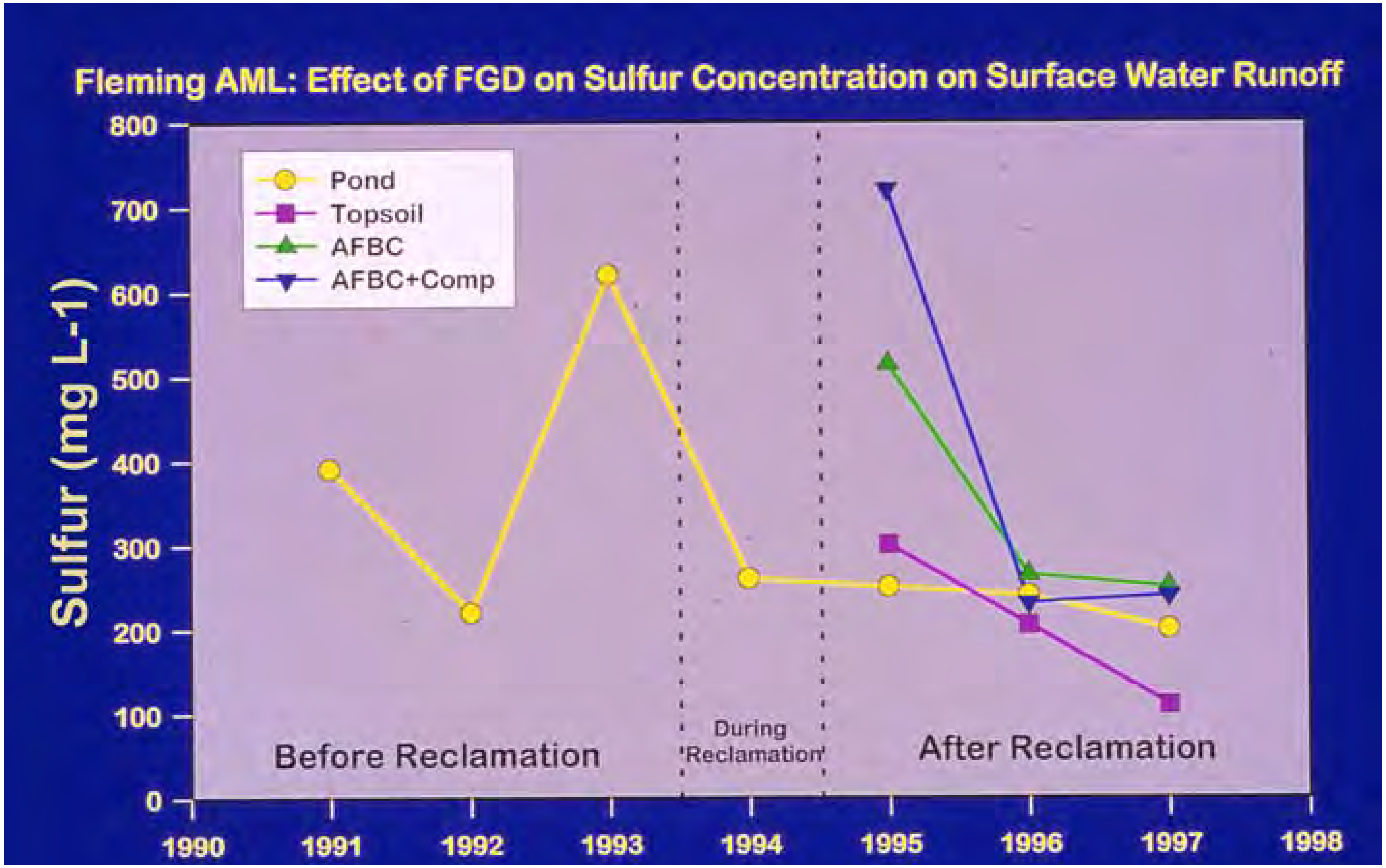
Fleming Site (Reclamation Results) Surface Water Data



Fleming Site (Reclamation Results) Surface Water Data



Fleming Site (Reclamation Results) Surface Water Data



Fleming Site (Reclamation Results) Ground Water Data

Constituent	Maximum Contaminant Level (mg/L)	Detection Limit (mg/L)	Total Number of Samples	Number of Detections Above Detection Limit	Number of Samples Exceeding MCL	Maximum Value (mg/L)
National Primary Drinking Water Regulations						
Antimony	0.006	0.106	160	8 (5)[a]	Unknown	0.16
Arsenic	0.05	0.001-0.002	185	37 (20)	0 (0)[a]	0.010
Barium	2	0.001	160	160 (100)	0 (0)	0.075
Beryllium	0.004	0.0001-0.002	160	79 (49)	30 (19)	0.037
Cadmium	0.005	0.001-0.08	206	90 (44)	61 (30)	0.17
Chromium	0.1	0.002-0.1	206	118 (57)	0 (0)	0.026
Coppper	1.3	0.002-0.05	206	66 (32)	0 (0)	0.31
Fluoride	4.0	0.1-1.0	216	105 (49)	36 (17)	15.0
Lead	0.015	0.001-0.01	196	9 (5)	1 (<1)	0.058
Mercury	0.002	0.0001	61	0 (0)	0 (0)	na
Nitrate	10	0.01-0.05	163	34 (21)	0 (0)	4.4
Selenium	0.05	0.001-0.005	178	38 (21)	0 (0)	0.006

[a] Percent of samples is given in parentheses.

Fleming Site (Reclamation Results) Ground Water Data

Constituent	Maximum Contaminant Level (mg/L)	Detection Limit (mg/L)	Total Number of Samples	Number of Detections Above Detection Limit	Number of Samples Exceeding MCL	Maximum Value (mg/L)
			National Secondary Drinking Water Regulations			
Aluminum	0.2	0.015-0.045	206	188 (91)[a]	104 (50)[a]	29.6
Chloride	250	0.1-1.0	216	188 (87)	1 (<1)	261
Copper	1.0	0.002-0.05	206	73 (35)	0 (0)	0.31
Fluoride	2.0	0.1-1.0	216	124 (57)	0 (0)	0.015
Iron	0.3	0.010	228	219 (96)	164 72	920
Manganese	0.05	0.0016	228	228 (100)	224 (98)	150
pH	6.8-8.5	na	267	na	192 (72)	3.2 (min) 7.9 (max)
Silver	0.10	0.003-0.046	206	183 (89)	0 (0)	0.063
Sulfate	250	0.11	216	216 (100)	212 (98)	13,500
TDS	500	computed	164	na	157 (96)	20,850
Zinc	5	0.001-0.06	206	188 (91)	0 (0)	3.8

[a] Percent of samples is given in parentheses.

Fleming Site (Reclamation Results) Ground Water Quality Hypotheses

Why was there such a minor influence of the FGD product on water quality?

1. The sampling schedule missed the highest concentrations of PFBC by-product leachate.
2. The mass of FGD product applied was so small that dilution by rainwater and the overwhelming influence of AMD obscured detection of changes.
3. Elements derived from the FGD product leachate have precipitated as secondary minerals in the unsaturated zone.

Fleming Site (2006)

Fleming Site (2006)

Conclusions

Reclamation at the Fleming AML site using FGD product was successful

1. Vegetation was reestablished and erosion was reduced.
2. Water quality showed a raised pH, which was maintained throughout the 7-year period after reclamation.
3. Surface water and ground water quality improved compared to the levels found prior to reclamation.

Conclusions

Reclamation at the Fleming AML site using FGD product was successful

4. Because of low application rates and sorption onto iron and aluminum hydroxides, it is believed none of the toxic elements of concern (arsenic, lead, or selenium) will cause water quality problems at these application rates.
5. Seven years later, however, ground-water quality remained poor and showed no signs of improvement.

GROUNDWATER EFFECTS OF COAL COMBUSTION BY-PRODUCT PLACEMENT IN COAL MINES

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View Presentation

Abstract

The effects of adding coal combustion by-products (CCB) to acidic mine waters are presented through a series of case studies. They include surface and underground mines. CCB applications include barriers and grouts. This paper focuses on beneficial uses of flue gas desulfurization (FGD) solids. In each case, FGD solids were applied with the object of mitigating acid mine drainage. The case studies include both successful and unsuccessful acid mine drainage control. The mines are located in the eastern and mid western USA in pyritic, bituminous coal measures. The effect of FGD application was also evaluated with respect to effects on groundwater. The case studies include pre- and post-application water quality monitoring data. Acid mine drainage typically contains a substantial suite of toxic elements. In most of the case studies, their concentrations are substantially reduced. However, concentrations of some constituents such as calcium, magnesium, and sulfate typically increase. Special attention is given toxic elements such as arsenic, selenium, and mercury.

Types of Coal Combustion Products

Coal combustion products can be grouped into four main classes: (1) Class F ashes; (2) Class C ashes; (3) Fluidized Bed Combustion ashes; and (4) Flue Gas Desulfurization solids. Class F and C ashes are produced in large pulverized coal boilers. They comprise the bulk of CCB produced in the U.S. They are distinguished by the American Society for Testing & Materials (ASTM) on the basis of their free lime (CaO) content[2]. Class F ashes have less than 10% lime while Class C ashes have more than 10% lime. Nearly all ashes produced by pulverized coal boilers in the Eastern U.S. are Class F while those burning western U.S. coal are typically Class C. Table 1 shows typical chemical compositions for both Class F and Class C ashes.

Fluidized Bed Combustion (FBC) ashes and Flue Gas Desulfurization (FGD) sludges result from relatively new, clean coal technologies. Both use lime or limestone ($CaCO_3$) to generate CaO to capture SO_x in the boiler exhaust gas stream. FBC ashes are produced when high sulfur coal and/or coal tailings are burned with limestone in a fluidized bed boiler. SO_x is precipitated as gypsum ($CaSO_4$) along with unreacted lime in a strongly alkaline ash (typically 25 to 30% free lime). Flue Gas Desulfurization solids are produced when lime or limestone slurries are injected into the exhaust gas downstream of the boiler. SO_x is precipitated either as gypsum or calcium sulfite ($CaSO_3$). Some utilities combine FGD solids with fly ash to improve solidification so FGD solids may or may not contain fly ash. In either case, sulfites may then be converted to gypsum by forced oxidation.

Currently about 31 million tons of FGD solids are produced each year with less than 2% of that total being beneficially used[1] as mine fill. The remainder is used in wallboard manufacture or landfilled. FGD solids normally have little inherent lime. However, they are often amended (fixated) with lime (CaO) for solidification, otherwise they have the consistency of a thin paste.

Table 1. Typical Composition of Class F and C ashes as defined by ASTM C 618[2].

Parameter	Class F	Class C
SiO_2	54.9%	39.9%
Al_2O_3	25.8%	16.7%
Fe_2O_3	6.9%	5.8%
CaO	8.7%	24.3%
SO_3	0.6%	3.3%
Moisture content	0.3%	0.9%
Loss on Ignition (LOI)(@750C)	2.8%	0.5%
Available alkalies as Na_2O	0.5%	0.7%
Specific gravity	2.34	2.67
fineness, retained on #325 mesh sieve	14%	8%

Beneficial CCB Applications in Coal Mines

CCBs are typically used in the following beneficial applications at coal mines:

- Neutralization of acid forming materials,
- Barriers to acid mine drainage (AMD) formation/transport,
- Subsidence control in underground mines,
- Pit filling to reach approximate original contour (AOC) in surface mines, and
- Soil reconstruction.

This report will only discuss the first four scenarios since soil reconstruction is fundamentally an agricultural application.

Coal Mine Environments and Their Implications for CCB use

Mine environments are complex and a given mine will contain zones of high groundwater flux and others, nearby, which are nearly stagnant. Mine groundwater can be oxidizing or reducing. Reducing conditions are often found in saturated zones while unsaturated zones tend to be oxidizing. Metals and oxyanions of elements such as arsenic tend to be more soluble in reducing conditions.

Mine groundwaters also vary accordingly to their acidity/alkalinity. Many mine waters, particularly in the Eastern U.S., range from slightly to strongly acidic with significant concentrations of iron, aluminum, and manganese. These ions are more soluble in acid conditions and alkalinity from CCB's are often used to neutralize acid mine drainage. The resulting metal hydroxides formed in these conditions will scavenge many trace elements such as arsenic and zinc.

In a given mine, one might encounter acid/oxidizing, acid/reducing, alkaline/oxidizing, and alkaline/reducing conditions. Care must be taken to ensure that CCB's are matched to zones which take advantage of their beneficial properties and which minimize their exposure to conditions which will mobilize toxic concentrations.

The CCBs can be placed in permeable or impermeable forms. At one end of the spectrum, bottom ashes have the hydraulic conductivity of gravel while fly ash is closer to silt. Class F ashes tend to be more permeable than class C ashes due to the tendency of class C ashes to self-cement. At the opposite extreme, fixated FGD solids have very low permeability and the various CCB grouts behave like concrete and are virtually impermeable.

Nearly all CCB's contain soluble and insoluble salts. If permeable and exposed to ground water, soluble salts will dissolve. These include salts of boron, chlorides, and sodium carbonates. On the other hand, the solubility of sulfates and calcium or magnesium carbonates is controlled by their concentrations in the mine water. It is not unusual to find mine waters which are already saturated with respect to gypsum or calcium carbonate. In such cases, little or no dissolution will occur. Care should be taken that CCB's containing substantial amounts of soluble salts are not exposed to zones of significant groundwater flux.

Case Studies of CCBs used in Mine Environments

Eastern U.S. Projects

Case Study 1. Winding Ridge

The Maryland Department of Natural Resources Power Plant Research Program and the Maryland Department of the Environment initiated a project in 1995 to demonstrate the use of CCBs for AMD abatement in an underground mine[3]. The strategy was to completely fill the mine voids and replace mine water with CCB grout. The demonstration occurred at the Frazee Mine on Winding Ridge, near Friendsville, MD. The mine was abandoned in the 1930's and continued to produce acid drainage. By filling the mine voids, the grout was intended to minimize contact between groundwater and pyrite remaining in the mine. A grout was developed consisting of solid phase (CCBs) with acid mine water used for slurry makeup. The grout was injected into both dry and inundated portions of the mine.

The grout consisted of FGD material and Class F fly ash from Virginia Power Company's Mount Storm power plant and FBC ash from Morgantown Energy Associates' Morgantown power plant. The FGD material, containing mostly calcium sulfite and calcium sulfate and no free lime, was used as an inert filler. The Class F ash was used as a pozzolan while the FBC ash was used as the cementing agent. The grout contained approximately 60% fresh FBC (<24 hours old), 20% FGD, and 20% Class F fly ash. The FBC ash arrived from the power plant containing about 15% moisture. The final design mix yielded 8 inches of spread using ASTM PS 28-95, and a 28 day unconfined compressive strength of 520 pounds per square inch (psi) as determined by ASTM C 39-94.

Prior to injection, the grout was subjected to a Toxicity Characteristic Leaching Procedure or TCLP for non-organics. None of the analytes exceeded their respective regulatory limits for characterization as a hazardous waste.

During the fall of 1996, more than 5,600 cubic yards of grout were injected into the mine. The original design was for 3,900 cubic yards but additional void space was encountered and grouted. During the injection, it became apparent that the Frazee Mine was larger and more complex than determined during the mine characterization phase. As a result, the mine was not completely filled and the mine continues to produce AMD.

The mine's discharge pH remained around 3.0 during and after grout injection while Ca, Na, and K concentrations increased by nearly an order of magnitude. Sulfate, Cu, Ni, Zn, and Cl all nearly doubled with both Ni and Zn in excess of water quality discharge limits. Both Ni and Zn had exceeded water quality limits prior to injection. Two years after injection, however, concentrations of both Ni and Zn were at or slightly above pre-injection levels. (Table 3).

In September 1997, nine core holes were drilled into the Frazee Mine to recover grout. The core hole locations targeted previously wet and dry sections of the mine. The grout samples were submitted to the laboratory for testing of density, permeability (hydraulic conductivity), and unconfined compressive strength. Grout was encountered at five holes. In general, the cores showed little sign of in-situ weathering and displayed good mine roof and pavement contact. Table 2 summarizes the results of the geotechnical core analysis.

Table 2. Analysis of grout in the Winding Ridge project. Samples were taken by coring about one year after grout injection.

Core hole	Depth	Permeability (cm/sec)	Strength (psi)	Dry Density (lbs/ft^3)
CH-1	84'4"-85'8"	1.89×10^{-6}	560	70.6
CH-3	71'8"-72'10"	2.58×10^{-7}	1208/1128	76.8
CH-3	73'3"-74'1"	2.58×10^{-7}	not tested	71.7
CH-6	83'2"-84'5"	1.29×10^{-7}	1339	80.4
CH-9	85'-87'1"	6.02×10^{-8}	1417	75.4

The measured permeabilities range from 6.02×10^{-8} to 1.89×10^{-6} cm/sec. Core hole 1 matched the target strength in the 28 day laboratory test. The other holes all had approximately twice the strength achieved in the laboratory after 28 days.

The behavior of calcium and sulfate after injection was significantly different than that of acidity, iron, and aluminum. Calcium concentrations increased by a factor of 3 to 6 and remained at these levels for more than 16 months after injection. Sulfate levels remained at about twice the pre-injection level. These persistent increases in calcium and sulfate can probably be attributed to the dissolution of these ions from the injected FBC and FGD materials. Trends in sodium, potassium, and chloride concentrations were similar to those of calcium. It is likely that their elevated concentrations result from some grout dissolution.

Also note that prior to injection the grout itself was subjected to a TCLP. The results were that arsenic and barium were found at levels of 0.13 and 0.11 mg/l respectively. Post grouting water quality of the mine discharge did not detect these constituents (the detection limit for arsenic in the mine water was 0.2 mg/l but the detection limit for barium is one order of magnitude below the TCLP result). The data show that with the exception of a short term increase in Ni and Zn, no toxins are leaching from the ash even though the ash is dissolving due to acid attack. The permeabilities exhibited by the ash (see Table 2) would indicate that the grout could withstand surface attack for some time.

The grout was placed under nearly worst case conditions. There was insufficient grout placement to neutralize acid in the mine water and as a result it was subjected to continuous weathering by pH 3.0 water. Further, the flow of this water through the mine was unhindered. It is understood that mine grouting projects would be expected to block out mine water. Thus, this project represents an effect of a high flux, aggressive mine water on a grout.

Case Study 2. Mettiki Coal, Underground Mine Backstowing.

In December 1996, Mettiki Coal began injecting a mixture of non fixated flue gas desulfurization solids (FGD), AMD metal precipitates and fine coal refuse into its underground coal mine near Redhouse, MD. The slurry is injected at about 15% solids content. There is some un-reacted lime in both the FGD and the AMD sludge, mush which would solubilize in the thin slurry. The mine is on the headwaters of the North Branch of the Potomac River. CCBs are injected into an inactive section of the mine and to date about 320,000 tons of CCB have been injected. The CCBs enter the low point in this synclinal structure and displace an otherwise acid mine pool. Since the FGD solids are not fixated they are not expected to solidify. On the other hand, since they are placed in the low point of the mine and well below regional drainage, the ambient mine water is expected to be stagnant. Thus, stratification of water layers above the CCBs is likely to occur with minimal mixing. Water was sampled and analyzed prior to injection of CCBs and these data are summarized in Table 4. Chloride was expected to be the most sensitive ion as the FGD solids have between 10,000 and 30,000 mg/l Cl. As chloride is an anion and extremely soluble it has been monitored closely. Maryland set a discharge limit of 860 mg/L on chloride. Materials are mixed in a specially designed building with slurry water added and monitored in the receiving bin directly underneath the truck loadout.

Table 3. Summary of pre and post injection water quality at the Frazee Mine, Friendsville MD. The data are for samples taken and analyzed by the USDOE National Energy Technology Center.

RCRA Element	TCLP Limit (mg/L)	EPA Drinking Water (mg/L)	Pre-CCB (mg/L)	Post-CCB (mg/L)
			Mean of 18 samples	Mean of 15 samples
Sb	1	0.006	<0.2	<0.2
As	5	0.05	<0.2	<0.2
Ba	100	2	0.029	<0.02
Be	0.007	0.004	<0.02	<0.02
Cd	1	0.005	<0.02	<0.02
Cr (6+)	5	0.1	0.03	0.04
Pb	5	0.015	<0.02	<0.02
Hg	0.2	0.002	na	na
Ni	70	0.01	0.62	1.13
Se	1	0.05	<0.5	<0.5
Ag	5		na	na
Tl	7	0.002	na	na

Other analytes (mg/L)

Al		37.4	55.66
Ca		25.23	223.25
Cl		2.32	7.33
Co		0.32	0.5
Cu		0.08	0.25
Fe		67.44	67.49
Mg		25.65	31.95
Mn		2.71	2.85
K		0.9	13.31
V		na	na
Zn		1.38	2.29
Na		1.02	7.99
SO4		564.37	1181.87

In conclusion, chloride concentration remains well below the Maryland limit of 860 mg/L, averaging about 120 mg/L. This is, nevertheless, above the pre-injection level of 3 mg/L. Other than the roughly 30% increase in sulfate concentrations, the injection has had little effect other than to increase the alkalinity in the mine pool. This has caused the pH to increase from about 3 to 4.5 while Al and Fe have both dropped substantially. Prior to discharge, mine water is treated in a high density lime treatment system and discharged through a polishing pond to the NPDES monitoring point. Trout are successfully raised in the polishing pond. They are exceptionally sensitive to chloride.

Table 4. Water Quality data from Mettiki FGD Underground Injection.

RCRA Element	TCLP Limit (mg/L)	EPA Drinking Water (mg/L)	Pre-CCB injection Date/tons cum. CCB added			Post-CCB injection						
			06/13/96	10/25/96	12/02/96	04/14/97	07/10/97	11/11/97	03/03/98	07/06/98	11/09/98	03/08/99
			0	0	60	17,718	51,716	115,060	167,749	219,675	271,269	320,828
Sb	1	0.006	<0.05	<0.05	<0.05	<0.05	<0.05					
As	5	0.05	<0.025	<0.025	<0.025	<0.025	<0.025					
Ba	100	2	0	0.035	0.042	0.033	0.033					
Be	0.007	0.004	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025					
Cd	1	0.005	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025					
Cr (6+)	5	0.1	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075					
Pb	5	0.015	<0.025	<0.025	<0.025	<0.025	<0.025					
Hg	0.2	0.002	na	na	na	na	na					
Ni	70	0.01	0.139	0.206	0.5	0.183	0.195					
Se	1	0.05	na	na	na	na	na					
Ag	5		<0.0025	<0.0025	<0.0025	<0.0025	<0.0025					
Tl	7	0.002	<0.13	<0.13	<0.13	<0.13	<0.13					

Other Elements (mg/L)	MD Limit										
Al		0.4	1.06	7.71	0.194	1.32					
Ca		224	267	258	421	541					
Cl	860	2.2	2.8	1.3	94	200	142	104	92	99	146
Co		0.1	0.146	0.34	0.133	0.137					
Cu		0	0.0431	0.123	<0.0062	0.0095					
Fe		37.8	61.1	133	24.8	34.4					
Mg		49.5	3.87	63.1	66.1	83.7					
Mn		2.72	3.87	4.77	4.28	4.8					
K		7.43	11	6.5	10	10.2					
V		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050					
Zn		na	0.273	0.111	0.201	0.266					
Na		77.2	86.4	52.8	75.3	79.2					
SO4		830	1090	918.5	1240	1345.7					

Midwestern Projects

The following case study describes several projects where CCBs were used in mine land reclamation. The title of the paper is "Use of Coal Combustion By-Products for Reclamation: Environmental Implications[6]."

Case Study 3. Forsythe Energy #5. FGD Pit Backfill

For one year before the final strip pit was filled at the Forsythe Energy #5 mine near Marion, Illinois, laboratory column leaching tests were run on the FGD material proposed for the fill. Monitoring wells were placed within 15 meters of the area to be filled and groundwater quality monitored for one year prior to filling the pit. Water from an up-gradient pit was used as the leaching medium in the column tests. Before filling the pit, a channel was dug in the bottom of the pit and perforated well pipe was laid in silica sand. The drain was piped to the surface and filling began. The constructed drain allowed for leachate from the fill to be sampled before significant attenuation into the environment. The source concentration of the leachate and the concentration in down-gradient wells allowed for the calibration of groundwater flow and contaminant transport models.

The water at the mine was of poor quality. The pH was 6.7, iron ranged between 100 and 350 mg/l and manganese was 35 mg/l. Lead, cadmium, and nickel were above class I water standards and many were above class II standards. The column experiments indicated that calcium, potassium, sodium, boron, and molybdenum could potentially leach from the fill.

In column tests, FGD solids removed most of the iron and manganese from solution and a significant part of the trace metals such as lead, cadmium, and nickel bringing most of these parameters into compliance with class I or II groundwater limits. The slight increase in pH and the oxidizing environment of the columns probably assisted in the precipitation of iron and the role of ferric oxyhydroxides in co-precipitation of other metals. The results of the column study mirrored the results of the field demonstration on all 24 elements analyzed.

While removing metals, FGD solids caused an increase in boron concentration reaching a maximum of 100 mg/l in the drain before falling off. Computer models indicated a boron enriched leachate plume of nearly 100 acres that exceeded the 2 mg/l class I groundwater standard for 20 years after placement. Most boron concentrations are too low to cause phytotoxicity in common reclamation grasses and legumes but more sensitive cultivated plant species may suffer if the water from the plume were used for irrigation.

Laboratory shake tests indicated that enough calcium will dissolve from FGD solids to cause hard water. For this reason one would want to avoid placing the FGD material in communication with high quality potable aquifers, but in mine settings with typically high total dissolved solids waters where toxic and heavy metal drainage is a problem, a case could be made that the environmental enhancements far outweigh the risks. In summary, boron and calcium (hardness) were the only two parameters that violated groundwater standards.

Conclusion

The use of CCBs as mine backfills has been beneficial in some settings, neutral in others and harmful in yet other settings. While each setting and CCB form a unique set of circumstances requiring individual analysis and evaluation, several generalizations can be made.

- As mine fills, CCBs are used to: (1) neutralize acid groundwater; (2) encapsulate toxic materials; (3) bring the land surface to approximate original contour; (4) prevent subsidence; and (5) control hydraulic pressure buildup in underground coal mines.

- CCB mine fills introduce an alkaline component into the mine fill. In acid environments, this can be beneficial. By neutralizing acid, metal laden water, CCBs tend to cause metals to precipitate, lowering the concentrations of nearly all metal ions. No case was found in which metal loadings increased beyond either TCLP or drinking water limits due to the application of CCBs in mine backfill. Neutralization of mine spoil or refuse is best accomplished by blending the CCB with pyritic materials in appropriate ratios.

- In already neutral or alkaline groundwater environments, CCBs can exacerbate soil salinity problems.

- The extent of positive or negative impacts is a function of the groundwater flux through the CCB, its chemistry, and the chemistry of the mine groundwater.

- Water flux is governed by local hydrology and the permeability of the CCB. In flat, arid regions, water flux due to precipitation may be negligible while flux along the mine pit floor may be high and regional. In mountainous, humid areas, precipitation driven flux can be very high while groundwater flux is high but localized.

- Some CCBs can be compacted or formulated as grouts such that they are nearly impermeable to water.

In mines suffering from acid mine drainage (AMD), most CCBs containing lime have positive effects. In nearly all cases, acid and metal loadings are substantially reduced or eliminated. Toxic element concentrations either decrease or increase to levels well below TCLP and even drinking water standards. In arid, alkaline mines, care should be taken to ensure that groundwater flux is minimized either by compaction/solidification or by keeping the CCBs above the re-established saturated zone above the pit floor.

Non-fixated FGD materials contain almost no neutralization potential and are presently not very useful in mine land reclamation. The non-fixated materials typically exhibit a high permeability, as well. However, fixated FGD contains excess alkalinity with low permeability. Fixated FGD materials can be useful in acid mine drainage abatement, subsidence control, high volume backfills, and as a barrier material to encapsulate acidic materials or seal pit floors on surface mines. Both materials can contain high chloride levels that are concentrated in the flue gas desulfurization units.

Other than FGD solids, most CCBs consist of fine particles that require the implementation of dust suppression techniques to be handled in the open environment. Typically, utilities will treat the CCBs with water as they leave the power plant to ensure dust suppression. Care needs to be taken as the fine particles do pose a human health hazard.

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Using Flue Gas Desulfurization Solids to Control Acid Mine Drainage:
Case Study

Paul Ziemkiewicz
National Mine Land Reclamation Center
West Virginia University

Today, We Will Address the Following Questions:

- Will FGD solids injection treat acid mine drainage?
- Will FGD release other toxins to groundwater?

Approach

- Laboratory leaching results
- Eight year monitoring results of a large scale FGD injection into an underground coal mine

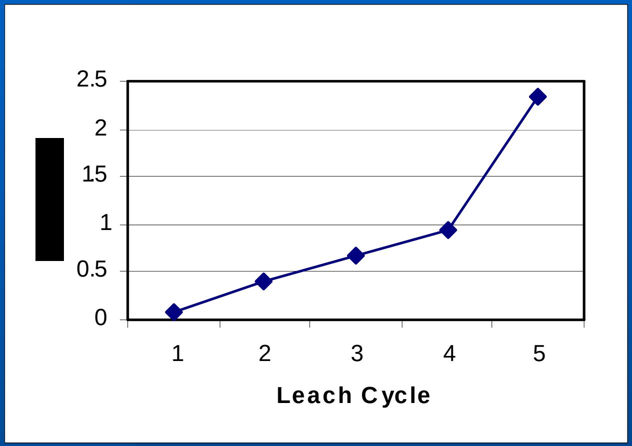
FOR MORE INFO...

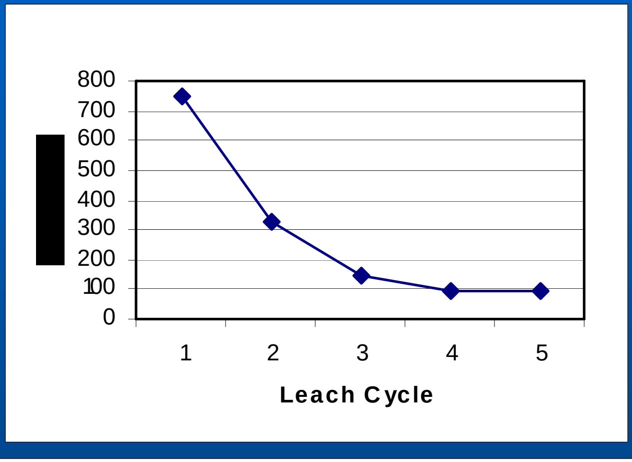
Stay tuned…..

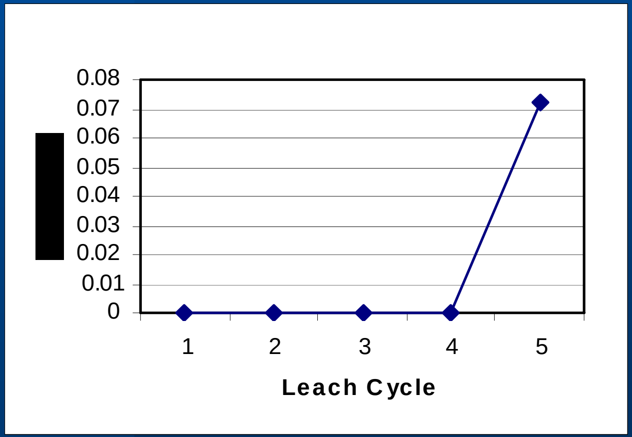
Laboratory Leaching:

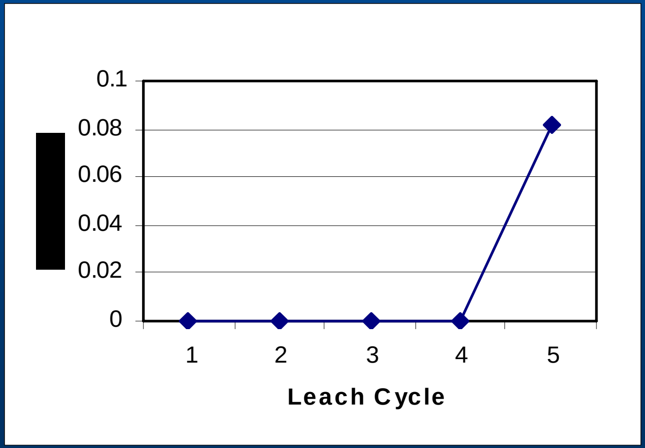
- **Dry Sorbent Injection FGD from South Carolina**
- **Sequential leaching with deionized water over five cycles**

Successive Leaching of FGD with Deionized Water

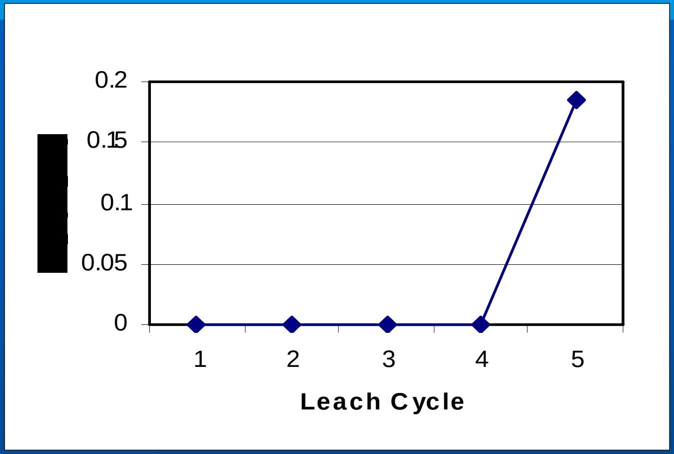


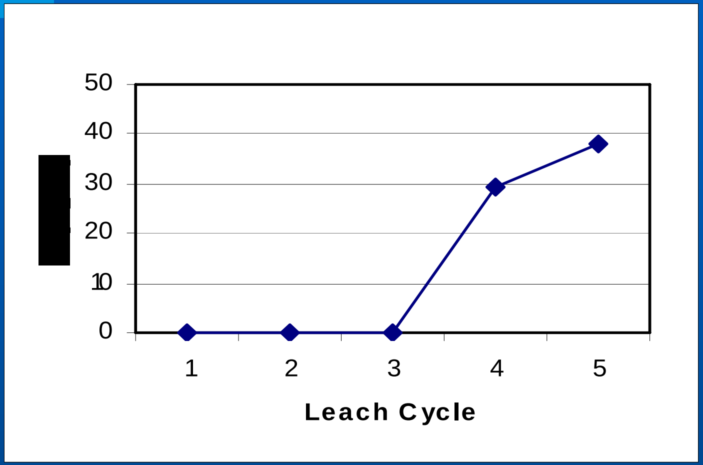


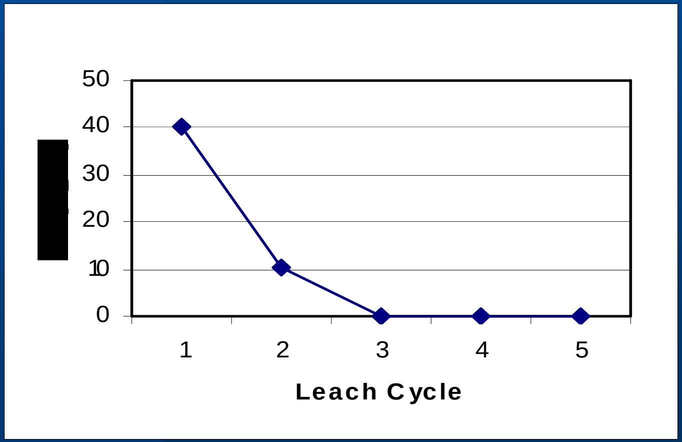


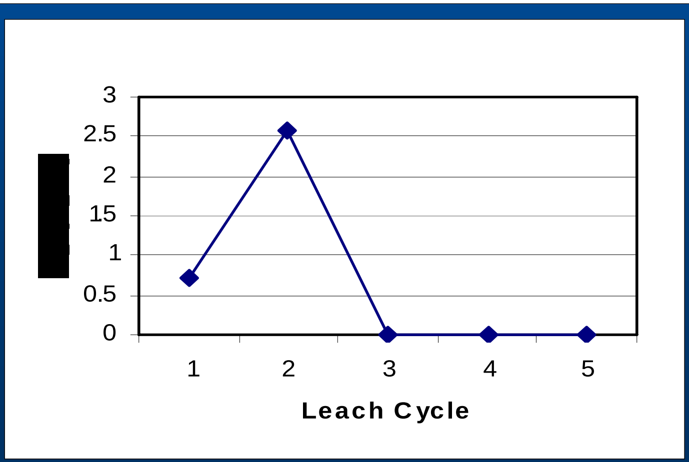


Successive Leaching of FGD with Deionized Water

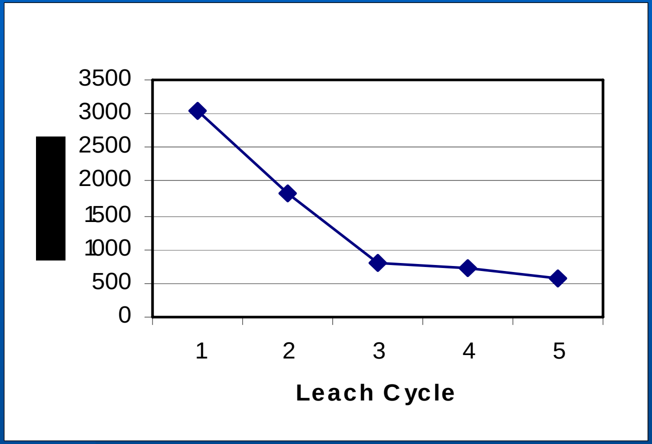


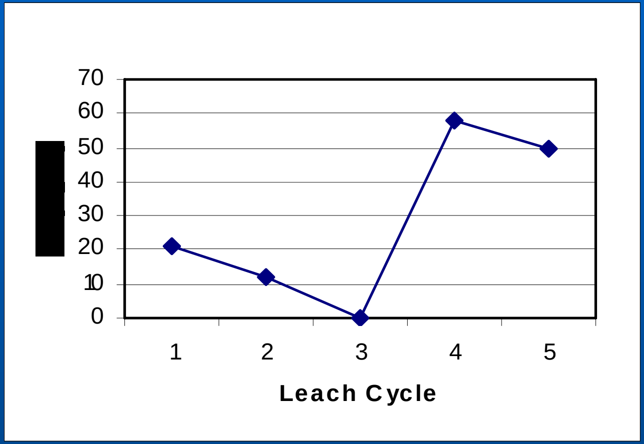


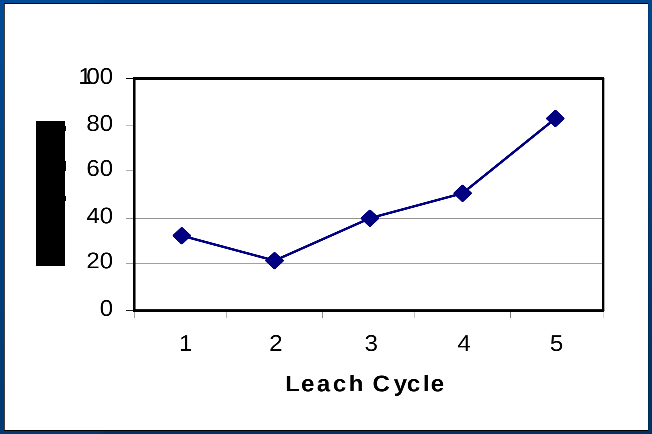


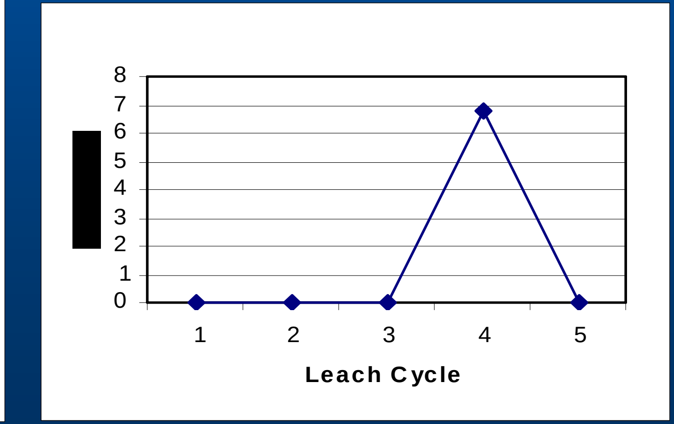


Successive Leaching of FGD with Deionized Water









Conclusions:

- This FGD had little alkalinity and most was gone by the third cycle
- Initial leaching removed:

  Ba, Ca, Hg, Zn
- Later leaching saw an increase in: Al, Cd, Fe, Mg, Mn, Ni, SO_4, V
- No leaching of:

  Ag, As, Sb, Be, Cu, Pb, Se, Tl

Case Study: Mettiki FGD Injection

- AMD treatment sludge injected to mine since 1984
- 740,000 tons of FGD solids injected between 1997 and 2004
- Target: Freeport seam A, B, C mines
- Underground coal mines
- Raw water sampling
- Raw water then treated
- Clean water discharged to stream

METTIKI A, B, C Mine Discharge (Pre-Treatment)

All Values in mg/L

	AMD Sludge Injection started in 1988				FGD Injection 1997 to 2003: 740,000 tons			
	Jun-96	Oct-96	Apr-97	Jul-97	May-99	Apr-00	Mar-01	Jan-04
As	<0.025	<0.025	<0.025	<0.025	<0.10	0.005	<0.010	<0.01
Sb	<0.05	<0.05	<0.05	<0.05		0.0084	<0.02	<0.02
Ba		0.035	0.033	0.033	<.10	0.0367	0.0254	0.0458
Be	<0.0025	<0.0025	<0.0025	<0.0025		<0.0011	<0.002	<0.005
B	0.065	0.073	0.47	0.937				
Cd	<0.0025	<0.0025	<0.0025	<0.0025	<0.01	<0.00081	<.0015	<0.005
Cr	<0.0075	<.0075	<.0075	<.0075	<0.03	0.0023	<0.003	0.005
Cu		0.0431	<0.0062	0.0095		<0.0029	<0.004	<0.010
Ag	<0.0025	<0.0025	<0.0025	<0.0025	<0.02	<0.0056		
V	<0.0050	<0.0050	<0.0050	<0.0050		0.0032	<0.004	<0.005
Tl	<0.13	<0.13	<0.13	<0.13				<0.020
Pb	<0.025	<0.025	<0.025	<0.025	<0.10	<0.0079	<0.02	<0.020
Se						0.0085		<0.010
Hg					**<0.0002**	**<0.0001**	**<0.0002**	**<0.0002**

So what’s up with Mercury?

- FGD is known to capture more than half of the mercury leaving the boiler
- In eastern coal that can be more like 80 to 90%
- The higher mercury capture reflects the preponderance of oxidized, Hg^{2+}
- I’m sure we’d all like to know why it doesn’t report to the ground water

Predominant species in mercury cycle

- Hg^{2+} (mercuric ion)
  - soluble in water, can be methylated
  - does not tend to accumulate in organisms
  - in presence of sulfides, such as H_2S, the insoluble compound HgS forms in sediment
- Hg^0 (elemental mercury)
  - Reduced from mercuric at the same redox condition as Ferric>Ferrous
  - not soluble in water
  - vapor pressure large enough for Hg vapor to become airborne

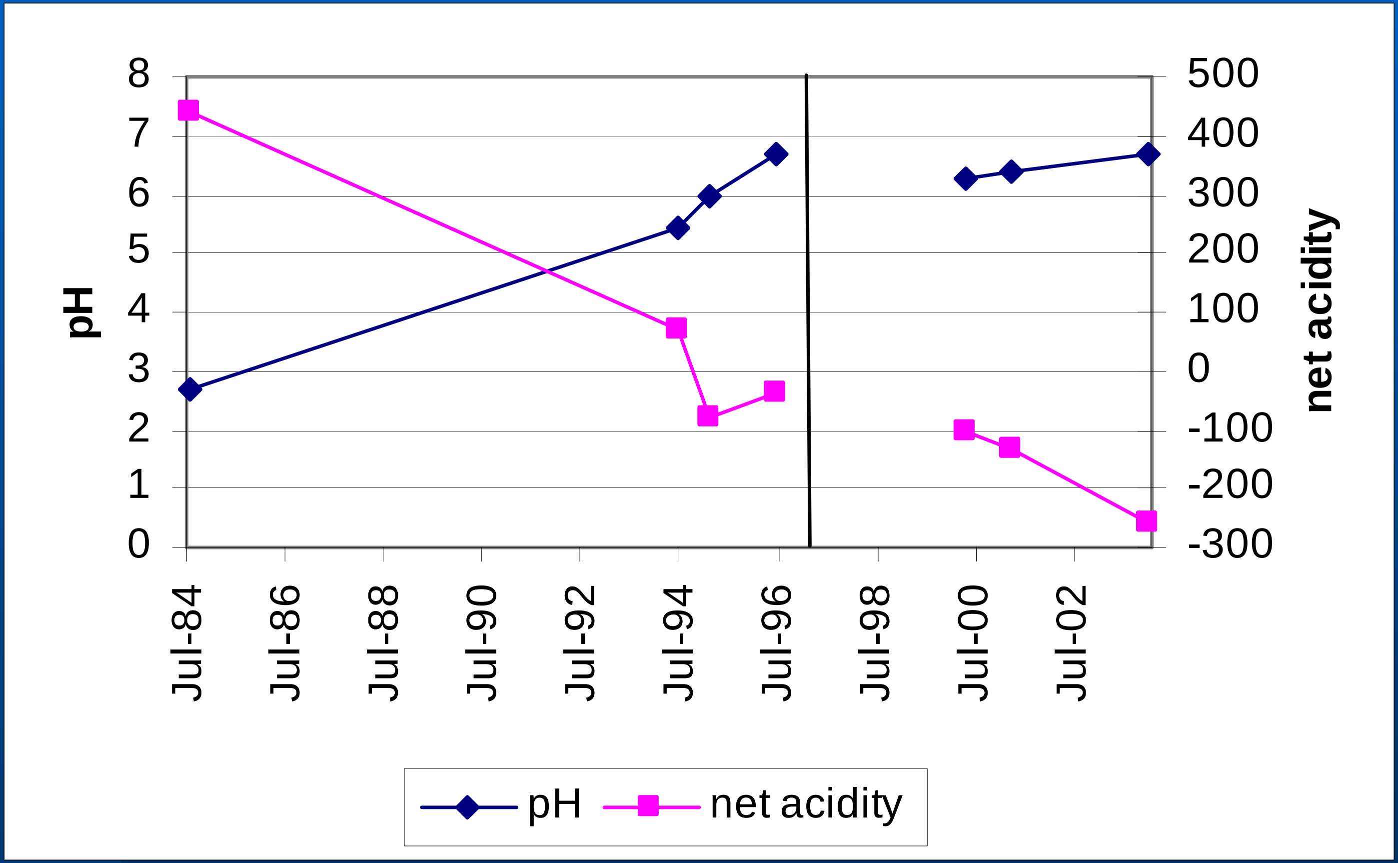
Aqueous Mercury Transformations

- **Mercuric ion forms insoluble sulfide under reducing conditions**
- **bacterium *Clostridium cochlearium* produces H_2S which can react with Hg^{2+}**
- **$Hg^{2+}_{(aq)} + H_2S_{(aq)} > HgS_{(s)} + 2H^{+}_{(aq)}$**

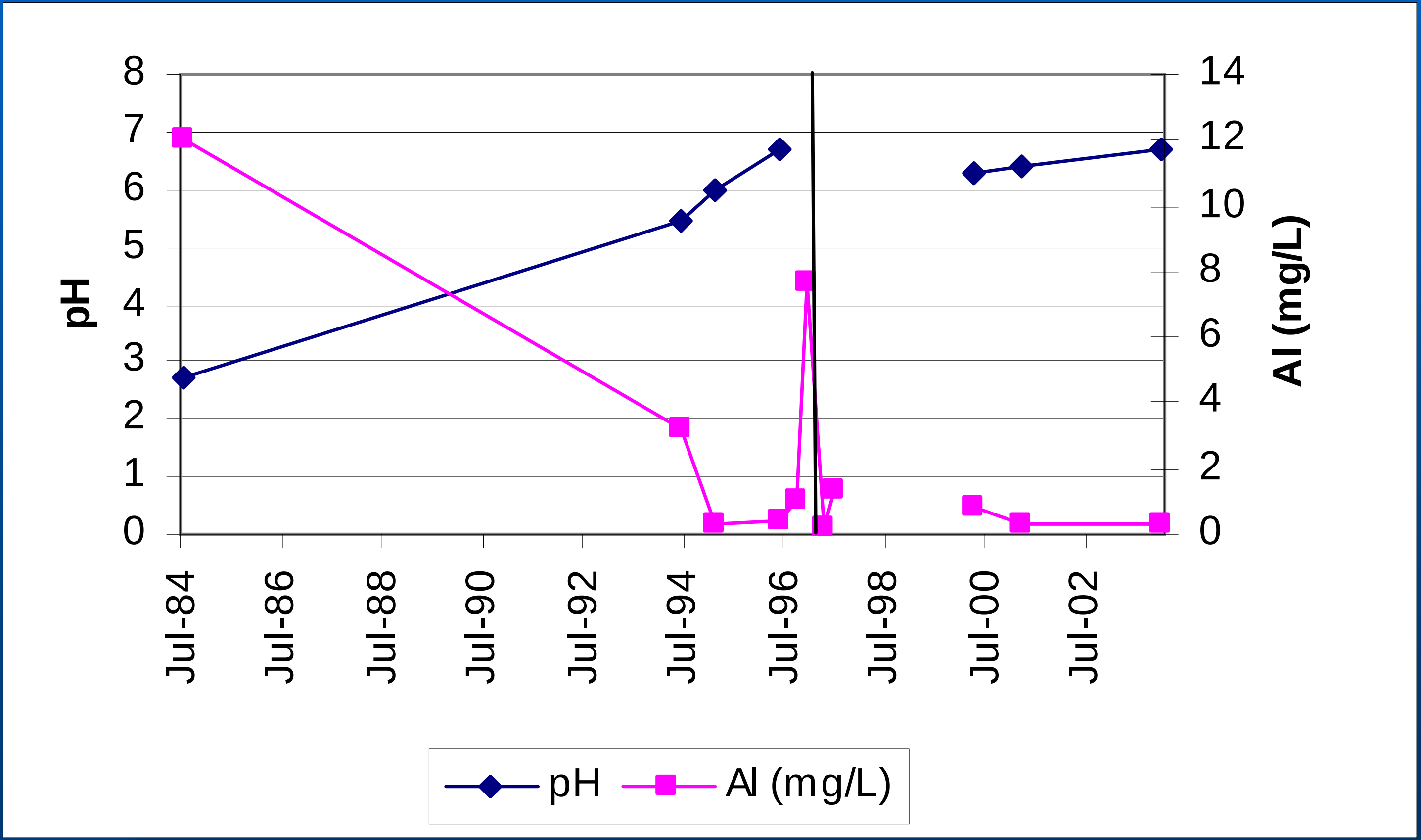
Don’t forget:

- Un fixated FGD has a lot of sulfite-generally as much or more than its gypsum content
- Sulfite is a powerful reducing agent
- Most metals are less soluble in their reduced state

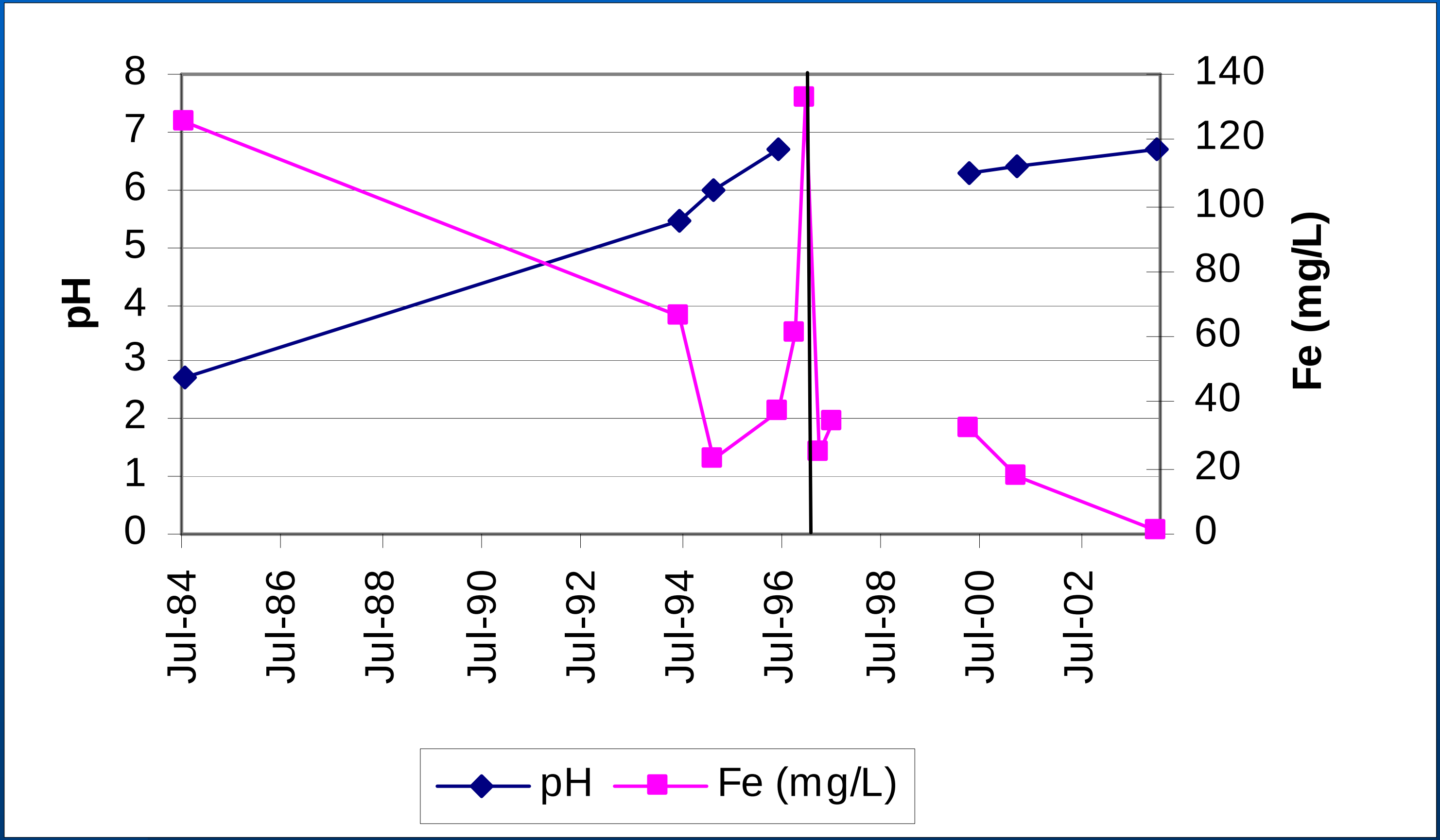
Raw Water, Mettiki Mine: pH vs. net acidity



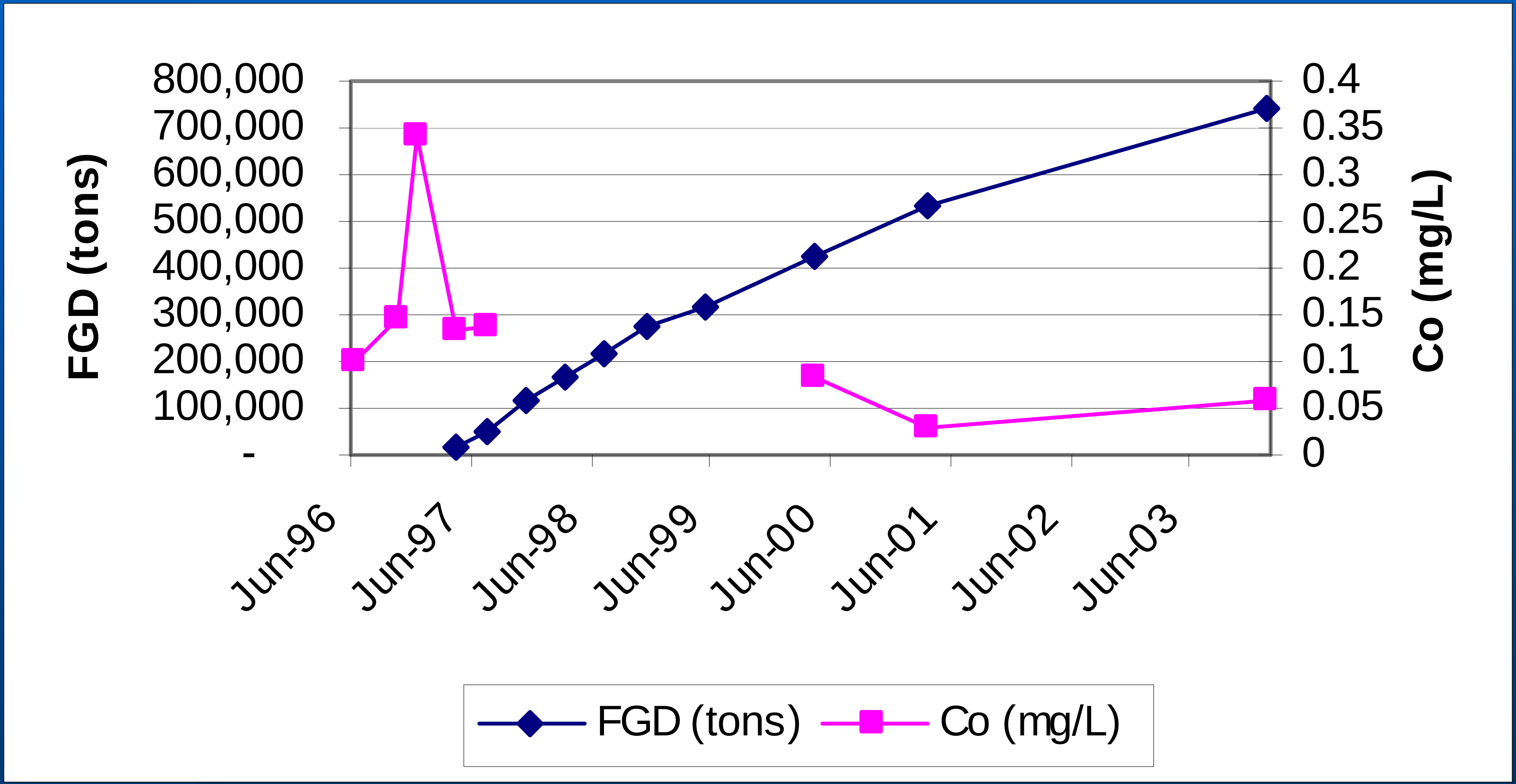
Raw Water, Mettiki Mine:
pH vs. Aluminum



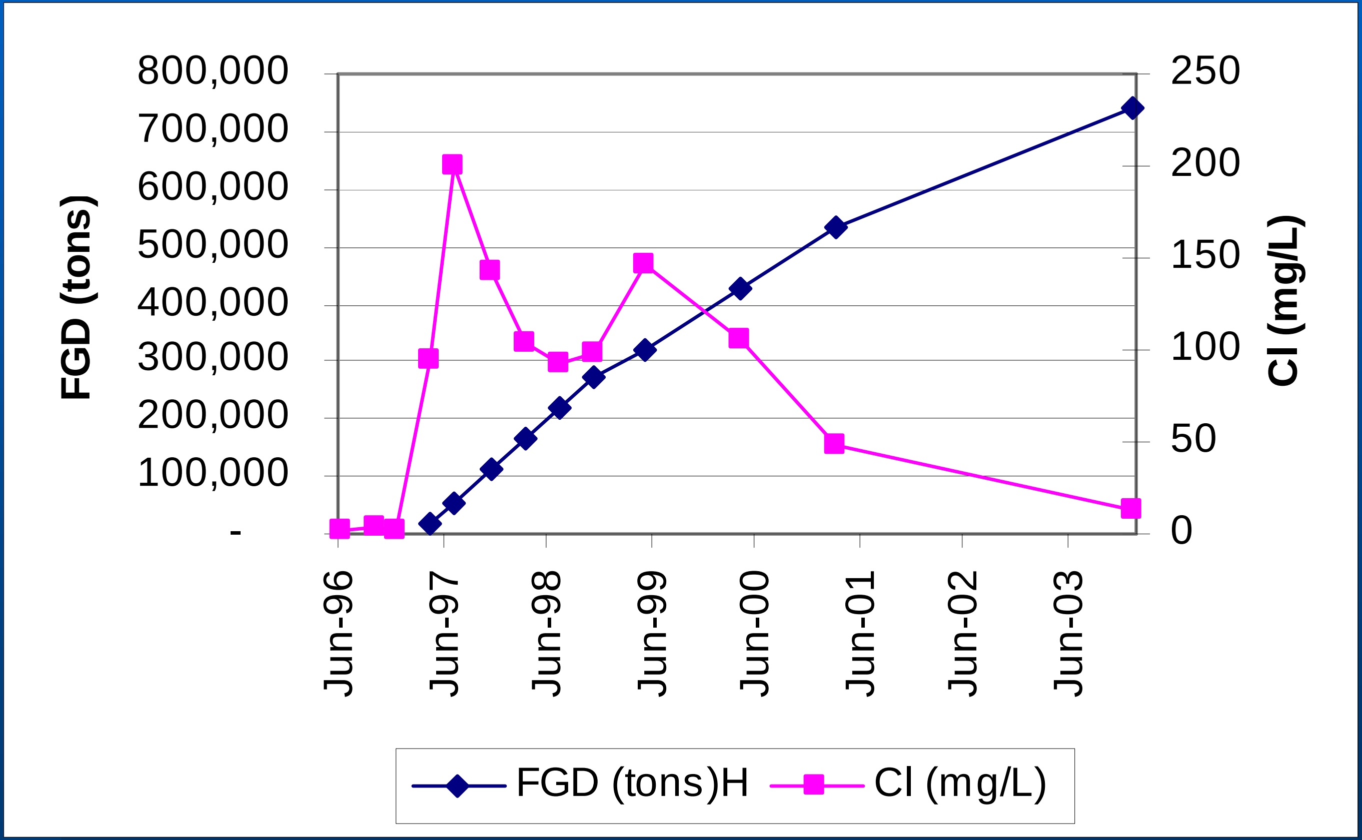
Raw Water, Mettiki Mine: pH vs. Iron



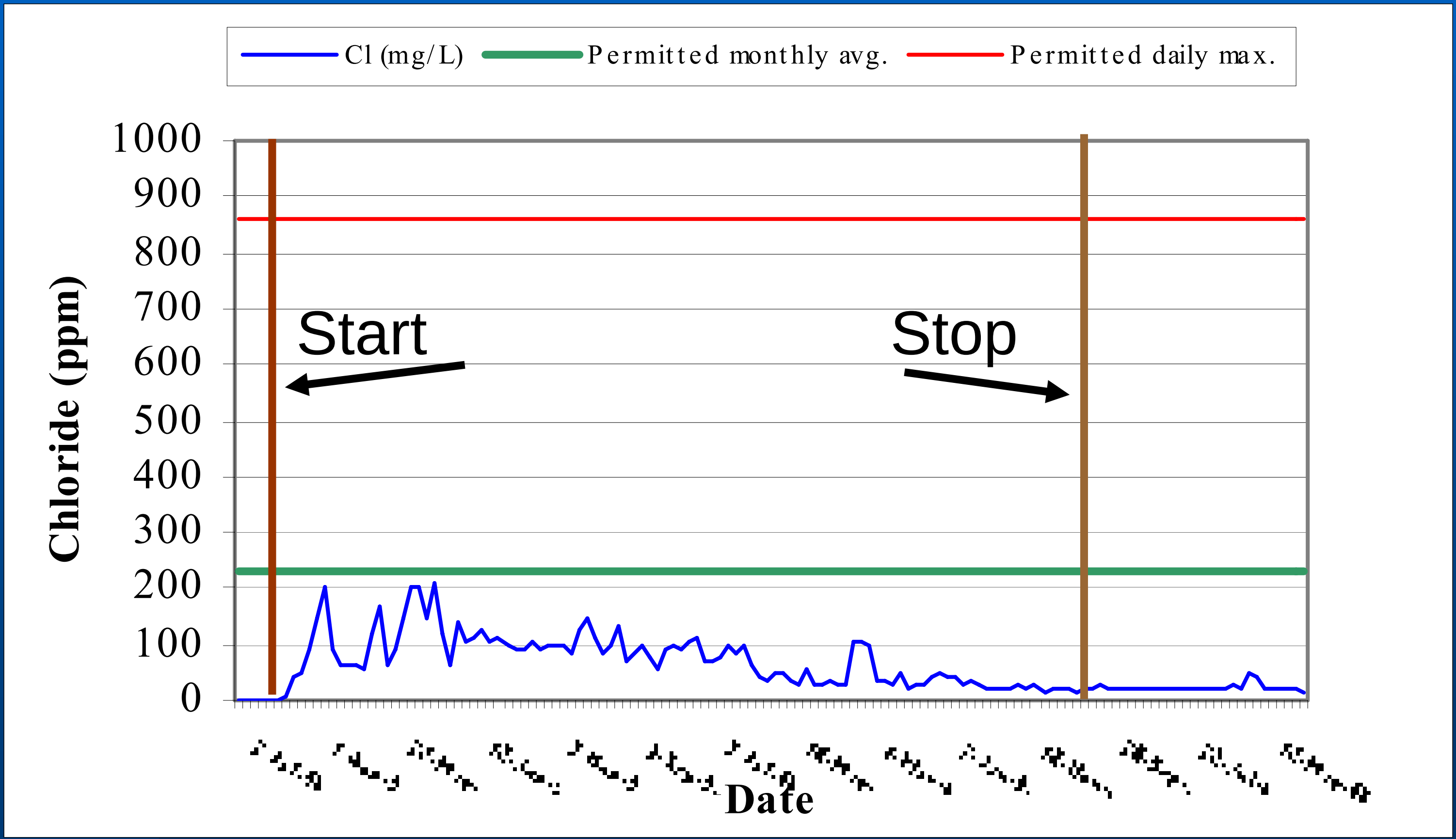
Raw Water, Mettiki Mine: Cobalt



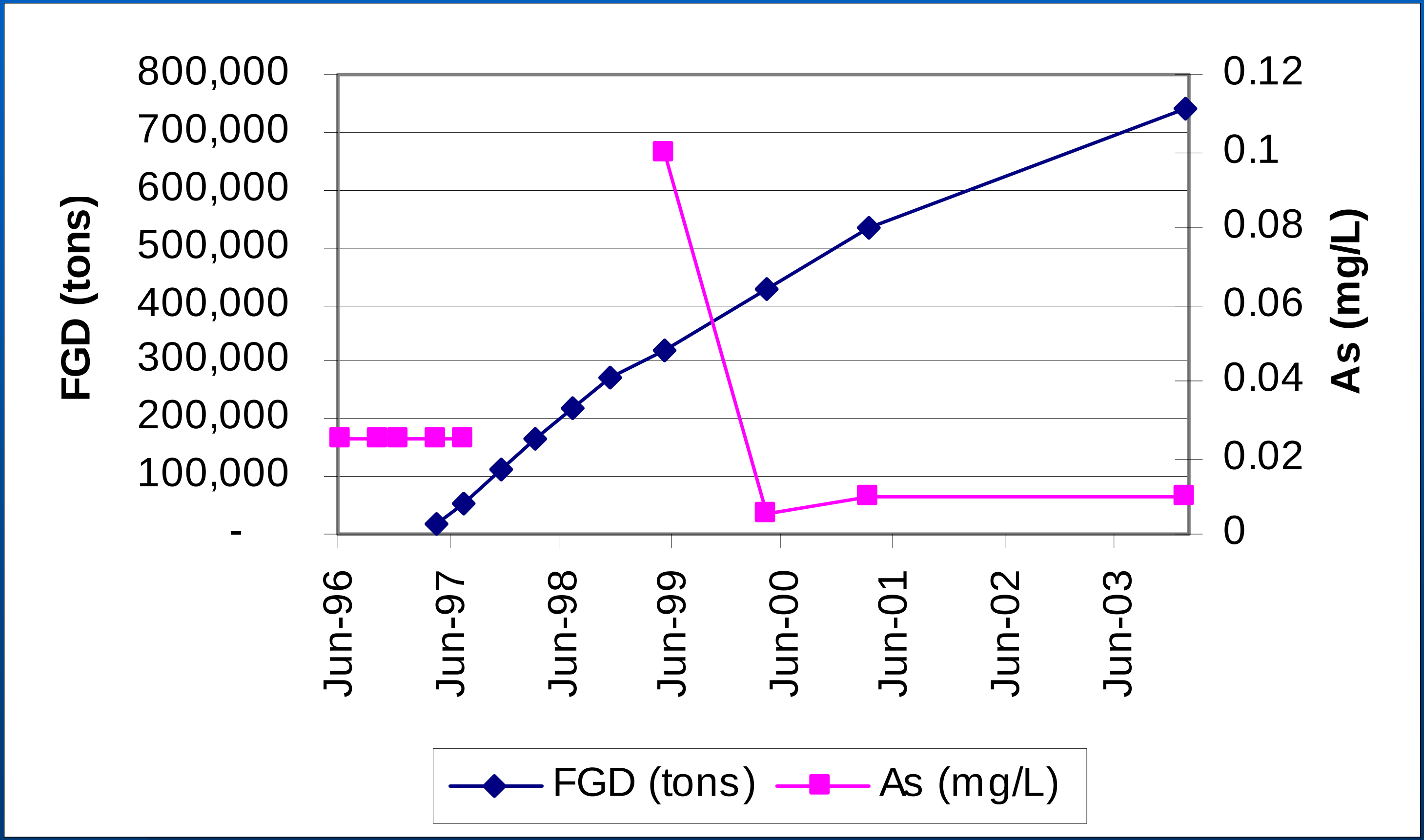
Raw Water, Mettiki Mine: Chloride



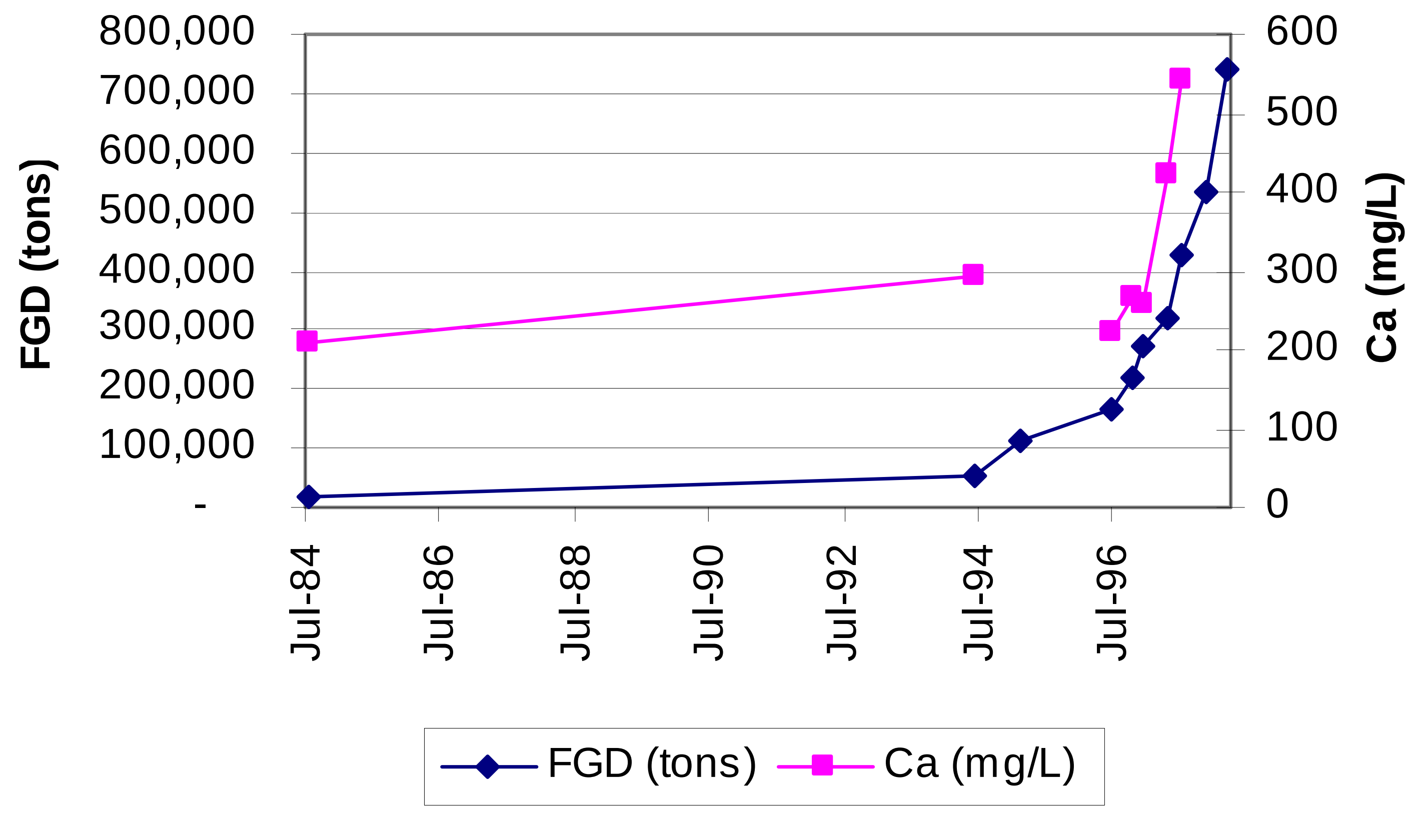
Mettiki Raw Water: Chloride



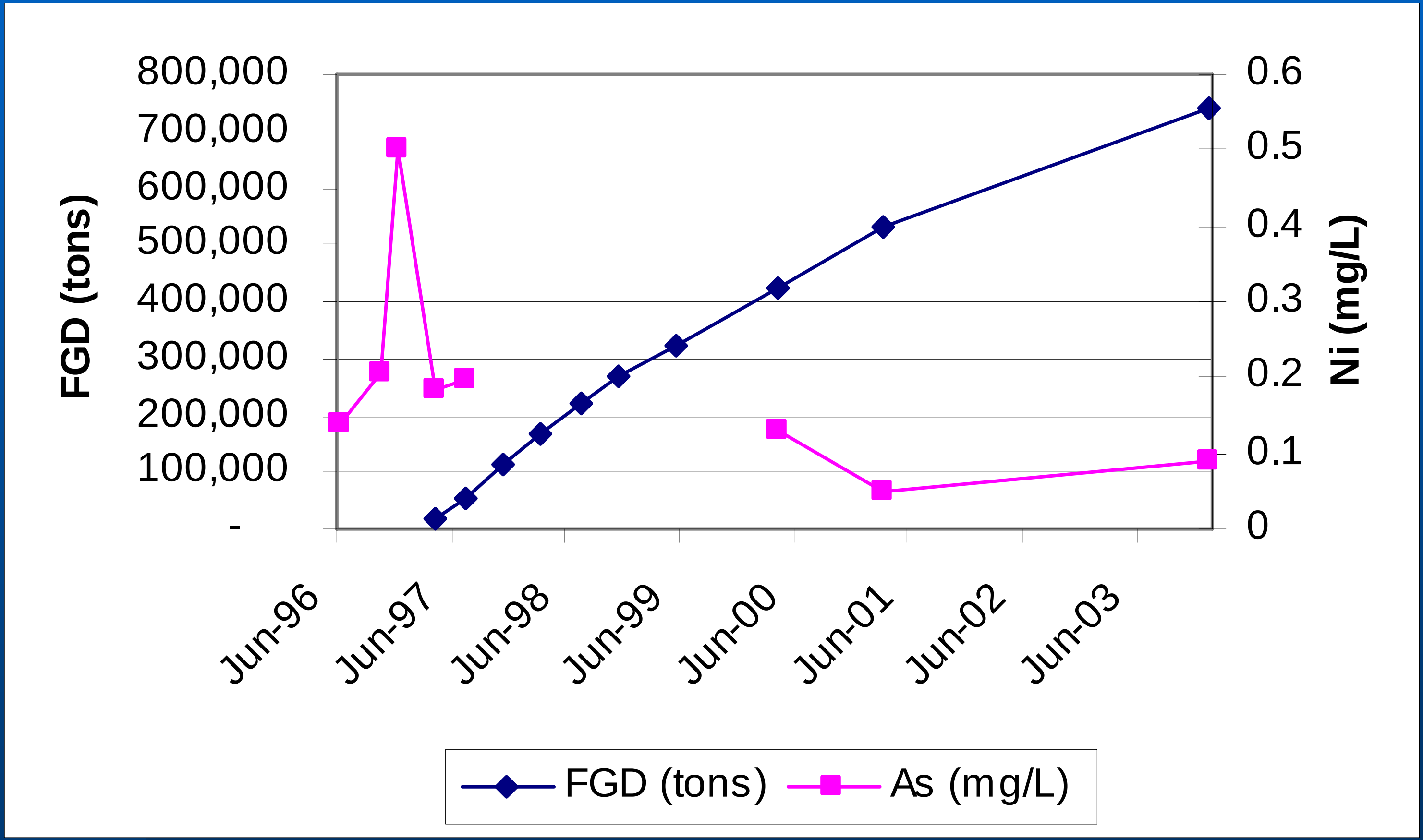
Raw Water, Mettiki Mine: Arsenic all values are below detection limit



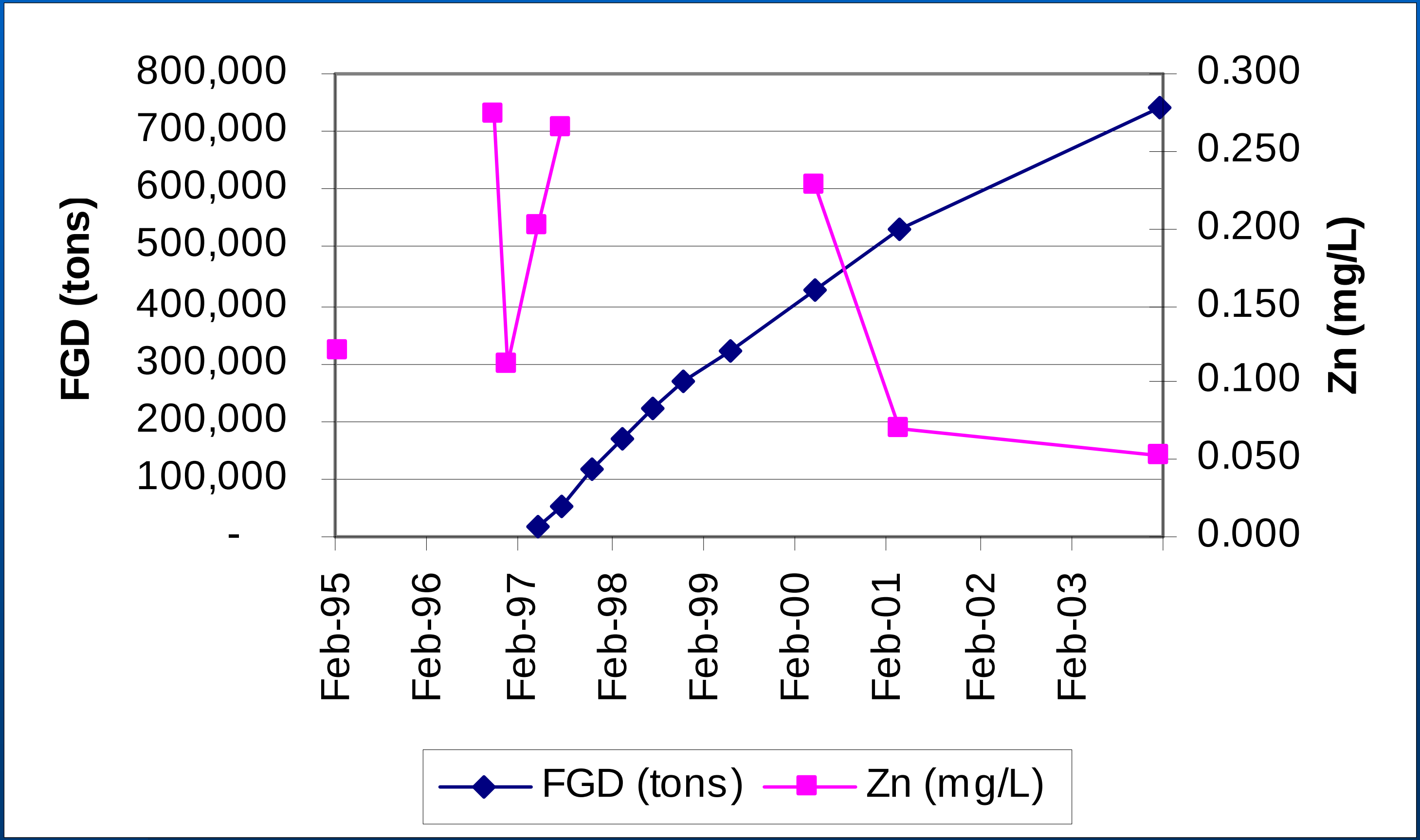
Raw Water, Mettiki Mine: Calcium



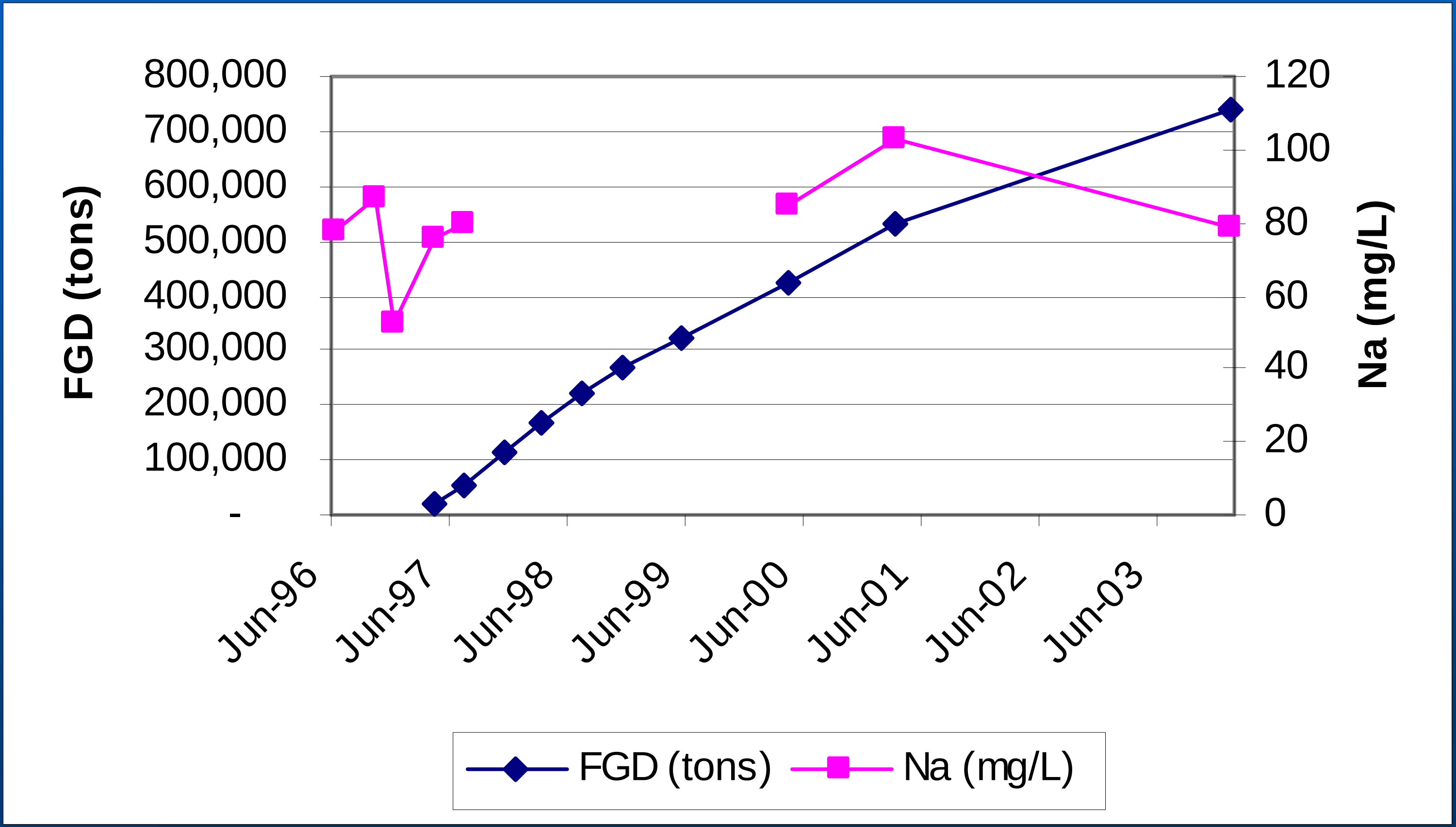
Raw Water, Mettiki Mine: Nickel



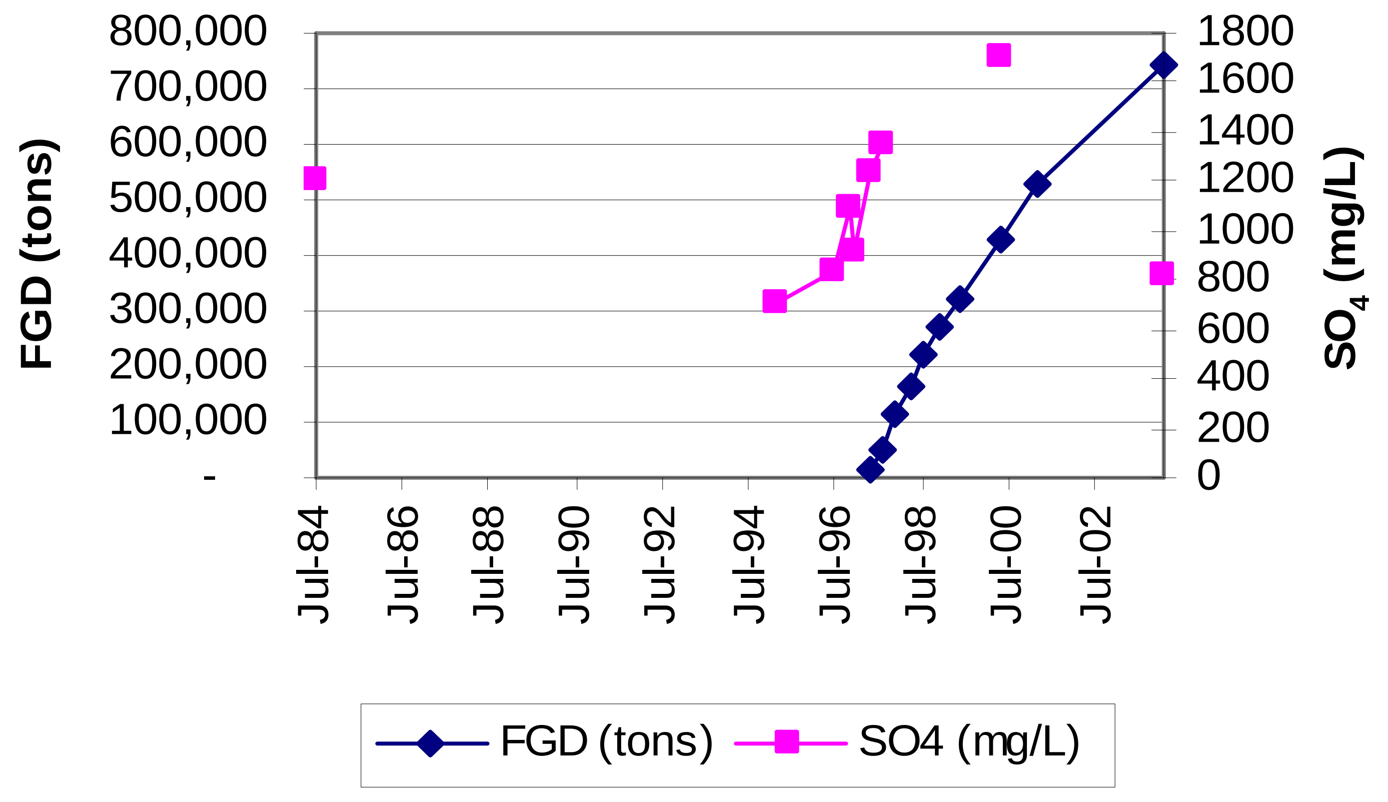
Raw Water, Mettiki Mine: Zinc



Raw Water, Mettiki Mine: Sodium



Raw Water, Mettiki Mine: Sulfate



Lab predictions vs. Mine 0bservations: 0=no change, inc.=increase, dec.=decrease

	Lab	Mine		Lab	Mine
As	0	0	Ba	inc	0
Sb	0	0	Cd	inc.	0
Be	0	0	Hg	inc	0
Cr	0	0	Al	inc	dec.
Cu	0	0	Fe	inc	dec.
Ag	0	0	Ni	0	dec.
V	0	0	Zn	inc	dec.
Tl	0	0	Ca	inc	inc.
Pb	0	0	SO4	inc	inc.
Se	0	0	Co		dec.
Mg	0	0	Cl		inc.
Mn	0	0	K		inc.
B		0	Na		inc.

Conclusions-AMD Treatment

(mindful that the laboratory and field studies looked at different FGD types)

- Field application of FGD treated AMD: It raised pH and brought Fe and Al into compliance
- FGD application did not bring Mn below 2.5 mg/L
- FGD application did not cause groundwater quality deterioration

Conclusions: Laboratory vs. Field Observations

- Tended to over estimate field leachate concentrations
- Lab study used DI water vs. AMD in field
- Agreed with field observations for 14 of 21 elements
- pH, redox and sorption phenomena in the mine probably accounted for most of the discrepancies between lab and field
- Only components of soluble salts increased in the mine: Ca, SO_4, Na, K, Cl

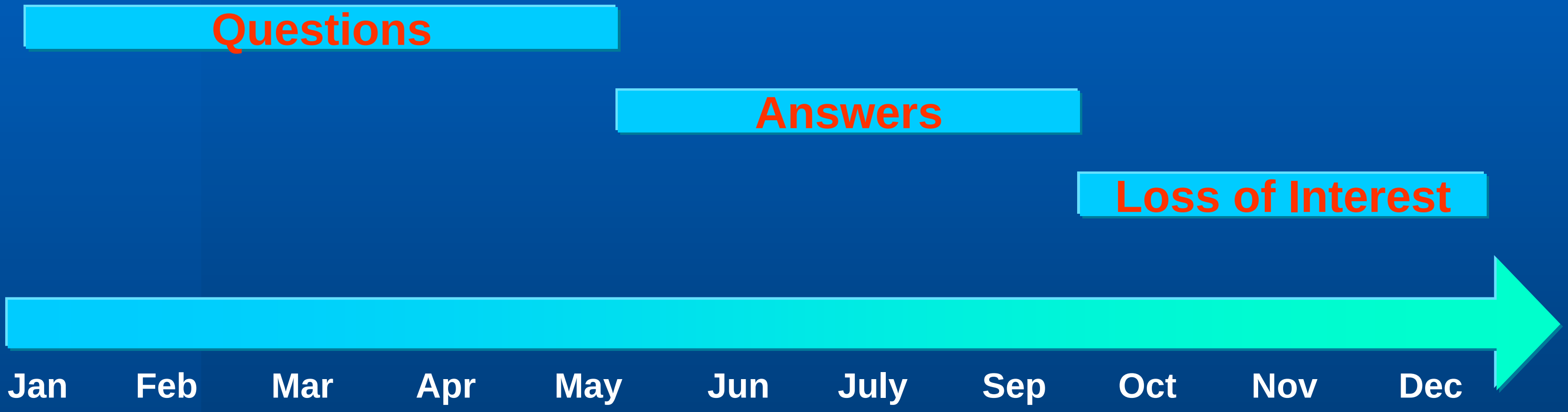
Overall Conclusion:

- Application of 740,000 tons of FGD at the Mettiki A, B and C mines between 1997 and 2004 treated AMD parameters and other metal ions without increased risk of contamination from other elements

- Increases were limited to soluble salt constituents: Ca, Na, K, Cl and SO_4 without approaching regulatory limits

Schedule

- **High-level scientific milestones:**



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Paul Ziemkiewicz
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FGD FOR HIGHWALL RECLAMATION

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Columbus, Ohio

Abstract

Ohio has over 100,000 acres of abandoned mine land (AML) in need of major reclamation efforts. Dangerous highwalls, acid mine drainage, and silt-laden runoff are just some of the problems associated with such sites. The AML trust fund, maintained from fees paid by active mining companies, has enabled some land in Ohio to be reclaimed, but conventional reclamation can rarely be justified due to the high cost.

An abandoned highwall in Coshocton County that is 1,800 feet long and up to 140 feet high, is being backfilled and reclaimed using alkaline flue gas desulfurization (FGD) residue produced at the Conesville Generating Station. Water emerging from the augered coal seam at the base of the abandoned highwall is acidic. Backfilling will reduce air and water infiltration and thereby reduce the quantity and improve the quality of runoff from the site.

Prior to the start of construction, a toxicity characteristic leaching procedure (TCLP) test was performed on the FGD residue using acidic seepage from the site to generate leachate for analysis. The results justified the use of the FGD fill for reclamation purposes. As scrubbers continue to be built to reduce air emissions at power plants, the use of FGD residue offers a cost effective way to reclaim abandoned highwalls. Performance monitoring data developed from the reclaimed highwall in Coshocton County can be used to document the benefits of such reclamation practices.

Background

Raw coal is processed at a coal preparation plant located adjacent to the Conesville Generating Station of American Electric Power Service Corporation. Coal refuse produced at the preparation plant is disposed in a refuse fill that is reclaimed in stages as the fill is completed. Runoff from the refuse disposal site mixes with runoff and acidic seepage from an abandoned surface mine and is collected in ponds for treatment before being discharged.

Flue gas desulfurization (FGD) residue from the Conesville Generating Station is used to aid in the reclamation of the refuse fill. Based on the successful use of the FGD residue in reclamation of the refuse fill, a plan was developed for also using it to reclaim the abandoned surface mine at the site to reduce the generation of acid mine drainage and eliminate the safety hazards associated with the exposed highwall. The presence of the existing water treatment system provides a unique opportunity to demonstrate the potential use of FGD residue to reclaim abandoned mine land with little risk of off-site impacts.

Existing Conditions

The abandoned surface mine selected for reclamation is bound on one side by a highwall that is up to 140 feet high and 1,800 feet long. On the opposite side, the site is bound by a spoil bank. Water discharging from the surface mined and partially augered coal seam at the base of the highwall mixes with surface runoff from the 30-acre surface mine, resulting in water with a pH of about 3. The quantity of acidic water discharging from the abandoned surface mine varies with rainfall and averages about 100 gallons per minute. A photograph of the abandoned surface mine prior to backfilling is shown in Figure 1.

Figure 1. Abandoned mine land with exposed highwall and acidic seepage at base of highwall prior to backfilling and reclamation using FGD residue.

Toxicity Characteristic Leaching Procedure (TCLP) Testing

Raw water from the acidic seeps was used in toxicity characteristic leaching procedure (TCLP) testing of the FGD residue to generate leachate for analysis. Results of the leachate analysis, as compared to the water quality of the raw acidic seepage, are presented in Table 1. Based on those results, FGD residue was judged as suitable backfill material. Engineering design analyses were then performed to assess the anticipated performance of the highwall backfilled with FGD residue.

Table 1. Results of TCLP testing of Conesville FGD residue using acidic seepage for leaching. Water quality of the acidic seepage prior to leaching is included for comparison.

Constituent	Concentration, mg/l	
	TCLP of FGD Residue	Raw Acidic Seepage
Antimony, Sb	<0.005	<0.005
Arsenic, As	0.016	<0.004
Barium, Ba	0.299	0.012
Beryllium, Be	0.0003	0.0043
Boron, B	1.02	0.15
Cadmium, Cd	<0.0005	<0.0005
Chromium, Cr	0.008	0.007
Cobalt, Co	<0.002	0.101
Copper, Cu	0.001	0.01
Lead, Pb	<0.002	0.004

(Table 1 continued).

Constituent	Concentration, mg/l	
	TCLP of FGD Residue	**Raw Acidic Seepage**
Mercury, Hg	<0.0002	<0.0002
Nickel, Ni	<0.003	0.188
Selenium, Se	0.009	0.005
Silver, Ag	<0.0002	<0.0002
Thallium, Tl	<0.02	0.002
Tin, Sn	<0.005	<0.005
Vanadium, V	0.011	<0.003
Zinc, Zn	<0.004	0.429

Highwall Backfill Design

The backfill for the highwall reclamation was designed for placement in 2-foot thick lifts and compaction using the hauling and spreading equipment. Additional consolidation of the FGD fill is predicted at the level of the coal seam due to the weight of the overlying fill. Approximately 1 million cubic yards of FGD residue will be used in the backfilling process.

After backfilling is completed, the exposed FGD residue will be covered with a minimum of 12 inches of soil and vegetated. Afterwards, drainage from the site will be diverted away from the toe of the fill where acidic seepage discharges. Currently, the acidic seepage from the coal seam mixes with surface runoff, increasing the quantity of acidic water generated at the site. After reclamation, the diversion of surface runoff away from the acidic seepage will greatly reduce the quantity of acidic water requiring treatment.

Results of Seepage Analyses

Finite element seepage analyses were performed for existing conditions and for conditions that will exist after backfilling. Hydraulic conductivity values used in the seepage analyses are presented in Table 2.

Table 2. Hydraulic conductivity values used in seepage analyses.

Material	Hydraulic Conductivity, feet per minute	
	Vertical Hori	**zontal**
FGD Residue	2×10^{-6}	1.8×10^{-5}
Mine Spoil	2×10^{-4}	1.8×10^{-3}
Bedrock	2×10^{-6}	1.8×10^{-5}
Coal	2×10^{-5}	1.8×10^{-4}

Figure 2 shows the finite element grid used in the modeling. As shown by the results presented in Figure 3, the model predicts that the coal seam is only partially saturated prior to backfilling. The modeling shown in Figure 4 predicts that backfilling will enable the coal seam to remain saturated, which will reduce exposure of the coal to air and thereby reduce the potential for generation of acidic seepage. The modeling was performed using the computerized method, SEEP/W as developed by Geo-Slope International, Ltd.

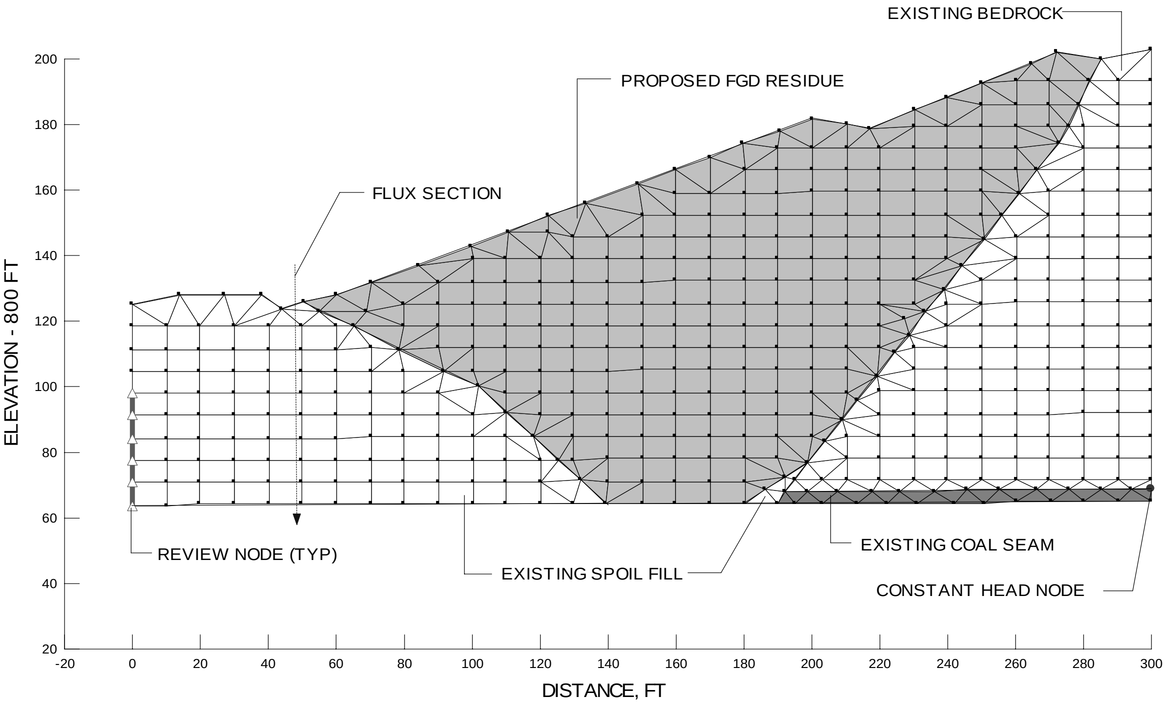


Figure 2. Finite element seepage analysis grid used to model effects of highwall backfilling using FGD residue.

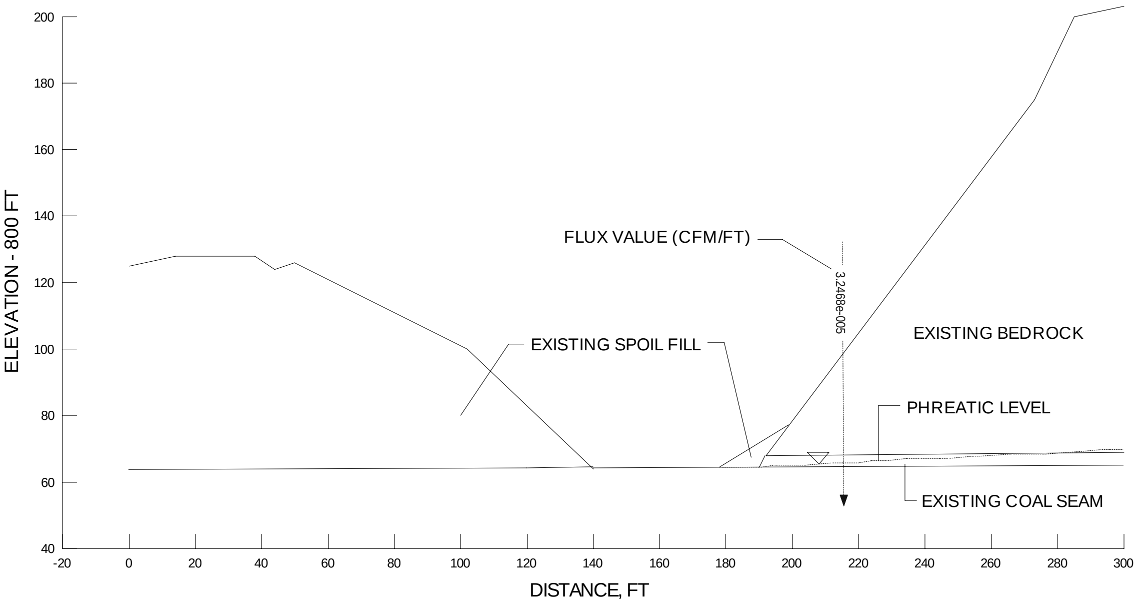


Figure 3. Results of finite element modeling of seepage prior to backfilling illustrating partial saturation of coal seam at base of highwall.

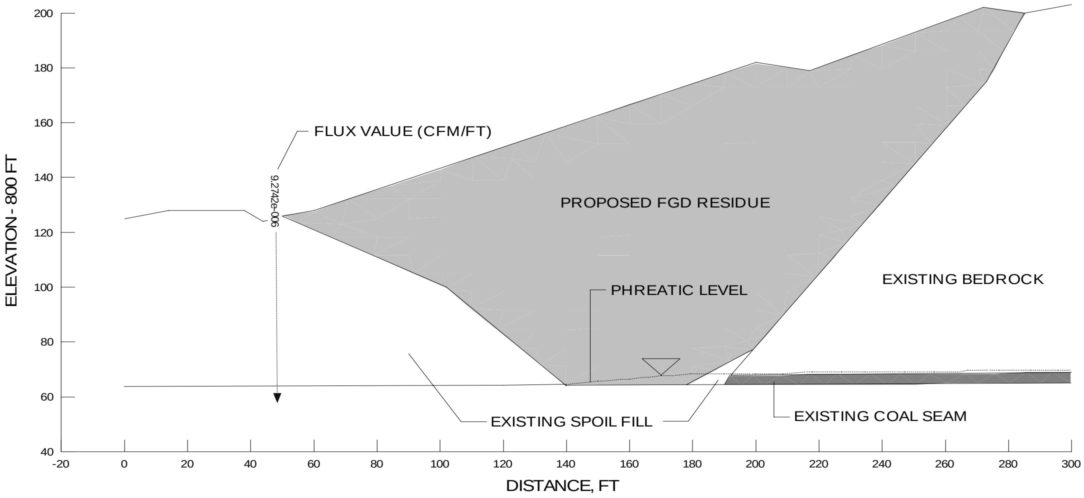
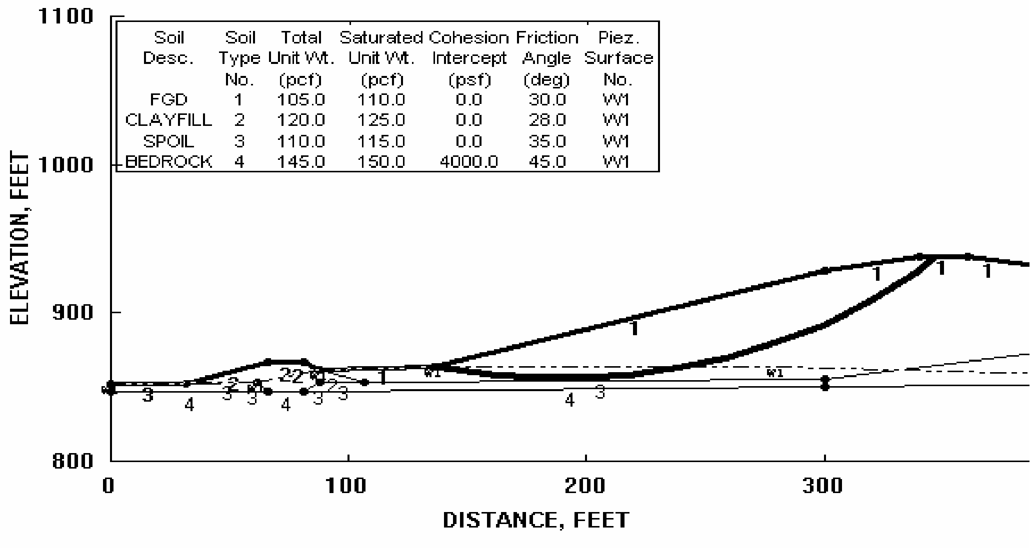


Figure 4. Results of finite element modeling of seepage after backfilling with FGD residue illustrating saturation of the coal seam at the base of the highwall.

Results of Stability Analyses

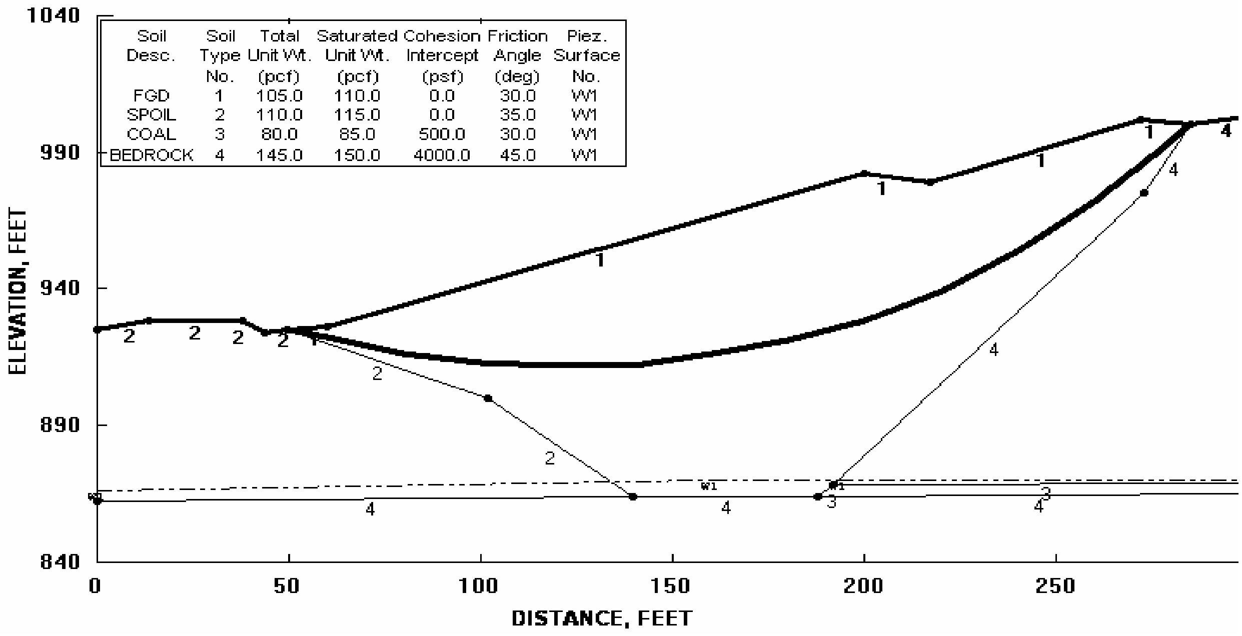
Slope stability analyses were performed for critical profiles of the reclaimed highwall. The Conesville FGD residue exhibits considerable apparent cohesion due to pozzolanic reactions after placement. However, because saturation of the lower portion of the backfill can occur, apparent cohesion was conservatively ignored in the stability analyses.

Figure 5 shows the results at Profile A-A (i.e. parallel to highwall) and Figure 6 shows the results at Profile B-B (i.e. perpendicular to highwall). Factors of safety in excess of 1.5 were determined from the stability modeling. The analyses were performed using the computerized method, PCSTABL, developed by Purdue University. Strength parameters for the various materials are shown on each of the respective figures.



Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
FGD	1	105.0	110.0	0.0	30.0	W1
CLAYFILL	2	120.0	125.0	0.0	28.0	W1
SPOIL	3	110.0	115.0	0.0	35.0	W1
BEDROCK	4	145.0	150.0	4000.0	45.0	W1

Figure 5. Results of slope stability analysis for Profile A-A of FGD residue backfill (i.e. referenced parallel to highwall) with factor of safety = 1.6.



Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
FGD	1	105.0	110.0	0.0	30.0	W1
SPOIL	2	110.0	115.0	0.0	35.0	W1
COAL	3	80.0	85.0	500.0	30.0	W1
BEDROCK	4	145.0	150.0	4000.0	45.0	W1

Figure 6. Results of slope stability analysis for Profile B-B of FGD residue backfill (i.e. referenced perpendicular to highwall) with factor of safety = 1.7.

Observations and Conclusions

Figure 7 shows the progress toward backfilling the highwall. As sections of the backfill are completed, they will be covered with soil and vegetated. Because the FGD residue is alkaline and non-toxic, a minimum of 12 inches of soil thickness will provide a suitable medium to allow vegetation to establish.

After vegetation is established, runoff from the reclaimed face will be diverted by ditches away from the acidic seepage emerging from the unmined portion of the coal seam at the site. Acidic seepage may still be generated, but at a much lower rate. Because the seepage will continue to be collected and treated, the highwall reclamation project at Conesville offers a unique opportunity to monitor and document the benefits of using FGD residue to reclaim abandoned mine land.

Ohio has over 100,000 acres of abandoned mine land (AML) in need of major reclamation efforts. Dangerous highwalls, acid mine drainage, and silt-laden runoff are just some of the problems that can be mitigated using FGD residue as backfill material on AML sites. American Electric Power Service Corporation is funding the reclamation effort at Conesville at no cost to taxpayers and without assistance from the AML trust fund that is maintained by active mining companies, and managed by the U.S. Office of Surface Mining, to reclaim abandoned mine sites. For power plants located near abandoned mine land, the use of FGD backfill to aid in reclamation is prudent when compared to disturbing virgin sites to build FGD landfills.

Figure 7. Photograph of abandoned mine site being backfilled and reclaimed using FGD residue.

Barry Thacker, P.E. is president of Geo/Environmental Associates, Inc., a consulting engineering firm in Knoxville, Tennessee. He is also founder of the Coal Creek Watershed Foundation, Inc., a non-profit watershed restoration group. Mr. Thacker holds a BS and MS in civil engineering from the University of Louisville and has published over 50 articles on engineering, watershed restoration, and regulatory compliance topics. He is a registered professional engineer in 12 states and received the 2003 Hoover Medal from an international consortium of engineering societies for his civic and humanitarian achievements.

Session 2

LEACHATE PROTOCOLS FOR HYDROLOGIC ASSESSMENT

Session Chairperson:
Debra Pflughoeft-Hassett
University of North Dakota
Energy & Environmental Research Center
Grand Forks, North Dakota

Development of a Standard Guide for Selection of a Leaching Protocol
Debra Pflughoeft-Hassett, University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota

Comparing Laboratory and Field Leaching of Coal Combustion By-Product Constituents
Dr. Ishwar P. Murarka, ISH Inc., Raleigh, North Carolina and Linda Lee, Purdue University, West Lafayette, Indiana

Field Leachate Characterization at Coal Combustion Product Management Facilities
B. Hensel, Natural Resource Technology, Inc., Pewaukee, Wisconsin and K. Ladwig, Electric Power Research Institute, Palo Alto, California

Leaching of Trace Elements from Soils Stabilized with Coal Fly Ash
Craig Benson and Tuncer B. Edil, Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin and Sazzad Bin-Shafique, Department of Civil and Environmental Engineering, The University of Texas-San Antonio, San Antonio, Texas

Solubility of FGD Gypsum Using a Continuously Stirred Tank Reactor
Dr. Candace Kairies, Karl T. Schroeder, Robert L. Thompson, Carol Cardone, and Paul Rohar, ORISE Faculty Fellow, U.S. DOE/NETL, Pittsburgh, Pennsylvania

An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials

Dr. David Kosson, Hans A. van der Sloot, Florence Sanchez, Andrew C. Garrabrants, Rob Keeney, Susan Thorneloe, Vanderbilt University, Nashville, Tennessee, ECN, Petten, The Netherlands, ARCADIS, U.S. EPA Office of Research and Development, Research Triangle Park, North Carolina

DEVELOPMENT OF A STANDARD GUIDE FOR SELECTION OF A LEACHING PROTOCOL

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University of North Dakota, Energy & Environmental Research Center
Grand Forks, North Dakota

View Presentation

Abstract

Many industrial resources have existing and developing markets in a wide variety of applications, including raw feed materials to other processes, components of building materials, and geotechnical materials. The use, reuse, and recycling of these industrial resources is generally considered a preferred management option to disposal. Many industrial resources are required to be evaluated for their potential to release contaminants into the environment. In the U.S. Environmental Protection Agency (EPA) Public Meeting on Development of New Waste Leaching Procedures under the Resource Conservation and Recovery Act (RCRA) Program in July 1999, it was indicated that leaching tests are likely still the best means of evaluating large volume wastes given the great uncertainties associated with both fate and transport models and health impact values. EPA summarized the issues associated with the toxicity characteristic leaching procedure (TCLP), which is based on a co-disposal mismanagement scenario where it is assumed the industrial resource in question will be disposed of in a sanitary landfill. While the TCLP may be appropriate for evaluating materials that are to be disposed of in sanitary landfills, the intent for the use of the TCLP is not consistent with use scenarios for industrial resources under most conditions. However, many states recommend or require that the TCLP be used in evaluating industrial resources that are intended for use, especially if the material is to be land-applied. While other leaching methods, developed and used for a variety of purposes, are available as options for characterizing industrial resources, identifying the most appropriate leaching method for a given industrial resource in a use application is frequently not based on relevant scientific criteria. An effort has been initiated by the ASTM (American Society for Testing and Materials) International E50 Committee on Environmental Assessment to develop a standard guide that delineates the steps for identifying and selecting a laboratory leaching procedure(s) for evaluating the potential environmental performance of industrial resource materials that are used, reused, and/or recycled. The guide will provide a logical sequence of criteria to aid chemists, laboratory analysts, and others in selecting one or more leaching procedures that will allow the development of scientifically valid and legally defensible data on environmental performance of industrial resources. Industrial resources are defined as products, by-products, co-products, or other materials that result from industrial activities, including power production, metal casting, metal refining, and paper or wood product manufacture.

Introduction

Leaching is a tool that has been used to facilitate appropriate management of coal combustion by-products (CCBs) and other industrial resources. While leaching is still likely the best tool available to evaluate large-volume industrial resources because of the uncertainties associated with both the fate and transport models and the health impact values, the means of selection of appropriate leaching procedures for these types of materials has not been developed. The stated uses of data from leaching tests range from use in groundwater or health impact models to simple comparison with existing limits developed for regulatory purposes. This range of uses has been instrumental in the development of a nearly overwhelming number of leaching procedures. Merit can be found in most published leaching procedures depending on how it is applied, to what material it is applied, and how the data are used and interpreted. What is missing for CCBs and other industrial resources is a means by which producers and users can select the appropriate leaching method and justify the method selection to ensure appropriate use of the material in the environment.

Scope of the Standard Guide

The standard guide delineates the steps for identifying and selecting a laboratory leaching procedure(s) for evaluating the potential environmental performance of materials that are used, reused, and/or recycled. This guide provides a logical sequence of criteria to aid chemists, laboratory analysts, and others in selecting one or more leaching procedures that will allow the development of scientifically valid and legally defensible data on the environmental performance of industrial resources. Industrial resources are defined as products, by-products, coproducts, or other materials that result from industrial activities, including power production, metal casting, metal refining, and paper or wood product manufacture.

Many industrial resources have existing and developing markets in a wide variety of applications, including raw feed materials to other processes, components of building materials, and geotechnical materials. The use, reuse, and recycling of these industrial resources are generally considered preferred management options to disposal, and most industrial resources have been evaluated to ensure that their performance in the application of choice is equal or superior to its competing materials whether those be other industrial resources or virgin materials. Many industrial resources also need to be evaluated for their potential to release contaminants into the environment in which they are used or where the end product is ultimately disposed of. This standard provides guidance in the selection of the appropriate leaching standard.

Laws and regulations governing the use of industrial resources may vary by state. The user of this standard has the responsibility to determine and comply with applicable requirements.

Significance and Use of the Standard Guide

In the EPA Public Meeting on Development of New Waste Leaching Procedures under the RCRA Program in July 1999, it was indicated that leaching tests are likely still the best means of evaluating large-volume wastes, given the large uncertainties associated with both the fate and transport models and the health impact values. EPA summarized the issues associated with the TCLP which is based on a co-disposal mismanagement scenario where the waste in question is assumed to be disposed of in a sanitary landfill. While TCLP may be appropriate for evaluating wastes that are to be disposed of in sanitary landfills, the intent for the use of the TCLP is not consistent with use scenarios for industrial resources under most conditions. However, many states recommend or require that the TCLP be used in evaluating industrial resources that are intended for use rather than disposal before the material can be used. This is especially true if the industrial resource is to be land-applied in any application. The use of TCLP, while inappropriate in these scenarios, is commonly applied because many of these materials are or have previously been characterized as wastes for disposal.

Many leaching methods have been developed and used for a variety of purposes, and complete listings of the methods available have been published by the American Coal Ash Association, the National Energy Technology Laboratory, and others. Many of the standard and published leaching methods have been developed for use on materials that will be used rather than disposed.

Sorini (1) categorized leaching methods according to the physical manipulations required in the methods and indicated that 70+ methods were published and could be applied to CCBs. Kim et al. (2) also summarized published leaching methods that could be useful in characterization of CCBs. Kim included regulatory methods and methods published by standards-setting organizations such as ASTM, EPA, ISO, and ANSI. Figure 1 provides a list of some leaching test methods that may be applied to CCBs.

- D3987-85(2004) Standard Test Method for Shake Extraction of Solid Waste with Water (3)
- D4793-93(2004) Standard Test Method for Sequential Batch Extraction of Waste with Water (4)
- D5284-93(2004)e1 Standard Test Method for Sequential Batch Extraction of Waste with Acidic Extraction Fluid (5)
- D6234-98(2002) Standard Test Method for Shake Extraction of Mining Waste by the Synthetic Precipitation Leaching Procedure (6)
- D4874-95(2006) Standard Test Method for Leaching Solid Material in a Column Apparatus (7)
- EPA Method 1312 Synthetic Precipitation Leaching Procedure (SPLP) (8)
- EPA Method 1320 Multiple Extraction Procedure (MEP) (9)

Figure 1. Leaching methods for CCBs.

Leaching is an empirical laboratory tool that provides data on the mobility or solubility of specific (or sets of specific) components present in the material being evaluated. Laboratory leaching tests do not provide predictive data that will indicate the concentration of any component in any environment. While some tests allow the leaching protocol to simulate approximate environmental conditions, the data should still not be considered predictive. More appropriately, the leaching data should be used in fate and transport (F&T) models. Of course, F&T models have limitations and may not adequately model the formation of secondary hydrated phases such as those that occur when moderate- to high-calcium fly ash is exposed to water (10, 11). It is important that leaching data be evaluated appropriately by experienced individuals to allow the best decision making regarding the material being evaluated. The standard under development will simply provide an additional tool that will allow environmental professionals to select a leaching test that will provide the most appropriate information on a specific material for a given application.

Summary

A standard guide that delineates the steps for identifying and selecting a laboratory leaching procedure(s) for evaluating the potential environmental performance of industrial resource materials that are used, reused, and/or recycled is in preparation. Numerous groups, including researchers, CCB producers and users, and other industrial resource producers and users have been invited to participate in the development of the standard. A formal draft is anticipated for first subcommittee ballot in 2007.

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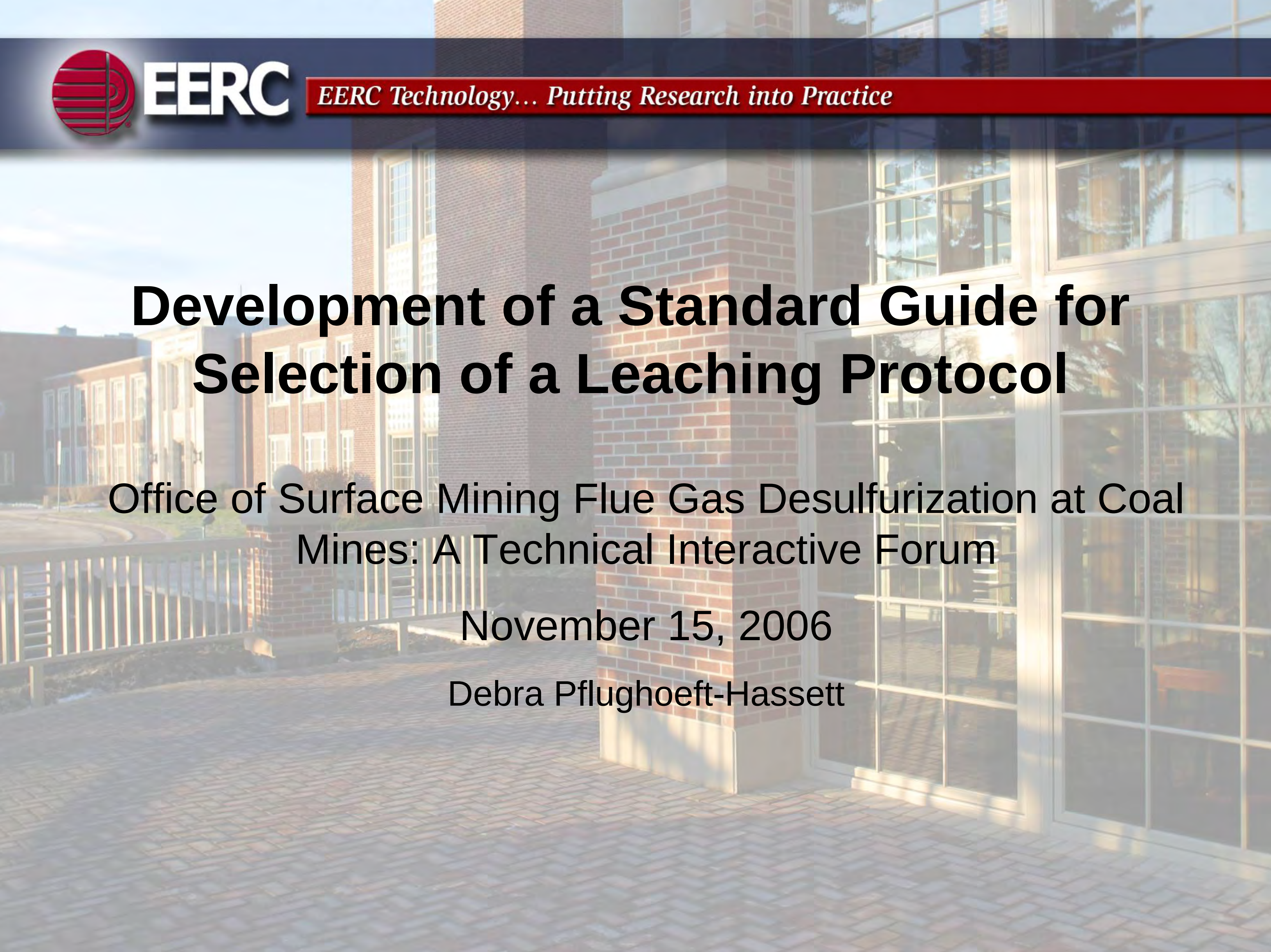
Ms. Debra Pflughoeft-Hassett is a Senior Research Advisor and the Program Manager for the Coal Ash Research Center at the EERC. Prior to her current position at the EERC, Ms. Pflughoeft-Hassett has performed CCB research related to characterization, regulation, and marketing. She has also worked on projects assessing environmental impacts of CCB management. She manages the research effort of the Coal Ash Resources Research Consortium® (CARRC®) and other CCB research at the EERC and has been instrumental in developing ASTM International standards for CCB use applications. Ms. Pflughoeft-Hassett is a member of several professional organizations, including the ASTM Committee on Environmental Assessment, Risk Management, and Corrective Action. In addition, she has co-authored over 100 publications. She received her BS in chemistry from the University of North Dakota in 1982.



EERC *EERC Technology… Putting Research into Practice*

Development of a Standard Guide for Selection of a Leaching Protocol

Office of Surface Mining Flue Gas Desulfurization at Coal Mines: A Technical Interactive Forum

November 15, 2006

Debra Pflughoeft-Hassett

Why Is Leaching so Important to the Use of CCBs?

- Leaching tests are used to address regulatory requirements to evaluate industrial resources for potential to release contaminants into the environment.
- Leaching tests are the best means of evaluating industrial resources because of the high level of uncertainty associated with both fate and transport models and health impact values.

Available Leaching Tests

- Summaries of documented leaching tests exist:
  - Sorini, S.S., A Summary of Leaching Methods. Prepared for American Coal Ash Association. April 1997. 73 pp. **(summarized 70+ tests)**
  - Kim, A.G., Leaching Methods Applied to CUB: Standard, Regulatory, and Other. Proceedings of the 15th International American Coal Ash Association Symposium on Management & Use of Coal Combustion Products; January 2003. (**indicated availability of 100+ tests)**

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Leaching Test Categories

- Sorini categorized by:
  - Agitated/nonagitated.
  - Sequential/concentration buildup/serial batch.
  - Flow-around/flow-through.
  - Multiple procedures.
- Kim categorized by:
  - Regulatory (to determine compliance).
  - Standard (ASTM, EPA, ISO, ANSI).
  - Research.

Examples of Standard Tests

- D3987-85(2004) Standard Test Method for Shake Extraction of Solid Waste with Water
- D4793-93(2004) Standard Test Method for Sequential Batch Extraction of Waste with Water
- D4874-95(2001) Standard Test Method for Leaching Solid Material in a Column Apparatus
- D6234-98(2002) Standard Test Method for Shake Extraction of Mining Waste by the Synthetic Precipitation Leaching Procedure
- EPA Method 1312 Synthetic Precipitation Leaching Procedure (SPLP)
- EPA Method 1320 Multiple Extraction Procedure (MEP)
- EPA Method Monofill Waste Extraction Procedure (MWEP)

Leachability ≠ Predictability

- EPA indicated there is great uncertainty associated with the fate and transport models.
- Leaching tests provide data for F&T models, sometimes incomplete or incorrect data.
- Leaching data should not be considered generically predictive of a material in the environment.

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Why Develop a Leaching Selection Standard?

- Leaching is a valid tool.
- Historical laboratory and field data are available.
- Good leaching procedures are available.
- Compliance issues need to be addressed appropriately.
- Use of the standard should facilitate the perception of “industrial resource” rather than “waste.”

Development of a Leaching Selection Standard

- ASTM International standards have always been upheld in court.
- Enlist assistance from individuals involved in management of industrial resources to prepare the draft.
- Enlist appropriate reviewers.
- Follow the ASTM consensus process.

Scope of Draft Standard Guide

- Industrial resources are defined as products, by-products, coproducts, or other materials that result from industrial activities, including power production, metal casting, metal refining, paper or wood product manufacture.
- Steps to identify and select a laboratory leaching procedure(s) for evaluating the potential environmental performance of materials that are used, reused, and/or recycled will be described.

Scope of Draft Standard Guide (continued)

- A logical sequence of criteria to aid selection of one or more leaching procedures that will allow the development of scientifically valid and legally defensible data on environmental performance of industrial resources will be included.

Significance and Use of the Standard Guide

- TCLP is not consistent with use scenarios for industrial resources under most conditions.
- At least some leaching methods have been developed for use on materials that will be **used**.
- Treating materials as resources with appropriate testing will facilitate utilization.

Significance and Use of the Standard Guide

- EPA indicated a willingness to accept leaching methods other than TCLP if a justification for method selection is made.

- The proposed standard guide will serve to provide the justification for EPA and state regulatory authorities.

Summary

- Researchers and CCB/industrial resource groups have been notified and have indicated varying levels of interest.
- Preliminary Standard Guide on Leaching Procedure Selection is in preparation.
- Draft standard will be routed, reviewed, and modified.
- A formal draft anticipated for first subcommittee ballot in 2007.

COMPARING LABORATORY AND FIELD LEACHING OF COAL COMBUSTION BY-PRODUCT CONSTITUENTS

Dr. Ishwar P. Murarka
ISH Inc.
Raleigh, North Carolina
and
Prof. Linda Lee
Purdue University
West Lafayette, Indiana

View Presentation

Abstract

Four commonly used laboratory leachate tests were compared with field leachate concentrations from actual wells placed within an ash fill in a surface mine pit. The ash was placed in the pit over a ten year period. The laboratory leachate methods included:

- 18-hour leaching test for ash samples using 20 to 1 liquid to solid extraction
- 30-day leaching test for ash samples using 20 to 1 liquid to solid extraction
- 4-hour to 14-day leaching test for ash samples using 4 to 1 liquid to solid extraction to simulate a typical landfill situation
- 24-hour leaching test for 10 to 17 sequential extractions using 4 to 1 liquid to solid extraction

Constituents that were measured in these tests included: aluminum, arsenic, boron, calcium, molybdenum, and sulfur. The authors conclude from the results that the laboratory leaching methods used for this study did not provide accurate leachate concentration values for aluminum, boron, calcium, and sulfur/sulfate when compared to field scale values in an ash landfill. Laboratory leaching test results are similar or somewhat higher for arsenic leachate concentrations. In future studies, more thought must be given to the potential for harmful leachate concentrations to be transported away from the disposal site. In this landfill situation, this is not the case. At best, laboratory leachate tests only provide part of the picture of environmental migration of constituents from a landfill. Migration involves leachate generation potential as well as attenuation mechanisms during the transport in the subsurface. Additional methods beyond leaching tests must be employed in order to make a determination of the potential for off-site contamination.

CCB Constituents of Interest

This paper is about the relationship between laboratory leachate data and water quality monitoring in the field where coal combustion by-products (CCBs) have been deposited in a fill. Although many people talk about testing coal ash for every element in the periodic chart, this is not necessary. There are really only a few elements that need to be tested to evaluate the potential for CCBs to leach constituents that would be a potential ground water pollution problem. In our opinion there are actually about 12 elements of potential concern. Arsenic is of concern because it is a household word for health concerns. Aluminum is an indicator of certain chemical conditions associated with coal combustion facilities. Boron is a key indicator of CCB leachate. Calcium is a very important indicator of chemical conditions related to water quality. Molybdenum that is not always present when CCBs are present but it is another element that can be very meaningful, when present, to the overall water chemistry. There are also regulatory concerns when molybdenum is present. Sulfur or sulfate, depending upon the type of chemical analysis employed, is an indicator of water quality associated with coal combustion products.

General Considerations Concerning Leachate Testing

When we talk about CCB constituents with the potential to leach and migrate into the environment, we need to consider all of the chemical, physical, and biological factors and processes involved. Leachate produced in the field is the result of the combination of all of these factors and processes. Concerning laboratory leaching procedures, we are trying to approximate the field conditions in a controlled environment which means we can only simulate a small number of environmental factors and processes. So at best, laboratory results will be able to account for some, but not all, of the complexity found in all field environments. There are a large number of leachate tests available and they are all accurate within the limitations of the individual test assumptions. The question we have to ask is: what is the specific purpose or objective in conducting a specific leachate test? The importance of choosing a specific leachate test is to appropriately match the capabilities of the test with the specific objective for requiring a leaching test. Because of the potential complexity of many field situations, there may not be a perfect leachate test available to fully characterize possible field leachate conditions. There are three basic types of leachate tests that could prove useful namely: (1) batch tests with a single extraction; (2) batch tests with sequential/multiple extractions; and (3) column tests.

Factors Involved in Leaching of Chemicals from Solids

Every chemical does not behave the same way in the solid matrix being tested. This is why we need to focus on the chemicals of greatest concern. The mineralogy of the fill material may be crystalline or non-crystalline powdery amorphous material. This will affect the leaching chemistry and the test results. We need to know the chemical composition of the leachate fluid. What is the pH, the redox, the iron content, is it buffered, etc.? We need to be concerned about the contact time between the liquid and solid matrix. Will we need to run the test for 18 hours, 36 hours, 72 hours, 200 hours, or 5 days? Is the liquid to solid ratio 4:1, 20:1, or 100:1? All of these different test conditions provide meaningful information, but the question is the interpretation of the result based on the objectives of the tests. We also need to be aware of the chemical reactions that will occur in the liquid phase such as precipitation/dissolution reactions, adsorption/desorption reactions to solid materials, redox reactions, and pH.

Methods Used in this Study

This study evaluated and compared results from several different types of leachate tests with samples collected from ground water wells that collected leachate in the field where CCBs had been placed. The data collected for this study used the following methods of leachate testing and sample collection.

- 18-hour leaching test for ash samples using 20 to 1 liquid to solid extraction
- 30-day leaching test for ash samples using 20 to 1 liquid to solid extraction
- 4-hour to 14-day leaching tests for ash samples using 4 to 1 liquid to solid extraction to simulate a typical landfill situation
- 24-hour leaching test for 10 to 17 sequential extractions using 4 to 1 liquid to solid extraction
- Field scale data from three leachate wells in the deposited fly ash in a landfill

Constituents that were measured in ash for these tests included:

• Aluminum	7,373 mg/Kg or ppm
• Arsenic	64 mg/Kg or ppm
• Boron	241 mg/Kg or ppm
• Calcium	5,755 mg/Kg or ppm
• Molybdenum	5 mg/Kg or ppm
• Sulfur	525 mg/Kg or ppm

Results

Table 1 shows the laboratory results comparing the 18-hour and 30-hour tests. These data summarize about 20 tests conducted over a number of years. This would represent the real world as the fly ash would be expected to exhibit a range of characteristics as a result of changes in power plant operations over the years in terms of coal supply and operating conditions. The mean values show very little variability between the two tests.

Table 1. Laboratory Leachate Concentrations.

Chemical	18-Hour Test (mg/L)			30-Day Test (mg/L)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Aluminum	1.1	18	3.43	0.23	11	2.73
Arsenic	ND	1.3	0.29	ND	0.86	0.3
Boron	1.1	5.5	2.65	1.4	7.9	3.39
Calcium	33	49	40.75	35	50	40.5
Sulfate	16	2500	135.5	ND	160	57

Table 2 shows the field leachate concentrations for the CCB landfill. A comparison of data between the laboratory values and the field values shows that, except for boron and sulfate, the mean values for the other chemicals are similar to the mean values for the laboratory tests. You will notice that Arsenic values are lower in the field leachate (0.01 – 0.09) than in the laboratory tests (0.29-0.3) in these two wells but is very similar to the laboratory results in a third well. Boron values are significantly higher in the field leachate (39-81.9) than the laboratory tests (2.65-3.39). Sulfate values are significantly higher in the field leachate (1336-1536) than the laboratory tests (57-135.5). This means that boron and sulfate are significantly underestimated by these laboratory tests but not arsenic.

Table 2. Field Leachate Concentrations.

Chemical	CB 1S (mg/L)			CB 1D (mg/L)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Aluminum	ND	0.6	0.15	0.4	3.34	1.03
Arsenic	ND	0.03	0.01	0.07	0.10	0.09
Boron	69.9	110	81.9	27	47	39
Calcium	538	660	607	450	790	669
Molybdenum	0.06	0.33	0.21	3.6	6.9	5.66
Sulfate	700	2080	1536	845	1850	1336

Table 3 shows field and kinetic leachate concentrations for the CCB landfill. The kinetic tests show that as the ash materials were leached from 4 hours to 10 days that the concentrations for each of the elements increased with leaching time. The concentration of arsenic went from 2 to 3 ppm. The concentration of boron went from 11 to 17 ppm but it is still not high enough to correspond to the average concentration in the field leachate (39-82). We find the same situation on sulfate that went from 300 to 340 ppm while the field leachate for sulfate is close to 1,800 ppm which is very close to solubility of pure gypsum.

Table 3. Field and Kinetic Leachate Concentrations.

Chemical	MW-8 (mg/L)			Kinetic Tests (mg/L)	
	Minimum	Maximum	Mean	Minimum	Maximum
Aluminum	ND	1.31	0.52	0.99	1.34
Arsenic	0.13	0.26	0.20	0.19	0.33
Boron	45	82.6	52	11.48	17
Calcium	580	810	703	145.6	183.6
Molybdenum	0.52	2.34	1.26	--	--
Sulfate	1400	3800	1798	300	340.5

Long-Term Field Leaching Results

The long term field data for arsenic from 1997 to 2006 (figure 1) show consistently different leachate levels based on different locations at the site. For arsenic, these leachate levels are fairly similar over time at the same location.

This indicates that field leachate values for arsenic are variable based on location within a given ash fill. This is a further indication of how difficult it is to get any given laboratory test to simulate field leachate conditions.

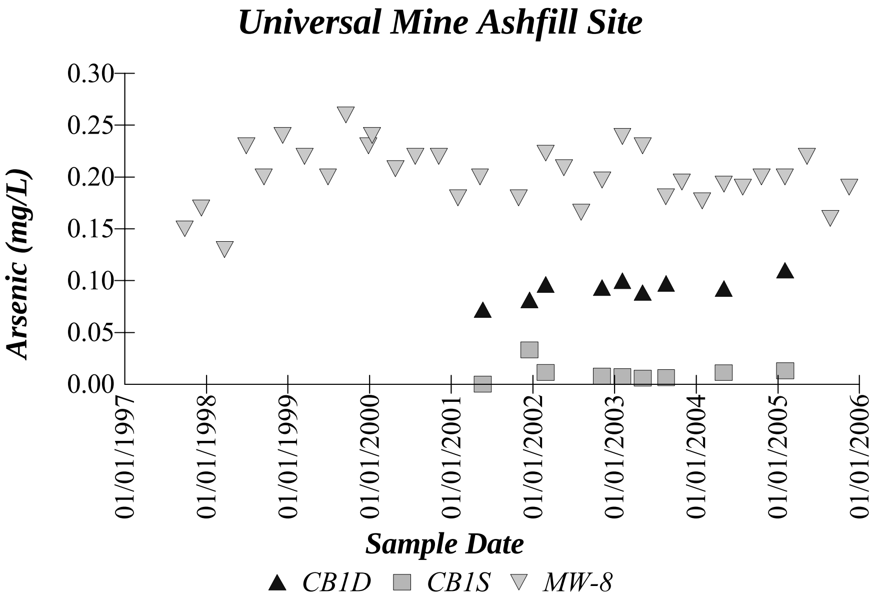

Figure 1. Arsenic field leachate concentration over time.

The boron leachate values are much higher in the field over the 10-year sampling period (figure 2).

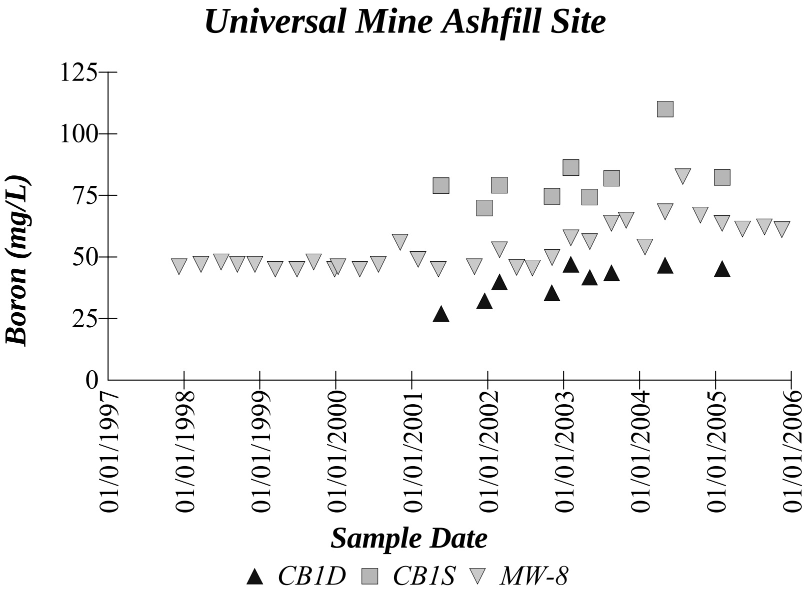

Figure 2. Boron field leachate concentration over time.

The sulfate levels were very similar at all three locations in the field over the ten-year period (figure 3).

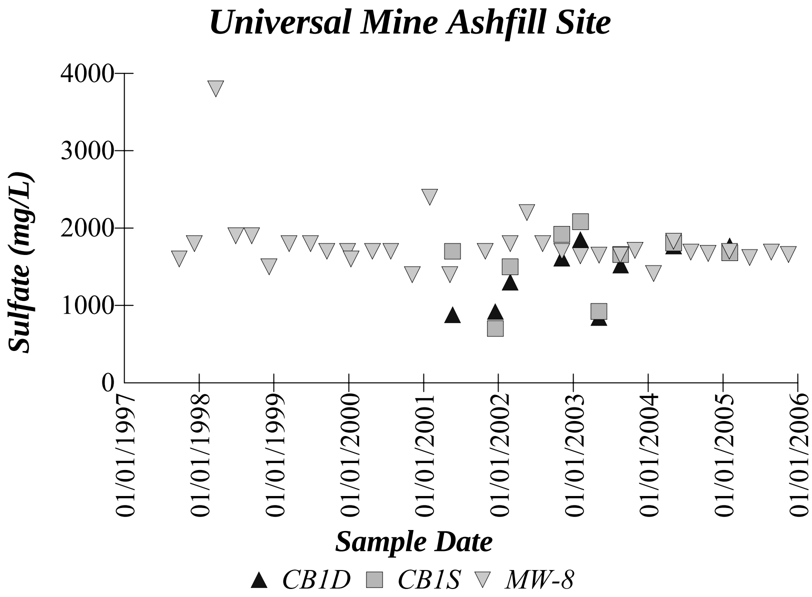

Figure 3. Sulfate field leachate concentration over time.

Kinetic Test Leaching Results

The kinetic leachate tests show the trend in leachate concentrations over time. This was done by having a large number of test tubes where one would sacrifice two test tubes for each sampling period. The kinetic tests for calcium (figure 4) showed the same increasing concentration over time as the other chemicals in laboratory tests.

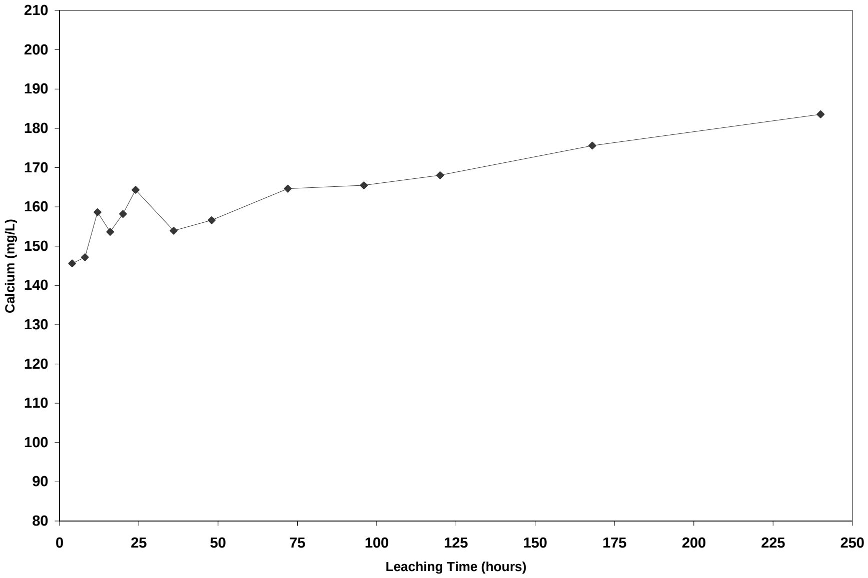

Figure 4. Calcium leaching kinetics.

The kinetic tests for sulfate (figure 5) showed the same increasing concentration over time as the other chemicals in the laboratory tests.

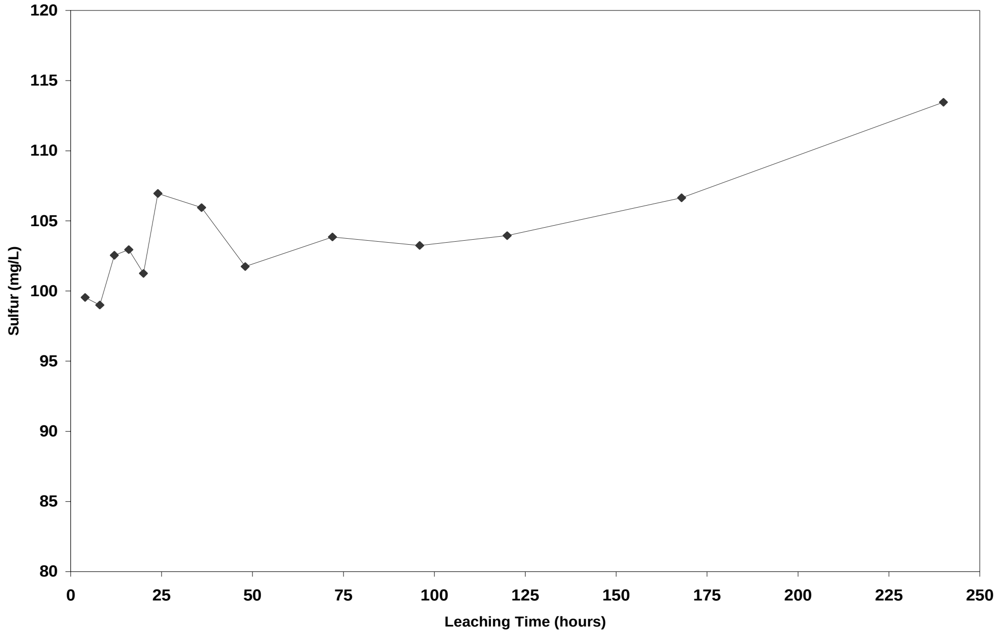

Figure 5. Sulfur leaching kinetics.

Boron differs from calcium and sulfate in that it achieves equilibrium much sooner (figure 6). This indicates there are fast kinetics of leaching involved and that boron is highly soluble and will leach rapidly.

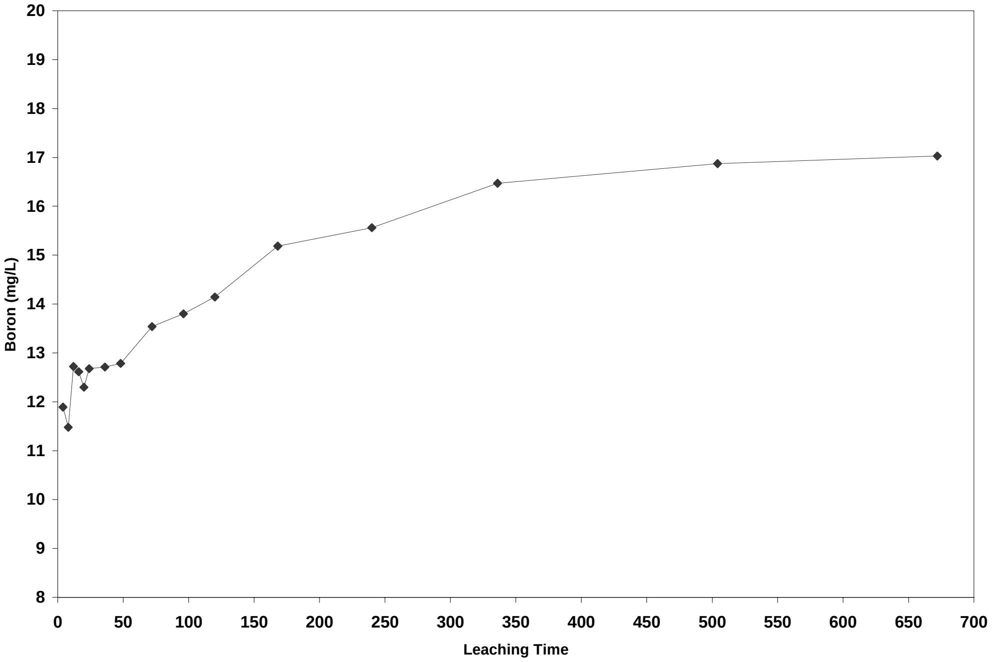

Figure 6. Boron leaching kinetics.

Arsenic reaches equilibrium in about 80 to 100 hours (figure 7).

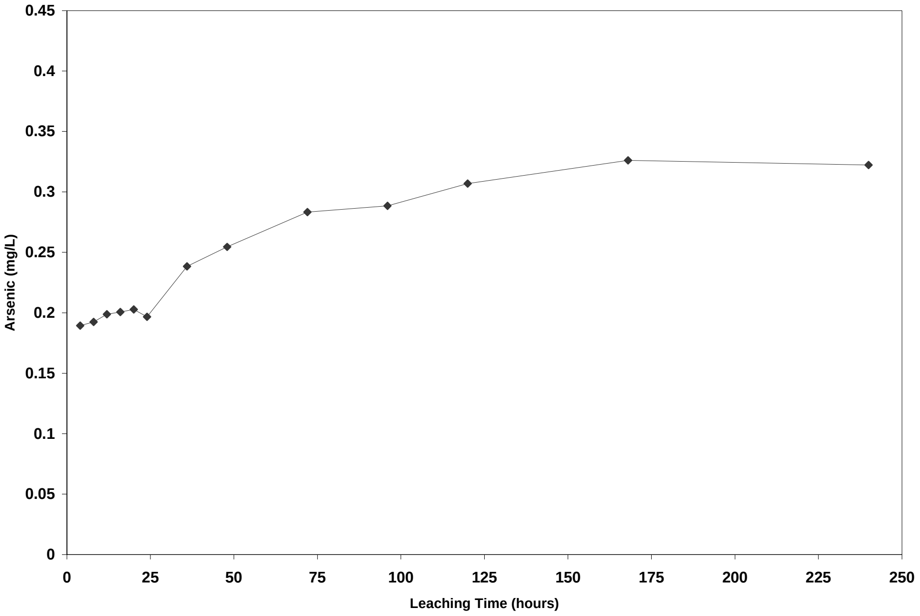

Figure 7. Arsenic leaching kinetics.

Sequential Leaching Results

The following test results from sequential leaching show that sulfur (figure 8), boron (figure 9), and arsenic (figure 10) are all being rapidly depleted by the leaching process.

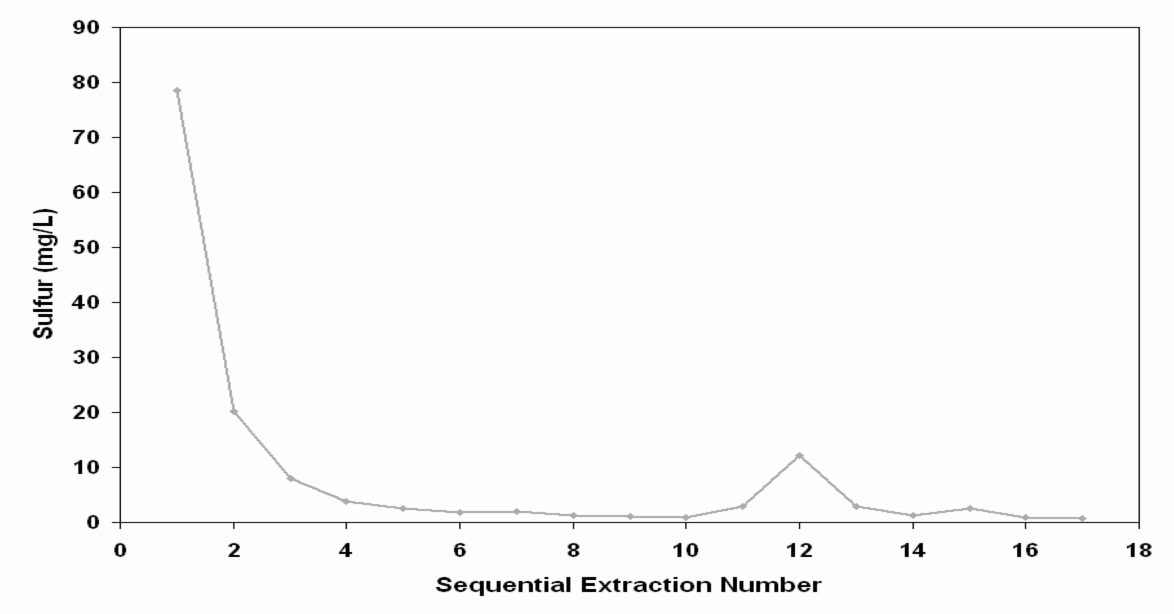

Figure 8. Sulfur sequential leaching.

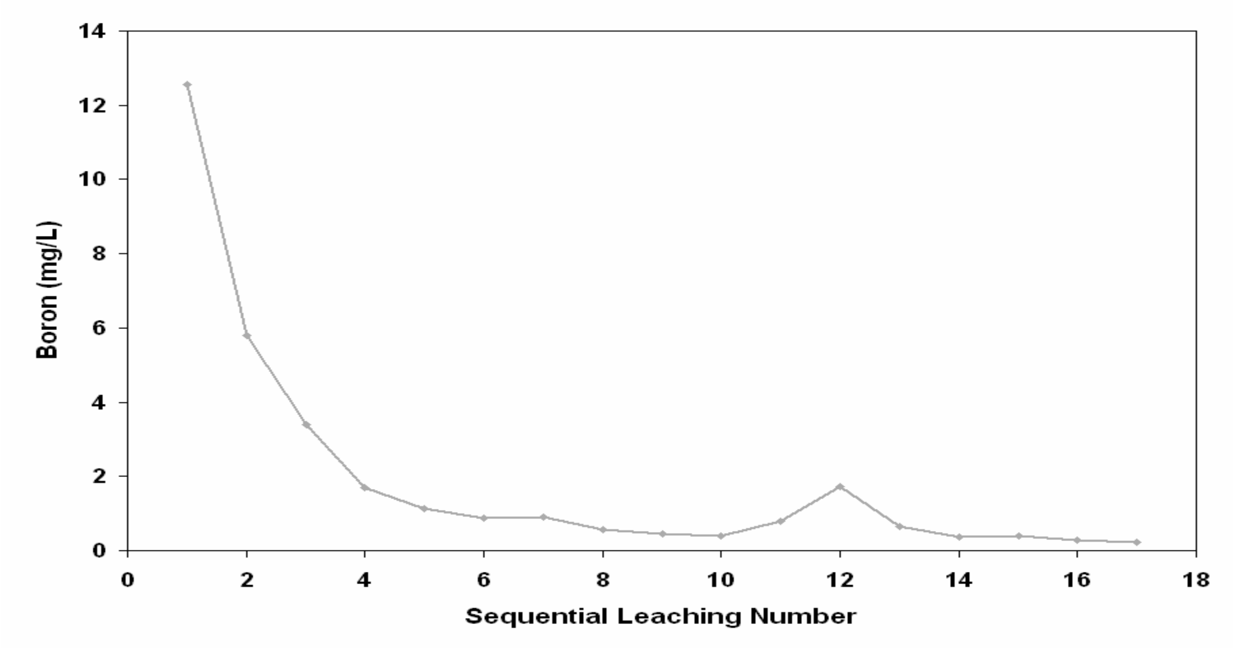

Figure 9. Boron sequential leaching.

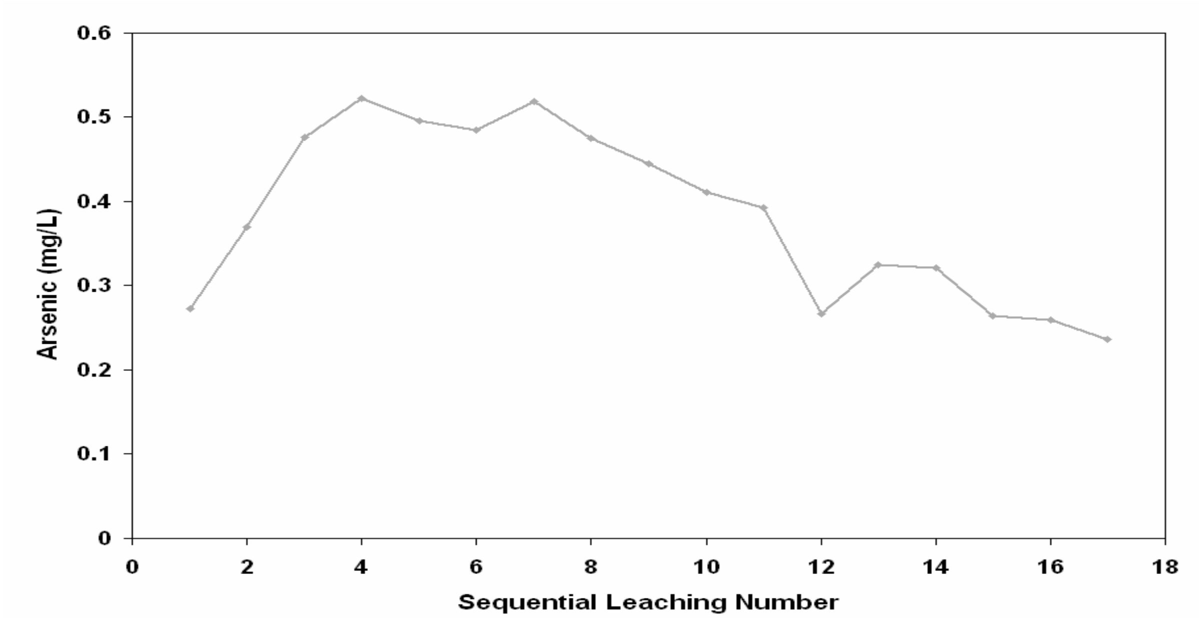

Figure 10. Arsenic sequential leaching.

When we compare aluminum and arsenic leachate concentrations by test method with leachate concentrations in the field (figure 11) we see that the laboratory methods provide larger values for arsenic and aluminum.

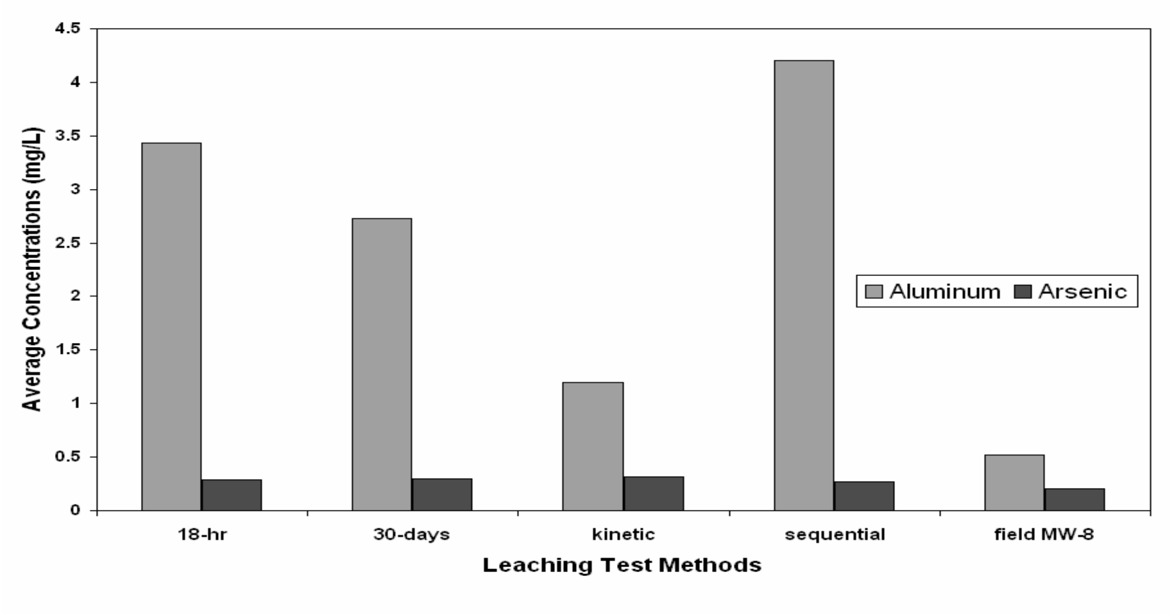

Figure 11. Aluminum and arsenic leachate concentrations by test method.

When we compare boron, calcium, and sulfate leachate concentrations by test method with leachate concentrations in the field (figure 12), we see that the laboratory methods consistently show lower values than the field leachate concentrations for all of these elements and compounds.

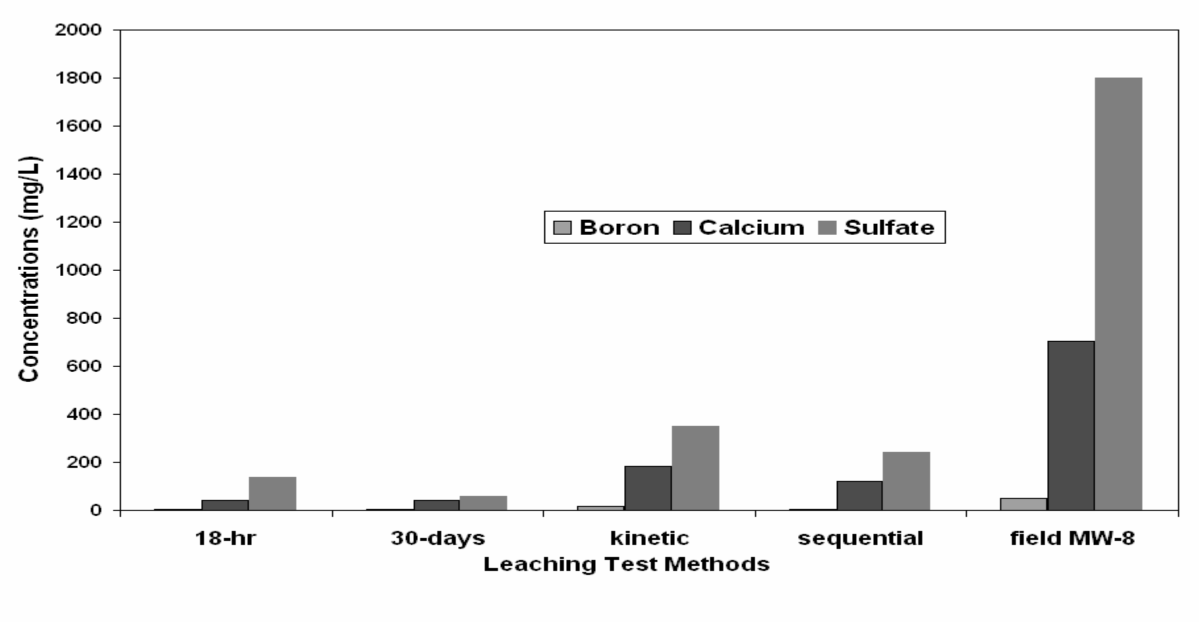

Figure 12. Boron, calcium, and sulfate leachate concentrations by test method.

Conclusion

The laboratory leaching methods used for this study did not provide accurate leachate concentration values for aluminum, boron, calcium, and sulfur/sulfate when compared to field scale values in an ash landfill. Laboratory leaching test results are similar or somewhat higher for arsenic leachate concentrations from the field. In future studies, more thought must be given to the potential for harmful leachate concentrations to be transported away from the disposal site. In this landfill situation, this is not the case. At best, laboratory leachate tests only provide part of the picture of leachate generation and transport. Additional methods beyond leaching tests must be employed in order to make a determination of the potential for off-site contamination.

Dr. Ishwar Murarka is the Chief Scientist and President of Ish Inc. that he created in 1998 as an environmental consulting company specializing in investigating, evaluating, and developing strategies for the remediation of soils, groundwater, and sediments contaminated with metals and organics. His current research interests include: leaching, attenuation, transport and fate of metals and organic compounds in soil, groundwater, surface water and sediments, and investigation and remediation of contaminated sites containing non-aqueous liquids (NAPL), cyanide, PCP, petroleum products, and metals from various sources, etc. He has been addressing Land and Water Environmental Issues for over 30 years. He has worked as an Environmental Professional for Texas Instruments, Argonne National Laboratory, and Electric Power Research Institute (EPRI). He continues to offer consulting services to address environmental issues associated with the disposal and utilization of fossil-fuel combustion byproducts. He has served on the U.S. EPA's Science Advisory Board (SAB) from 1988 through 2001 in various capacities and continues to be a consultant to the SAB. He is most experienced with the scientific and regulatory deliberations on the management of fossil fuel combustion wastes and the former manufactured gas plant sites. He continues to perform research on leaching, attenuation, and environmental fate of metals and organic constituents. He holds a Ph.D. in soil science and statistics from Oregon State University and an MBA from the University of Chicago. He was an NIH postdoctoral fellow in biomathematics at North Carolina State University.

Comparing Laboratory and Field Leaching of Ash Constituents

By

Ishwar P. Murarka, Ish Inc.
Linda Lee, Purdue University

November 15,2006

Some Ash Constituents of Interest for this Presentation

- Arsenic
- Aluminum
- Boron
- Calcium
- Molybdenum
- Sulfur/Sulfate

Background Thoughts

- Field Scale leachate represent the result of combination of all factors and processes involved
- Laboratory leaching tests represent an approximation consisting of some factors and processes for leaching

Laboratory Tests

- Many laboratory leaching tests used to obtain leaching data
- Each laboratory test satisfies a specific purpose and objective
- Laboratory tests can be grouped in
    - Batch tests with single extraction
    - Batch tests with sequential/multiple extractions
    - Column tests

Review of Some Factors Involved in Leaching of Chemicals from Solids

- Specific chemical constituent
- Mineralogy/solid phase characteristics
- Chemical composition of leaching fluid
- Contact time between solid and liquid
- Solid to liquid ratio
- Chemical reactions

Chemicals Reactions for leaching of Inorganics

- Precipitation/Dissolution reactions
- Adsorption/Desorption Reactions
- Redox reactions
- pH
- Etc.

Data Types and Comparisons

- 18-hour leaching test for ash samples using 20 to 1 liquid to solid extraction
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Field & Kinetic Leachates

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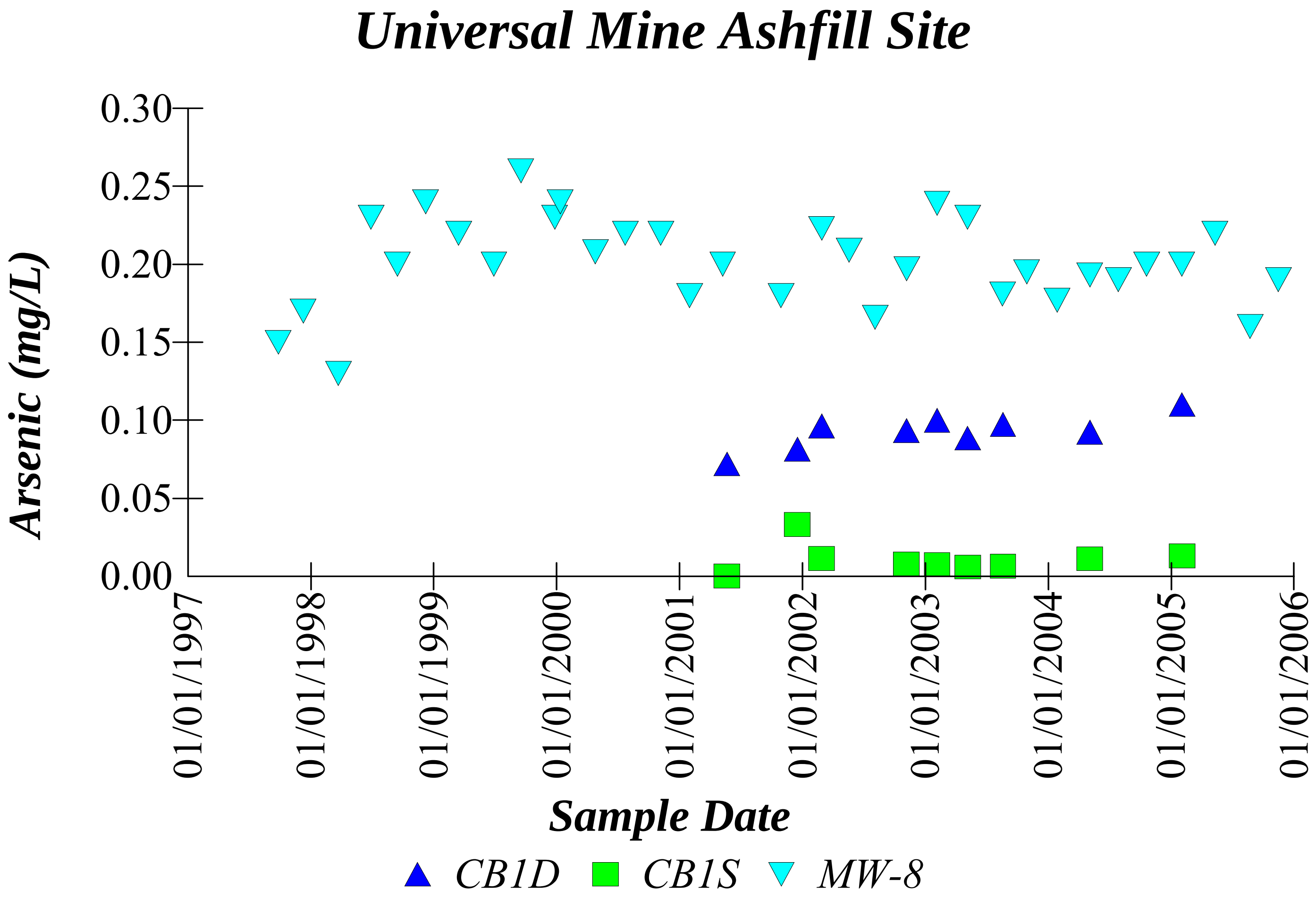
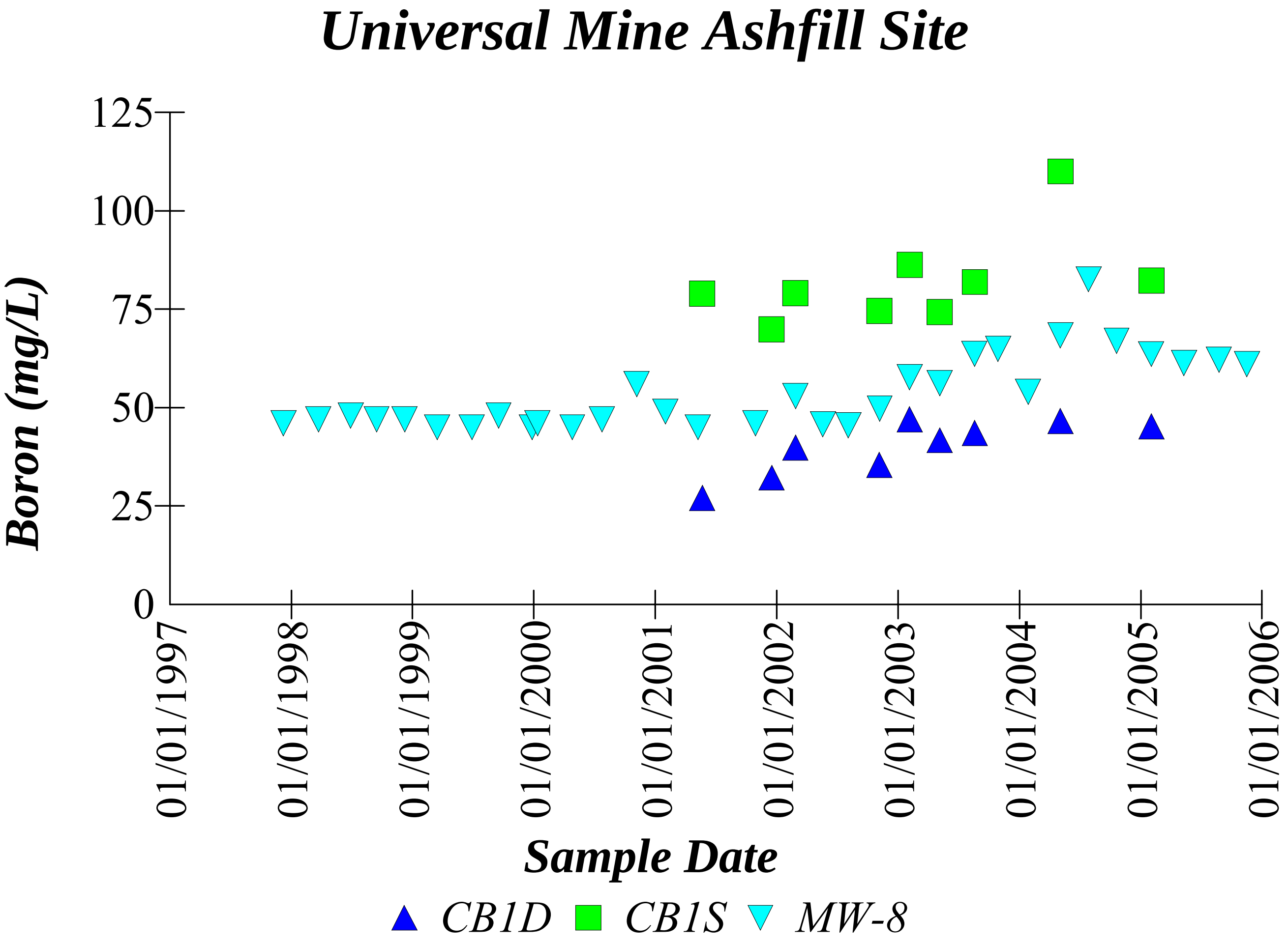
Calcium	580	810	703	145.6	183.6
Moly	0.52	2.34	1.26	--	--
Sulfate	1400	3800	1798	300	340.5

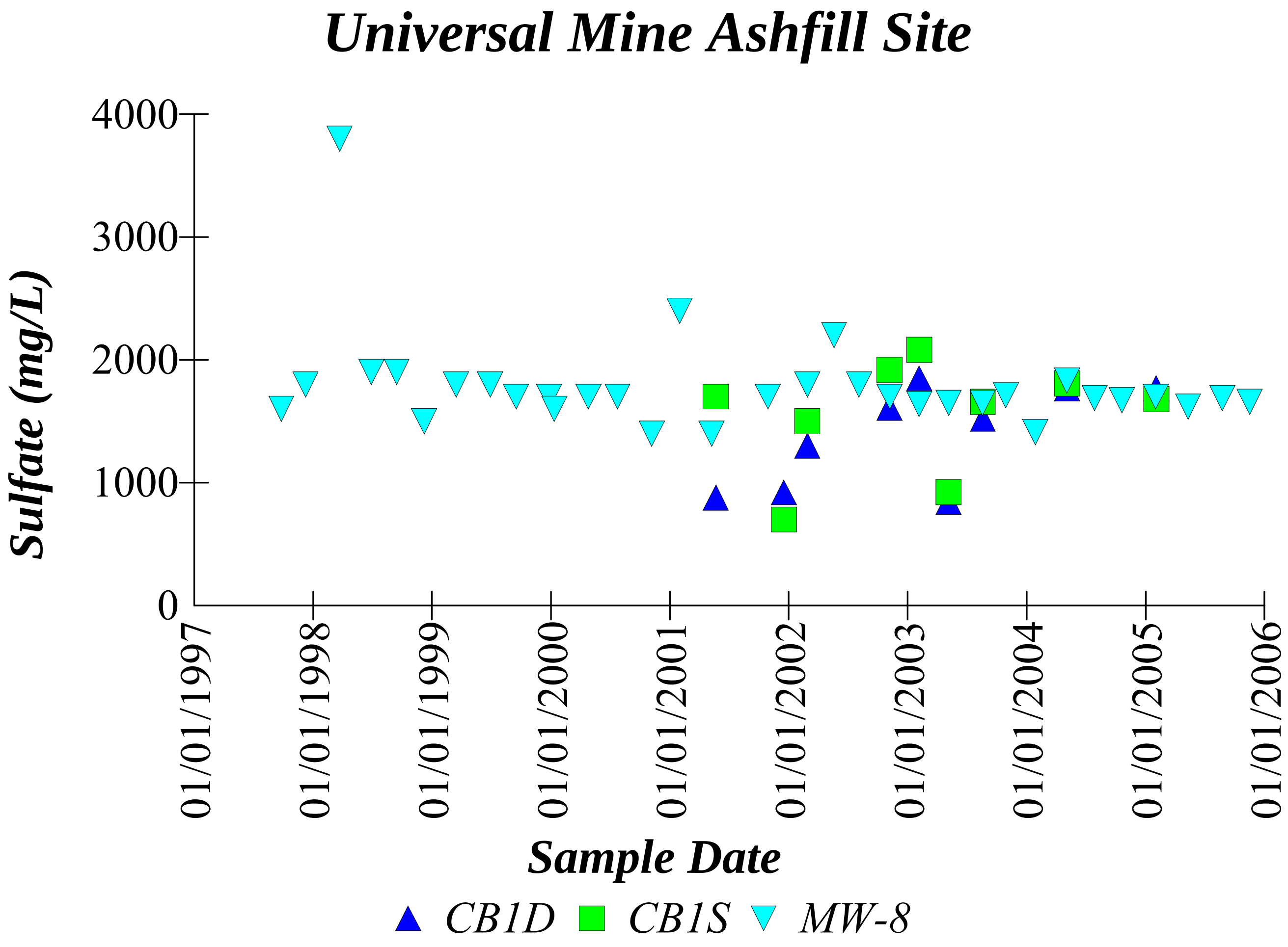
Field Leachate concentration over time for Arsenic



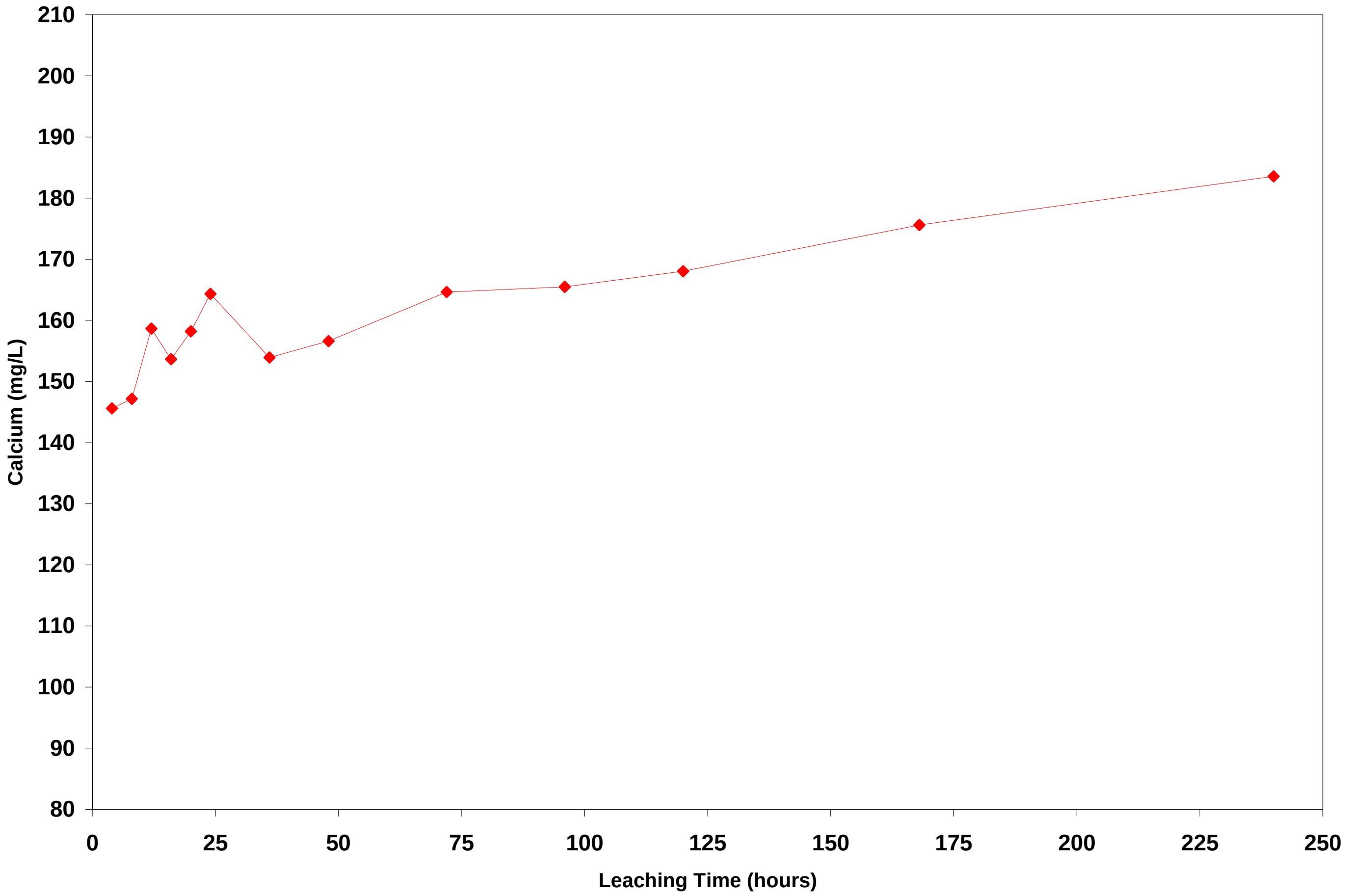
Field leachate concentrations over time for Boron



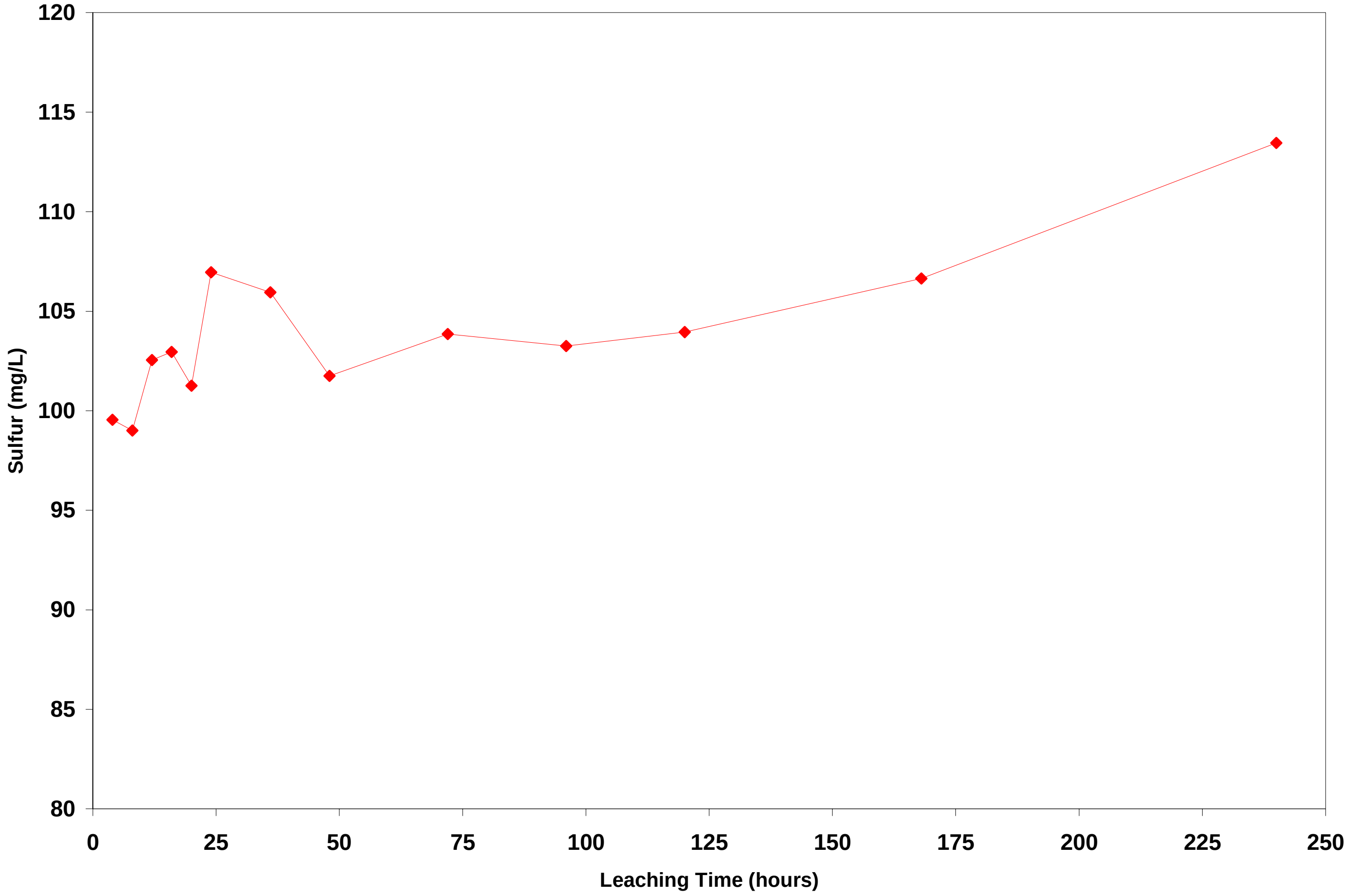
Field Leachate concentration over time for sulfate



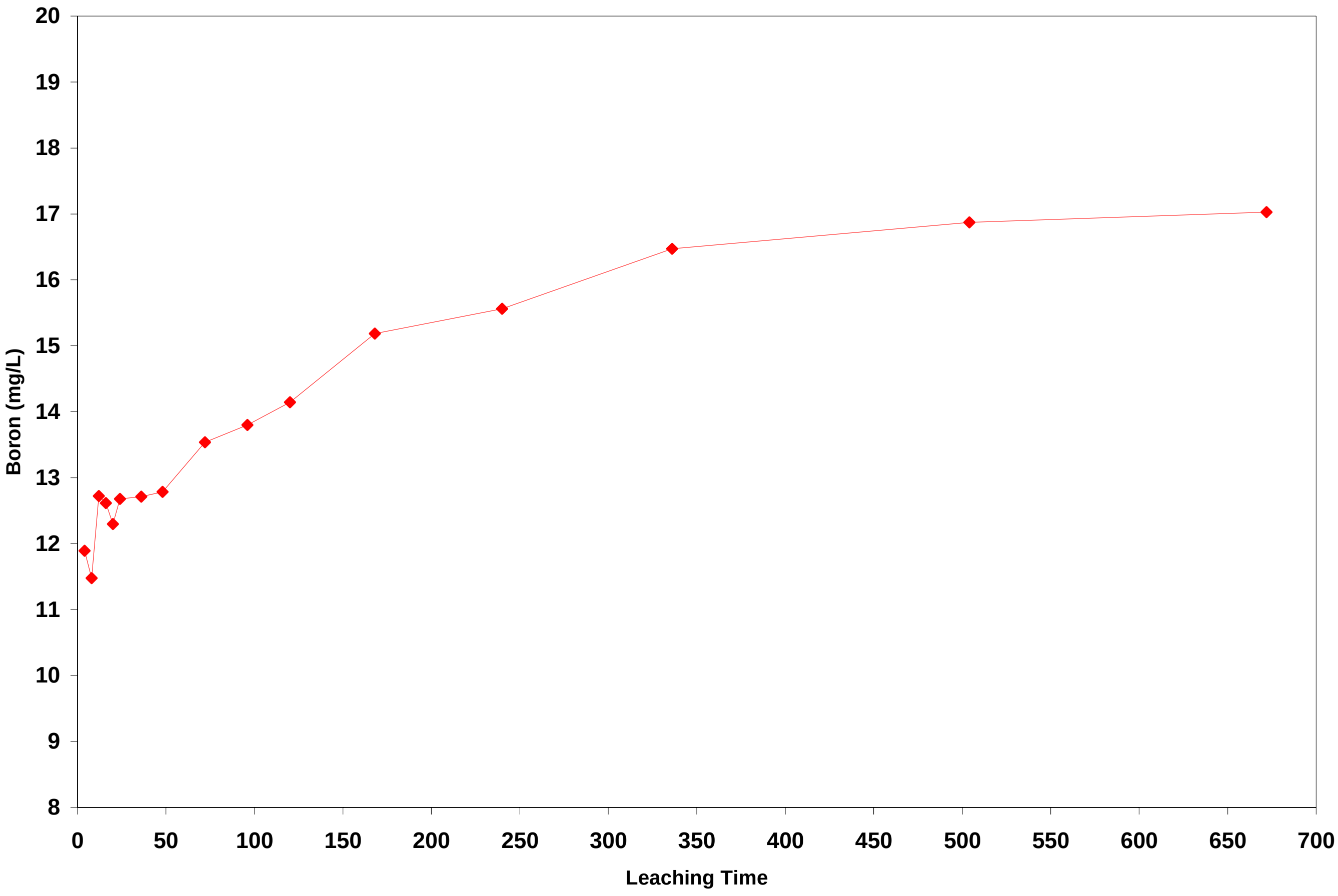
Leaching Kinetics for Calcium



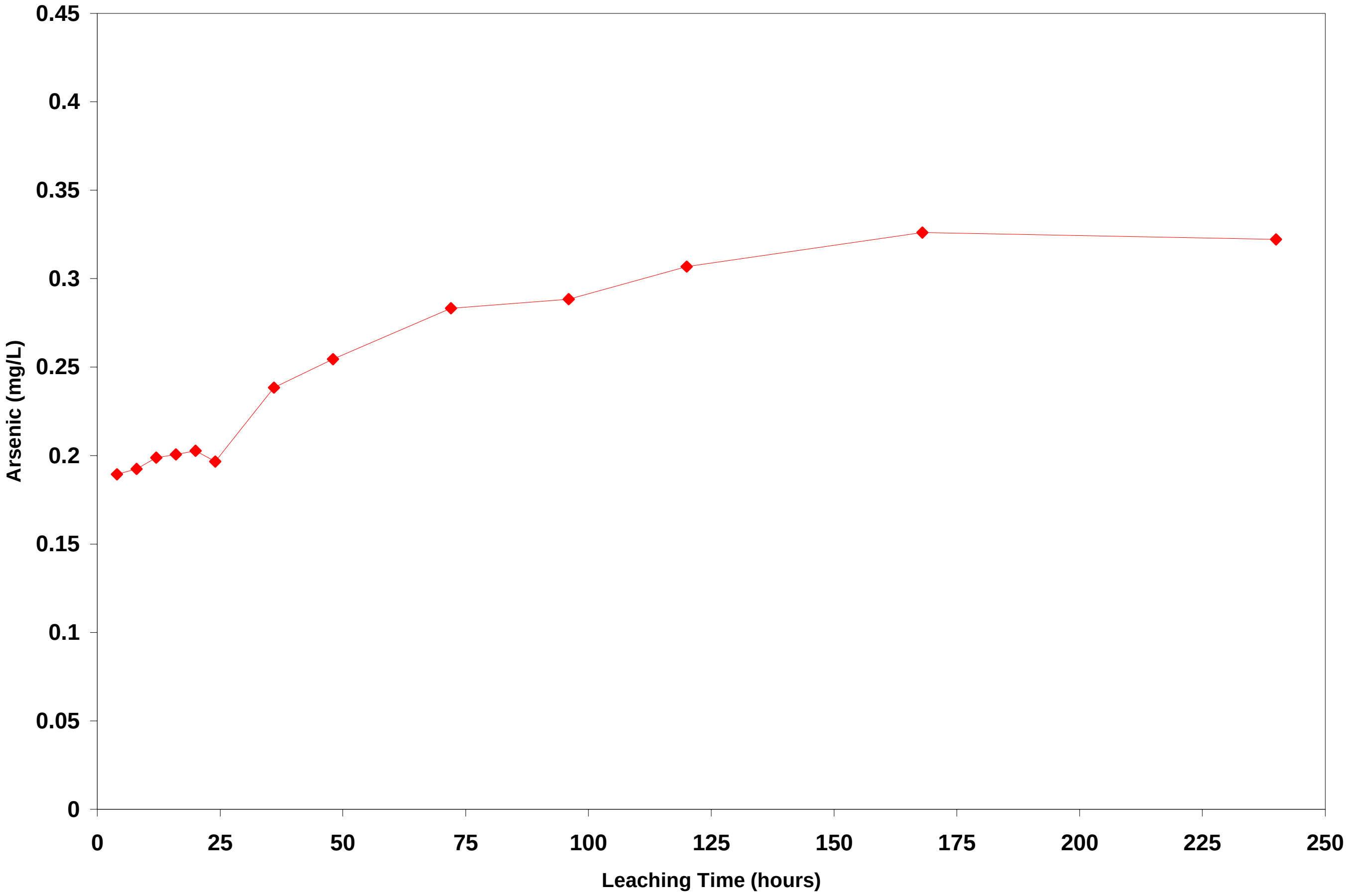
Leaching Kinetics for Sulfur



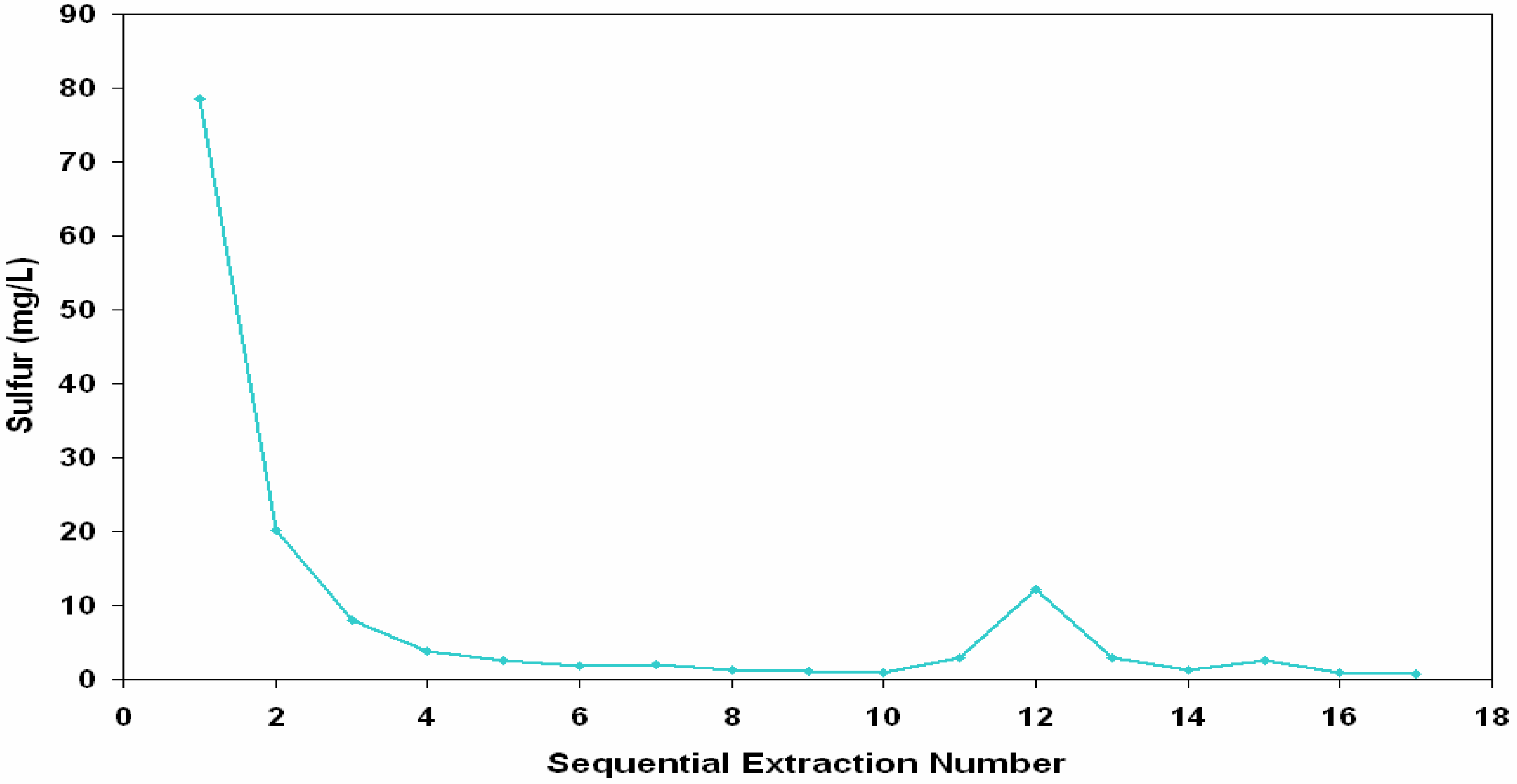
Leaching Kinetics for Boron



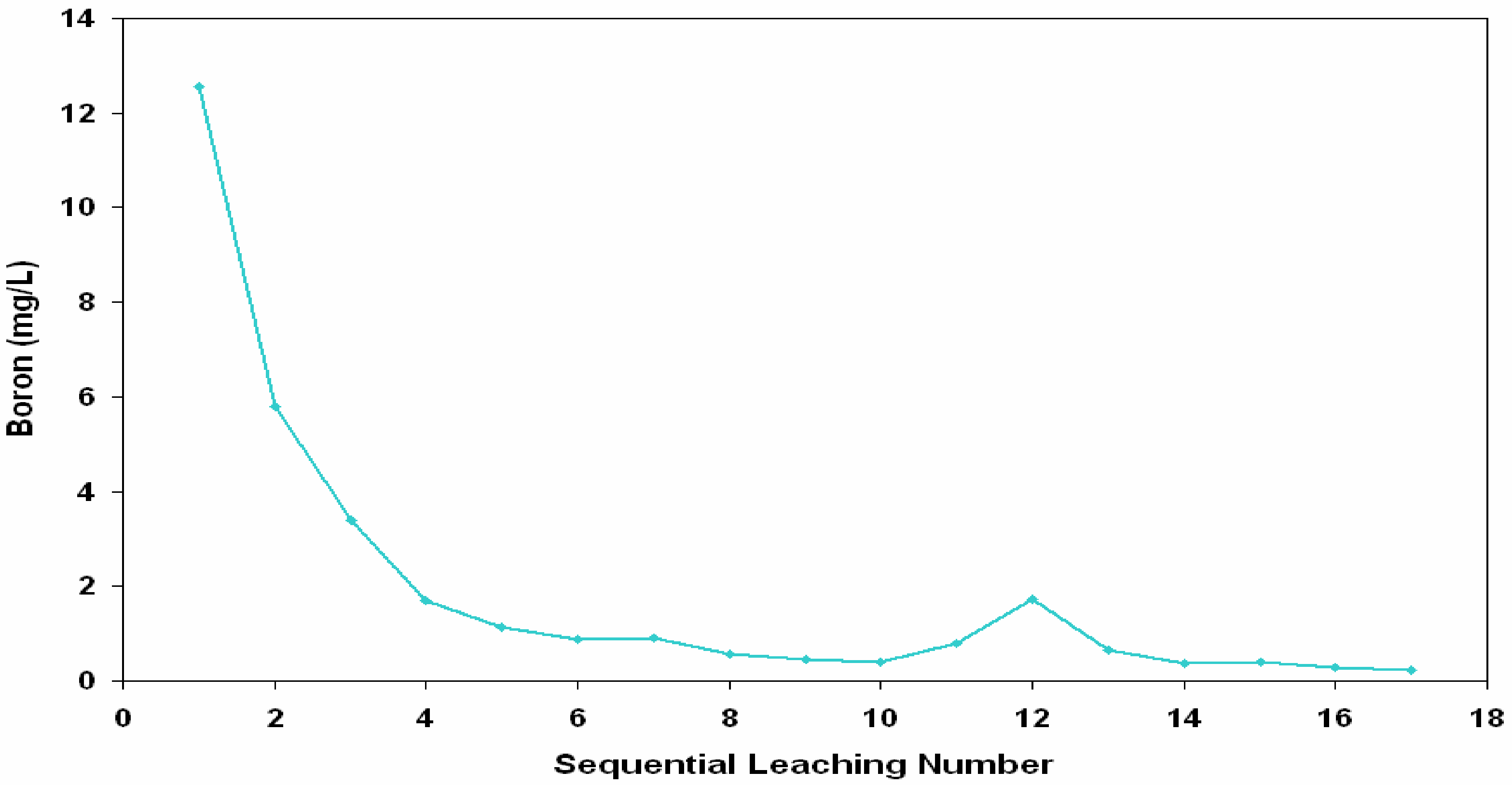
Leaching kinetics for Arsenic



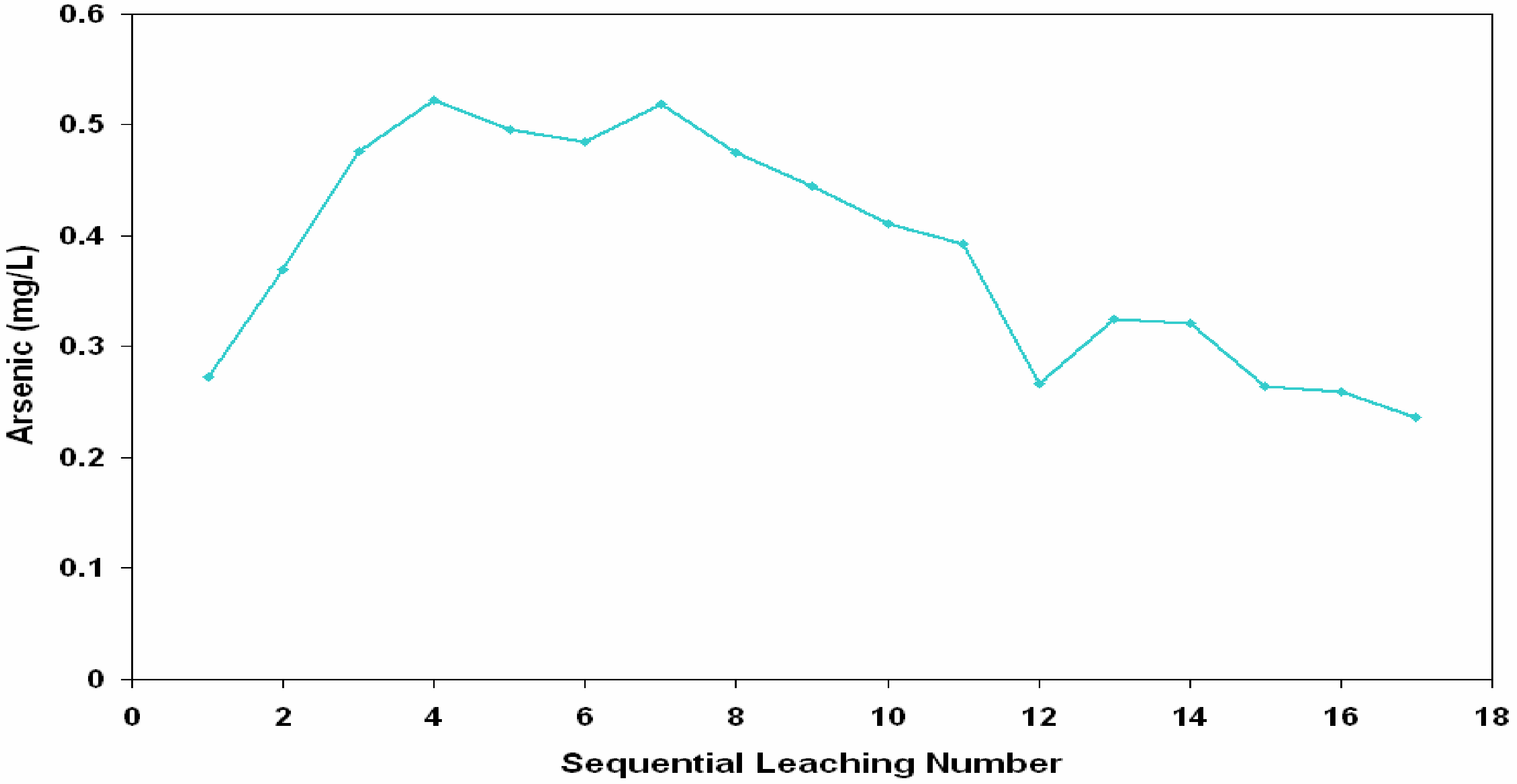
Sequential Leaching of Sulfur



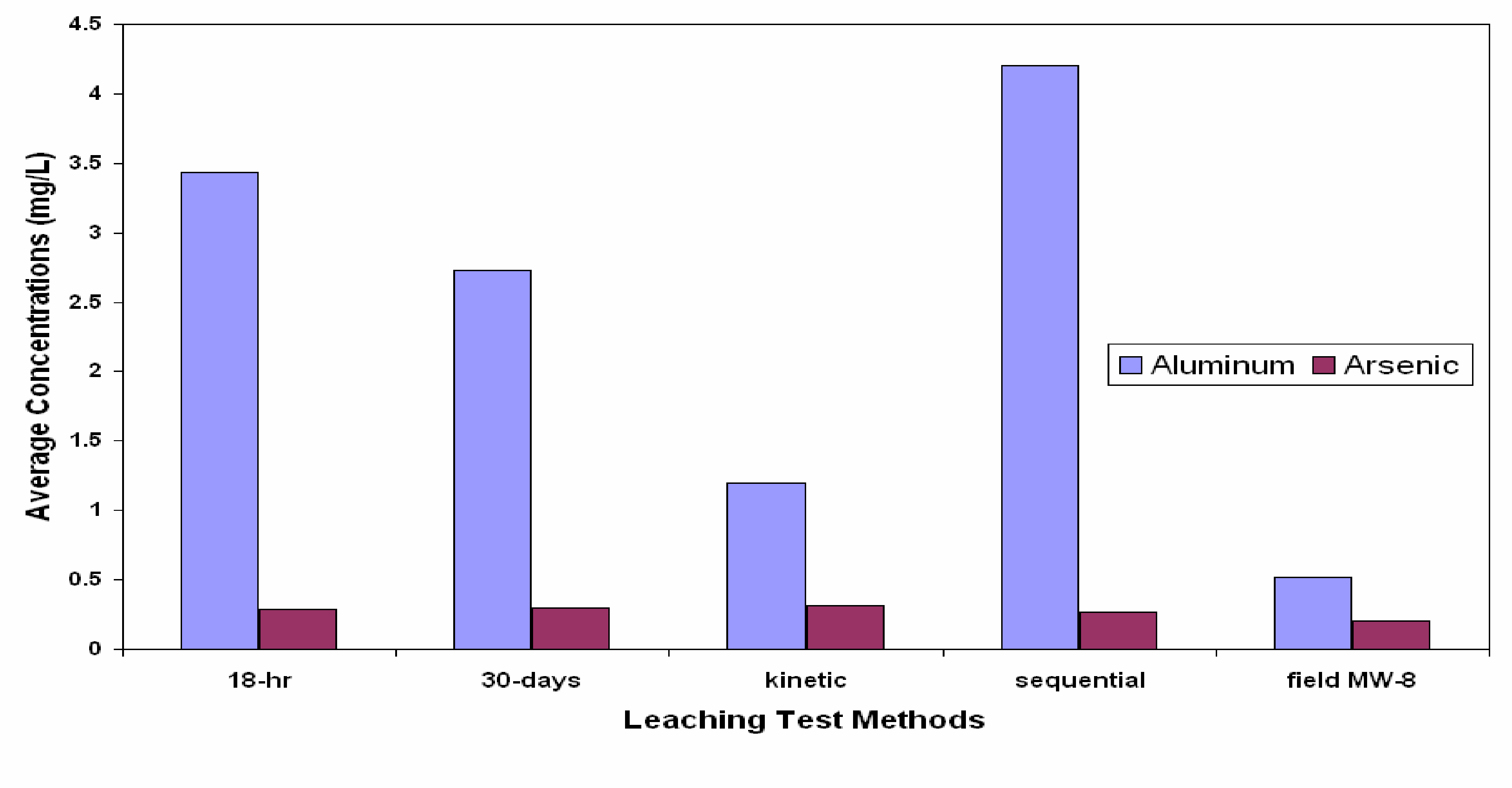
Sequential leaching of Boron



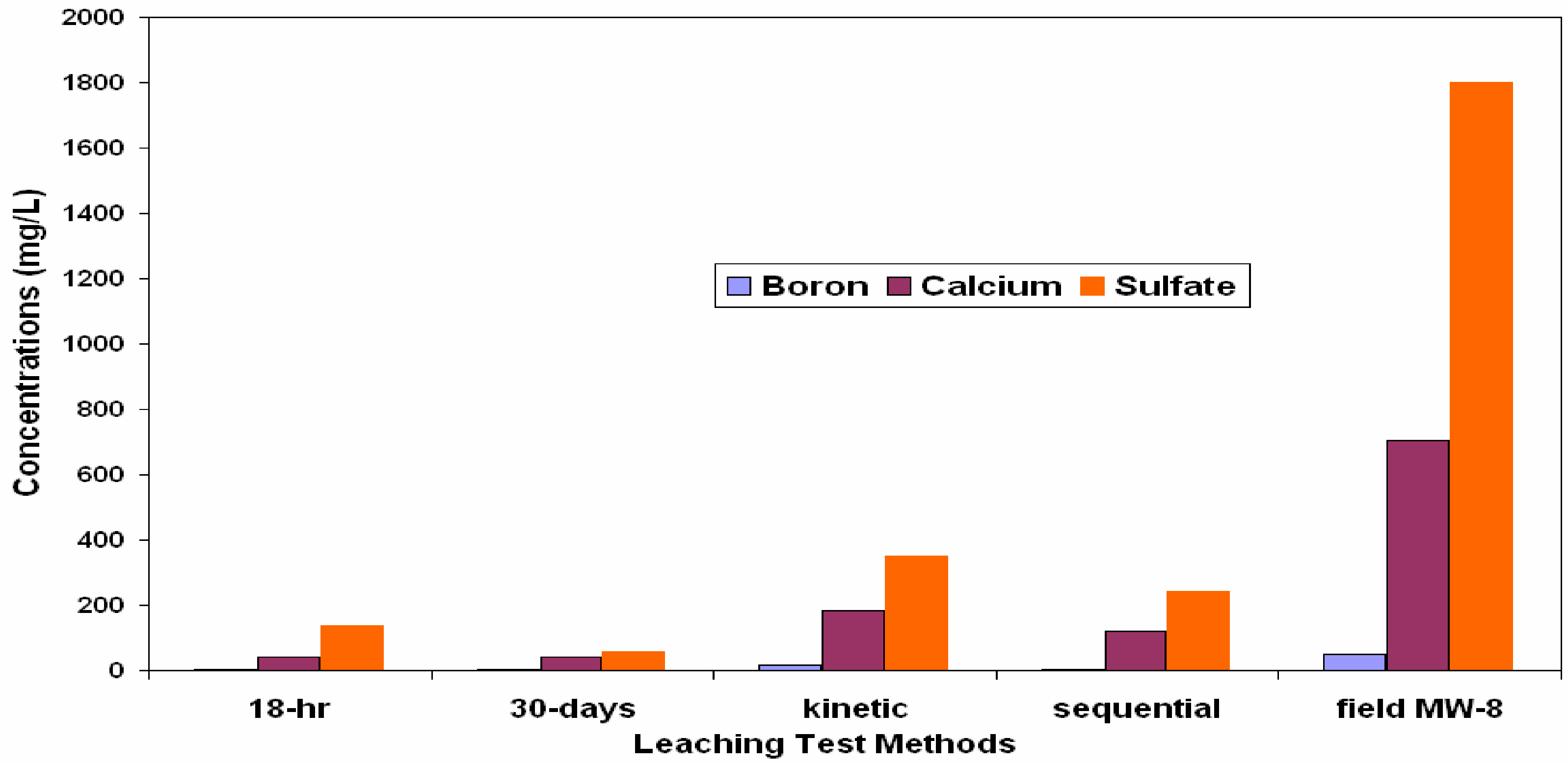
Sequential leaching of Arsenic



Comparison of Leachate Concentrations



Comparison of Leachate Concentrations



Conclusions

- Various laboratory leaching methods tested did not provide an accurate leachate concentrations for Aluminum, Boron, Calcium, and sulfur/sulfate for the field scale values in an ash landfill
- Laboratory leaching test results are similar or somewhat higher for arsenic leachate concentrations.

FIELD LEACHATE CHARACTERIZATION AT COAL COMBUSTION PRODUCT MANAGEMENT FACILITIES

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View Presentation

Abstract

The overall objective of this project was to evaluate the impact of key constituents captured from power plant air streams (principally arsenic, selenium, and mercury) on the disposal and utilization of coal combustion products (CCPs). Specific objectives of the project were: (1) to develop a comprehensive database of field leachate concentrations from a wide range of CCP management sites, including speciation of arsenic, selenium, and mercury; (2) to perform detailed evaluations of the release and attenuation of arsenic species at three CCP sites; and (3) to perform detailed evaluations of the release and attenuation of selenium species at three CCP sites. This paper presents field leachate characterization results associated with the first objective.

Field leachate samples were collected from 29 fly ash and FGD solids management sites from several geographic locations in the United States to provide a broad characterization of major and trace constituents in the leachate. In addition, speciation of arsenic, selenium, chromium, and mercury in the leachates was determined. Results were used to compare leachate characteristics for different management scenarios (impoundments and landfills) and different CCP types (e.g., ash and FGD solids). Arsenic and chromium in ash leachate are usually dominated by the oxidized forms, As(V) and Cr(VI). Selenium was mostly in the form of Se(IV), although there were a significant number of samples dominated by Se(VI). Se(IV) dominated in impoundment settings when the source coal was bituminous or a mixture of bituminous and subbituminous, while Se(VI) was predominant in landfill settings and when the source coal was subbituminous/lignite. Mercury concentrations were very low in all samples, with a median of 3.8 ng/L in ash leachate and 8.3 ng/L in FGD leachate. The organic species of mercury always had low concentration, usually less than 5 percent of the total mercury concentration.

Introduction

Coal combustion products (CCPs)—fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) solids—are derived primarily from incombustible mineral matter in coal and sorbents used to capture gaseous components from the flue gas, and as such contain a wide range of inorganic constituents. Concentrations of these constituents in CCPs and their leachability can vary widely by coal type and combustion/collection processes. Since CCP leachates commonly have neutral to alkaline pH, mobility of heavy metal cations such as lead and cadmium is limited. Other constituents, such as arsenic, chromium, and selenium, typically occur as oxyanions, which are more mobile than metal cations under alkaline pH conditions. Knowledge of factors controlling the leachability of different constituents is critical to development of appropriate CCP management practices.

The overall objective of this project was to evaluate the impact of key constituents captured from power plant air streams on the disposal and utilization of coal combustion products (CCPs). Specific objectives of the phase of the project reported here were to develop a comprehensive database of field leachate concentrations from a wide range of CCP management sites, including speciation of arsenic, selenium, chromium, and mercury.

Sampling and Analysis Methods

Leachate Sample Collection

Leachate samples were collected from several access points, including leachate wells, lysimeters, leachate collection systems, sluice lines, direct push drive-points, and ponds. The goal was to obtain undiluted samples representative of CCP leachate. Samples were collected by a variety of methods, depending on sample type and accessibility. In all cases, the samples were filtered in-line and collected directly into bottles containing appropriate preservatives.

Porewater Samples

Shallow porewater leachate samples were collected from within the CCP using direct-push methods. Two types of direct-push sample devices were used, drive-point piezometers and t-handle probes. In both cases, samples were drawn through the sample device using a peristaltic pump.

Leachate wells, lysimeters, and leachate collection systems were sampled to collect deep porewater within or immediately beneath the CCP. The leachate wells sampled for this study were installed in the ash to monitor leachate quality. The lysimeters sampled for this study were installed immediately beneath the CCP to collect porewater as it drains from the material, and were sampled via stand-pipes. Leachate collection systems also collect porewater draining from the CCP, and samples were collected at clean-out ports where the pipes emerge from beneath the fill deposit, or at the tanks where the collected leachate is stored prior to processing.

Whenever possible, low-flow methods were employed while sampling leachate wells to minimize disturbances within the sampling zone. Purging and sampling were performed with a peristaltic pump or, for deeper wells, a bladder pump. In a few cases with restricted access, a hand-operated Waterra™ pump or bailer was used to retrieve samples. Minimum purge sampling was used in a few instances where the CCP surrounding the well had relatively low permeability, would not achieve a stable drawdown during low-flow pumping, and when the well was constructed of PVC. Maximum purge sampling was used in the few instances where an existing well was constructed of stainless steel or any other metal that could potentially influence the water sample, if the well could not support low-flow sampling flow rates. In these instances, the well was completely purged the day before sampling.

Lysimeters and leachate collection systems were sampled by lowering the peristaltic pump tubing to the water surface. However, in some cases, the depth to water was too great for sampling with a peristaltic pump, in which case the Waterra pump or a bladder pump connected to Teflon™ tubing was used to withdraw the sample.

Surface Water and Sluice Samples

Surface water samples were collected from CCP impoundments. FEP tubing was lowered into the water and connected to a peristaltic pump via a short length of clean flexible silicone tubing. Samples were collected from different depths by attaching the FEP tubing to a clean water level indicator and lowering the tubing to the desired depth. In most cases, samples were collected from as near the ash/water interface as possible. Seep, sluice, and outfall samples were collected directly from the sluice pipe or outfall structure in a clean plastic container or plastic dip cup sampler (figure 1). FEP tubing connected to a peristaltic pump via a short length of clean flexible silicone tubing was used to collect the sample from the dip cup.

Figure 1. Surface water (seep) sampling using a dip cup.

Leachate Sample Preservation

Liquid leachate samples were filtered in the field and then split for the individual analyses. A 0.45 µm filter was used for all liquid samples, and turbid samples were prefiltered using either a 1.0 or 5.0 µm filter.

Samples for arsenic, selenium, and chromium speciation were immediately cryofrozen in the field using liquid nitrogen (figure 2), and then kept frozen on dry ice with minimal air contact until analysis to prevent changes in speciation by oxidation.

Figure 2. Cryofreezing a leachate sample in liquid nitrogen.

Separate water samples were collected for the determination of dissolved mercury ($\mathrm{Hg_{diss}}$), dissolved methyl mercury ($\mathrm{MeHg_{diss}}$), and dimethyl mercury (DMM). New tubing, filter materials, and sampling containers were used to prevent sample contamination. Samples for $\mathrm{Hg_{diss}}$ and $\mathrm{MeHg_{diss}}$ were collected using in-line filtration of a defined sample volume (40 mL for $\mathrm{Hg_{diss}}$ and 250 mL for $\mathrm{MeHg_{diss}}$) and preserved immediately with HCl. The fresh filters used for each of these filtration steps were collected and stored in Petri dishes for the determination of particulate mercury ($\mathrm{Hg_{part}}$) and particulate methyl mercury ($\mathrm{MeHg_{part}}$). DMM was purged from the collected water samples with an argon stream (30 min at 1 L/min) in the field, and collected on Carbotrap™ adsorbent tubes. These tubes were dried with an argon stream opposite to the adsorption direction (10 min at 1 L/min), sealed, and kept cold and dark until analysis. All collected samples were double-bagged to prevent contamination, and clean sampling protocols (consistent with U.S. EPA method 1631) were followed.

Field parameters including pH, conductivity, redox potential, and temperature were measured using an in-line flow cell and/or multi-probe sample collected during sampling.

Core Samples

Core samples were collected at selected sites where porewater samples could not otherwise be obtained. A hollow-stem auger drill rig was used to advance a lined split-spoon sampler or core barrel sampler into the CCP deposit. Typically, a preliminary borehole was drilled in advance of the sample borehole in order to log the intervals where the wettest CCP was encountered, and the sampler was then advanced in a second, adjacent borehole to the selected depth.

Core samples for leachate analyses were collected in clear, large-diameter, plastic or Teflon™ liners. After the liner tubes were recovered, the ends were cut so that no air volume or disturbed sample was included in the tube, and the ends of the tubes were sealed with Parafilm™, plastic end caps, and tape. Tubes were stored in coolers with dry ice for shipment to the laboratory via overnight delivery. Leachate was extracted from wet ash samples in the laboratory by centrifuge, then filtered and preserved as described above for leachate samples.

Laboratory Analysis

Leachate samples were analyzed for as many as 43 constituents, including species of arsenic, chromium, mercury, and selenium. Analytical methods and detection limits are listed in table 1. Laboratory methods are described in detail in DOE (2006). The detection limits listed in table 1 are typical for this study; lower detection limits were often achieved with field blank samples, and higher detection limits were sometimes necessary for leachate samples due to matrix interference or to account for dilution of highly-concentrated samples.

Table 1. Constituents Analyzed, Methods, and Typical Detection Limits.

Constituent	**Analytical Method**	**Detection Limit (mg/L)**
Aluminum	DF-ICP-MS	0.002
Antimony	DF-ICP-MS	0.0001
Arsenic	DRC-ICP-MS	0.00002
As(III)	IC-ASRS-ICP-MS	0.00004
As(V)	IC-ASRS-ICP-MS	0.00008
Barium	DF-ICP-MS	0.0002
Beryllium	DF-ICP-MS	0.0002
Bicarbonate	Calculated	0.01
Boron	DF-ICP-MS	0.0001
Cadmium	DF-ICP-MS	0.0002
Calcium	Cation-exchange chromatography	0.05
Carbonate	Calculated	0.01
Chloride	Anion-exchange chromatography	0.01
Chromium	DF-ICP-MS	0.0002
Cr(III)	IC-ASRS- DRC-ICP-MS	0.00001
Cr(VI)	IC-ASRS- DRC-ICP-MS	0.00001
Cobalt	DF-ICP-MS	0.00004
Copper	DF-ICP-MS	0.0002
Iron	DF-ICP-MS	0.003
Lead	DF-ICP-MS	0.0001
Lithium	DF-ICP-MS	0.001
Magnesium	Cation-exchange chromatography	0.05
Manganese	DF-ICP-MS	0.0001
Mercury	Cold vapor-ICP-MS	4.00E-09
Mercury, dimethyl	Gas chromatography–ICP-MS	5.00E-09
Mercury, monomethyl	Gas chromatography–ICP-MS	2.00E-08
Molybdenum	DF-ICP-MS	0.0001
Nickel	DF-ICP-MS	0.0006
Potassium	Cation-exchange chromatography	0.2
Selenium	DRC-ICP-MS	0.00002
Se(IV)	IC-ASRS-ICP-MS	0.0001
Se(VI)	IC-ASRS-ICP-MS	0.0001
Silica	DF-ICP-MS	0.1
Silver	DF-ICP-MS	0.0002
Sodium	Cation-exchange chromatography	0.1
Strontium	DF-ICP-MS	0.03
Sulfate	Anion-exchange chromatography	0.05
Thallium	DF-ICP-MS	0.0001
Total Inorganic Carbon	Flow injection-infrared spectrometry	0.09
Total Organic Carbon	Flow injection-infrared spectrometry	0.09
Uranium	DF-ICP-MS	0.00001
Vanadium	DF-ICP-MS	0.00004
Zinc	DF-ICP-MS	0.0003

DF-ICP-MS: Double focusing-inductively coupled plasma-mass spectrometer
DRC-ICP-MS: Dynamic reaction cell- inductively coupled plasma-mass spectrometer
IC-ASRS-ICP-MS: Ion chromatography-anion self regenerating suppressor-ICP-MS
IC-ASRS- DRC-ICP-MS: Ion chromatography-anion self-regenerating suppressor-dynamic reaction cell-ICP-MS

Site Selection

Leachate samples were collected from 33 sites (Figure 3), concentrated in the eastern United States where coal-fired power plants predominate. Sites were selected based on a variety of criteria to represent as broad as possible of a spectrum of power plant attributes, CCP types, and CCP management scenarios (EPRI 2006).

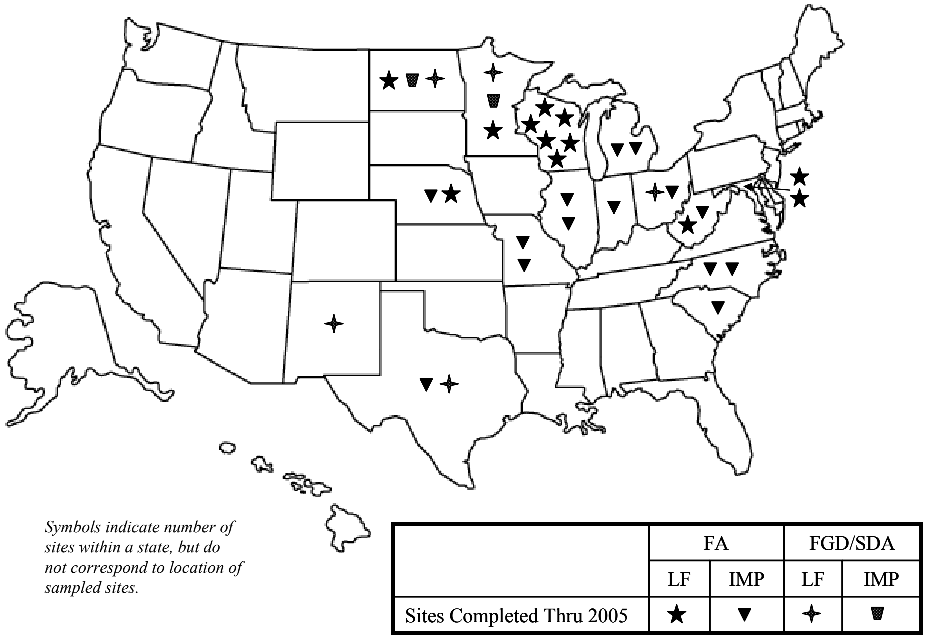

Figure 3. Sample site locations by state.

Samples were collected at 15 impoundments, 17 landfills, and one site where ash was landfilled over a former impoundment. Four of the landfills did not have a liquid leachate sampling point, and cores collected at these sites did not yield sufficient leachate for analysis; therefore, 81 samples collected at 29 sites were analyzed.

The majority of sites (24 of 29) sampled received CCP from pulverized coal (PC) plants with dry-bottom boilers, representing 71 of the 81 leachate samples. One site (one sample) received CCP from a wet-bottom PC boiler, and three sites (four samples) received CCP from cyclone boilers. The remaining site (five samples) received CCP from a plant that has both dry-bottom PC boilers and cyclones.

Most sites (11 sites, 48 samples) received CCP from power plants that burned bituminous coal. Seven sites (13 samples) received CCP from plants that burn subbituminous coal, and four sites (five samples) received CCP from lignite-burning plants. The samples derived from low-rank (subbituminous and lignite) coal were grouped together for most of the data review. In addition, four sites (seven samples) received CCP from plants that burn a blend of fuels, and three sites (eight samples) have CCP derived from a mixture of sources.
Six of the 29 sites received CCP from flue gas desulfurization (FGD) systems, the other 23 sites received coal ash, either from plants without FGD systems or that was collected prior to installation of the FGD system.

Results

Most coal ash leachate samples were moderately to strongly oxidizing and moderately to strongly alkaline (figure 4). The sub bituminous/lignite ash samples had higher median pH (10.0) than bituminous ash (6.9). The lowest Eh or pH values were in samples collected from impoundments; although no sample had both low Eh and pH.

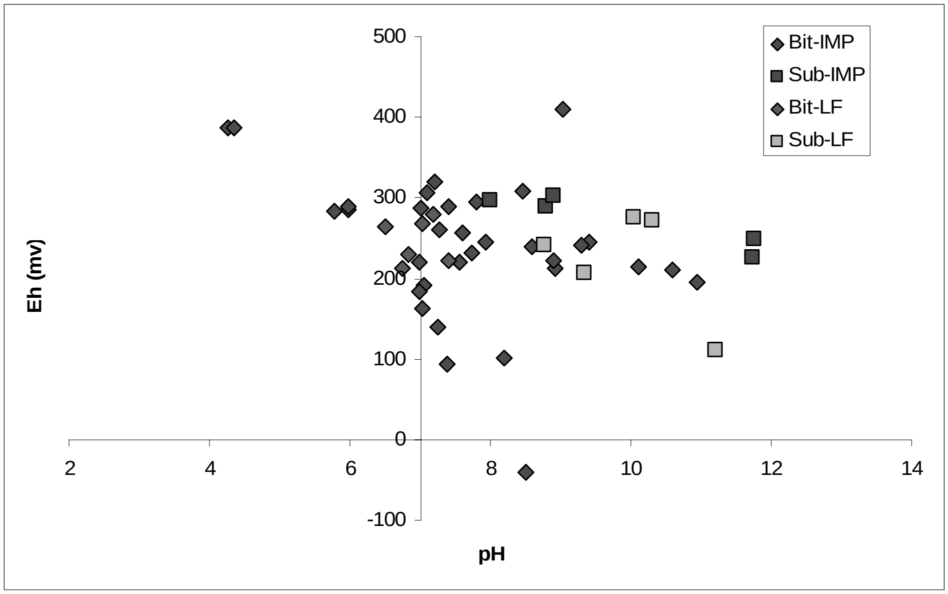

Figure 4. Eh-pH of coal ash leachate samples.

The FGD leachate samples were moderately to strongly oxidizing and moderately to strongly alkaline (figure 5). Landfill samples, as a group, were less oxic and more alkaline than impoundment samples, although the lowest Eh value was for an impoundment.

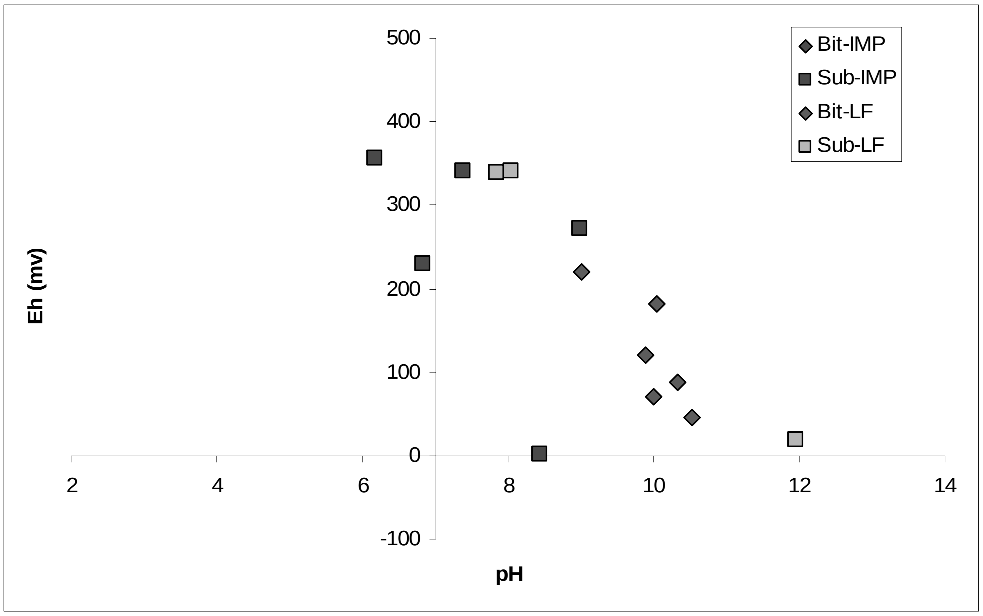

Figure 5. Eh-pH of FGD leachate samples.

The anion chemistry of coal ash leachate samples was dominated by sulfate (figure 6). The median concentration of this constituent was 339 mg/L, and it was the only constituent in the ash leachate with a median concentration greater than 100 mg/L. Concentrations of most major constituents (specifically, calcium, chloride, potassium, sodium, and sulfate) in FGD leachate were higher than in ash leachate. The median sulfate concentration was 1,615 mg/L (figure 7). The maximum sulfate concentration (30,500 mg/L) was obtained from an impoundment where sluice water is recirculated.

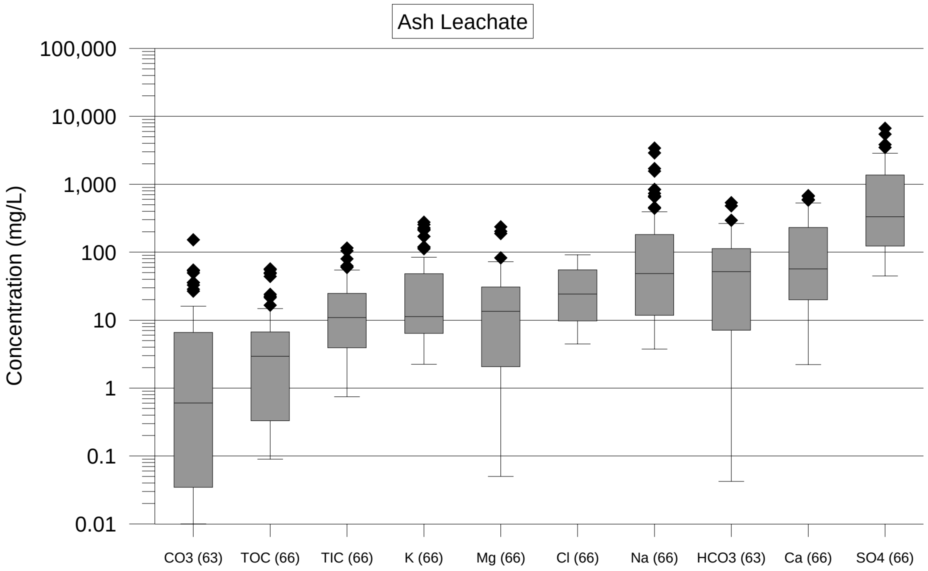

Figure 6. Concentration ranges for major constituents in coal ash leachate.

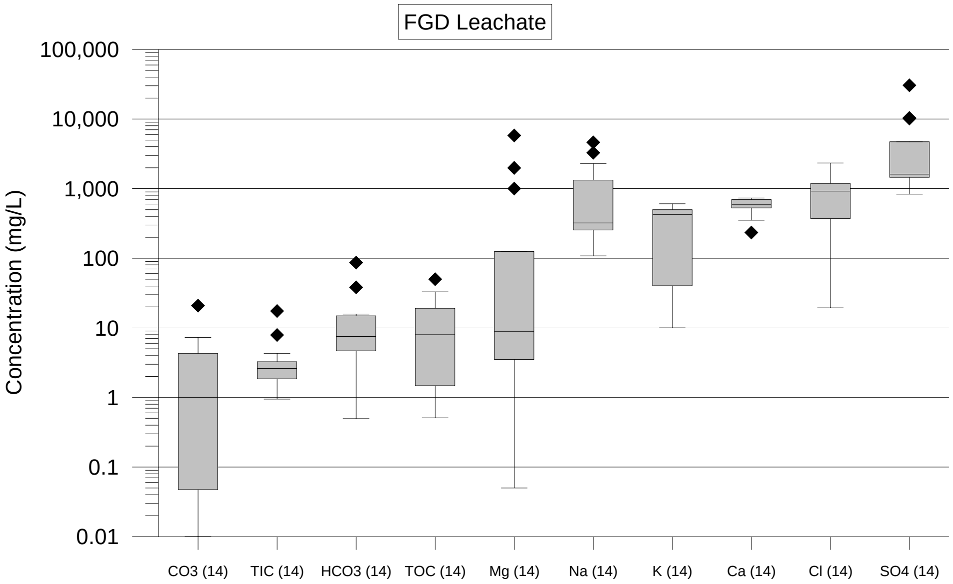

Figure 7. Concentration ranges for major constituents in FGD leachate.

Silica and boron had the highest median concentrations (4,645 and 2,160 µg/L, respectively) of the minor and trace constituents in coal ash leachate (figure 8). Median concentrations of strontium, molybdenum, lithium, aluminum, and barium were greater than 100 µg/L. Conversely, median concentrations of chromium, beryllium, thallium, silver, lead, and mercury were lower than 1 µg/L; with silver and beryllium detected in less than 10 percent of the samples (figure 9).

Median concentrations of boron, strontium, lithium, and silica were greater than 1,000 µg/L in FGD leachate, and median concentrations for molybdenum, aluminum, and manganese were greater than 100 µg/L (figure 10). Conversely, median concentrations of chromium, beryllium, thallium, silver, lead, and mercury were lower than 1 µg/L; with silver and beryllium detected in less than 10 percent of the samples (figure 11).

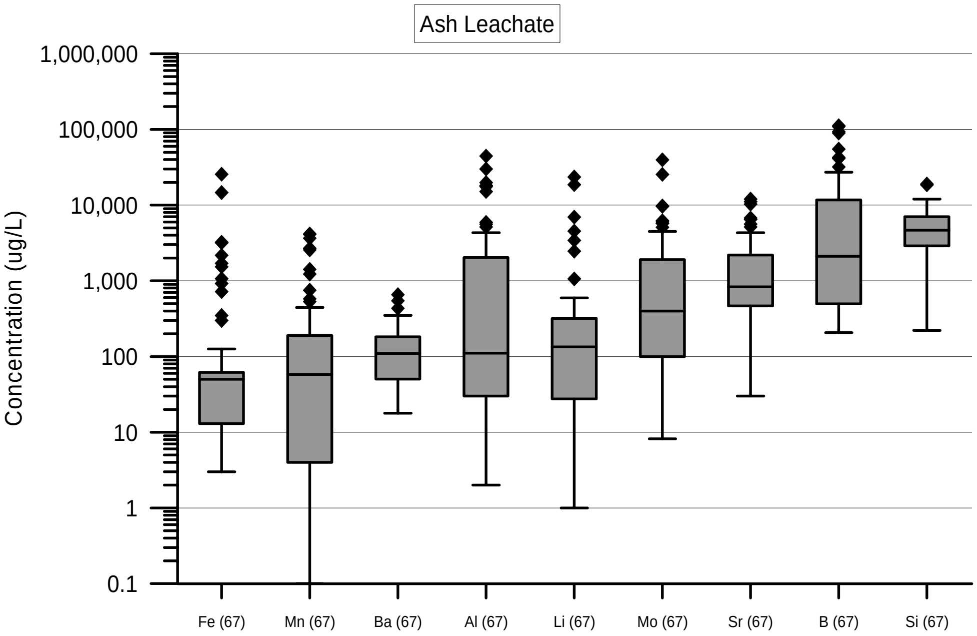

Figure 8. Concentration ranges for minor constituents in coal ash leachate.

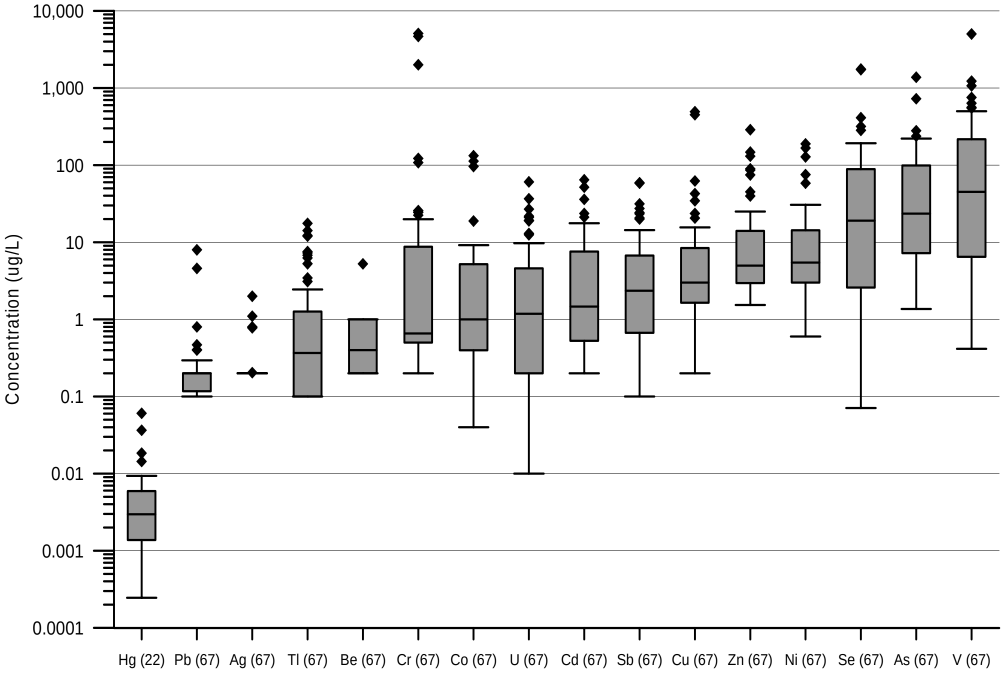

Figure 9. Concentration ranges for trace constituents in coal ash leachate.

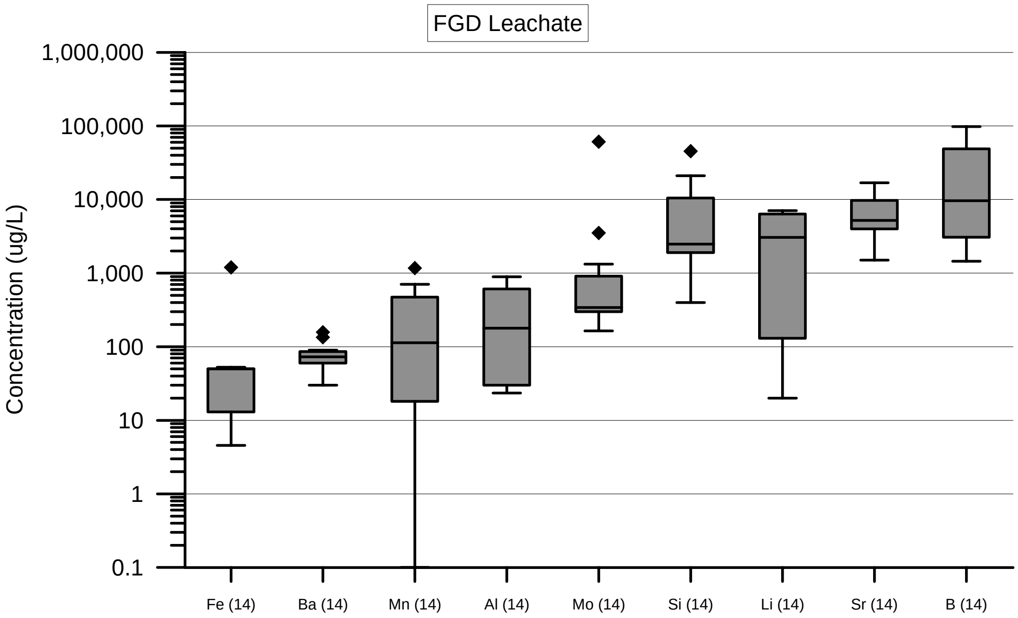

Figure 10. Concentration ranges for minor constituents in FGD leachate.

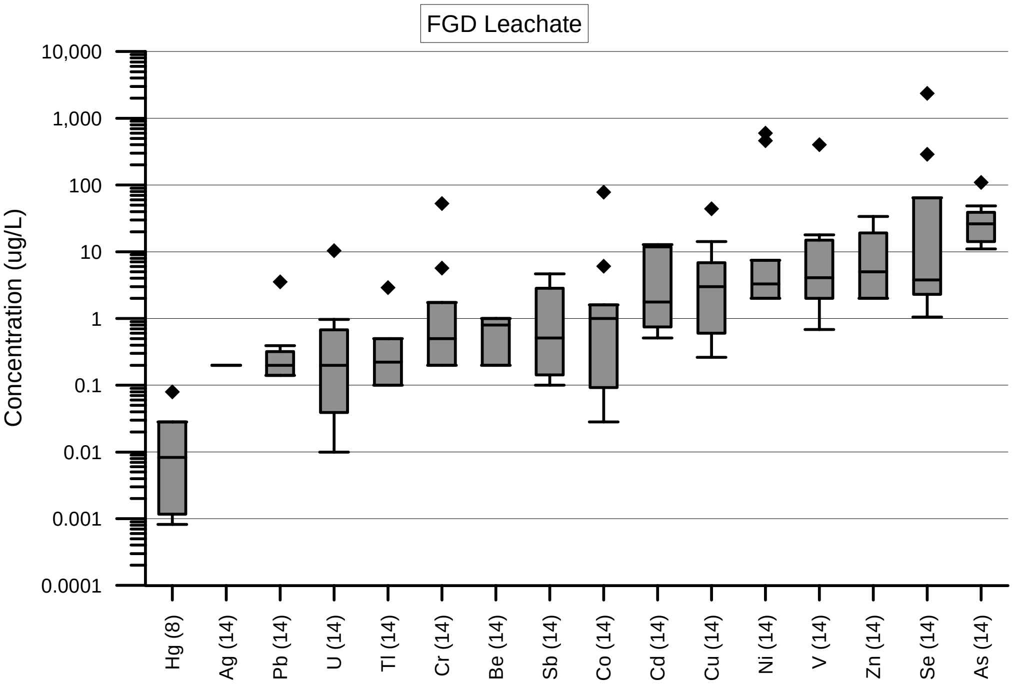

Figure 11. Concentration ranges for trace constituents in FGD leachate.

Arsenic concentrations varied by an order of magnitude for any given combination of management environment (landfill or impoundment) and source coal type. There was a tendency for relatively high concentrations when ash from bituminous coal was managed in impoundments or when ash from subbituminous coal was managed in landfills. Most arsenic leachate samples were dominated by the As(V) species.

Selenium and chromium concentrations in ash leachate were highest when the source coal was subbituminous, and when managed in landfills. For selenium, leachate samples from landfills tended to be dominated by Se(VI), while leachate samples from impoundments tended to be dominated by Se(IV). Chromium was dominated by Cr(VI) except for samples managed in impoundments where pH was lower than 4.

Mercury concentrations were very low, ranging from 0.25 to 61 ng/L, with a median concentration of 3.8 ng/L. Mercury concentrations in FGD leachate samples were also very low, ranging from 0.82 to 79 ng/L, with a median concentration of 8.3 ng/L. There was a tendency for mercury concentrations to be higher in ash leachate when managed in landfills, rather than impoundments.

The organic species of mercury always had low concentration, usually less than 5 percent of the total mercury concentration. Monomethyl mercury concentrations ranged from <0.02 to 6.7 ng/L, with a median concentration of 0.08 ng/L. Dimethyl mercury concentrations ranged from <0.02 to 0.06 ng/L, with a median concentration of <0.02 ng/L. There was no relationship between inorganic and organic mercury concentrations.

Summary and Conclusions

Field leachate samples were collected from 29 CCP management sites and analyzed for a suite of 43 inorganic constituents that included species of arsenic, selenium, chromium, and mercury. Results of this research have demonstrated that the concentration of individual constituents in samples collected from sites where CCPs are similarly managed, and where a similar source coal is utilized, can range over an order of magnitude; although the ranges may be sufficiently different such that relationships between CCP management method and source coal type can be established.

Arsenic and chromium in ash leachate are usually dominated by the oxidized forms, As(V) and Cr(VI). Selenium was mostly in the form of Se(IV), although there were a significant number of samples dominated by Se(VI). Se(IV) dominated in impoundment settings when the source coal was bituminous or a mixture of bituminous and subbituminous, while Se(VI) was predominant in landfill settings and when the source coal was subbituminous/lignite. Mercury concentrations were very low in all samples, with a median of 3.8 ng/L in ash leachate and 8.3 ng/L in FGD leachate. The organic species of mercury always had low concentration, usually less than 5 percent of the total mercury concentration.

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Acknowledgements

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Field Leachate Characterization at Coal Combustion Product Management Facilities

Technical Interactive Forum
November 15, 2006

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- **Researchers**
  - Natural Resource Technology
  - Trent University
  - Illinois Waste Management and Research Center

Objectives

- To broadly characterize field leachate for a wide variety of CCP management settings.
- To determine speciation of As, Se, Cr, and Hg in field leachates

Study Sites

Symbols indicate number of sites within a state, but do not correspond to location of sampled sites.

	FA		FGD/SDA	
	LF	IMP	LF	IMP
Sites Completed Thru 2005	★	▼	✦	⛊

Power Plant Attributes

- Boiler Types
- Fly Ash Collection
- FGD Systems
- Flue Gas Conditioning
- SCR/SNCR
- Mercury Control
- SO3 Mitigation

Study Parameters

Major Elements/ Field Parameters

Bicarbonate (calc)
Calcium
Carbonate (calc)
Chloride
Magnesium
Potassium
Sodium
Sulfate
Carbon, total inorganic
Carbon, total organic

Dissolved Oxygen
Electrical Cond.
ORP
pH
Temperature

Minor and Trace Elements

Aluminum
Antimony
Arsenic (total)
Arsenic (III)
Arsenic (V)
Barium
Beryllium
Boron
Cadmium
Chromium (total)
Chromium (VI)
Cobalt
Copper
Iron
Lead
Lithium
Manganese
Mercury (dimethyl)
Mercury (monomethyl, diss.)
Mercury (monomethyl, part.)
Mercury (total, dissolved)
Mercury (total, particulate)
Molybdenum
Nickel
Selenium (total)
Selenium (IV)
Selenium (VI)
Silica
Silver
Strontium
Thallium
Uranium
Vanadium
Zinc

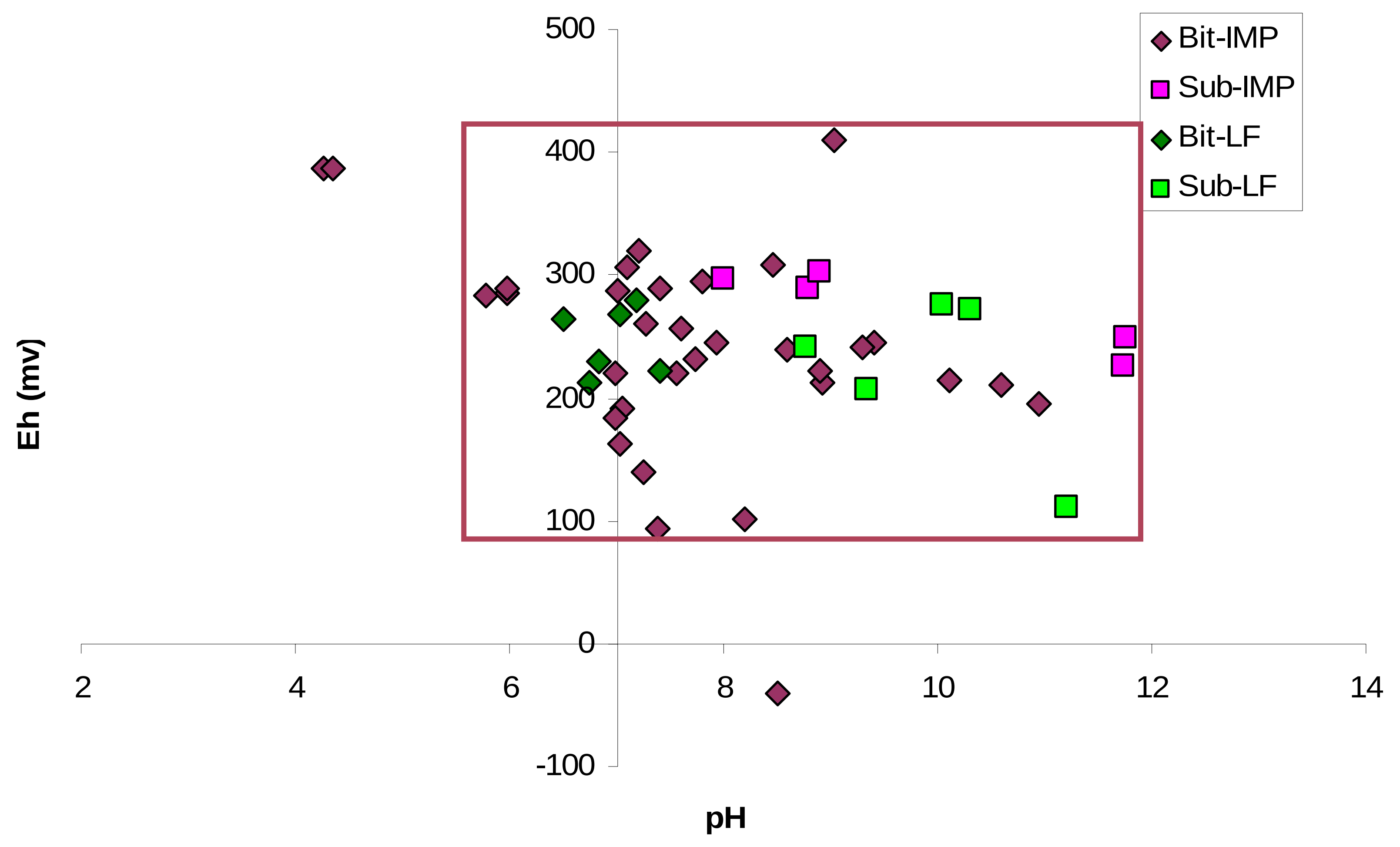
Sample Preservation for Speciation of As and Se

Sample Location Summary

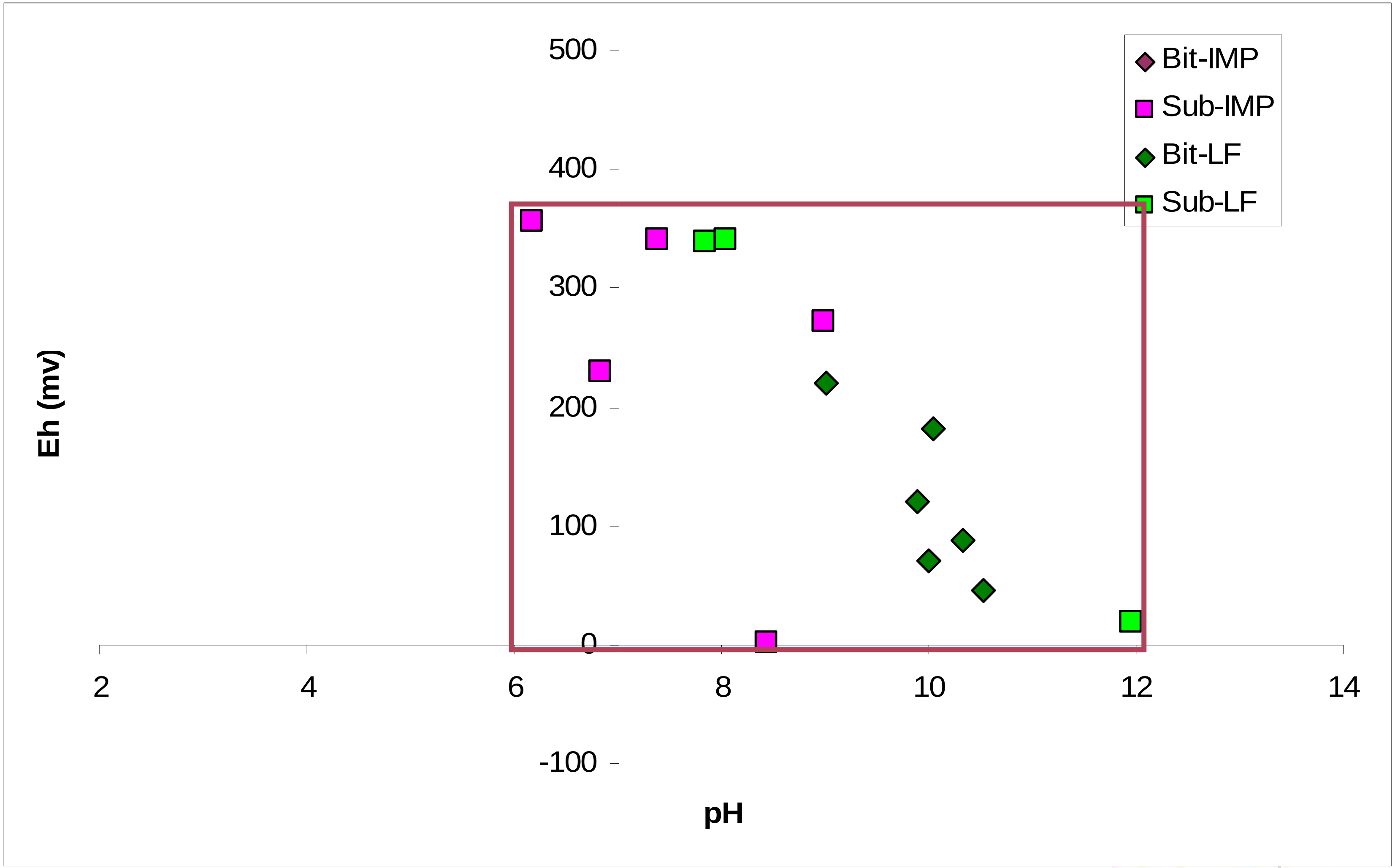
81 Field Leachate Samples

- leachate wells
- lysimeters
- leachate collection systems
- drive point
- direct push
- pond/seep grab
- sluice lines

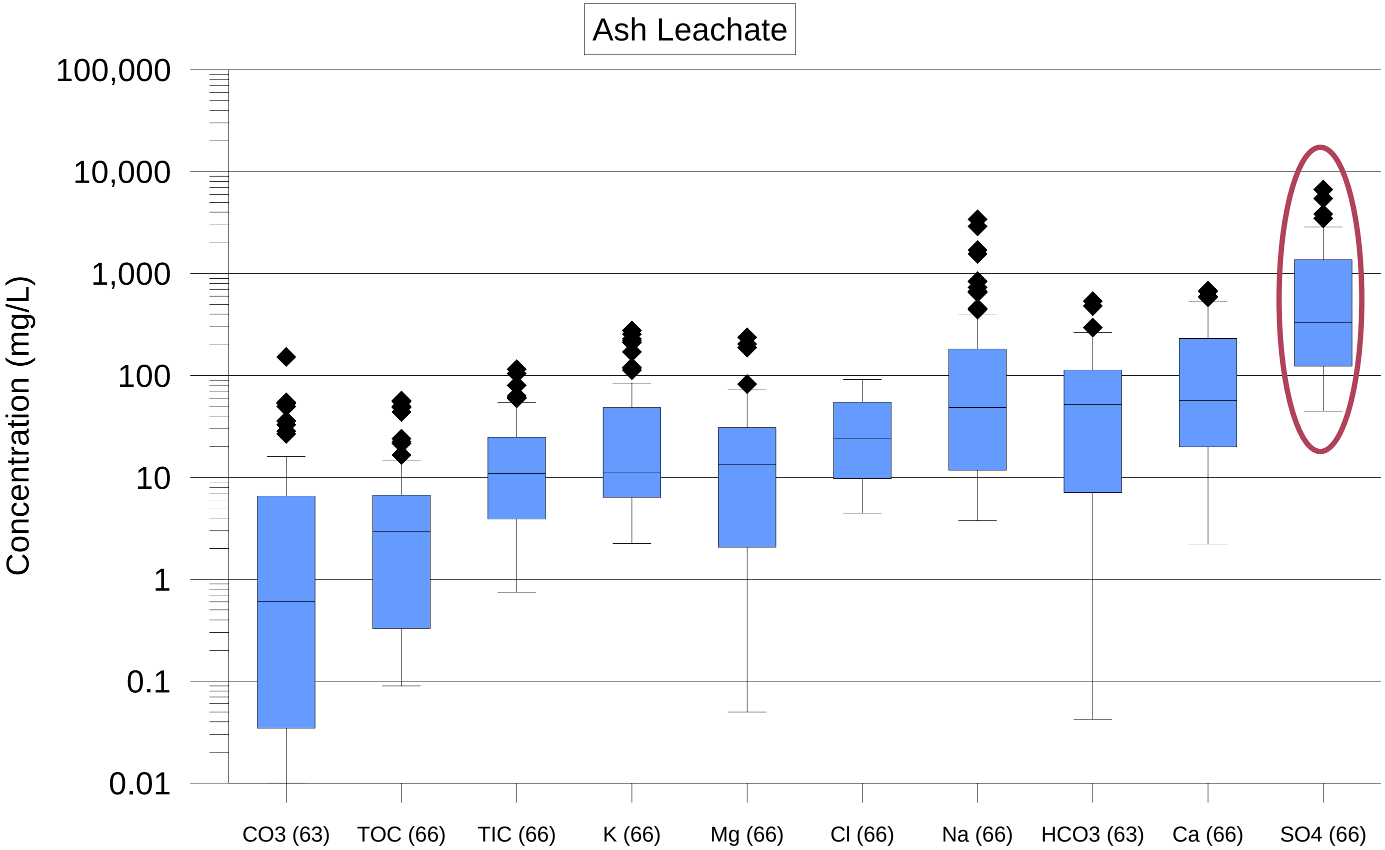
Eh-pH of Coal Ash Leachate Samples



Eh-pH of FGD Leachate Samples



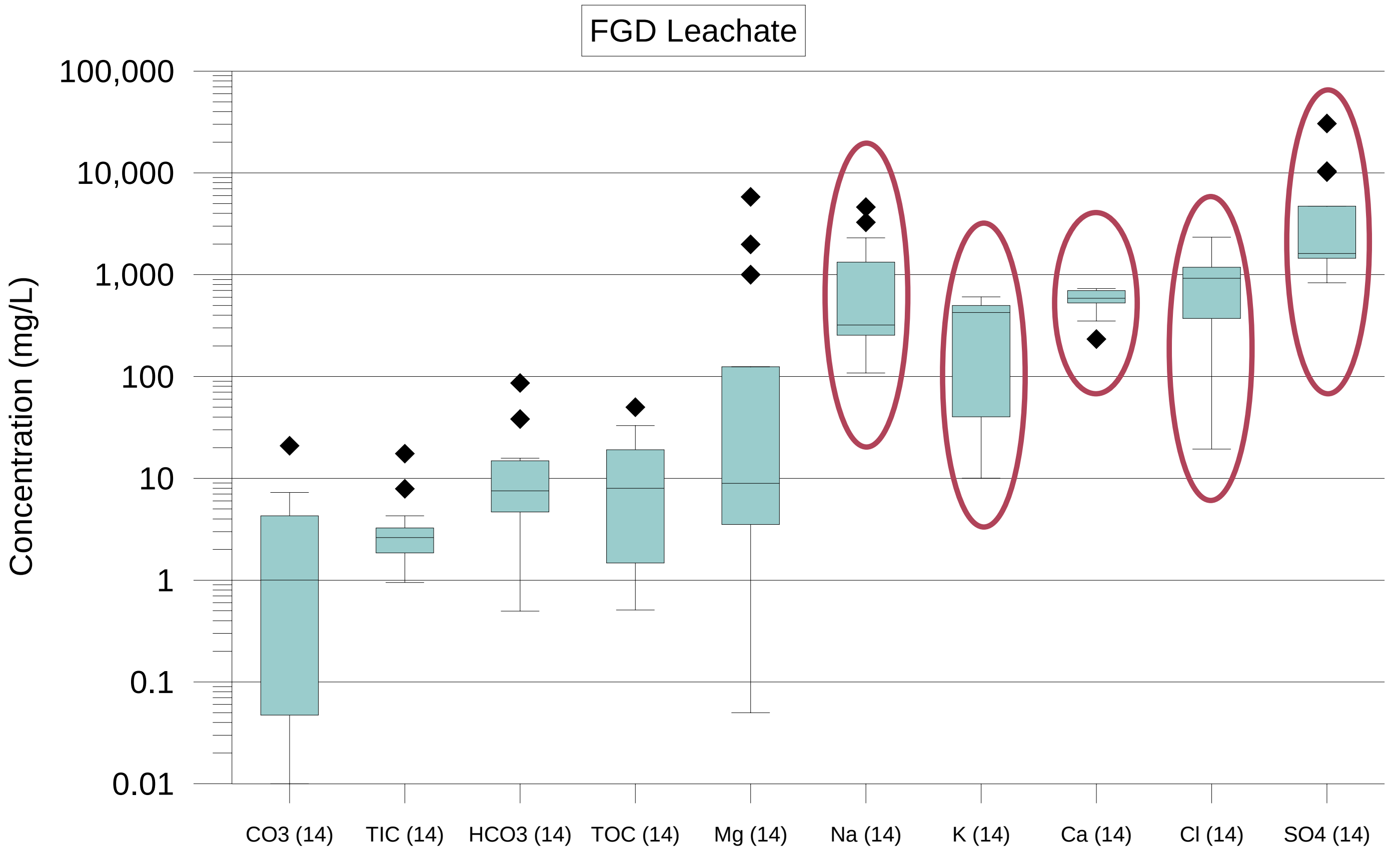
Ash Leachate
Major Constituents



Median>100 mg/L

Sulfate

FGD Leachate
Major Constituents



Median>100 mg/L

Sulfate

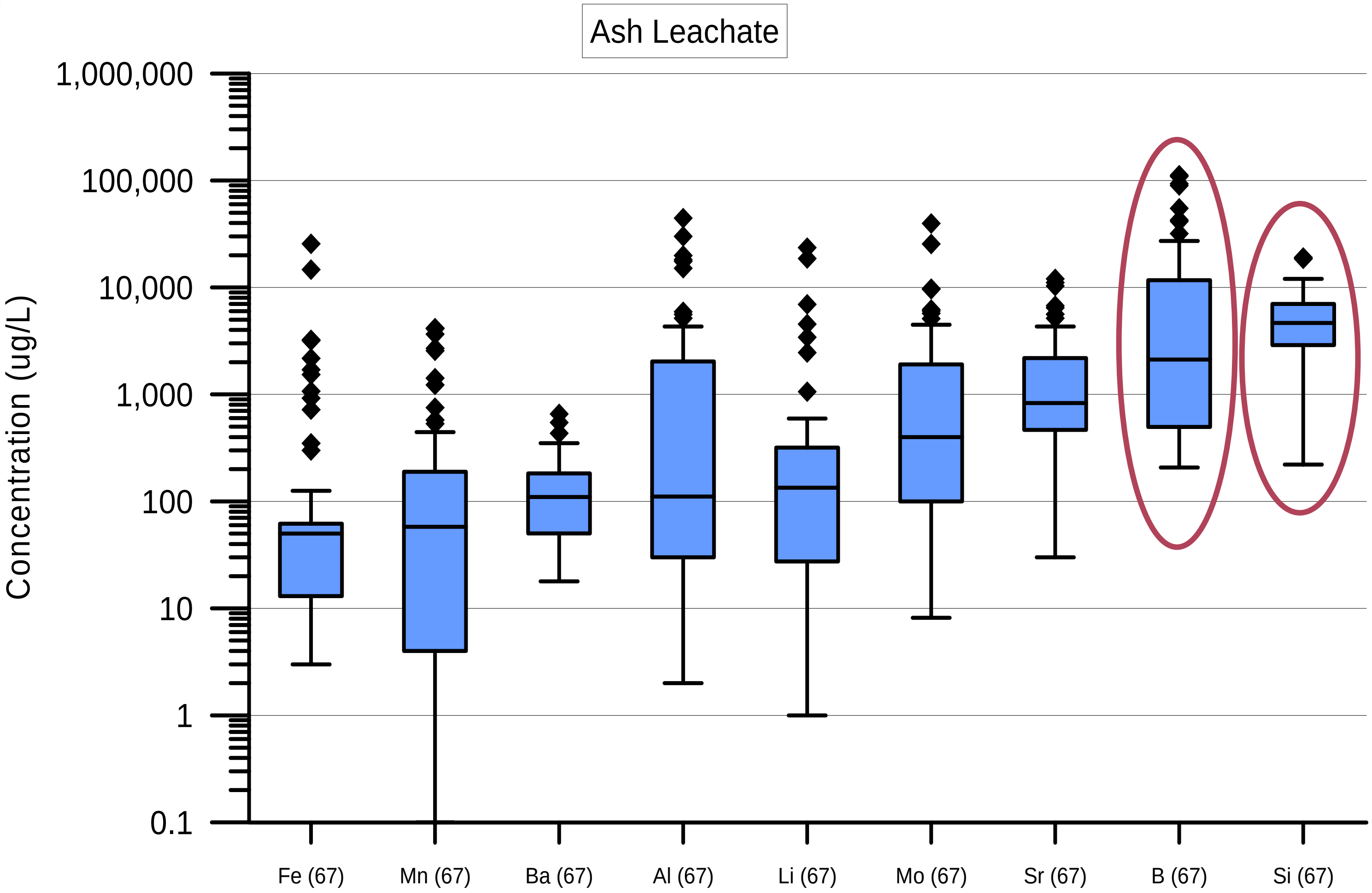
Chloride

Calcium

Potassium

Sodium

Ash Leachate
Minor Constituents

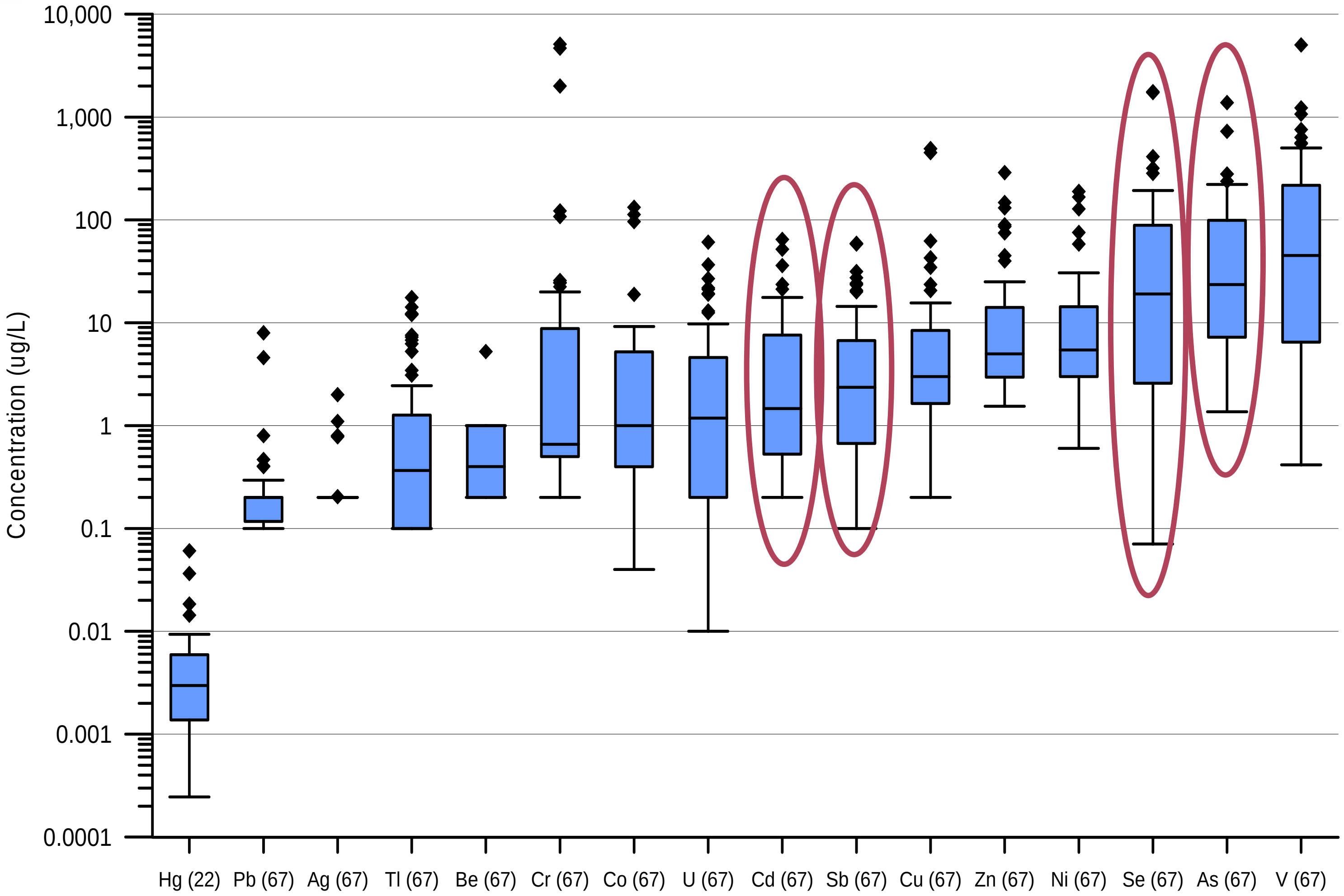


Median>1 mg/L

Silicon

Boron

Ash Leachate
Trace Constituents



25% > MCL

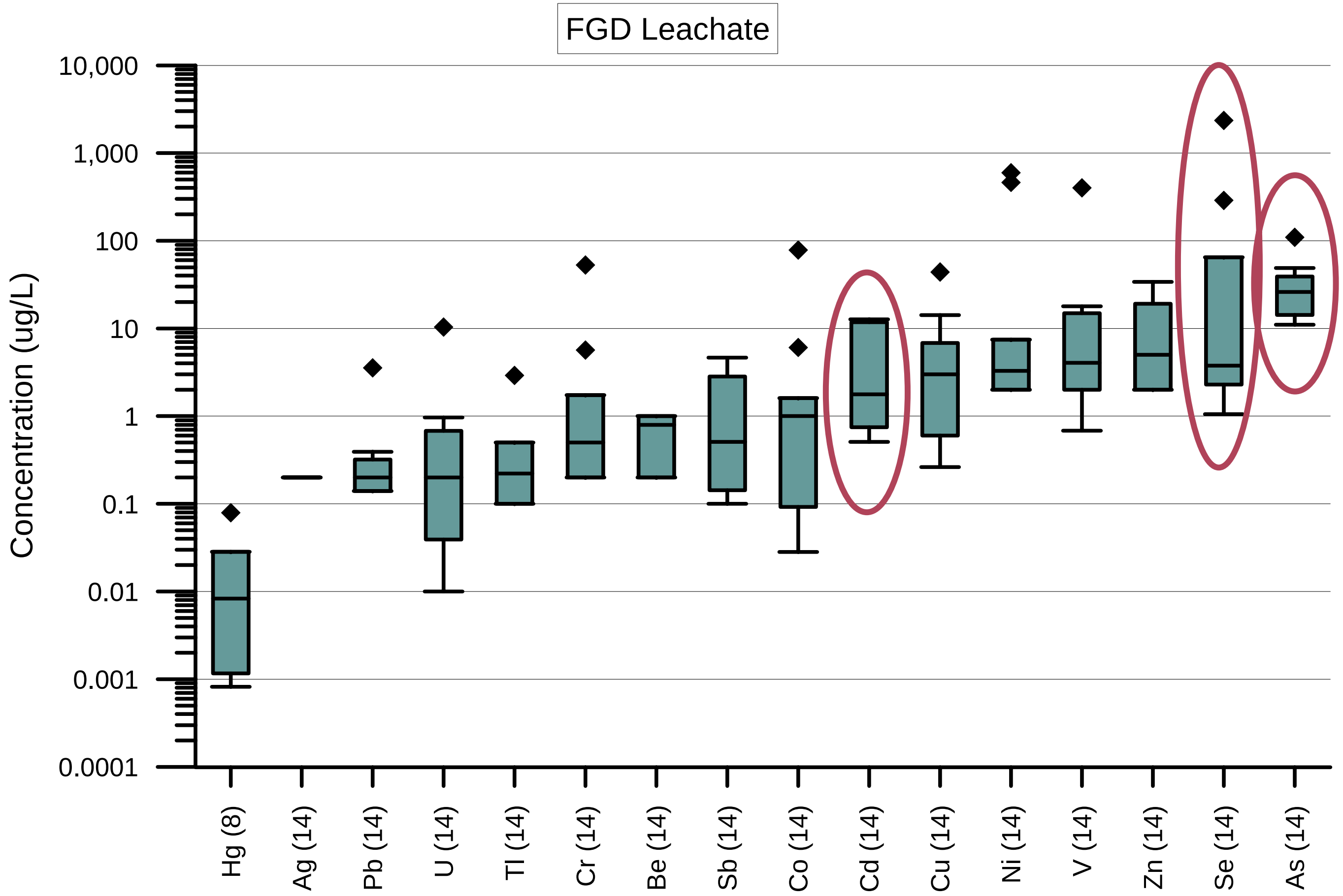
Arsenic

Selenium

Antimony

Cadmium

FGD Leachate
Trace Constituents



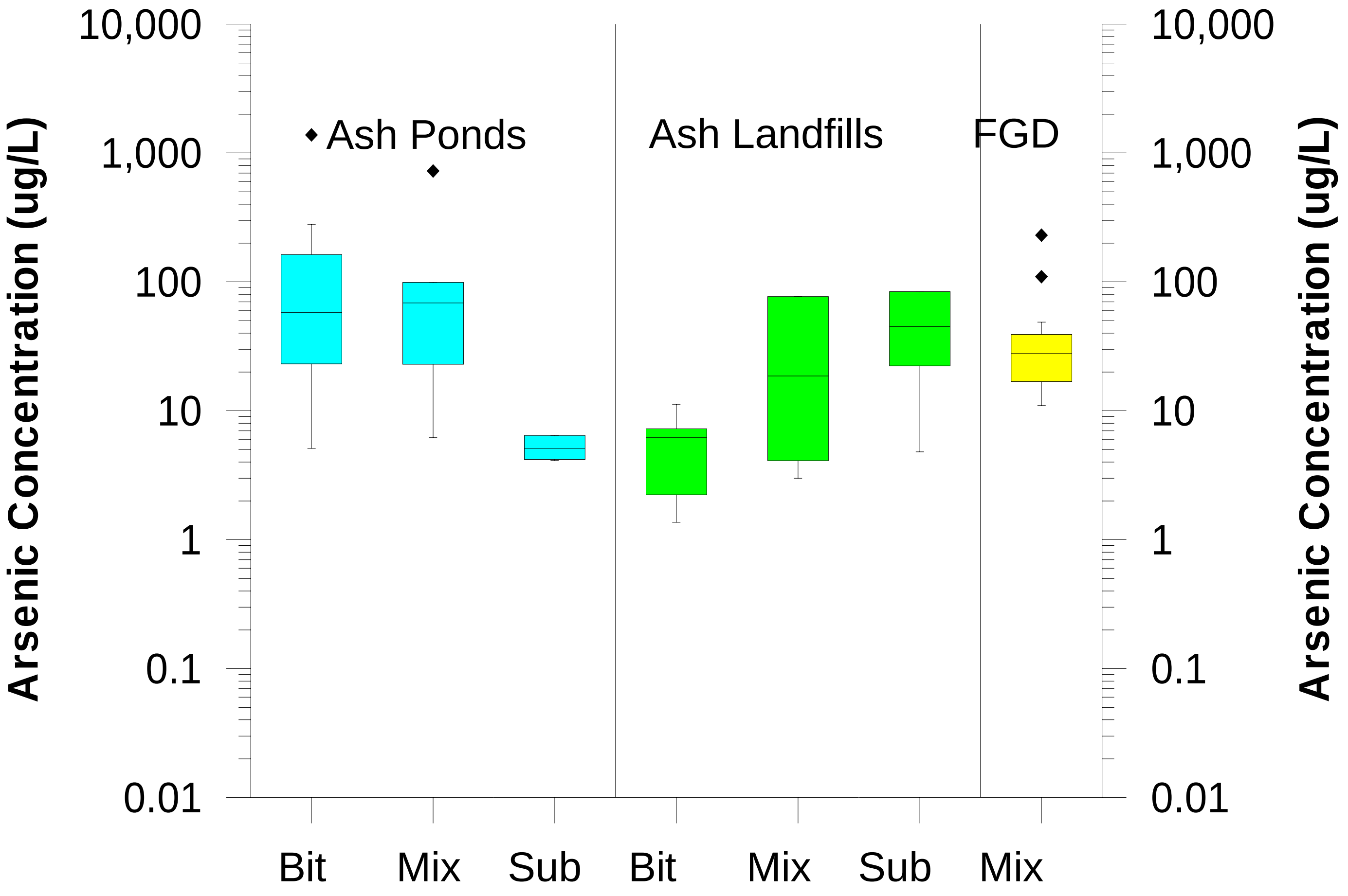
<u>25% > MCL</u>

Arsenic

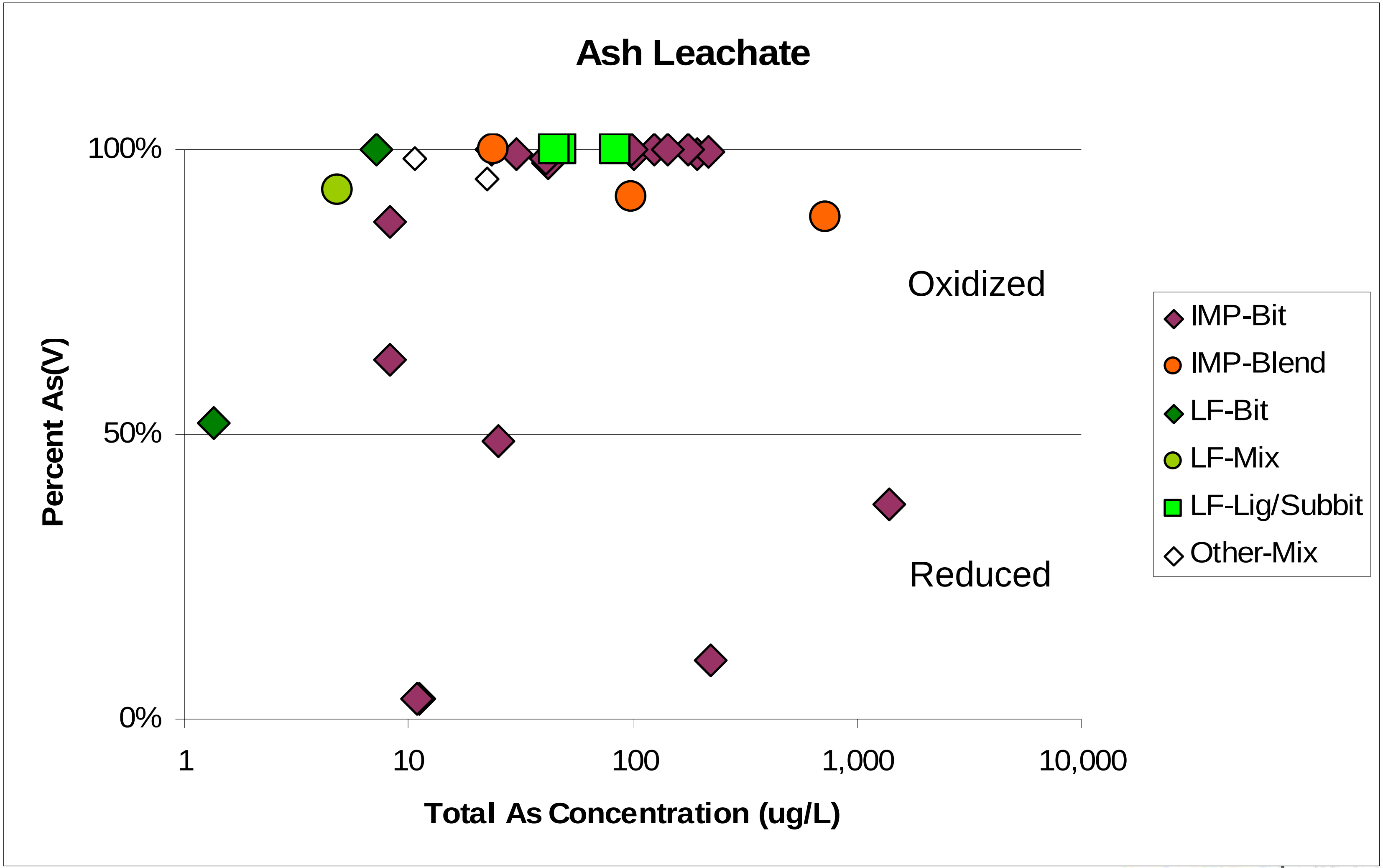
Selenium

Cadmium

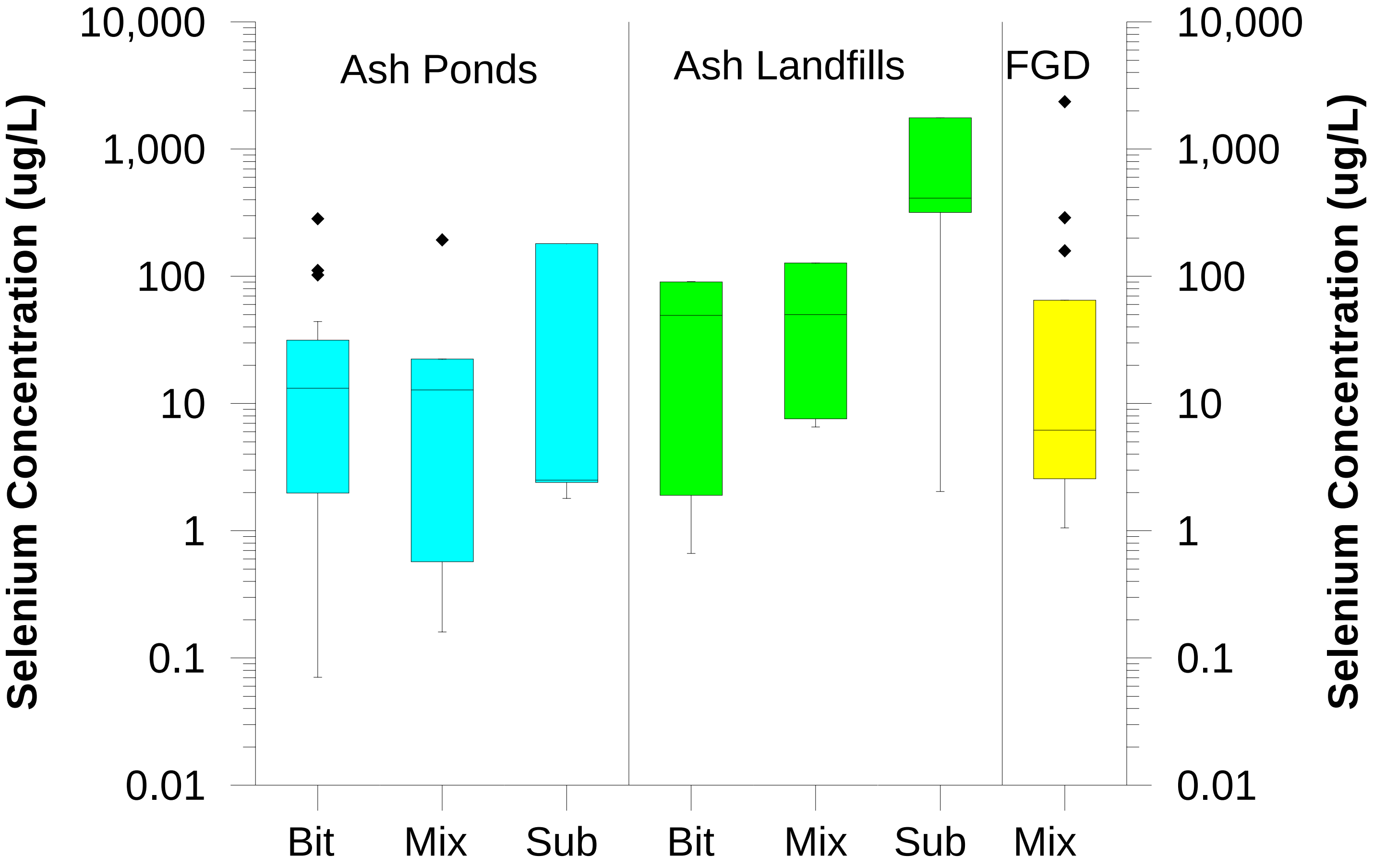
Field Leachate - Arsenic



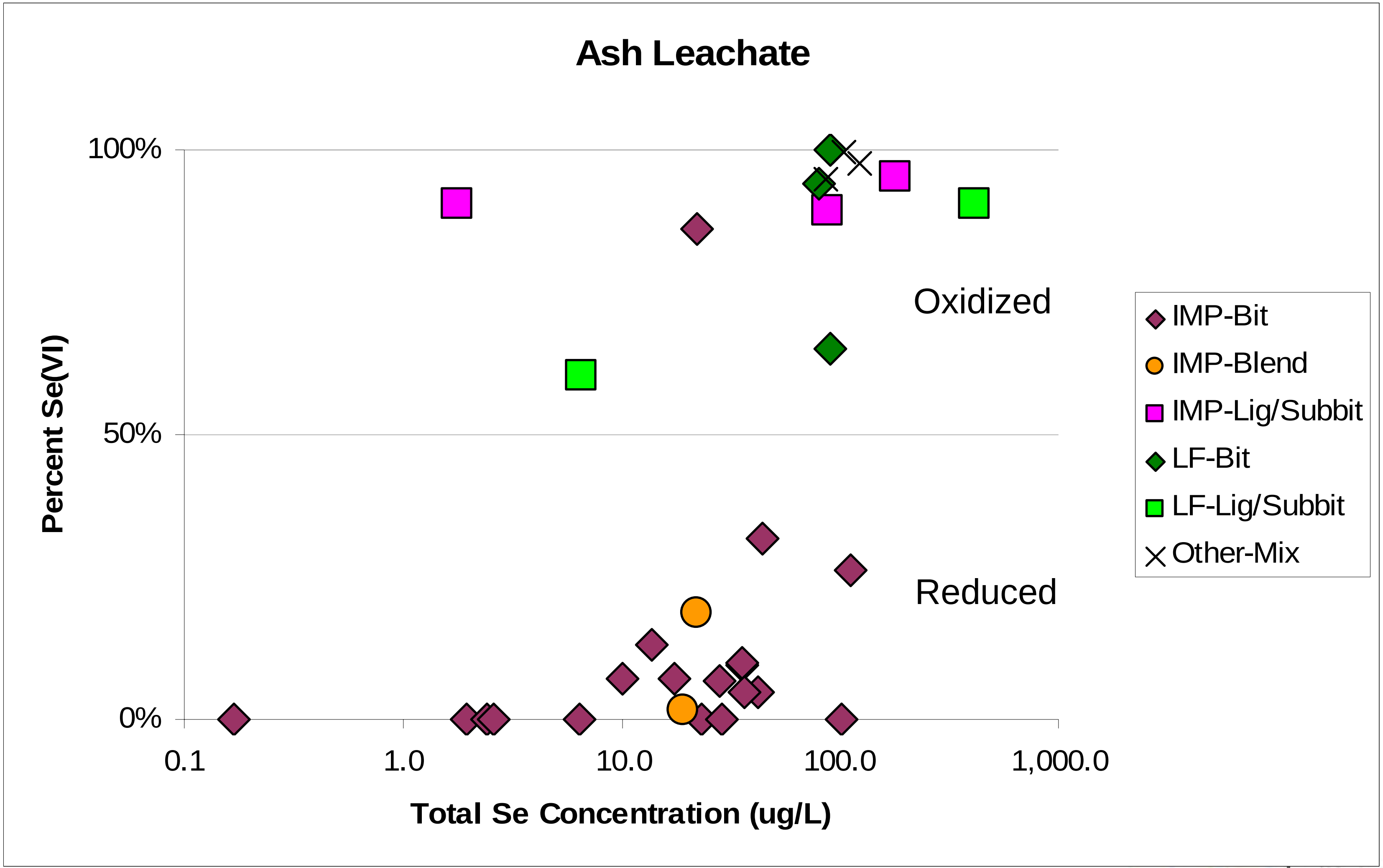
Arsenic Speciation



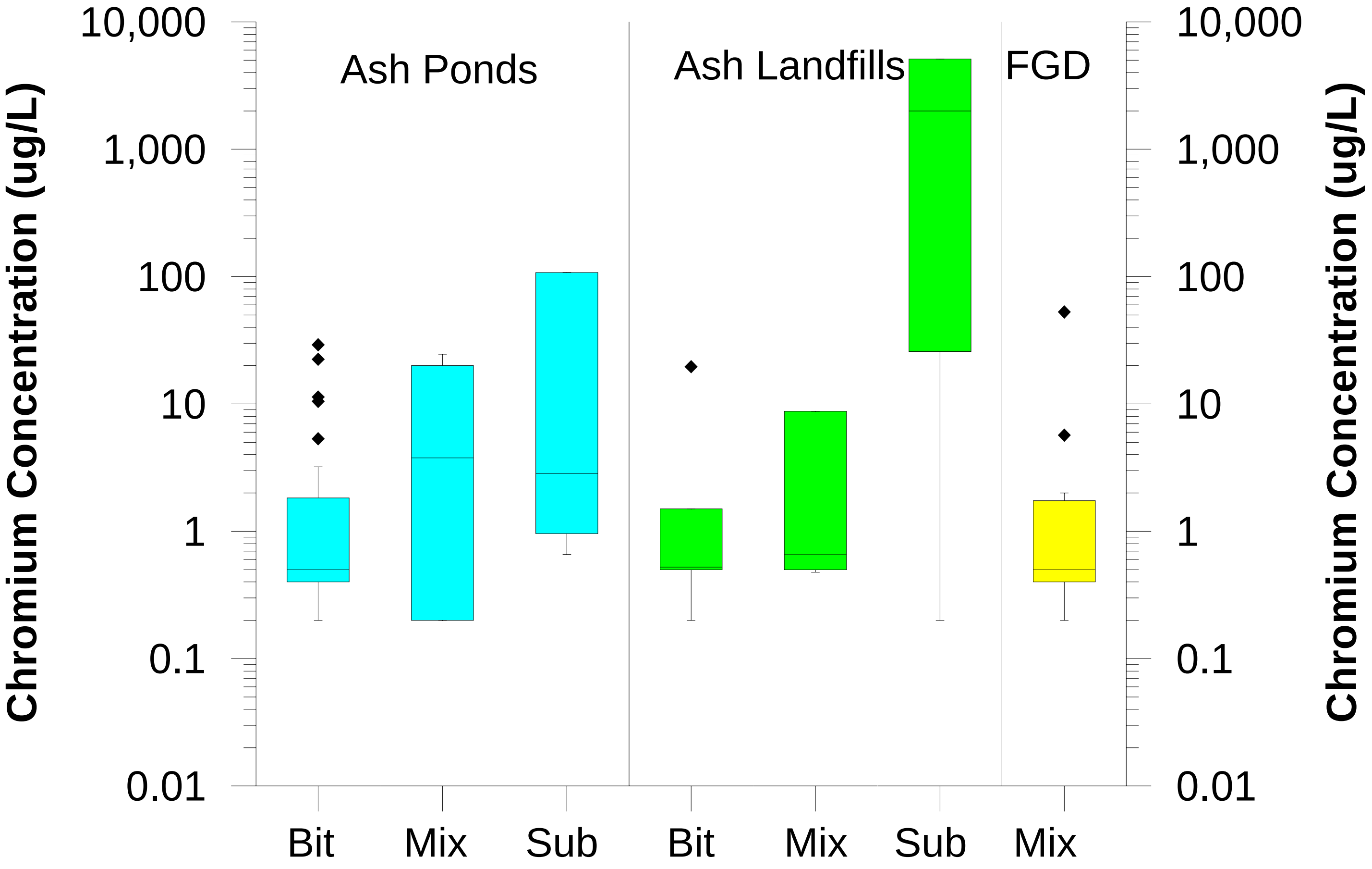
Field Leachate - Selenium



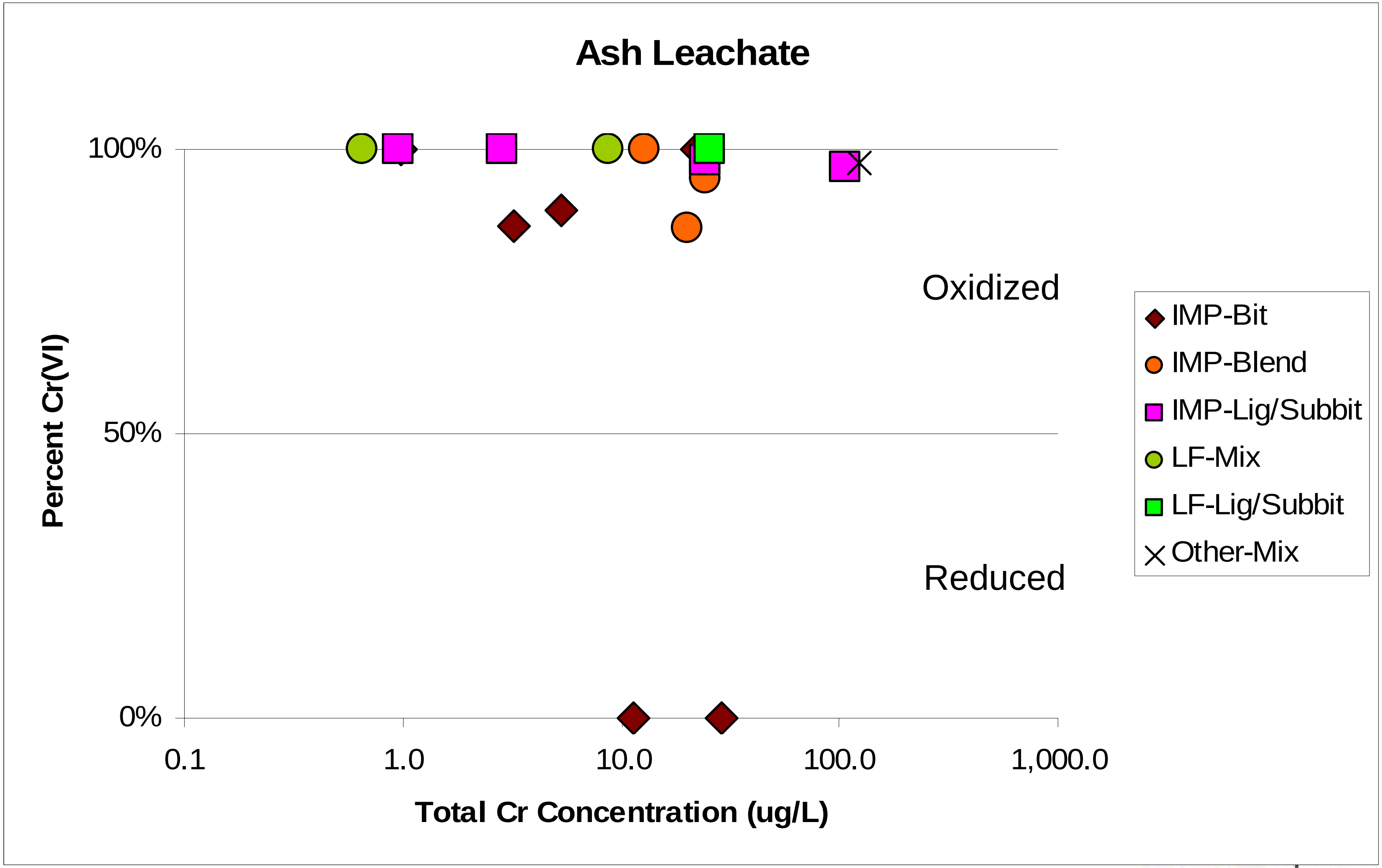
Selenium Speciation



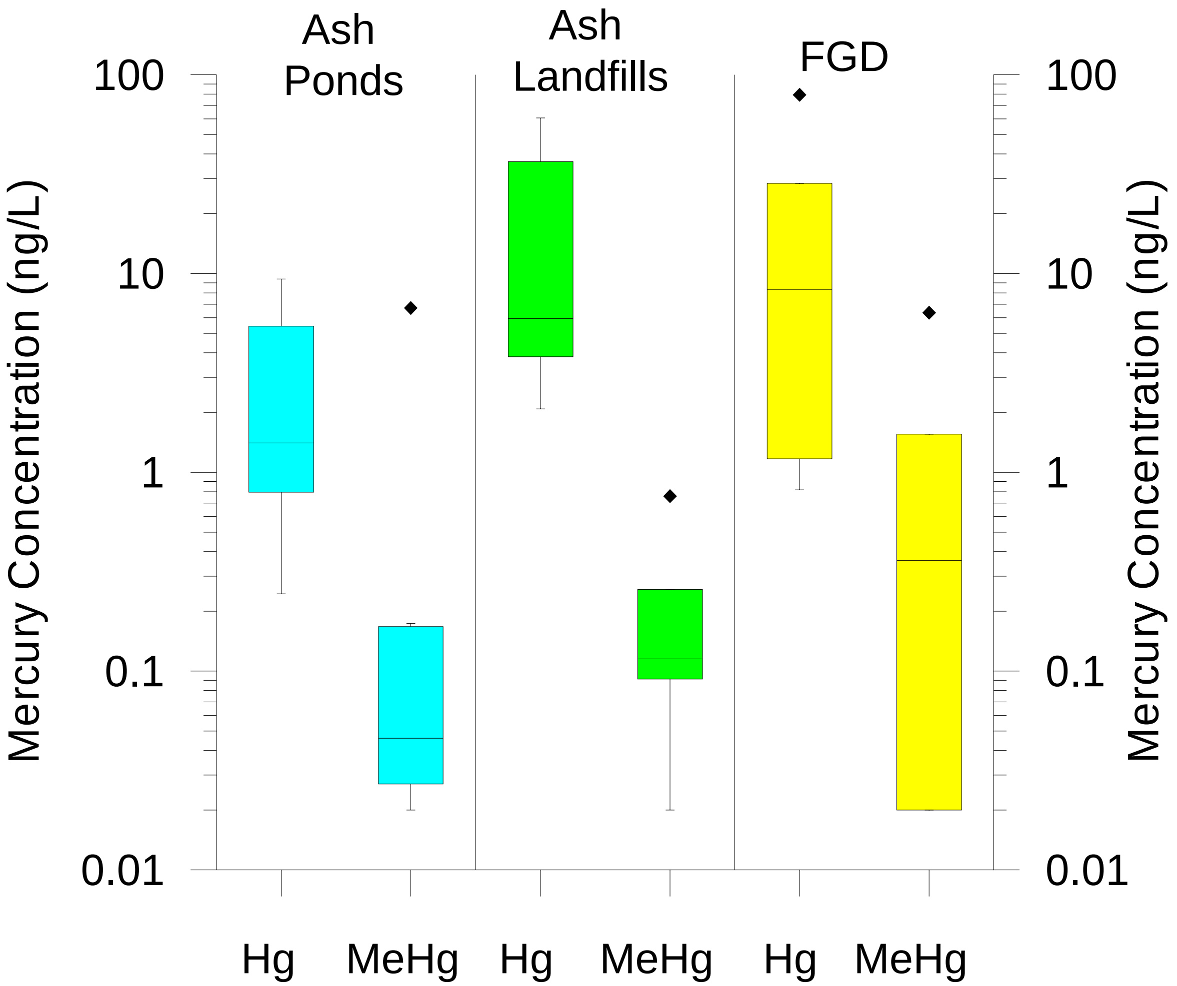
Field Leachate - Chromium



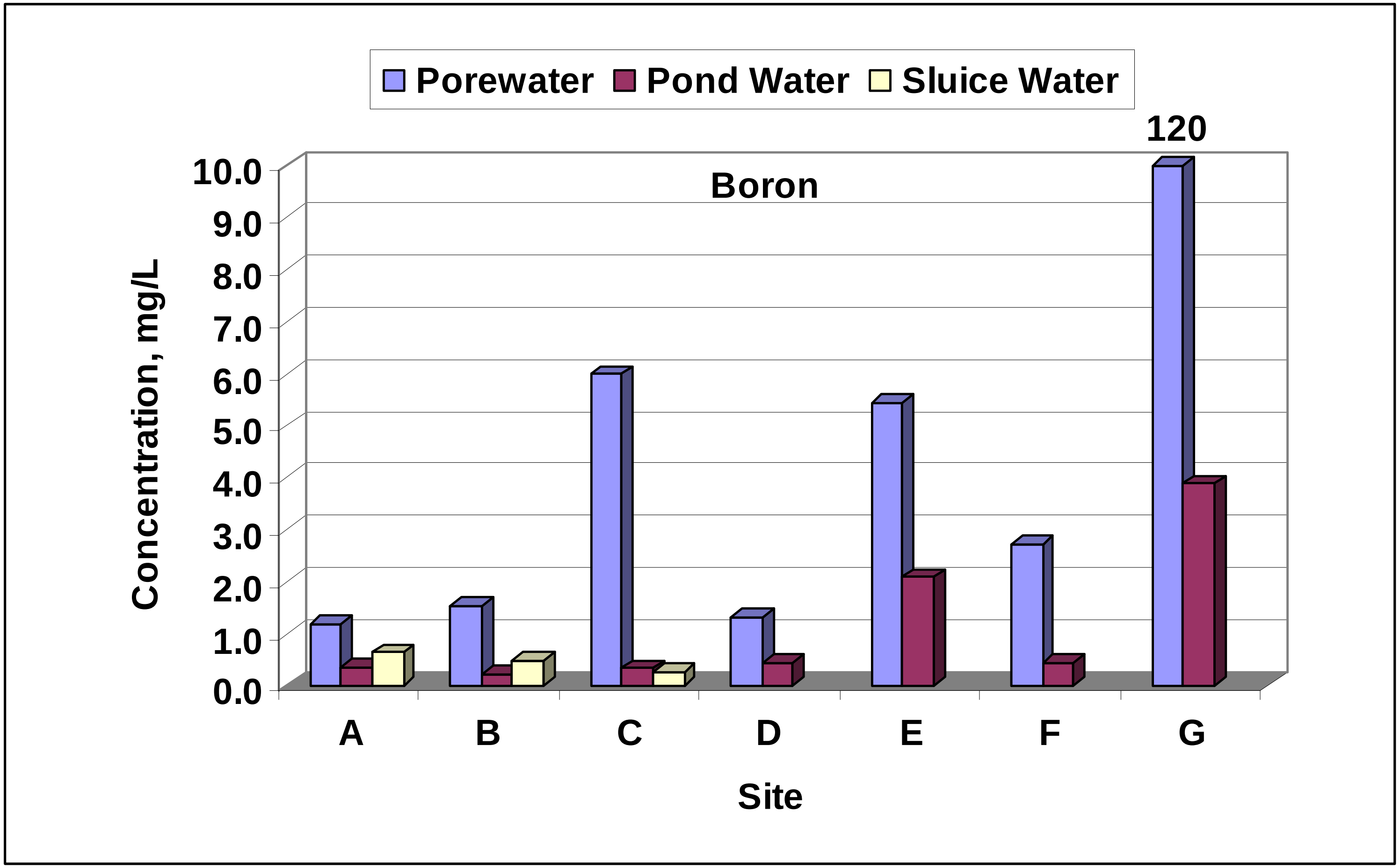
Chromium Speciation



Field Leachate – Mercury Speciation



Effect of Sample Type



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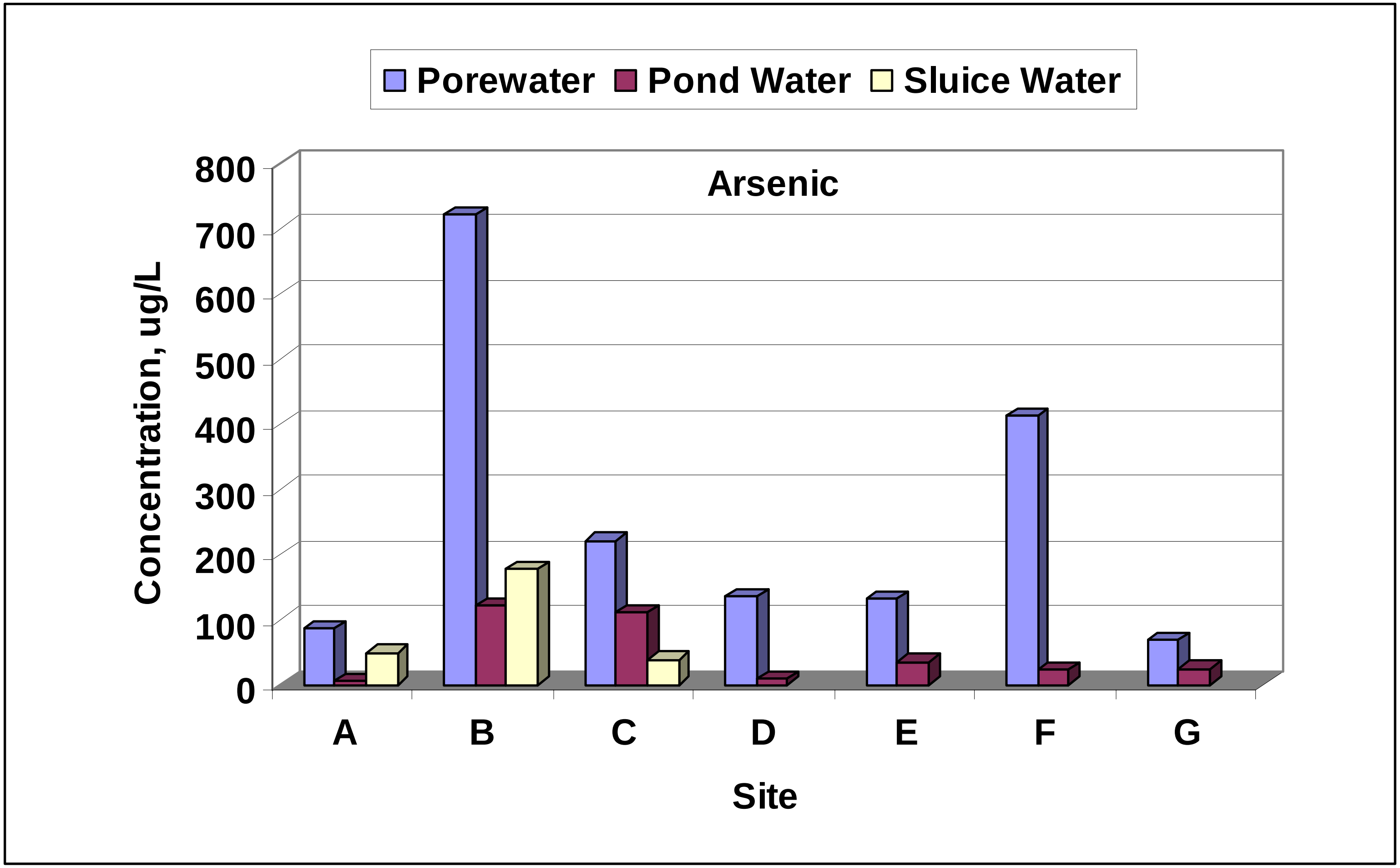
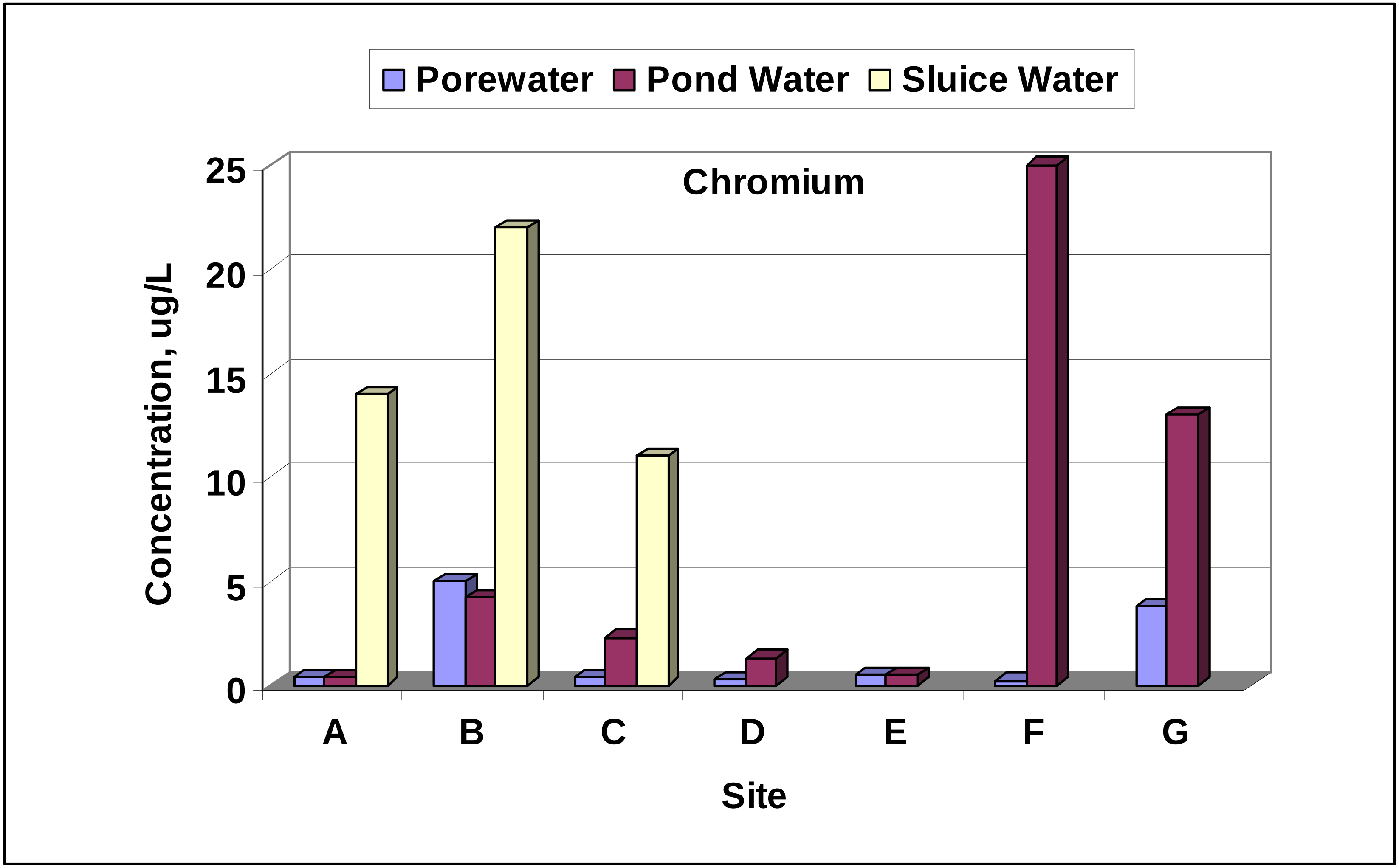


Effect of Sample Type



Questions

LEACHING OF TRACE ELEMENTS FROM SOILS STABILIZED WITH COAL FLY ASH

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View Presentation

Abstract

Batch water leaching tests (WLTs) and column leaching tests (CLTs) were conducted on coal-combustion fly ashes, soil, and soil-fly ash mixtures to characterize leaching of Cd, Cr, Se, and Ag. Concentrations in leachate from the WLTs on soil-fly ash mixtures are different from those on fly ash alone and cannot be estimated accurately based on linear dilution calculations using concentrations from WLTs on fly ash alone. The concentration varies non-linearly with fly ash content due to the variation in pH with fly ash content. Initial concentrations from CLTs are higher than concentrations from WLTs. However, both WLT concentrations and initial concentrations from CLTs exhibit similar trends as a function of fly ash content, leachate pH, and soil properties. Scaling factors can be applied to WLT concentrations (50 for Ag and Cd, 10 for Cr and Se) to estimate initial concentrations for CLTs.

Keywords: Leaching, trace elements, cadmium, chromium, selenium, silver, stabilized soil, fly ash, industrial byproduct, column test, batch test

Introduction

A variety of laboratory and field studies have shown that cementitious fly ashes are very effective in improving the mechanical properties of soft fine-grained soils encountered during highway construction (Ferguson 1993, Turner 1997, Edil et al. 2002, 2006). Far less attention has been placed on the potential environmental impacts of stabilizing soils with fly ash. Issues to be addressed include dust control, contamination of runoff, and ground water impacts. Of these, the effect on ground water is a primary concern because fly ash contains toxic trace elements that may leach into infiltrating rain water passing through a pavement system (Goh and Tay 1993, Erbe et al. 2003). This paper describes a study conducted to evaluate leaching of trace elements from soft fine-grained soils stabilized with fly ashes. Batch water leaching tests (WLTs) and column leaching tests (CLTs) were conducted on six soils, five fly ashes, and mixtures of the soils and fly ashes.

Materials

Soils

Six fine-grained soils and one coarse-grained soil (sand) were used in the study. Four of the fine-grained soils (Joy silt loam, Plano silt loam, Superior clay, and Theresa silt loam) are from geographically diverse regions of Wisconsin. One fine-grained soil is from Montana (Clark sandy clay) and another is from Nebraska (Peorian loess). At their natural water content, all of the fine-grained soils are considered to be problematic soft soils in terms of highway construction. The four fine-grained soils from Wisconsin were used for most of the tests.

Basic physical and chemical properties of the fine-grained soils are summarized in Table 1. These soils classify as low plasticity, high plasticity, or organic high plasticity clays (CL, CH, or OH) and have a 2-μm clay fraction ranging between 17 and 65%. The natural gravimetric water contents are high (25-35%), which is why the soils are soft in their *in-situ* state. The paste pH of the soils ranges between 6.9 and 10.6 and the cation exchange capacity (CEC) ranges between 9.9 and 35.3 cmol$^+$/kg. The highest CEC is associated with the highly plastic Superior clay, which also has the largest clay content.

Table 1. Properties and classifications of soils.

Soil	Liquid Limit	Plasticity Index	Specific Gravity	USCS Classification	w_N (%)	pH	CEC (cmol$^+$/kg)
Joy silt loam	39	17	2.70	CL	25	6.9	9.9
Plano silt loam	44	20	2.71	CL	27	7.1	14.2
Superior clay	69	38	2.71	CH	35	7.4	35.3
Theresa silt loam	61	19	2.24	OH	35	7.1	27.6
Clark sandy clay	72	51	2.64	CH	NA	10.6	32.0
Peorian loess	39	20	2.56	CL	NA	7.1	18.0

Note: w_N = natural water content, CEC = Cation exchange capacity, NA = Not available.

The sand was used as a control where adsorption on the soil solids would be negligible. The sand that was used is uniformly graded, has a median particle size of 0.24 mm, and a fines content (percent finer than 75 µm) of 6.5%. The sand was washed in DI water to remove soluble salts and other contaminants prior to use in the testing program.

Fly Ashes

Five fly ashes were used. Two of the fly ashes are from Wisconsin (Columbia and Dewey), one is from Minnesota (King), and two are from North Dakota (Coal Creek and Stanton). The fly ashes from Wisconsin and Minnesota were used for most of the testing program.

Physical properties and chemical composition of the fly ashes are shown in Table 2 along with classifications per ASTM C 618. Three of the ashes (Columbia, Coal Creek, and Stanton) are Class C fly ashes. All others are considered “off-specification” ashes because they do not meet the criteria for Class C or Class F. Oxide contents were not available for the Coal Creek ash and CEC was not available for the Coal Creek and Stanton ashes. All of the fly ashes are effective for mechanical stabilization of soft fine-grained soils (Edil et al. 2006).

Table 2. Properties and composition of fly ashes.

Fly Ash	Class. (ASTM 618)	G_s	w (%)	LOI (%)	CaO (%)	Other Oxides (%)	Sulfur Trioxide Content (%)	pH	CEC ($cmol^+/kg$)
Columbia	C	2.70	0.09	0.7	23.0	55.5	3.7	11.7	102.2
Dewey	Off-spec	2.53	0.23	16.2	9.8	38.7	11.8	10.1	49.3
King	Off-spec	2.68	0.44	14.4	25.8	44.9	6.4	11.0	77.5
Stanton	C	2.63	2.80	0.8	21.3	63.5	1.0	12.8	53.0
Coal Creek	C	2.59	2.60	0.5	13.3	74.0	NA	11.9	53.0

Note: G_s = specific gravity of solid, w = moisture content, LOI = loss on ignition, other oxides = $SiO_2 + Al_2O_3 + Fe_2O_3$, CEC = cation exchange capacity, NA = not available.

Methods

Water Leach Tests

Water leach tests (WLTs) were conducted on the fly ashes, the soils, and soil-fly ash mixtures in accordance with ASTM D 3987 using ASTM Type II deionized water. The soil-fly ash mixtures were prepared with fly ash contents of 10% and 20% to bracket the typical range of fly ash contents used for soil stabilization (Edil et al. 2006). A 2-kg sample of soil and fly ash was mixed homogeneously on a tray and tap water was sprayed onto the mixture to achieve a molding water content 2% dry of optimum water content. The mixture was blended until it appeared homogeneous. A portion was cured in a sealed plastic bag for 7 d before conducting the WLT. The remainder was used to prepare a specimen for column testing.

Column Tests

Column leaching tests (CLTs) were conducted on the soil-fly ash mixtures to provide a more realistic assessment of leaching under flow-through conditions (Bin Shafique et al. 2006). Mixtures were compacted using standard Proctor effort (ASTM D 698) approximately one hour after mixing to simulate the delay between mixing and compaction that was observed in the field construction. The compaction water content was 2% dry of optimum. After compaction, the specimens were cured for 7 d at 100% humidity and constant temperature (21°C).

The CLTs were conducted immediately after curing. Specimens were placed in flexible-wall permeameters and permeated with 0.1 M LiBr solution using a hydraulic gradient between 7 and 10. Leachate (effluent) from the CLTs was collected in Teflon sampling bags. Additional details on the column tests can be found in Bin Shafique et al. (2006).

Chemical Analysis

Leachate from the WLTs and CLTs was analyzed for concentrations of Cd, Cr, Se, and Ag using furnace atomic absorption (AA) spectrometry following US EPA Methods 213.2, 218.2, 270.2, and 272.2. All analyses were conducted using a Varian SpectrAA-800 Atomic Absorption (AA) Spectrometer controlled by a computerized Varian SpectrAA-880 Data Station. The SpectrAA-800 was equipped with a graphite tube atomizer (GTA 100).

Results and Discussion

Water Leach Tests

Concentrations of Cd, Cr, Se, and Ag in the leachate from the WLTs are summarized in Tables 3 (soils and fly ashes) and 4 (soil-fly ash mixtures). Maximum concentrations cited in the *Wisconsin Administrative Code* for subgrade stabilization beneath highway pavements are also shown in Tables 3 and 4. All of the concentrations from the WLTs are lower than the maximum concentrations.

Concentrations of Cd, Cr, Se, and Ag from the WLTs exhibit two types of behavior (Figure 1). For Cd and Ag, the concentration is essentially independent of fly ash content, decreases slightly with fly ash content, or increases slightly with fly ash content for the mixtures prepared with fine-grained soil (Figure 1a, Tables 3 and 4). In contrast, the concentration of Cr or Se increases appreciably as the fly ash content increases (Figure 1b, Tables 3 and 4). Thus, for mixtures of fine-grained soil and fly ash, WLTs on bulk fly ash provide a reasonable estimate of concentrations of Cd and Ag for WLTs on mixtures (perhaps fortuitously), whereas WLTs on bulk fly ash overestimate concentrations of Cr and Se from WLTs on mixtures.

Table 3. Concentration of Cd, Cr (T), Se, and Ag from WLTs on fly ashes and soils.

Fly Ash or Soil	Leachate pH	Concentration (μg/L)			
		Cd (0.1)	Cr (T) (2.0)	Se (2.0)	Ag (0.2)
Joy silt loam	7.0	0.8	23.8	11.0	1.6
Superior clay	7.5	1.1	40.4	10.0	3.1
Theresa silt loam	7.2	1.4	46.9	6.0	4.4
Peorian loess	8.9	0.2	24.3	19.0	1.8
Clark sandy clay	10.0	0.7	23.1	33.9	3.1
Silica sand	7.5	0.0	0.0	0.0	0.0
Columbia	11.8	0.7	95.0	26.0	2.2
Dewey	10.5	3.2	59.0	82.0	6.2
King	11.5	1.7	123.2	41.0	4.5
Coal Creek	10.7	3.6	84.6	18.0	3.1
Stanton	11.8	2.3	91.2	20.1	4.1
Wisconsin Criteria	NA	25	500	250	250

Notes: Detection limits shown in parentheses, T = total chromium, NA = not applicable.

Table 4. Concentrations of Cd, Cr (T), Se, and Ag from WLTs on soil-fly ash mixtures.

Fly Ash	**Soil**	**Fly Ash Content (%)**	**Leachate pH**	**Concentration (μg/L)**			
				Cd (0.1)	**Cr (T) (2.0)**	**Se (2.0)**	**Ag (0.2)**
Columbia	Joy silt loam	10	11.0	0.6	46.0	16.2	1.8
		20	11.6	0.5	56.2	17.3	1.7
	Superior clay	10	10.9	0.8	52.0	13.0	2.2
		20	11.6	0.8	63.1	14.0	2.4
	Theresa silt loam	10	10.7	0.9	66.0	11.0	2.6
		20	11.4	1.0	73.0	13.0	2.5
	Silica sand	10	11.4	0.4	41.1	13.8	1.1
		20	11.7	0.4	58.4	18.0	1.8
Dewey	Joy silt loam	10	9.7	1.7	32.4	35.0	2.9
		20	10.4	1.7	36.8	45.4	2.7
	Superior clay	10	9.3	1.6	47.0	25.0	2.8
		20	10.1	1.8	50.0	36.0	3.1
	Theresa silt loam	10	9.0	1.8	56.0	32.0	3.6
		20	9.4	2.3	65.8	47.0	3.2
	Silica sand	10	10.4	1.3	29.8	42.0	2.3
		20	10.5	1.8	38.9	53.0	2.8
King	Joy silt loam	10	10.9	0.7	74.6	24.0	3.2
		20	11.5	1.0	86.0	32.0	3.3
	Superior clay	10	10.8	1.2	76.0	20.0	3.3
		20	11.4	1.2	84.0	24.0	3.2
	Theresa silt loam	10	9.9	1.0	83.0	22.0	3.6
		20	11.1	1.3	93.5	30.0	3.5
	Silica sand	10	11.2	1.0	62.8	28.4	2.2
		20	11.5	1.1	79.0	33.0	2.8
Coal Creek	Peorian loess	10	9.6	2.1	49.6	13.3	2.2
		20	10.0	2.4	53.5	20.3	2.5
	Clark sandy clay	10	9.3	0.5	63.0	6.6	3.1
		20	9.9	0.7	72.0	22.6	3.4
Stanton	Peorian loess	10	10.7	1.4	64.2	19.2	2.9
		20	10.9	1.4	75.3	12.4	3.2
	Clark sandy clay	10	10.4	1.1	79.3	19.5	4.1
		20	10.5	1.3	94.3	7.6	4.3
Wisconsin Criteria		100	NA	25	500	250	250

The Cd and Ag concentrations are insensitive to fly ash content because these elements leach from the fine-grained soils and fly ashes alone at comparable concentrations (Table 3). The fine-grained soil also tends to adsorb Cd and Ag. In contrast, when sand is used in the mixture, the Cd and Ag concentrations increase with fly ash content (Figure 1a, Table 4). Cd and Ag are not present in the leachate from sand alone (Table 3) and the sand has essentially no sorptive capacity. In contrast, the concentrations of Cr and Se increase with fly ash content regardless of soil type because Cr and Se leach from fly ash at much higher concentrations than from fine-grained soil or sand.

The concentrations of Cr and Se increase non-linearly with fly ash content (Figure 1b), even though the mass of both elements in the soil-fly ash mixture increases approximately linearly with increasing fly ash content. Thus, concentrations for soil-fly ash mixtures estimated based on linear dilution calculations using results from WLTs on fly ash alone are incorrect and may underestimate the concentration of the mixture. The non-linear behavior is believed to be due to the higher pH associated with higher fly ash content, which increases adsorption onto the solid surfaces and diminishes leaching. Thus, the potential of metal leaching from soil-fly ash mixtures cannot be estimated from the leaching potential of fly ash alone using a simple dilution calculation based on the relative masses of soil and fly ash in the mixtures.

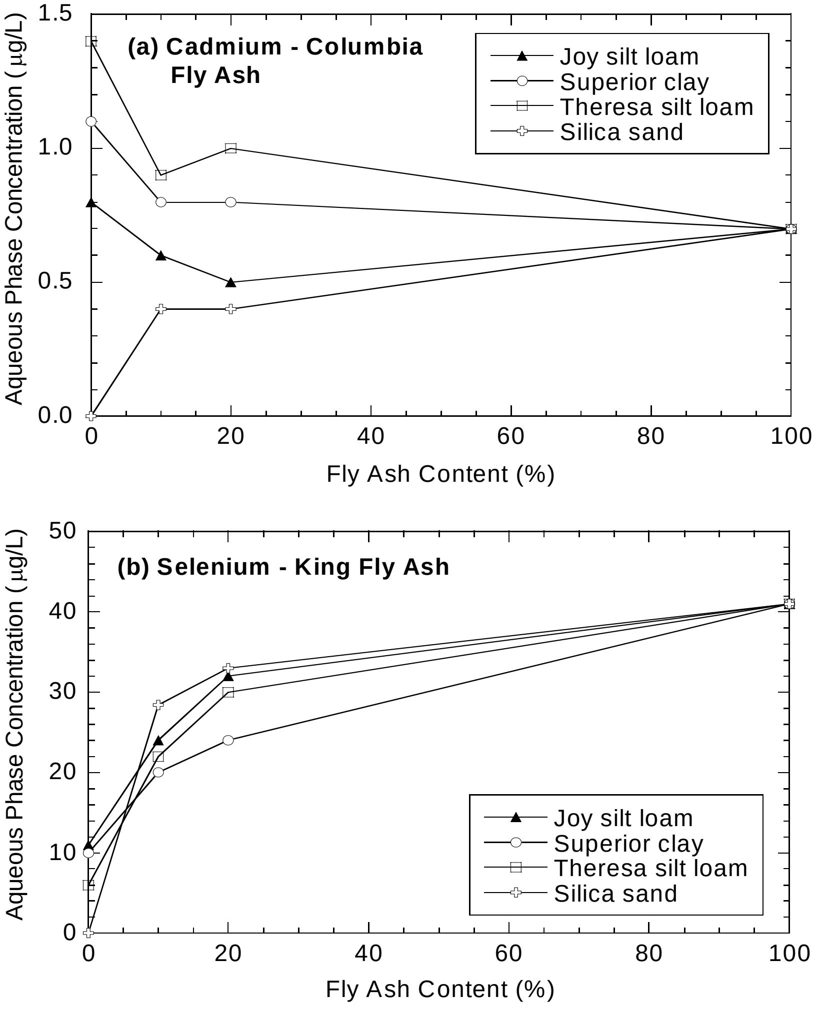

Figure 1. Concentrations from WLTs: (a) cadmium from soil-fly ash mixtures prepared with Columbia fly ash and (b) silver from soil-fly ash mixtures prepared with King fly ash.

Column Tests

Elution curves for Cr from CLTs conducted on mixtures of Theresa silt loam and King fly ash (10 and 20%) are shown in Fig. 2 along with fits of the analytical solution of the advection-dispersion-retardation equation (ADE) with instantaneous sorption. Similar elution curves were obtained for all of the tests, indicating that the initial concentration (C_i) from a CLT is a good indicator of the maximum leachate concentration from the mixtures for flow-through conditions. A summary of the average effluent pHs and the initial effluent concentrations obtained from the CLTs is in Tables 5 (soil alone) and 6 (soil-fly ash mixtures).

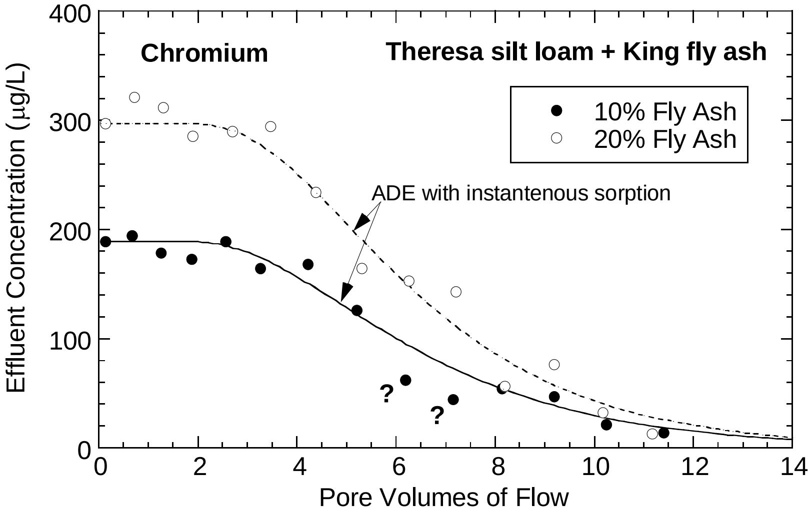

Figure 2. Typical elution curves for total chromium from a CLT. Smooth lines are fits of analytical solution of the advection-dispersion equation (ADE) with instantaneous sorption.

Table 5. pH and initial effluent concentration from column leaching tests on soils alone.

Soil	**Fly Ash Content (%)**	**Average Effluent pH**	**Initial Effluent Concentration (μg/L)**			
			Cd (0.1)	**Cr (T) (2.0)**	**Se (2.0)**	**Ag (0.2)**
Joy silt loam	0	7.1	6.0	13.1	14.1	3.1
Superior clay	0	7.6	9.2	23.9	8.8	5.6
Theresa silt loam	0	7.3	11.8	31.2	7.2	7.2
Peorian loess	0	8.1	2.3	18.4	13.8	3.9
Clark sandy clay	0	9.6	3.8	22.7	15.5	7.1
Silica sand	0	7.5	0.0	0.0	0.0	0.0

Table 6. pH and initial effluent concentration from CLTs on soil-fly ash mixtures.

Fly Ash	**Soil**	**Fly Ash Content (%)**	**Avg. Effluent pH**	**Initial Effluent Concentration (μg/L)**			
				Cd (0.1)	**Cr (T) (2.0)**	**Se (2.0)**	**Ag (0.2)**
Columbia	Joy silt loam	10	9.9	4.0	60.1	32.1	6.2
		20	11.0	5.5	83.3	48.7	6.3
	Superior clay	10	10.0	8.3	102.0	35.6	NA
		20	10.9	6.3	NA	38.9	5.1
	Theresa silt loam	10	9.6	9.1	254.4	NA	8.2
		20	10.3	10.6	223.1	37.8	9.8
	Silica sand	10	11.4	19.2	297.0	109.6	28.6
		20	11.9	22.1	NA	151.8	26.4
Dewey	Joy silt loam	10	9.7	22.1	81.8	106.0	21.6
		20	10.2	28.4	216.8	143.1	19.2
	Superior clay	10	9.2	NA	107.2	96.2	16.2
		20	9.9	24.6	111.2	187.6	21.3
	Theresa silt loam	10	8.9	36.1	NA	121.6	24.1
		20	9.6	35.1	233.5	162.2	25.6
	Silica sand	10	10.6	38.4	237.4	237.4	61.5
		20	11.2	42.1	288.8	289.1	72.0
King	Joy silt loam	10	9.6	9.8	263.4	105.5	12.6
		20	10.9	11.2	192.3	132.0	15.1
	Superior clay	10	9.8	9.6	136.2	NA	14.1
		20	10.9	9.2	156.2	87.4	21.2
	Theresa silt loam	10	9.2	13.5	188.6	122.2	16.5
		20	10.3	15.1	296.5	102.3	15.9
	Silica sand	10	11.1	NA	546.2	NA	NA
		20	11.6	26.9	684.5	202.7	46.4
Coal Creek	Peorian loess	10	7.2	10.2	236.7	43.6	8.6
		20	7.1	13.4	253.4	62.7	7.4
	Clark sandy clay	10	8.2	9.5	287.3	18.4	24.3
		20	8.1	10.2	357.4	48.4	32.5
Stanton	Peorian loess	10	10.4	9.2	195.6	64.8	15.6
		20	10.9	9.7	203.7	47.2	18.3
	Clark sandy clay	10	10.9	14.6	362.4	64.5	24.8
		20	11.0	17.3	487.2	10.8	25.7

The C_i exhibit similar behavior as observed in the WLT concentrations; i.e., C_i of Cd and Ag change modestly with fly ash content for mixtures prepared with fine-grained soil (Figure 3a, Tables 5 and 6), whereas C_i of Cr and Se increase appreciably for all mixtures as the fly ash content increases (Figure 3b, Tables 5 and 6). The C_i also varies non-linearly with fly ash content in response to the variation in pH, as shown by the examples in Figure 3 for mixtures prepared with Dewey and King fly ashes. The largest changes in Ci are associated with the sand-fly ash mixtures because the sand has little adsorptive capacity.

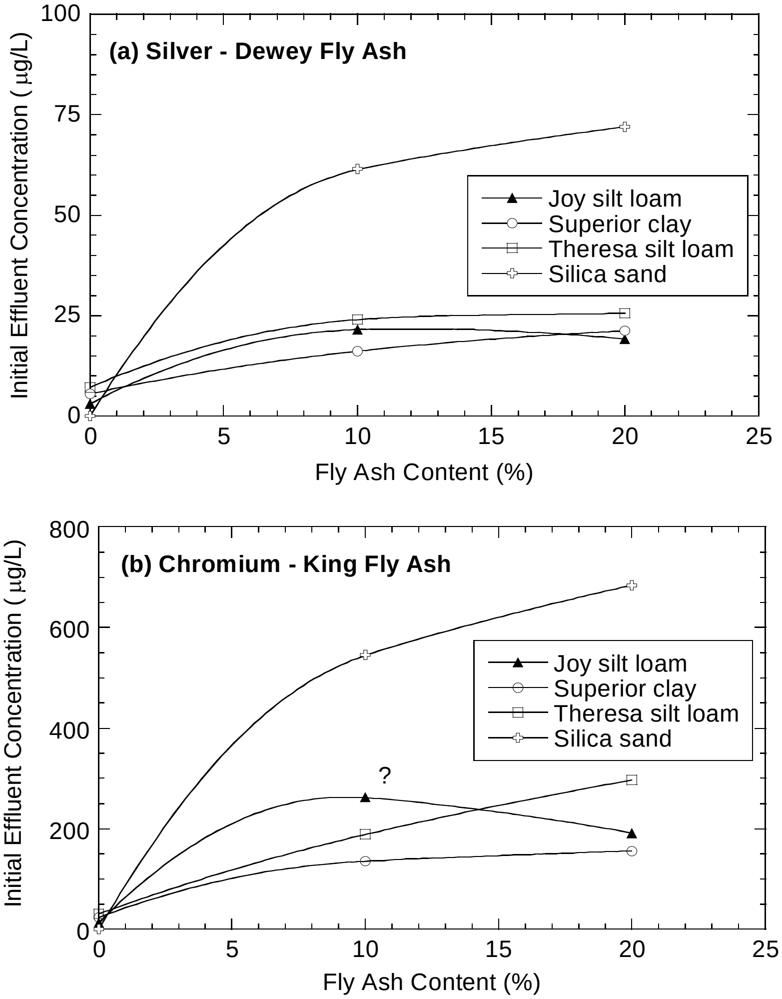

Figure 3. Initial effluent concentrations from CLTs for (a) silver from soil-fly ash mixtures prepared with Dewey fly ash and (b) total chromium from soil-fly ash mixtures prepared with King fly ash.

Comparison of Initial Effluent Concentrations and WLT Concentrations

Comparisons are shown in Figure 4 between C_i from the CLTs and concentrations from the WLTs (C_w) on soil-fly ash mixtures for Ag, Cd, Se, and Cr. Data are shown for the Wisconsin soils mixed with Wisconsin-Minnesota fly ashes along with the Nebraska and Montana soils mixed with fly ashes from North Dakota. The two data sets are similar in all cases, suggesting that the trends observed with the mixtures of Wisconsin soils and Wisconsin-Minnesota fly ashes apply generally to mixtures of fine-grained soil and fly ash. The graphs also show that C_i for Ag and Cd is between 3-50 times higher than C_w (Figures 4a, b). Similarly, C_i for Cr and Se are 1-10 times higher than C_w (Figures 4c, d). Thus, C_i can be conservatively estimated as $50C_w$ for Ag and Cd and $10C_w$ for Cr and Se.

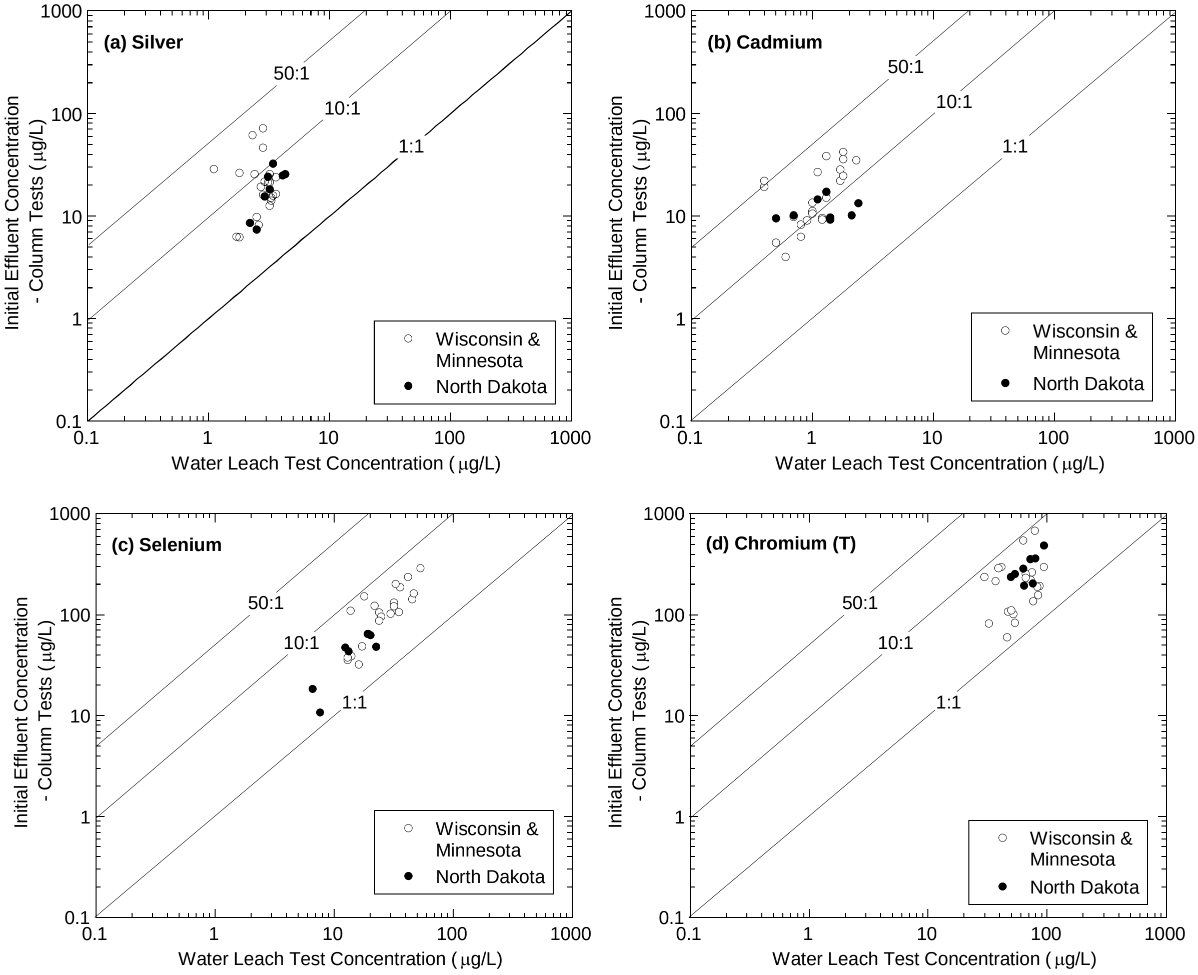

Figure 4. Comparison of initial effluent concentrations from CLTs and concentrations from WLTs for soil-fly ash mixtures: (a) Ag, (b) Cd, (c) Se, and (d) Cr.

Conclusions

Water leach tests and column leach tests were conducted on soils, fly ashes, and soil-fly ash mixtures to study leaching of Ag, Cd, Cr, and Se from soft fine-grained soils mechanically stabilized with fly ash for highway construction. Concentrations in leachate from the WLTs on soil-fly ash mixtures tend to be lower (1.5 to 2.5 times) than those from fly ash alone and vary non-linearly with fly ash content. Thus, concentrations for soil-fly ash mixtures estimated based on linear dilution calculations using results from WLTs on fly ash alone are incorrect and may underestimate the concentration of the mixture. The non-linearity in concentration is attributed to the non-linear relationship between pH and fly ash content, and the effect of pH on adsorption. The WLTs also showed that characteristics of both the fly ash and soil influence concentrations in the leachate.

Initial concentrations from the CLTs showed similar trends with fly ash content, leachate pH, and soil properties as the concentrations from the WLTs. In all cases, initial concentrations from the CLTs were higher than concentrations from WLTs on comparable soil-fly ash mixtures. Comparison of initial concentrations from the CLTs and concentrations from the WLTs on soil-fly ash mixtures showed that scaling factors can be used to estimate initial concentrations for CLTs conservatively from WLT concentrations. A scaling factor of 50 can be used conservatively for Ag and Cd, whereas 10 is suitable for Cr and Se.

Acknowledgements

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Leaching of Trace Elements from Soils Stabilized with Coal Combustion Fly Ash

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- > 50% of Wisconsin has "poor" subgrade soils for roadway construction.
- Conventional approach is to undercut soft soil & replace with crushed rock.
- Alternative is to stabilize soft soil using cement or coal fly ash.

Fly ash lay down

Blending

Compacting

Finishing

Practical Benefits

- Fast & efficient. Construct sturdy working platform over kilometers in days.
- Conventional construction equipment.
- Large savings in cost and time.

Concern

- Will trace elements in ash leach and contaminate ground water?

Wisconsin Maximum Concentrations from ASTM Water Leach Test (D 3987) on Coal Ash

Parameter	Standards (ppm)		
	Category-1	Category-2 & 3	Category-4
Aluminum	1.5	15	
Antimony	0.0012	0.012	
Arsenic	0.005	0.05	
Barium	0.4	4	
Beryllium	0.0004	0.004	
Cadmium	0.0005	0.005	0.025
Chloride	125		
Chromium(T)	0.01	0.1	0.5
Copper	0.13		
Iron	0.15		
Lead	0.0015	0.015	
Manganese	0.025	0.25	
Mercury	0.0002	0.002	
Molybdenum	0.05		
Nickel	0.02		
Nitrite & Nitrate	2		
Selenium	0.01	0.1	0.25
Silver	0.01	0.1	0.25
Sulfate	125	1250	2500
Thallium	0.0004	0.004	
Zinc	2.5		

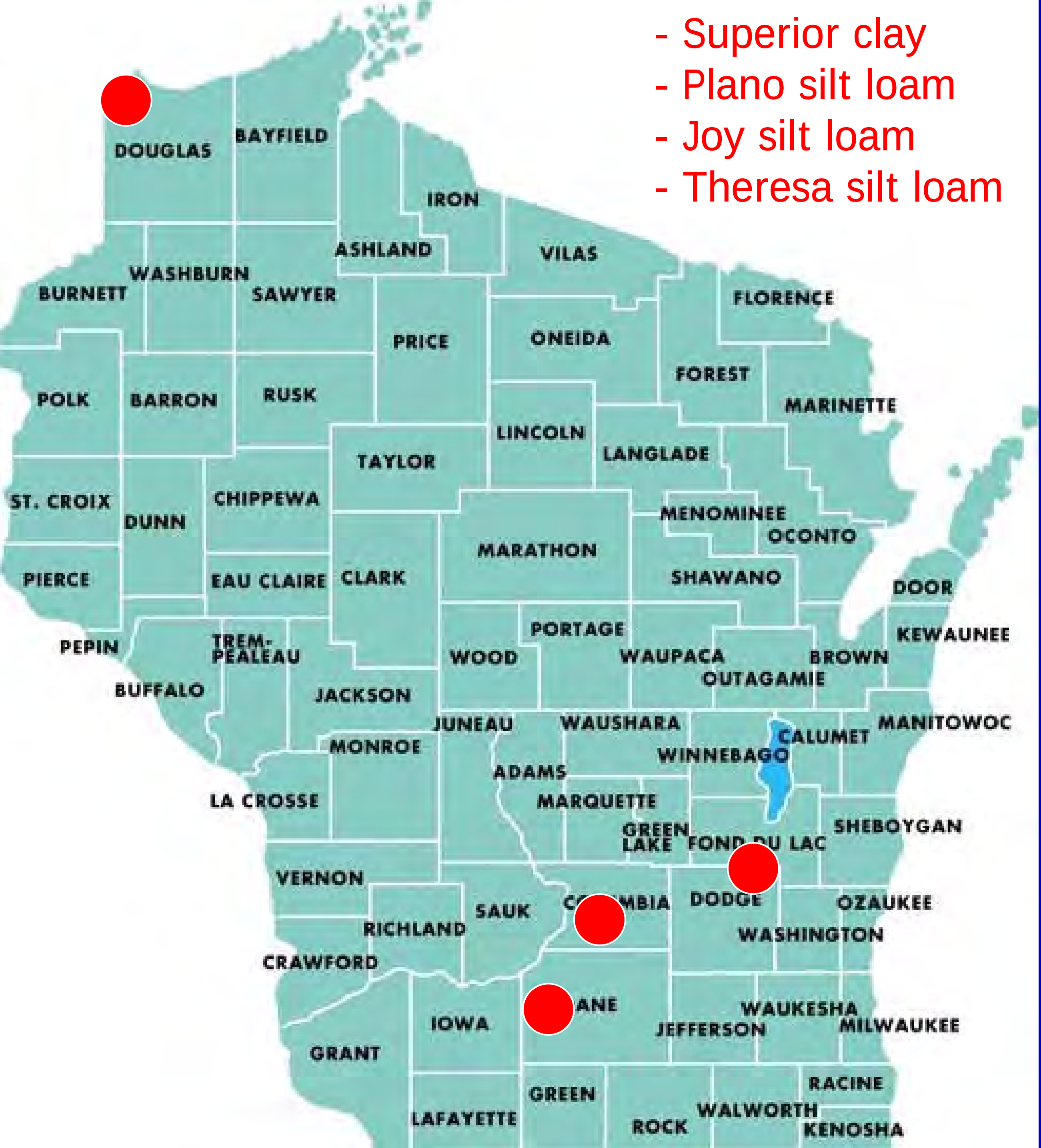
Objectives

1. How does leaching of soil-fly ash mixtures compare to fly ash alone?
2. Does soil type affecting leaching from soil-fly ash mixtures?
3. How do leachate concentrations from flow-through conditions compare to those from WLT?
4. Can leaching from flow-through conditions be described using classical advection-dispersion theory?

Methods

1. Laboratory batch and column leach tests.
2. Monitoring full-scale field construction.
3. Development of numerical leaching models for risk evaluation.

Soils



- Superior clay
- Plano silt loam
- Joy silt loam
- Theresa silt loam

- **<u>Four primary soils</u> obtained from four sites in WI where soft subgrades are problematic**

- **<u>Two additional soils</u> from diverse locations (Clark sandy clay from Helena, MT; Peorian loess from Omaha, NB)**

Geotechnical Properties of Soils

Soil	Liquid Limit	Plasticity Index	Specific Gravity	USCS Class.	w_N (%)	pH	CEC (meq/100g)
Joy Silt Loam	39	17	2.70	CL	25	6.9	9.9
Plano Silt Loam	44	20	2.71	CL	27	7.1	14.2
Superior Red Clay	69	38	2.71	CH	35	7.4	35.3
Theresa Silt Loam	61	19	2.24	OH	35	7.1	27.6
Clark sandy clay	72	51	2.64	CH	-	10.1	32.0
Peorian loess	39	20	2.56	CL	-	7.1	18.0

Notes: w_N = natural water content, CEC = Cation exchange capacity.

Sources of Fly Ashes

Columbia Plant - Portage, WI (Alliant)

Allen King Plant - Minneapolis, MN (Xcel)

Nelson Dewey Plant – Cassville, WI (Alliant)

Stanton Plant – ND (Great River)

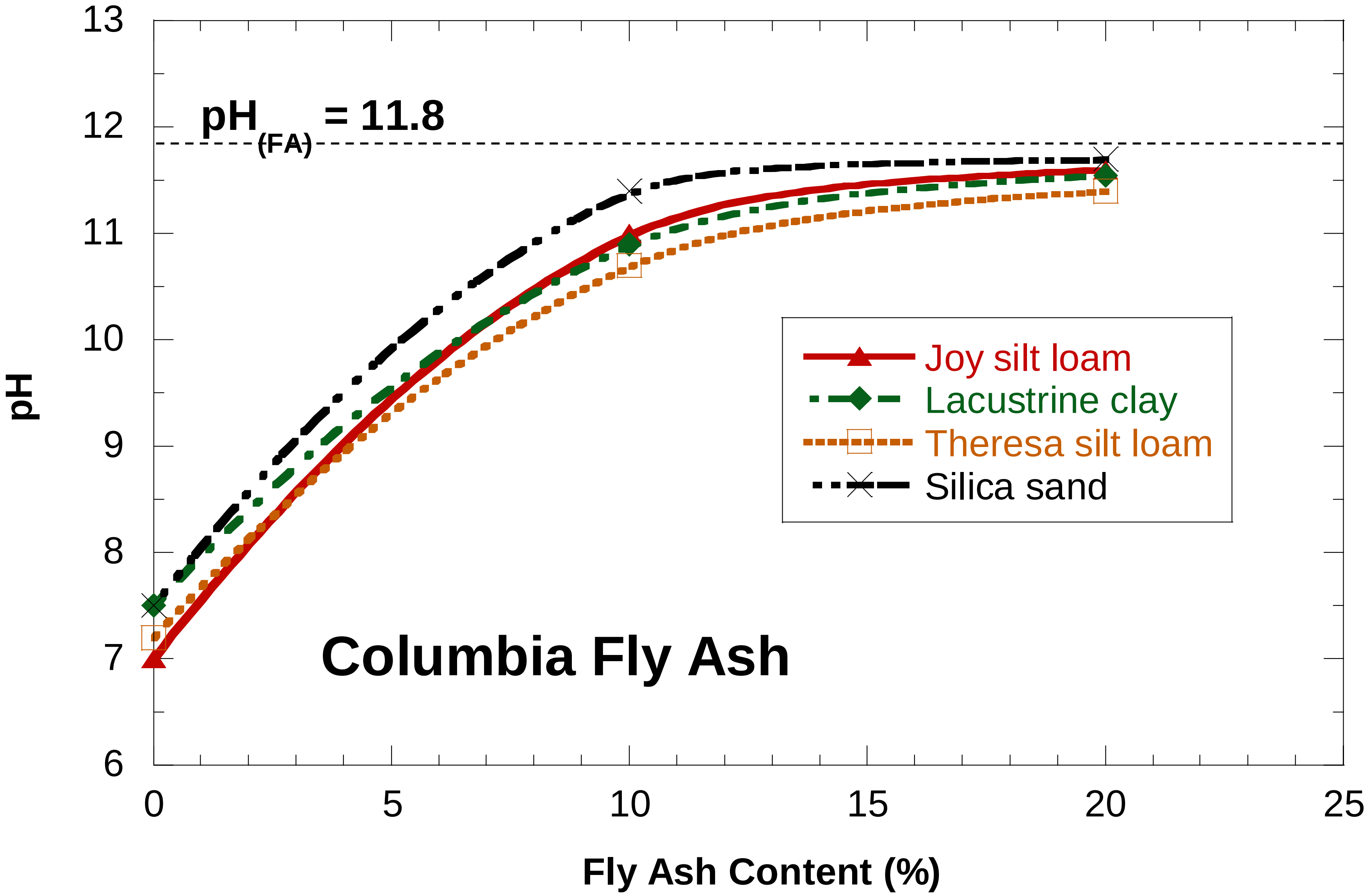
Coal Creek – ND (Great River)

Properties & Composition of Fly Ashes

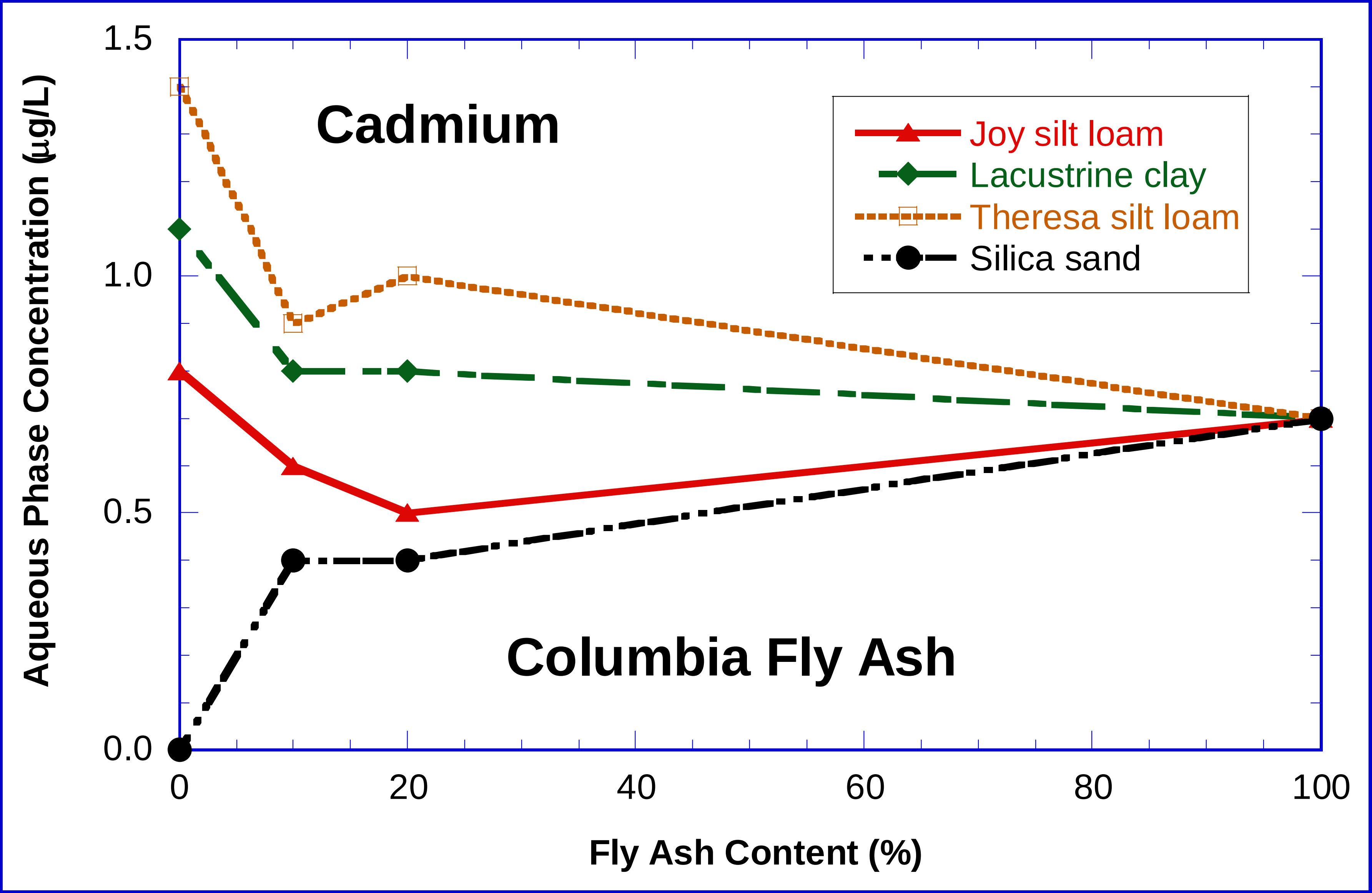
Fly Ash	ASTM Class-ification	G_s	w (%)	LOI (%)	CaO (%)	SiO_2 + Al_2O_3 +Fe_2O_3 (%)	$S0_3$ (%)	pH	CEC (meq/ 100 g)
Colum-bia	C	2.70	0.09	0.7	23.0	55.5	3.7	11.7	102.2
Dewey	Off-spec	2.53	0.23	16.2	9.8	38.7	11.8	10.1	49.3
King	Off-spec	2.68	0.44	14.4	25.8	44.9	6.4	11.0	77.5
Stanton	Off-spec	2.63	2.8	0.8	21.3	63.5	0.99	12.5	53.0
Coal Creek	C	2.59	2.6	0.5	13.3	74.0	-	11.6	53.0

All ashes are effective in stabilizing soft inorganic fine-grained soils.

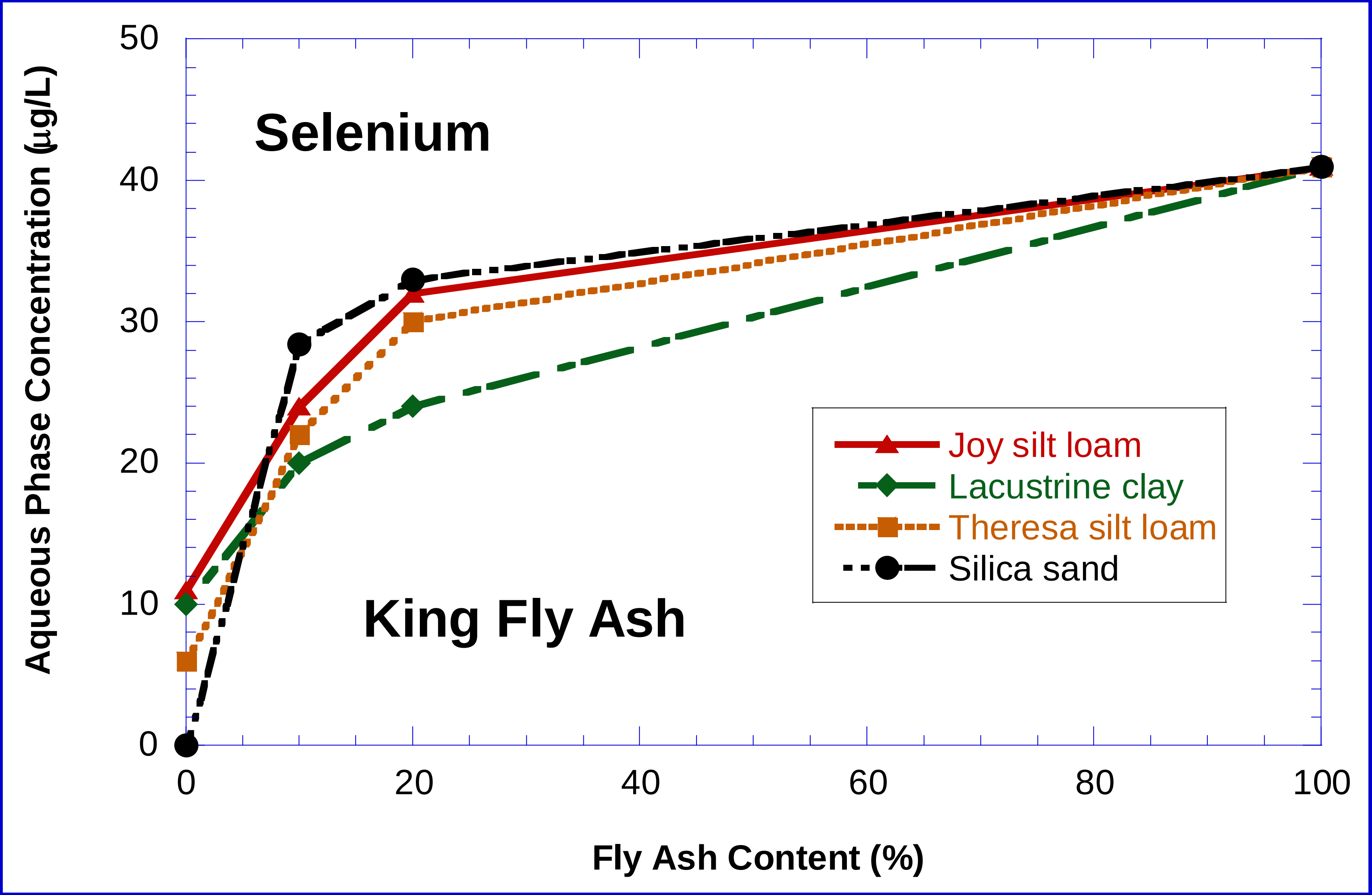
WLT Results – pH of Leachate



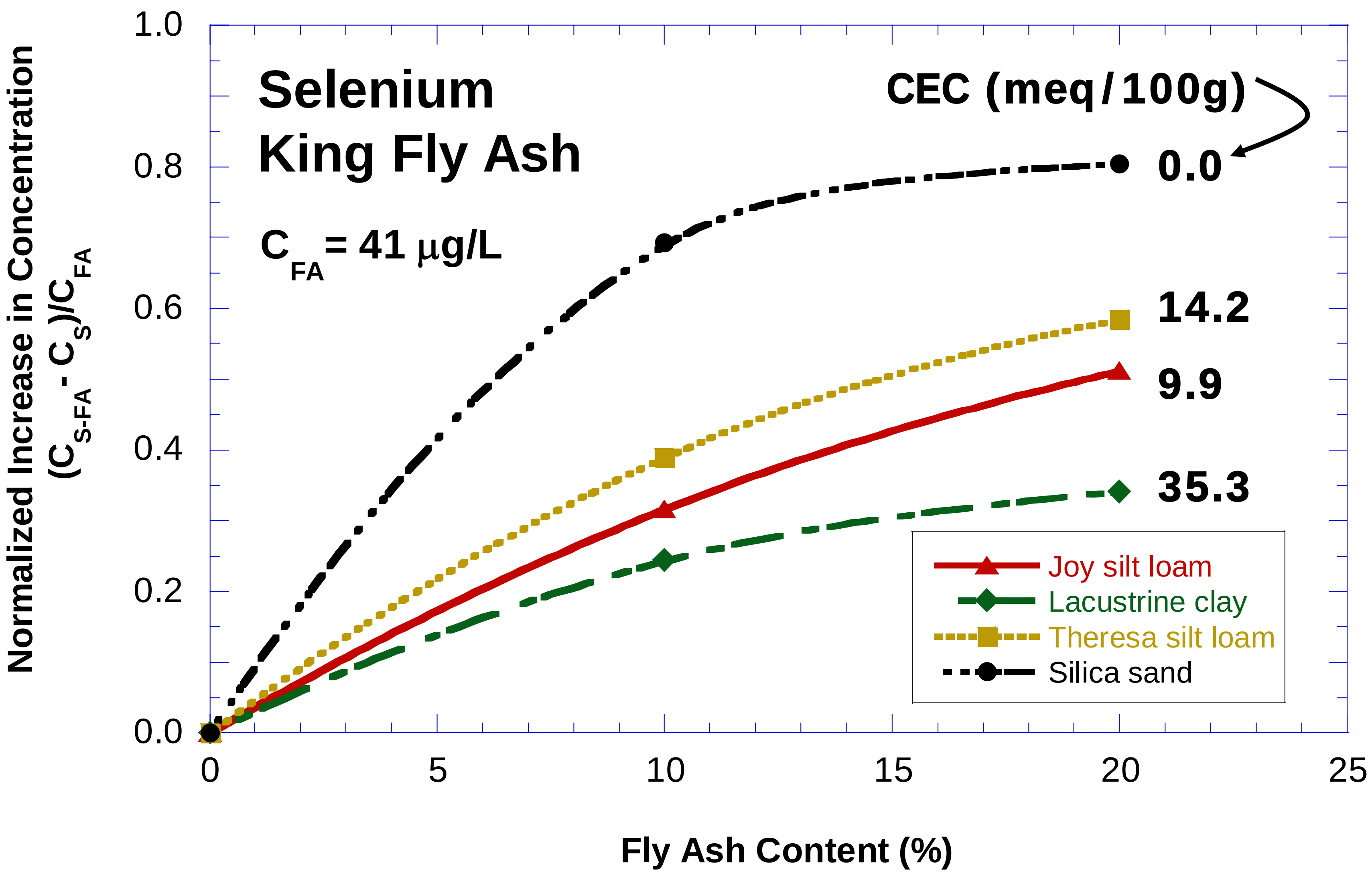
Effect of Fly Ash Content: Cd (or Ag)



Effect of Fly Ash Content: Se (or Cr)



Increment in Concentration

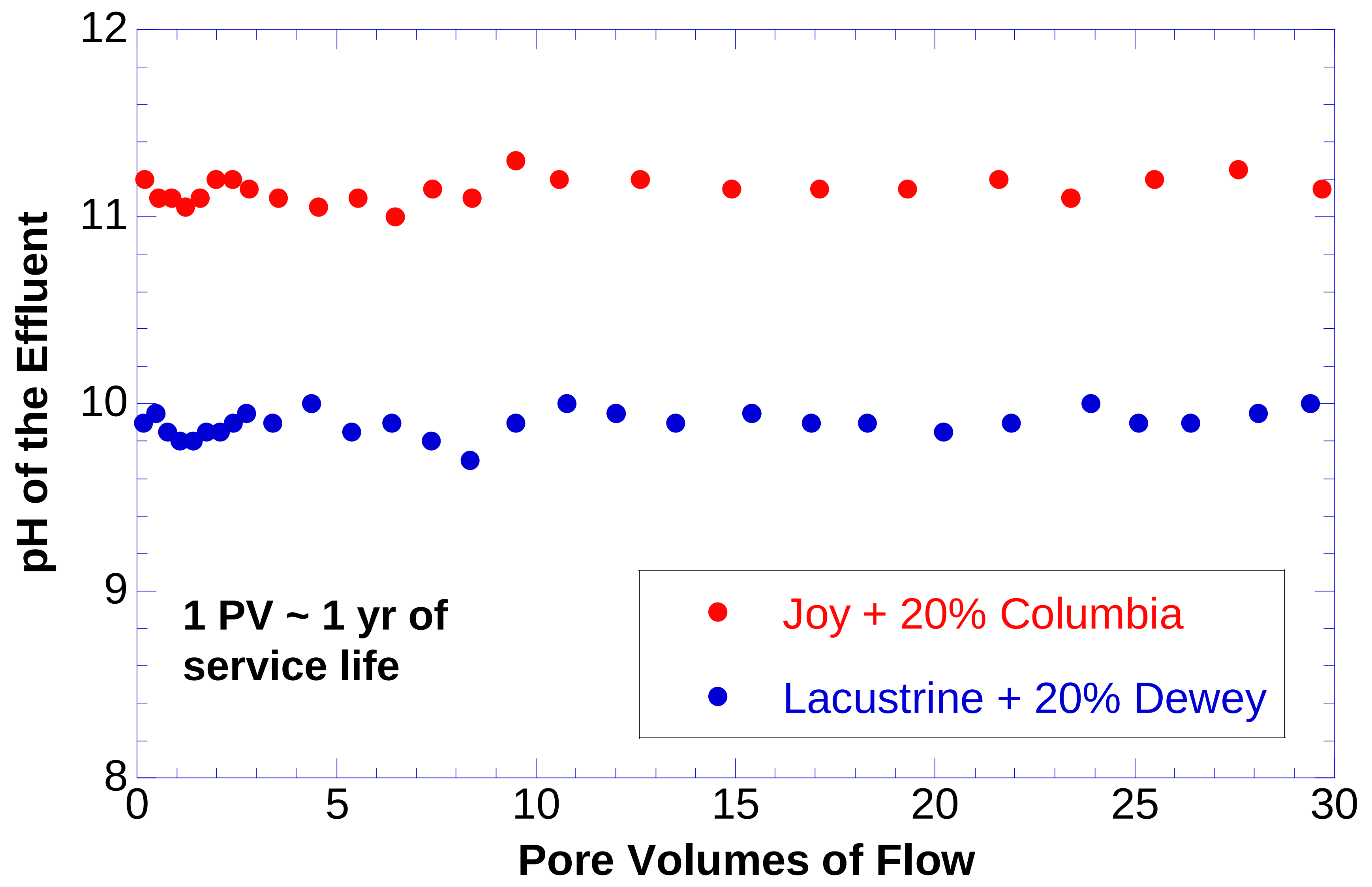


Column Leaching Tests (CLTs)

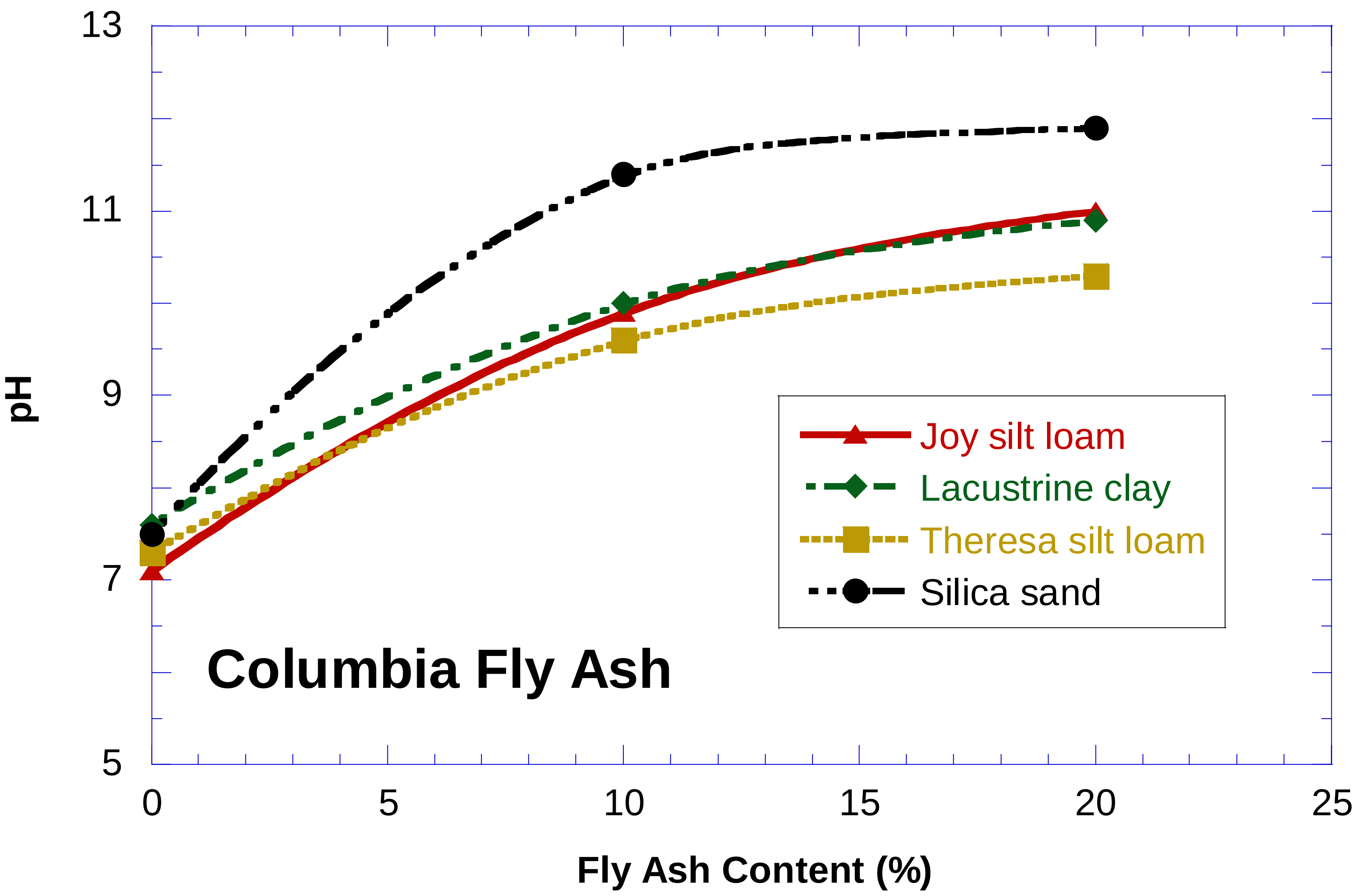
1. **Objective:** determine leaching **pattern** and transport **parameters** (C_o, α, n_e, R or K_p).

2. **Experimental Set up**
   - compacted soil & soil-fly ash specimens
   - cured 7 d prior to testing
   - flexible-wall permeameters
   - hydraulic gradient between 7 and 10
   - 0.1 M LiBr as influent

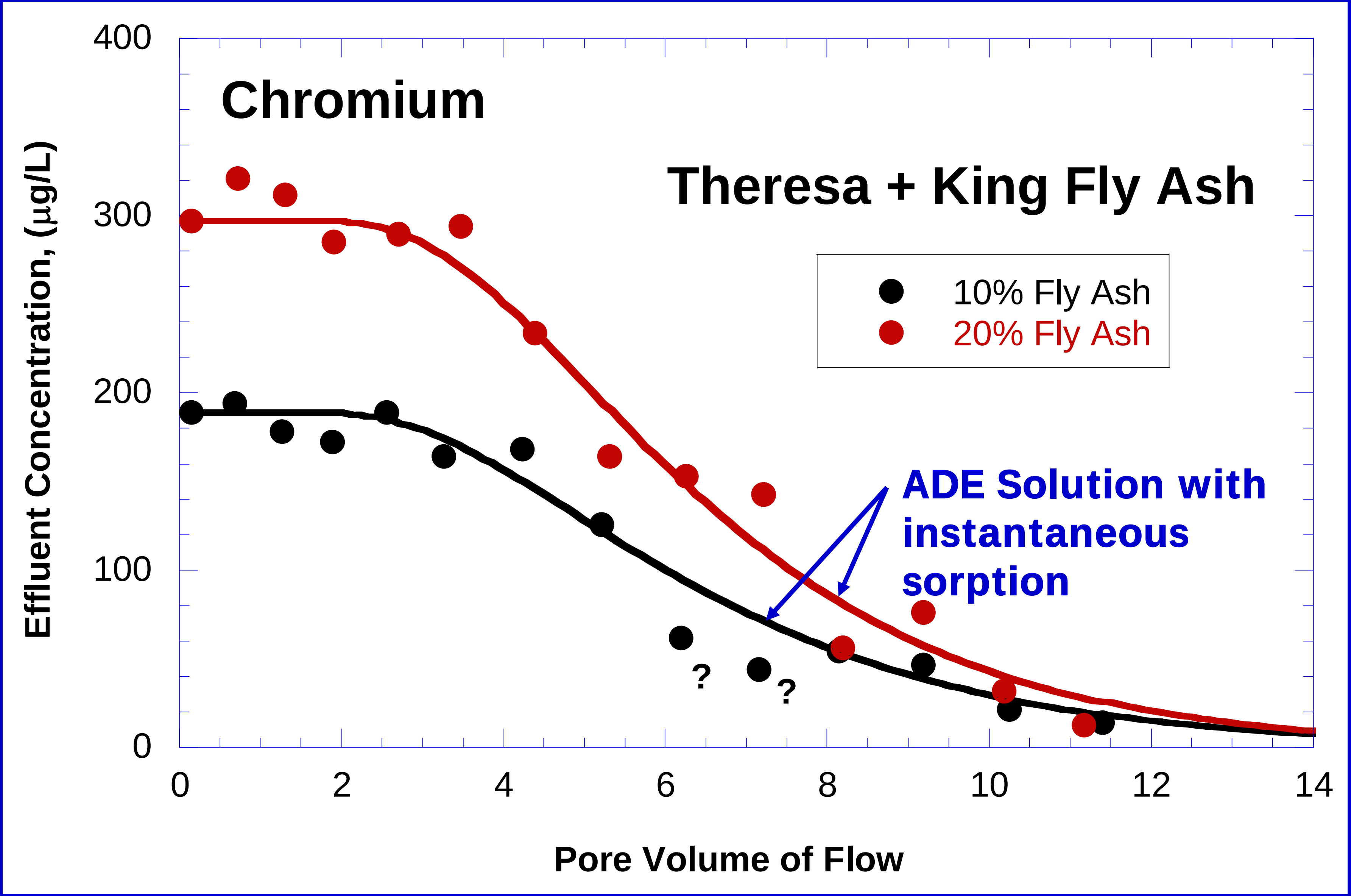
Persistent Effluent pH



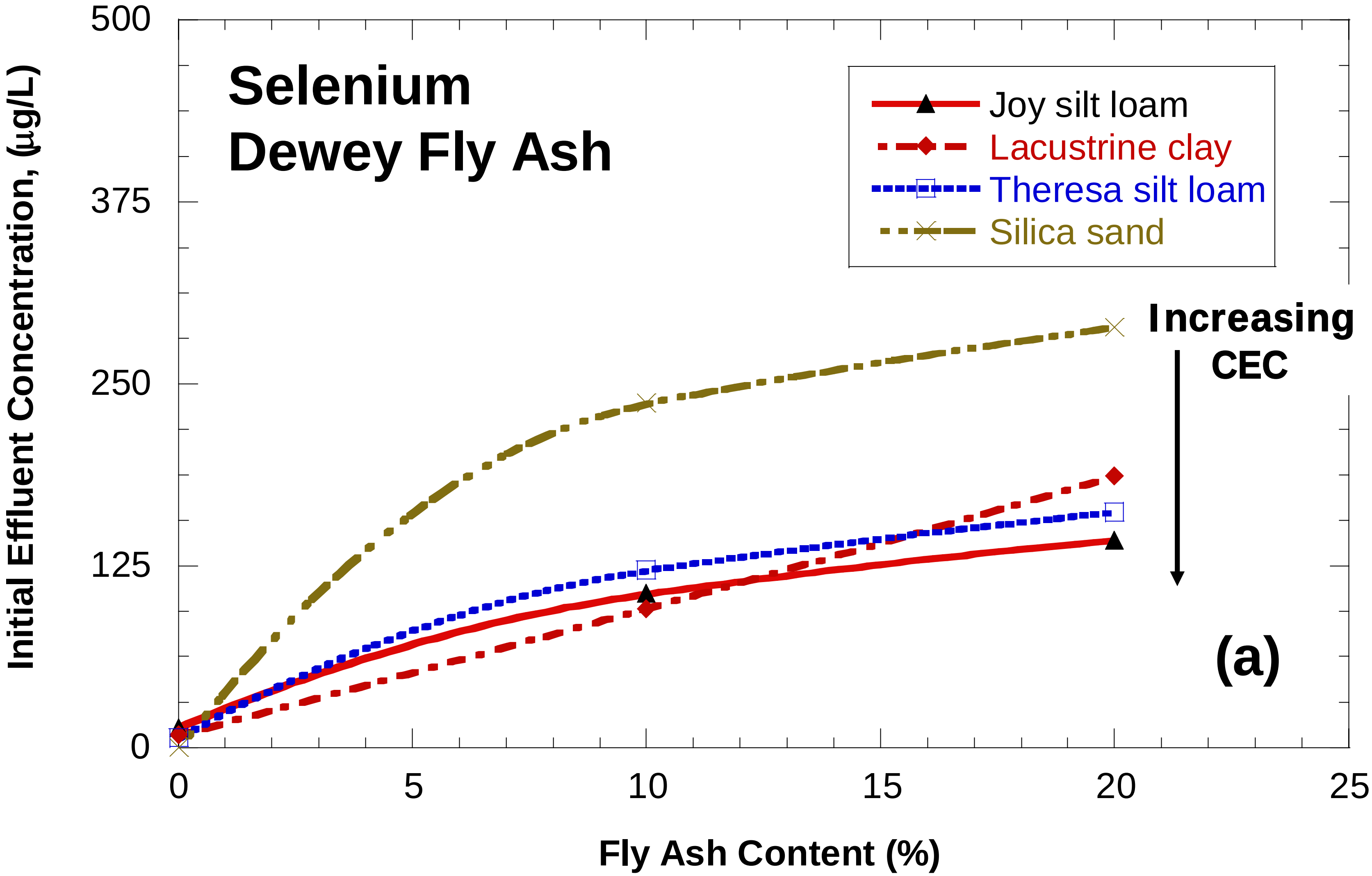
Effluent pH from CLTs



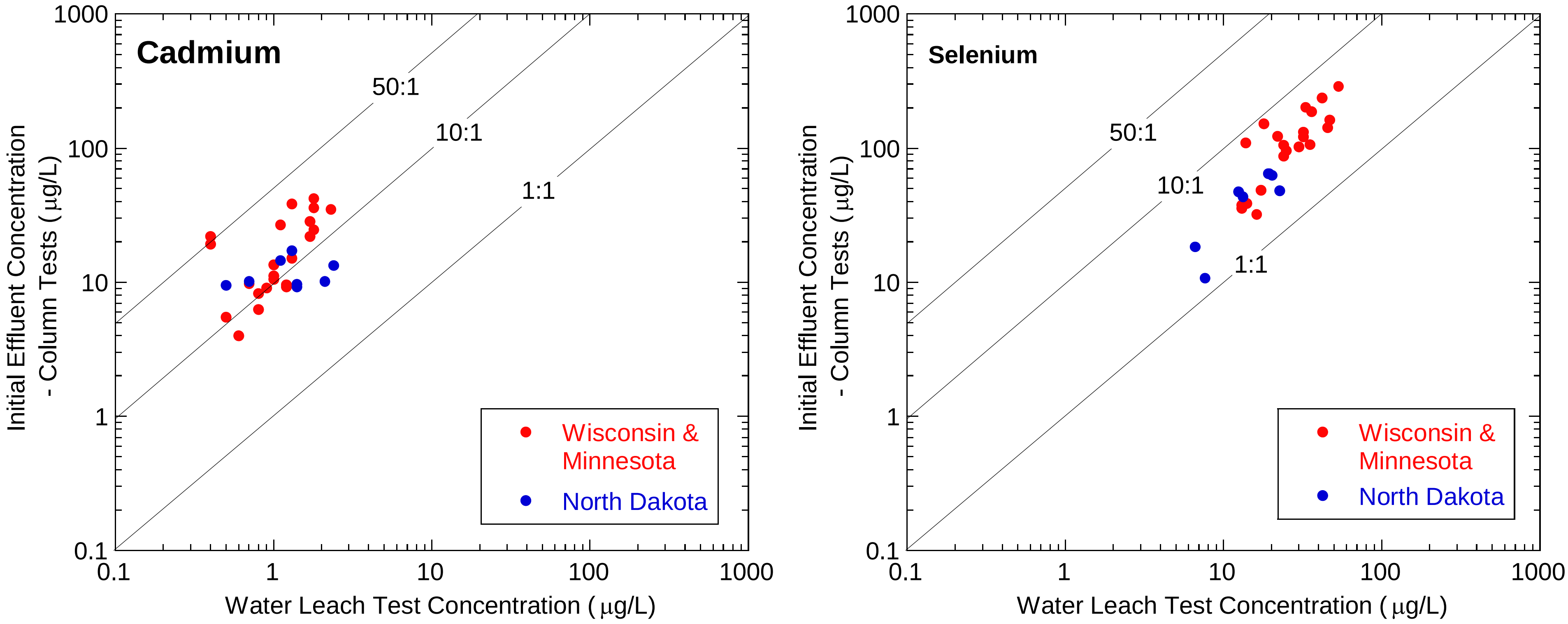
CLTs – Elution Curves



CLT Results – Initial Effluent Concentration



Initial Effluent Concentration and WLT Concentration



- Initial concentrations of Cd and Ag from CLTs < 50 x WLT concentrations.

- Initial concentrations of Cr and Se from CLT < 50 x WLT concentrations.
- No difference between WI soil-fly ash mixtures and mixtures from other locations.

Conclusions

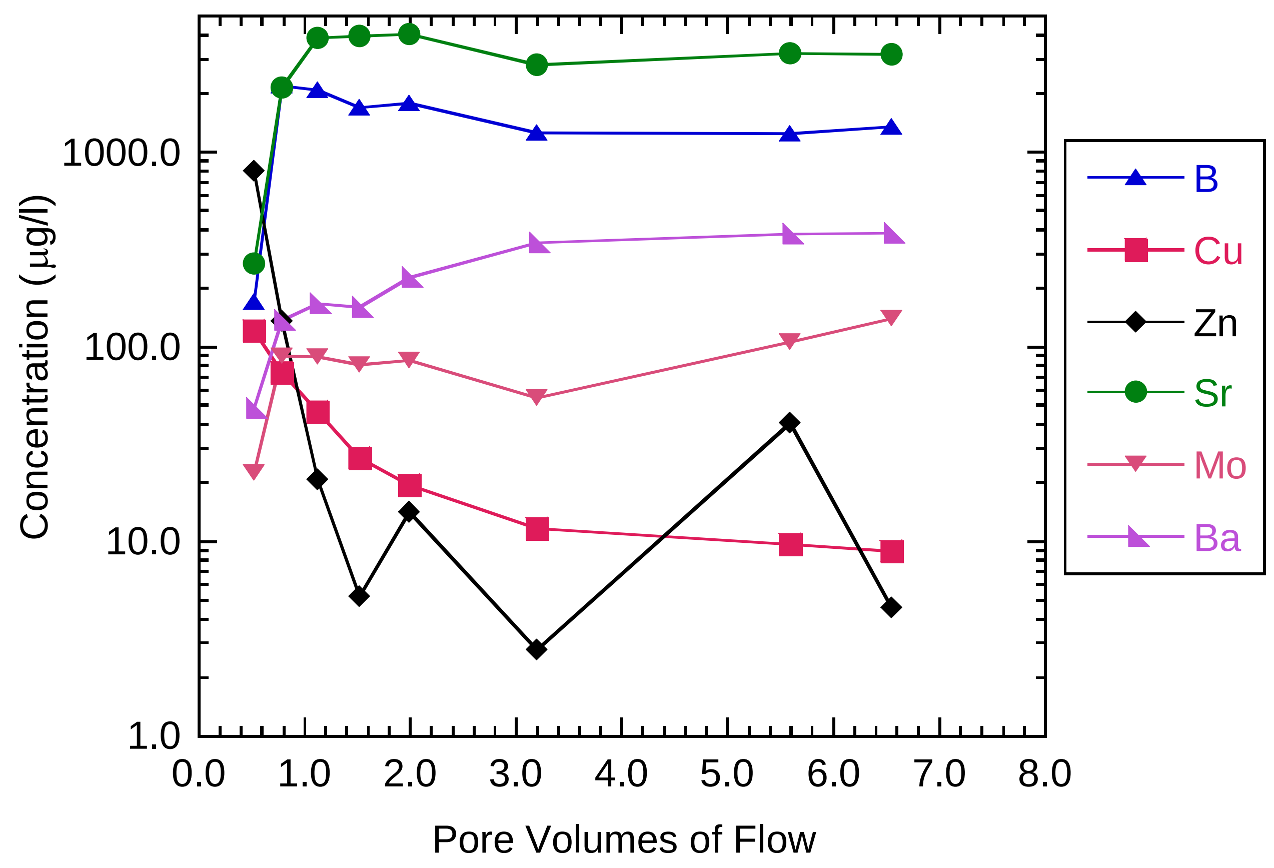
1. Leachate concentrations from soil-fly ash mixtures are lower than ash alone, but do not follow a linear dilution calculation.

2. Leachate concentrations are lower for soil-fly ash mixtures prepared with greater adsorptive potential (e.g., sand vs. lean clay vs. plastic clay).

3. Leachate concentrations from flow-through conditions are higher than those from WLTs. Can be conservatively estimated from WLT concentrations using scaling factors.

4. Leaching of Ag, Cd, Cr, and Se from inorganic soil-fly ash mixtures can be described with ADRE using K_p.

How general are these findings?



Reclaimed HMA pavement blended with 10 % Class C ash.

High organic matter content (asphalt) mixed with gravel base and subgrade.

Other elements.

Research Questions:

1. When can conclusions from inorganic soil-fly ash mixtures be applied to other materials?

2. Do leaching patterns observed for Ag, Cd, Cr, and Se apply to other trace elements leaching from inorganic soil-fly ash mixtures.

3. For cases where findings do not apply, can a generic reactive transport model be developed to predict leaching patterns?

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SOLUBILITY OF FGD GYPSUM USING A CONTINUOUSLY STIRRED TANK EXTRACTOR

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View Presentation

Abstract

A continuous, stirred-tank extractor (CSTX) is a highly effective technique for evaluating the leachability of contaminants from flue gas desulfurization (FGD) products and other materials with low permeability or cementitious properties. The continuous stirring provides constant mixing as occurs in more traditional batch-leaching tests while the continuous flow provides data over a wide range of pH values and liquid/solid ratios such as those seen in column leaching studies. In this study, the release of a number of elements was examined in detail over a range of pH values extending from the material's natural, slightly alkaline pH to the acidic pH conditions commonly associated with mine sites. The results indicate that the leaching behavior of individual elements depends on several factors including, but not limited to, the solubility of the mineral phases present and the pH. The bulk gypsum is moderately soluble. Dissolution is controlled by its solubility product and hydration reactions but does not depend on the pH. Elution and pH profiles indicate the presence of alkaline material(s) that buffer the system during the initial leaching of the FGD gypsum. Many elements are not leached until the buffering capacity is exhausted and the pH drops. Certain metals, including arsenic, lead and mercury, are not released during the leaching of most samples and become concentrated in a minor, highly insoluble residue remaining at the end of each experiment. Differences in behavior among the samples investigated in this study indicate the need to evaluate FGD gypsum prior to use at a particular mine site.

Introduction

Over 50% of the electricity generated in the United States comes from the combustion of coal at pulverized coal-fired power plants that burn an estimated one billion metric tons of coal annually.[1,2] In 2004, coal combustion processes and air pollution control technologies produced over 122 million tons of solids, including fly ash, bottom ash, boiler slag, fluidized bed combustion (FBC) ash and flue gas desulfurization (FGD) material.[3] As a group, these materials are referred to as coal utilization by-products (CUBs), many of which can be used in beneficial and economically favorable ways.

By-products can contain a variety of major elements, including silicon (Si), aluminum (Al), calcium (Ca), iron (Fe), magnesium (Mg), sulfur (S), and trace elements including arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn), that originate from the mineral matter in coal or additives used in pollution control processes.

By-products not utilized are typically disposed of in mines either as a monofill or as a backfill mixed with the overburden, landfills, or surface impoundments.[4] Currently, CUBs are designated as non-hazardous wastes under Subtitle D of the Resource Conservation and Recovery Act (RCRA). There is the potential for future review by the Environmental Protection Agency (EPA) as a result of growing public concern, real and perceived, surrounding the presence of Hg and other trace metals, including As and Se, in by-products. This could result in the listing of CUBs as hazardous waste under RCRA subtitle C. The designation of CUBs as hazardous material is projected to result in a sharp decline in the use of these materials, a corresponding decrease in revenue generated from the sale of these products, and a significant increase in costs associated with disposal of hazardous wastes. It is anticipated the cost of electricity will increase, with the costs being passed along to the consumer.[5]

Reduction of SO_2 emissions through cap-and-trade practices as mandated by the Clean Air Interstate Rule (CAIR) will be achieved primarily through the installation of additional FGD units. Production of FGD solids is estimated to increase to 133 million tons annually by 2030. Flue gas desulfurization processes are broadly classified as either wet or dry, and the majority of coal-fired power plants in the U.S. employ wet FGD technologies.[6] In wet FGD processes, an aqueous lime, limestone or a magnesium-enhanced lime reagent reacts with sulfur dioxide (SO_2) gas to form calcium sulfite ($CaSO_3$). If forced oxidation is employed in the FGD system, the material is converted to gypsum ($CaSO_4 \bullet 2H_2O$). FGD-produced gypsum is suitable for use in agriculture, construction, and other commercial applications. Most of this material is used as a substitute for natural gypsum in the manufacturing of wallboard, and of the 29 million tons of FGD material produced in 2004, an estimated 8 million tons was used solely for this purpose.[3]

In the absence of forced oxidation, the calcium sulfite material is often dewatered and mixed with lime and/or fly ash to form fixated FGD (also known as stabilized FGD). Injection of fixated FGD in mine voids aids in stabilization and/or precludes the flow of water through the mine. Previous investigations have described the short- and long- term effects of placement of fixated FGD in underground mines.[7-9] Immediately following grout placement at an underground coal mine in Ohio, elevated concentrations of certain metals were observed that were attributed to the rerouting of mine waters or an increase in water levels and subsequent dissolution of pyrite. Levels decreased quickly back to pre-grouting conditions.[7] Data collected at the mine site four years after grout emplacement showed localized neutralization of the mine waters, insignificant weathering of the grout material and slightly elevated concentrations of metals, but determined impact on water quality was minimal.[9] Rudisell et al. (2001) determined mine grouting resulted in a decrease in both metals concentration and flow rates, reducing metal loading to a nearby river by up to 97.5%. Results of laboratory studies indicate that the FGD grout degrades over time when exposed to acid mine drainage as minerals are removed and the calcium sulfite material is converted to calcium sulfate.[10]

Leaching techniques are frequently used to predict the fate of heavy metals in surface and groundwater environments, soils, and sediments and can indicate potential problems associated with use and/or disposal. Commonly, batch, sequential batch, or fixed-bed column techniques have been used to determine the compatibility of CUBs in particular end-use or disposal environments.[11-15] Individual batch leaching techniques utilize a single, predetermined volume of leaching solution to provide information on metals release at a set pH, rather than a range. Sequential batch leaching procedures involve multiple steps, typically at decreasing (increasing) pH to provide information regarding the effect of increasing acidity (basicity). Parallel batch procedures provide similar information by using a new portion of the solid for leaching at each pH. The fixed-bed column approach employs a continuous flow of leaching solution to the material under investigation. Elution profiles, with changing elution volume and pH, are produced for each metal under investigation. In contrast to batch techniques, clogs can form in fixed-bed leaching columns, either because of the cementitious properties of the material, such as is seen for FBC ash, or because of precipitate formation, such as can occur when a high-calcium ash is subjected to sulfate-containing leaching solutions. Coarse-grained materials are more amenable to column leaching compared to fine-grained materials, such as FGD gypsum, because of permeability problems that can arise with decreasing grain size. A continuous, stirred-tank extractor (CSTX) is an alternative leaching method that can produce elution profiles similar to those obtained in column leaching, but eliminates problems associated with the permeability of the material to be examined. One notable advantage of the CSTX over fixed-bed column and batch leaching techniques, is the ability to obtain fundamental chemical information involved in the leaching process, including reaction rates, equilibrium constants, effective solubility products, as well as the effect of pH changes. Fundamental data can subsequently be used in geochemical models to predict behavior in a particular environment.

Several researchers successfully developed small scale, flow-through and continuous-flow sequential extraction techniques for metals speciation and fractionation in solids, and demonstrated several benefits of continuous-flow extraction methods compared to more traditional approaches.[16-22] Advantages of this approach include: (1) a decreased risk of contamination and sample loss such as can occur with solid-liquid separation in sequential batch leaching procedures; and (2) a more complete leaching of the material compared to batch leaching procedures where phases with low solubility may not be completely leached by the set volume of extracting solution.[16,17,19-22]

One notable disadvantage of a CSTX is that leaching data do not reflect an actual, end-use environment, as there are very few environments where continual mixing occurs. Solubilized elements are not removed from the reactor as a concentrated band of material as occurs in column leaching. They are sequentially diluted by incoming leachant over time. The possibility exists for interactions between the solubilized material and solids remaining in the tank. Similar reactions can also occur with batch leaching techniques.

The objectives of this study were to develop a method for using a CSTX to determine the extent of and conditions necessary for mobility of certain metals and to use it to investigate metal release behavior from FGD-produced gypsum. Release of a number of elements was examined in detail over a range of pH values extending from the material's natural, slightly alkaline pH to the acidic pH conditions commonly associated with mine sites.

Materials and Methods

On-site, reverse osmosis water was further purified using a Millipore® purification system to give Milli-Q® water (MQW) with a specific conductivity of 18 MΩ•cm. All acids were trace-metal grade. For solids, Hg analyses were performed using a Milestone DMA-80 analyzer. Solutions were analyzed for Hg by Cold Vapor Atomic Adsorption (CVAA) spectrometry or Cold Vapor Atomic Fluorescence (CVAF) spectroscopy. QA/QC samples included method blanks, sample dilutions, and sample spikes as outlined in EPA Method 1631, Revision B.[23] Concentrations of other metals in the solids were determined using ASTM D6349 or EPA Methods 3051 and 3052.[24-26] The resulting solutions, as well as those obtained from leaching in the CSTX (described below), were analyzed using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) or Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

The CSTX apparatus (Figure 1) consisted of a 6-liter, all-glass and Teflon reactor (Ace Glass 6386-28) with a mechanical paddle stirrer and a bottom-outlet filter (porosity D, 10 – 20 µm) upon which was placed a 0.45-µm-membrane filter.

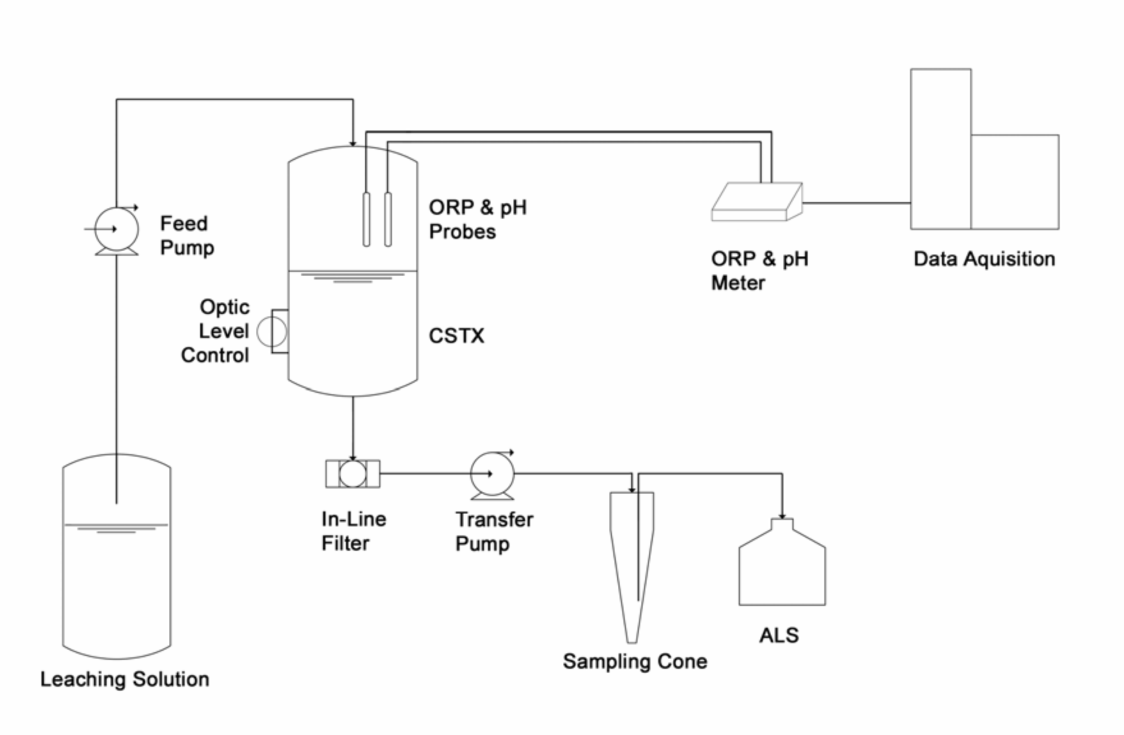

Figure 1. Schematic of CSTX.

Solid material was continually kept in suspension effectively eliminating the majority of potential settling and clogging problems. Oxidation-reduction potential (ORP) and pH data were collected using a Mettler Toledo SevenMulti unit interfaced to a computer. Care was taken to seal the apparatus from the laboratory atmosphere by using appropriate joint seals and a continuous nitrogen flush. The two ports containing the pH and ORP leads were sealed with sealing wax. An initial MQW rinse was employed until the pH in the tank stabilized. After this rinse, the material underwent leaching with HCl (Table 1). Influent and effluent flow rates were controlled using FMI model RHSY pumps operating at 5 mL/minute. An optical level controller was used to protect against flooding the tank should a clog or other failure retard the effluent flow. After exiting the tank through the bottom-outlet filter, the effluent flow: (1) passed through an additional in-line, 0.45 µm filter that provided extra protection to the outlet pump; (2) was accumulated in a nitrogen-purged receptacle; and (3) was collected at one-hour intervals in an ISCO model 3700 Automatic Liquid Sampler (ALS). Samples were removed from the ALS daily and each sample was split into separate glass and HDPE containers for Hg and metals analysis, respectively. All aqueous samples were analyzed as described above. The leaching continued until pH < 3. Residue remaining in the tank after the leachings were terminated was removed and filtered. The solid residues were dried in a desiccator and elemental concentrations determined using the methods described above.

Four FGD gypsum samples were selected for extensive leaching investigations using the CSTX. The samples were received as a fine, granular material and were used as-received with no grinding, sieving, or other sample preparation.

Initial acid concentrations were based on the alkalinity of the samples as determined using a Hach® digital titrator. The concentrations of HCl used in the leachant for each sample are listed in Table 1. The acid concentration for Plant A, the first sample investigated, was initially decreased by an order of magnitude to allow elution profiles to develop for any element that might be extracted at higher pH values. This was subsequently discontinued when it was realized that no pH dependent solubilization occurred at higher pH. For Plant D, the acid concentration was increased to 0.01 N when the Fe concentration in the leachate samples began to drop in an attempt to dissolve the residue, the phase that appeared to be responsible for retention of metals in prior CSTX experiments. For experiments with Plants A, B, and D, approximately 200 g of the gypsum sample and 4 L of MQW were placed in the tank. For Plant E, the amount of solids was decreased to 60 grams and the acid concentration was increased to 0.01 M in order to shorten the lengthy (more than 3 weeks) run times experienced with the other three samples and the quantity of leachate samples generated (> 300 in some cases).

In a separate experiment, ammonium chloride was used as soluble tracer. Approximately 0.8 grams of the compound was added to 4 L of MQW in the tank and its removal was monitored by measuring conductivity to establish the elution behavior of material from the back-mixed reactor. The measured elution agreed well with that calculated from the inlet and outlet flows and the tank liquid volume. This elution profile was used to aid interpretation of the patterns of metal elution observed during the subsequent leaching experiments.

Table 1. Concentration of HCl used in leaching.

	Acid Concentration (N)
Plant A	0.00036/0.0036
Plant B	0.004
Plant D	0.001/0.01
Plant E	0.01

Results and Discussion

The cumulative amounts leached and the compositions of the residues and original materials are presented in Tables 2 - 4 for the four FGD gypsum samples. In Table 2, the amounts are in ug per gram of starting solid. Depending on the sample, certain metals, including As, Pb, and Se are detectable in the residue, the leachate, or both, but not in the original solid, indicating that the elements in the original bulk materials are likely present in quantities below the detection limit and become concentrated in the residue, as opposed to simply not being present. Most elements, with the exception of Ca, S, and Se, preferentially partition to the residue rather than to the extract. Material balances for Ca and S are all close to 100% for all samples, indicating essentially complete recovery of the bulk gypsum.

Table 2. Cumulative leached amounts (ug/g).

	Plant A	**Plant B**	**Plant D**	**Plant E**
Al	50.2	97.5	51.5	179
As	< 0.05	< 0.04	0.6511	0.0514
Ca	279000	235000	289000	272000
Cd	0.0571	< 0.01	< 0.01	< 0.03
Cr	0.6936	< 0.01	< 0.01	1.89
Fe	117	212	912	495
Hg	< 0.0001	0.0017	0.0025	0.0040
Mg	2010	475	391	433
Mn	4.83	14.8	17.4	7.94
Ni	0.029	0.078	1.74	0.041
Pb	< 0.03	< 0.03	0.165	0.993
S	228000	192000	269000	249000
Se	6.96	7.88	25.5	29.7
Zn	10.1	8.71	25.3	5.99

Table 3. Amount in residue (ug/g).

	Plant A	**Plant B**	**Plant D**	**Plant E**
Al	30900	40100	75400	88900
As	16.5	19.0	173	18.5
Ca	3080	1820	1900	6760
Cd	5.40	< 2	< 2	<2
Cr	222	257	287	145
Fe	28500	23800	102000	89200
Hg	33.1	6.53	57.0	54.2
Mg	7080	14100	7990	7410
Mn	118	80.0	394	171
Ni	33.2	171	134	115
Pb	29.6	25.0	39.6	40.6
S	10400	350	8710	7010
Se	54.6	< 9	<9	276
Zn	592	285	340	139

Table 4. Amount in starting solid (ug/g).

	Plant A	Plant B	Plant D	Plant E
Al	24000	1610	2000	73000
As	< 2	16.0	18.6	< 6
Ca	304000	258000	287000	741000
Cd	<2	<2	<2	<1
Cr	11.6	26.6	20.1	35.4
Fe	775	23800	3320	7050
Hg	0.143	0.251	1.46	0.55
Mg	2220	1020	635	2200
Mn	15.7	29.5	35.8	57.8
Ni	3.47	13.5	14.2	< 4
Pb	<8	<8	<8	<3
S	212000	213000	348000	574000
Se	< 9	23.8	28.0	< 6
Zn	35.7	58.2	41.1	68.1

Metal Release Patterns

By examining patterns of metals release it is possible to identify and interpret processes occurring in the CSTX. Several patterns (discussed in detail below) indicating different processes operating in the tank are evident, including: solubility driven release, neutralization reaction driven release, and release followed by re-adsorption. Complex behaviors not explained by a single process are also evident. Several elution profiles were obtained in which a more or less rapid rise in concentration was followed by an initially rapid but progressively slower decrease in concentration. The post-maximum decrease was compared to that expected from a simple washing of the material out of the CSTX by the continuous flow of fresh eluant. This "predicted" decrease was calculated using the inlet and outlet pump flow rates and the tank liquid volume to determine the extent of dilution for each successive effluent sample. The validity of the calculations was established using the tracer experiment described in the experimental section.

Solubility driven release is exhibited by Ca and S for all samples with the exception of Plant D (Figure 2 a-d). As seen in Figure 2 a and b, the concentrations of Ca and S measured at the beginning of the leaching remain relatively, but not totally, constant throughout the experiment, indicating continuous dissolution at steady-state conditions. At flow rates sufficiently slow compared to dissolution rates, steady state concentrations approach equilibrium values. Under these conditions, dissolution of $CaSO_4$ is controlled by its solubility product (K_{sp}) and hydration reactions occurring in the tank, and does not necessarily depend on the pH. It is informative to compare the experimental molar concentrations for Ca and S to predicted molar concentrations based on the K_{sp}. Using the literature value of 2.51×10^{-5} for the K_{sp} of gypsum at 25°C, a predicted molar concentration for Ca and S can be determined.[27]

The dissolution of gypsum is described by the following reaction (waters of hydration are not considered):

$$CaSO_{4(s)} = Ca^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \qquad (1)$$

Defining x as the number of moles per liter of $CaSO_4$ that dissolve gives:

$$K_{sp} = 2.51 \times 10^{-5} = [Ca^{2+}][SO_4^{2-}] = x^2 \qquad (2)$$

$$x = 5.01 \times 10^{-3} \text{ mol/L} \qquad (3)$$

Thus, under ideal conditions, the molar solubility of $CaSO_4$ in water at 25°C is expected to be 5.01×10^{-3} mol/L. In contrast, the concentration of Ca (average of 600 mg/L) is about 15.6×10^{-3} mol/L, 3 times higher than predicted. The difference between the predicted and actual values indicates that the liquid in the tank is supersaturated compared to ideal behavior. An examination of the QA/QC data showed that, at most, a ±15% change in the calculated original solution concentration was obtained upon dilution and that the change was more random than regular for both Ca and S. This indicates that an analytical error due to being outside the calibration range, if present, was too small to account for the 3-fold higher-than-expected values. It is possible that the FGD materials used in this study are less crystalline than the gypsum used to determine K_{sp} and therefore have a higher solubility due to less crystal lattice energy stabilization. Additionally or alternatively, finely divided material may have passed through the 0.45 um filters and this could account for the higher "dissolved" amounts.

The plot for Plant E (Figure 2 d) shows a gradual increase in Ca and S concentrations as the hydrochloric acid addition begins, but the concentration becomes fairly constant after 10L of leachant had been added. This is not seen for gypsums from Plants A and B that were leached with a less concentrated acid. A separate experiment in which NaCl was added to the MQW wash of an FGD gypsum showed an increased solubility in the presence of the salt indicating that the chloride ion is likely responsible for at least a portion of the increased solubility

The data for Plant D (Figure 2 c) show that Ca and S did not elute at constant concentrations as was seen for the other materials. The patterns appear well-behaved during the first 40 L of elution where the increase in Ca and S upon starting the HCl addition at about 10 L mimic the behavior describe for the sample from Plant E. However, the effect appears much more pronounced. Unlike the other plots, the Ca and S concentration undergo an obvious decrease at about 30 L, become erratic, and appear to regain their original 700-800 mg/L concentrations just before the gypsum is totally consumed. The decrease in Ca and S correspond to a decrease in pH from a plateau of about 5.5 to a plateau of about 3.5. During this time, Mg, Al, and Fe dissolution begins (*vide infra*), thus providing numerous other ions in solution. These ions appear to interfere with the large increase in solubility afforded by the chloride ion. Thus, this material appears to display more sensitivity to both enhanced dissolution in the presence of chloride ion and inhibited dissolution by other ions in solution. The reason for this is not clear.

The solid lines in Figure 2 b-d represent the expected Ca concentrations for each sample as the last-dissolved material was washed from the tank. Sulfur displays similar behavior and is omitted for simplicity. The predicted values are not shown for Figure 2 (a) because the experiment was terminated prior to the dissolution of all of the soluble material in the tank. The post-dissolution behavior of the Ca for Plants B, D, and E closely follows the predicted behavior. This indicates that, physically, the tank is behaving as would be expected from a well back-mixed system.

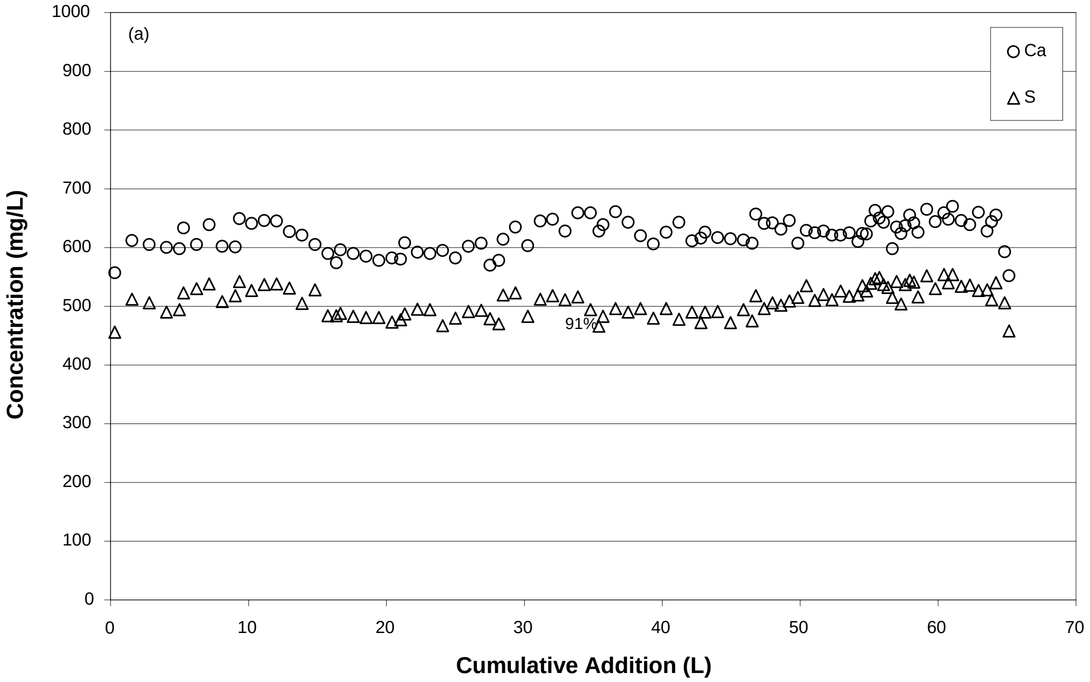

Figure 2a. Concentration of Ca and S with cumulative addition of eluant: Plant A.

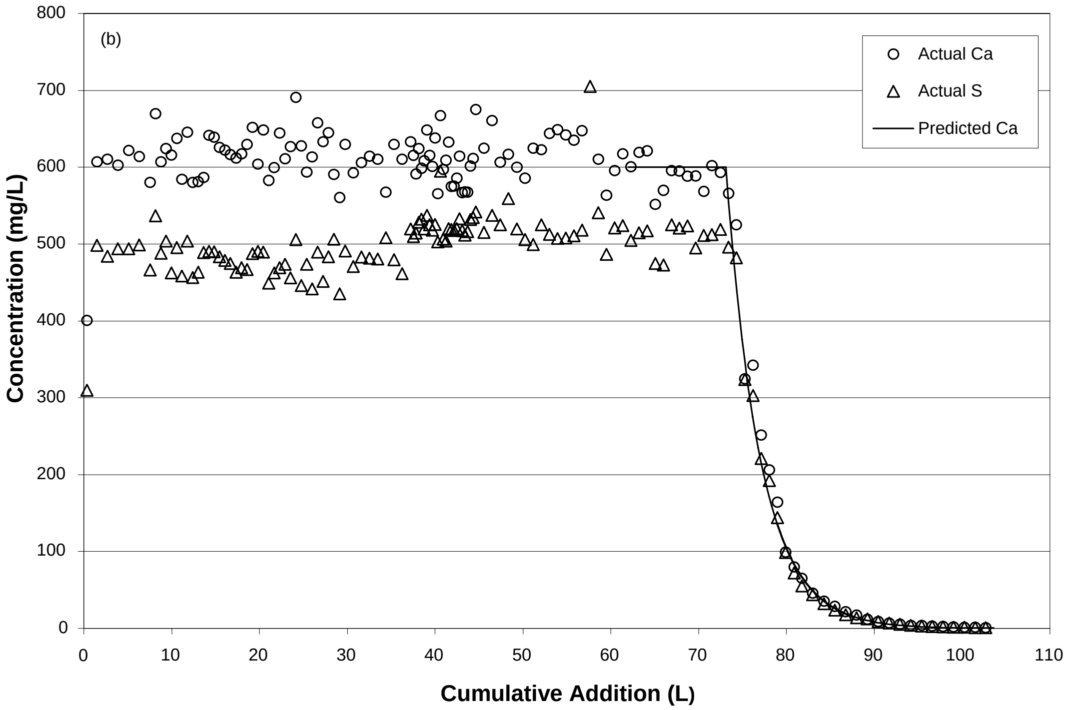

Figure 2b. Concentration of Ca and S with cumulative addition of eluant: Plant B.

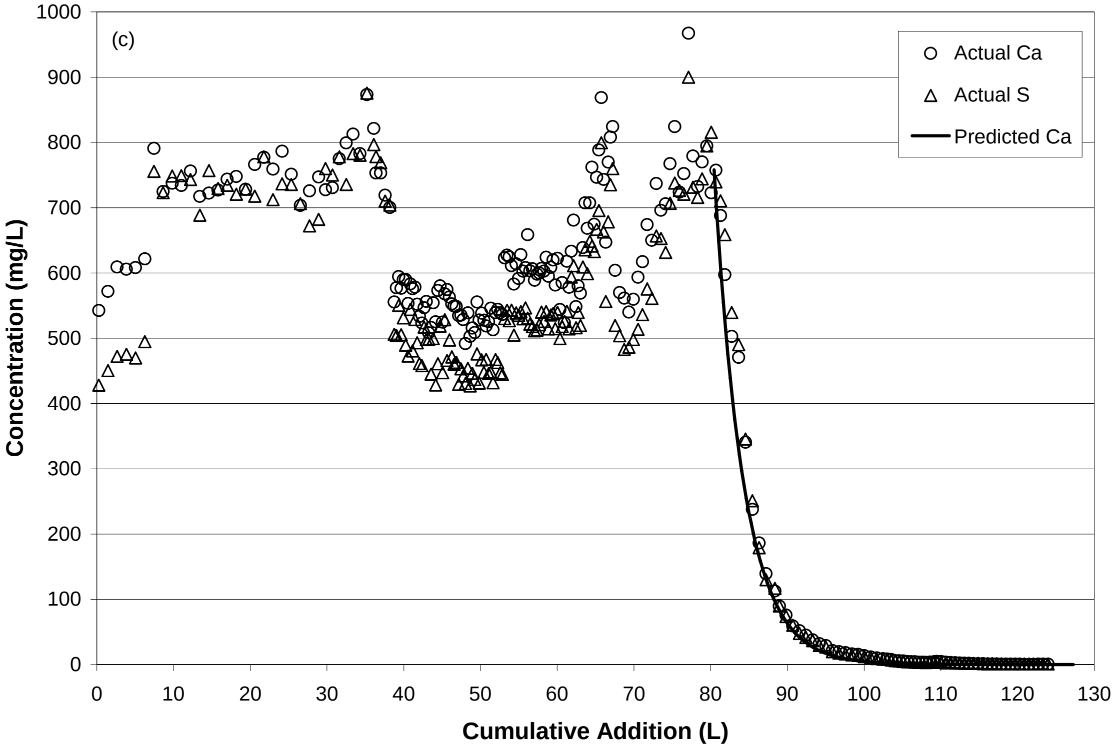

Figure 2c. Concentration of Ca and S with cumulative addition of eluant: Plant D.

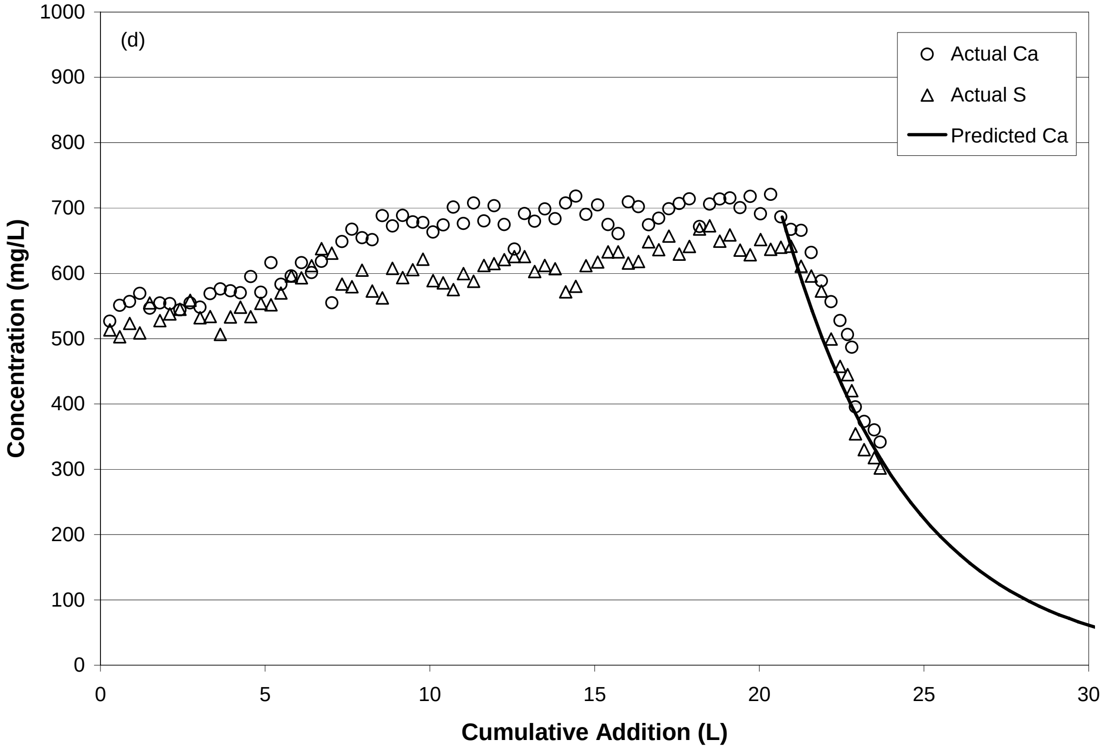

Figure 2d. Concentration of Ca and S with cumulative addition of eluant: Plant E.

Figure 3 a-d show the molar ratios (MR) of Ca/S over the duration of the experiments. The molar ratios range from 0.75 to 1.1, indicating that either an essentially stoichiometric ratio or an excess of S is being obtained. The ratio remains close to unity when MQW or the more dilute HCl is being added but, in general, tends to be lower when the more concentrated HCl is used. Although the protonation of sulfate anion (SO_4^{2-}) by HCl to give bisulfate ($HSO_4^{)}$ such as occurs when gypsum is dissolved in hot dilute hydrochloric acid, may be occurring, it would not be expected to change the molar ratio of Ca/S from 1.

$$CaSO_4 + HCl \;=\; Ca^{2+} + HSO_4^- + Cl^- \qquad (4)$$

The excess sulfur might possibly be due to the presence of separate, minor sulfur bearing phase such as calcium bisulfate $Ca(HSO_4)_2$, which would decrease the Ca/S ratio.

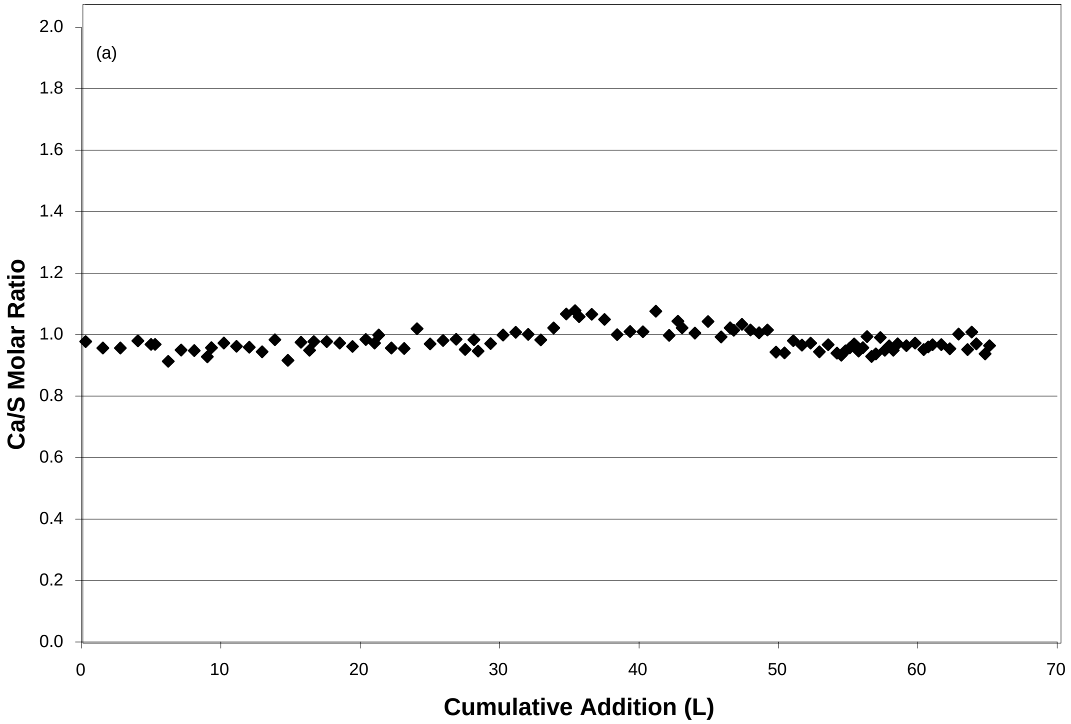

Figure 3a. Molar ratio of Ca/S with cumulative addition of eluant: Plant A.

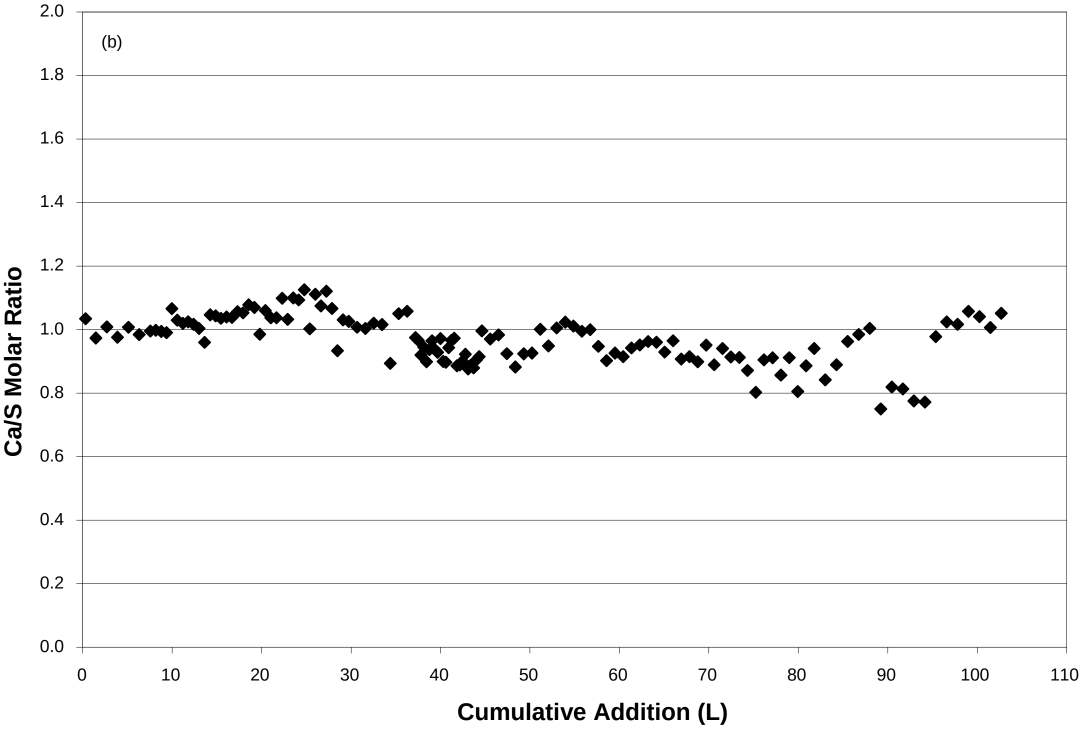

Figure 3b. Molar ration of Ca/S with cumulative addition of eluant: Plant B.

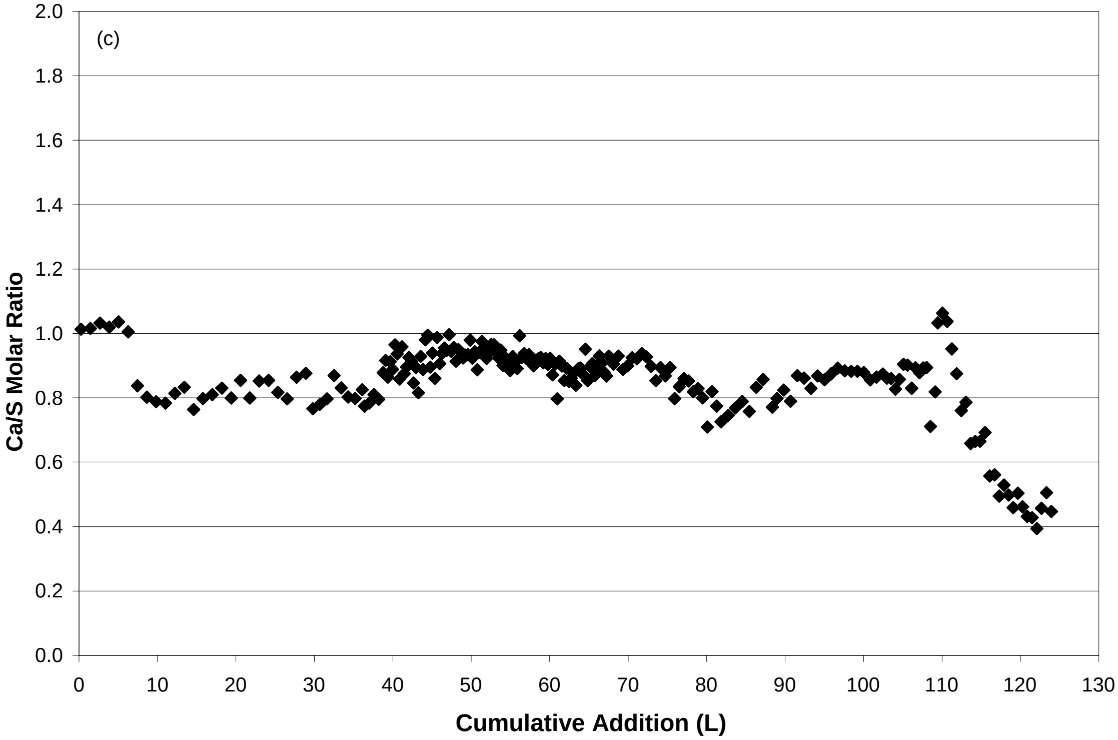

Figure 3c. Molar ration of Ca/S with cumulative addition of eluant: Plant D.

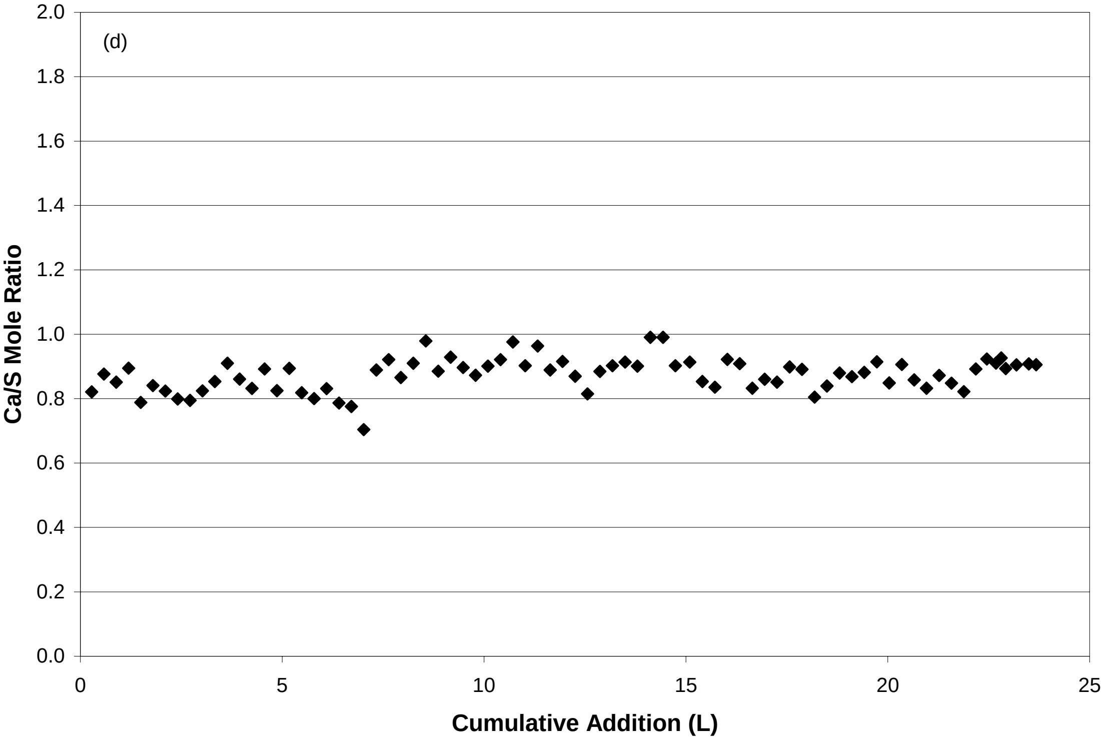

Figure 3d. Molar ratio of Ca/S with cumulative addition of eluant: Plant E.

Magnesium exhibits a neutralization reaction driven release. Figure 4 a-d present the actual (triangles) and modeled/predicted (solid line) concentrations obtained for Mg for the four gypsum samples. The elution of Mg seen initially with the MQW rinse could be associated with non-carbonate phases such as $MgCl_2$ or other soluble Mg-bearing phase. In general, heightened Mg elution begins with the addition of the stronger acid, increases to a maximum, then drops in conjunction with the drop in pH. Such behavior is indicative of the acid neutralizing capacity of the material. Mg could be present as a carbonate (e.g. dolomite, high-Mg calcite, magnesite) that acts to buffer the system. It is reasonable to expect the presence of excess alkaline material, especially the more slowly reacting magnesium carbonate, in FGD products. The pH in the CSTX does not drop until this material is consumed. The post neutralization behavior of Mg in all samples is closely modeled by the successive dilution calculations. The solubilized Mg washes out over time, producing the tail on the curve. The stronger concentration of HCl used for leaching the gypsum from Plant E causes neutralization to occur at a much faster rate than the other samples, resulting in pH < 3 after the addition of about 4 L, compared to the much higher volumes (> 40 L) required with more dilute concentrations of HCl for the other samples.

In addition to $MgCO_3$, mineral phases such as $CaCO_3$ could assist in buffering the sample slurries, although the data suggests that this contribution is negligible. The presence of the alkalinity is important because it controls the release of most elements other than Ca, S, and Sr. Little mobilization of metals occurs at higher pH, only when the pH starts to drop after the alkalinity has been exhausted do other elements begin to appear in the leachate.

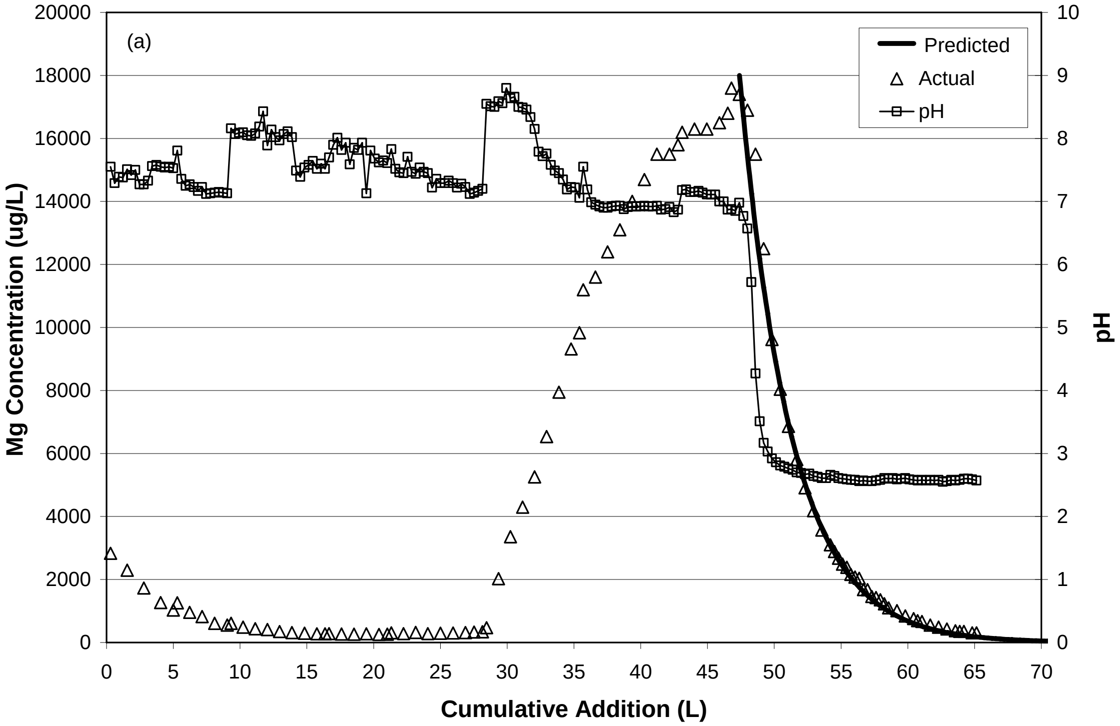

Figure 4a. Concentration of Mg with cumulative addition of eluant: Plant A.

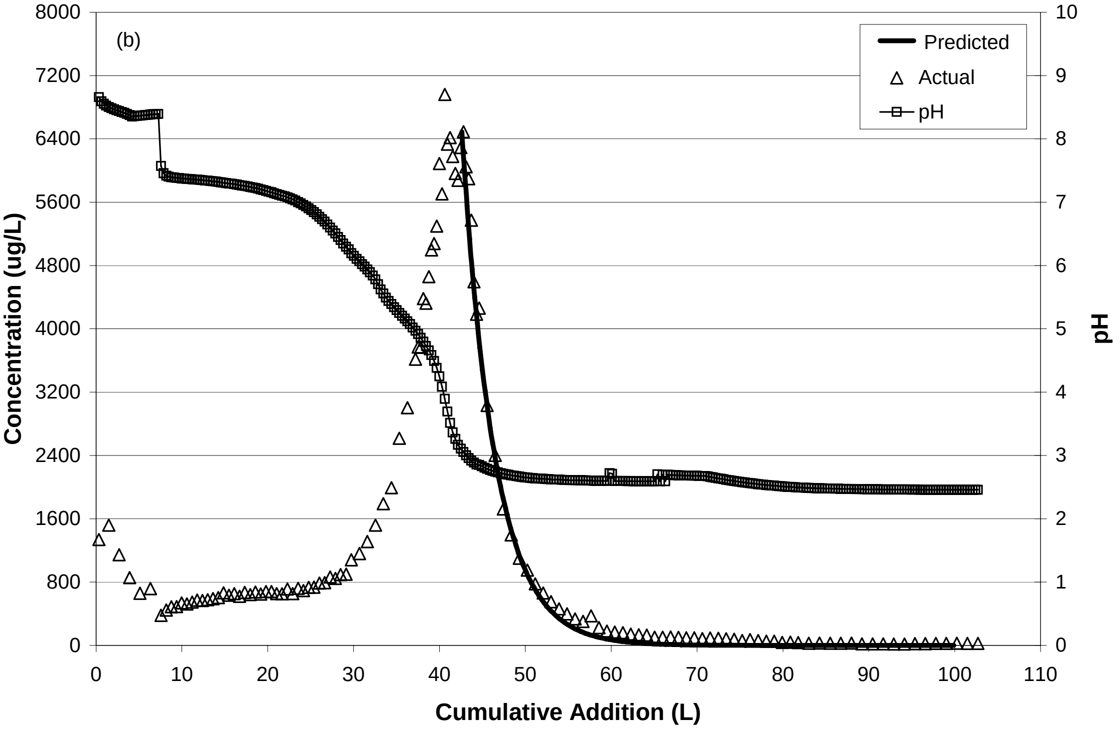

Figure 4b. Concentration of Mg with cumulative addition of eluant: Plant B.

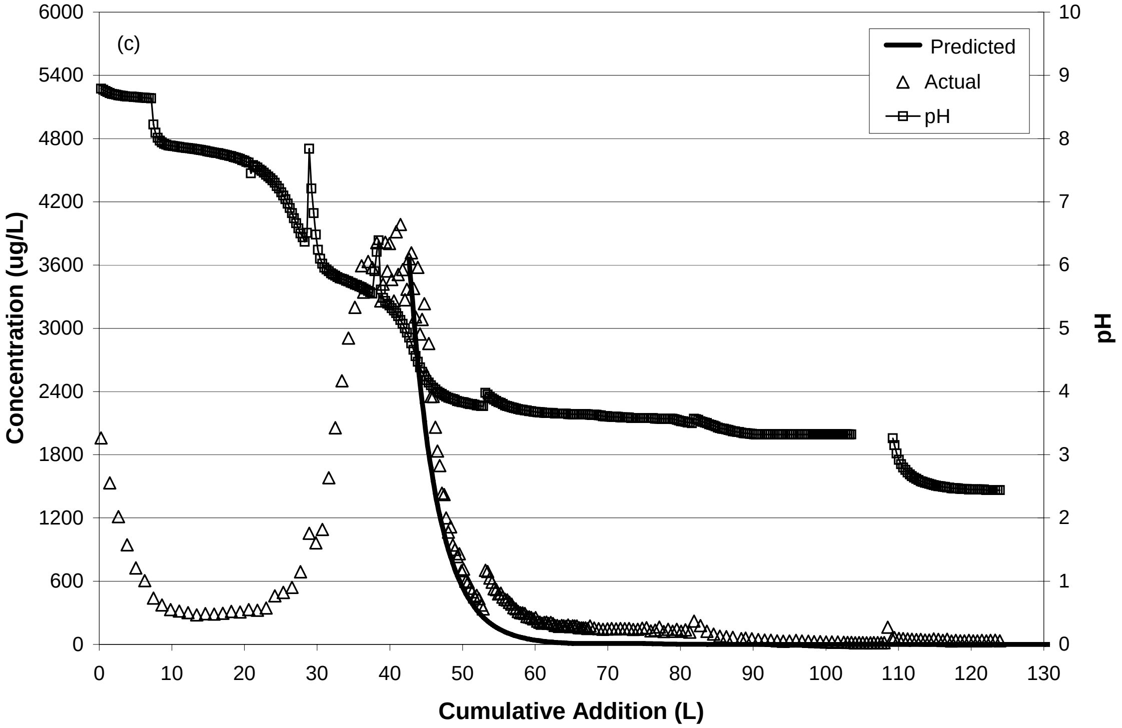

Figure 4c. Concentration of Mg with cumulative addition of eluant: Plant D.

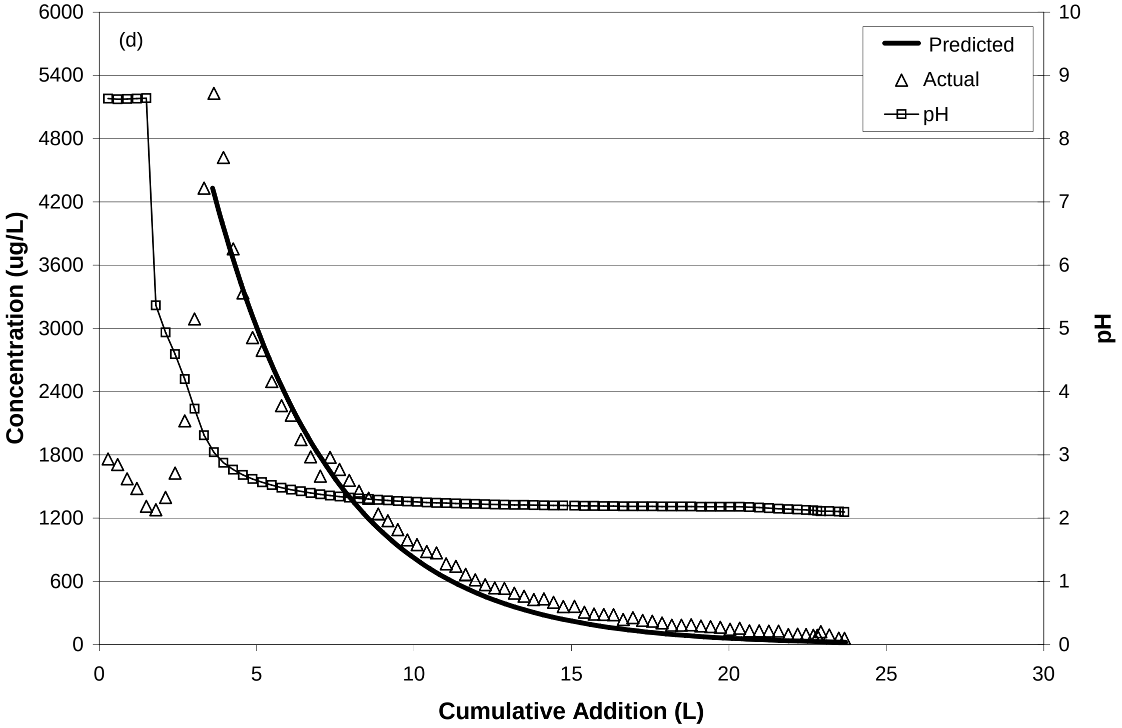

Figure 4d. Concentration of Mg with cumulative addition of eluant: Plant E.

Leaching of many metals is controlled by proton promoted reactions and is strongly dependent on the pH of the system. The effect of the depletion of the Mg buffering mineral and the resultant pH drop can be seen in Figure 5. For each FGD gypsum studied, the loss of Mg is immediately followed by the appearance of first Al and then Fe as the pH falls to and below 4.

Neutralization occurs rapidly due to the strength of acid used in leaching the gypsum sample from Plant E (Figure 5d). In this case, the curves are more compressed than with the other samples. However, the dissolution of Al and Fe is still controlled by the dissolution of the buffering Mg phase and the corresponding drop in pH.

Several un-planned, temporary shutdowns of the inlet pump, which stopped the acid addition, occurred during the experiment using the Plant D sample (Figure 5c). This resulted in the small blips around 38 L and the larger spikes around 52 L and 80 L in Fe and Al concentrations. They indicate that the concentrations of Al and Fe under steady-state conditions were far from their equilibrium values. Yet, in spite of these interruptions, the elution order was retained. For the same sample, the increase in Fe and Al concentrations around 110 L is a result of increasing the HCl concentration from 0.001 N HCl to 0.01 N HCl.

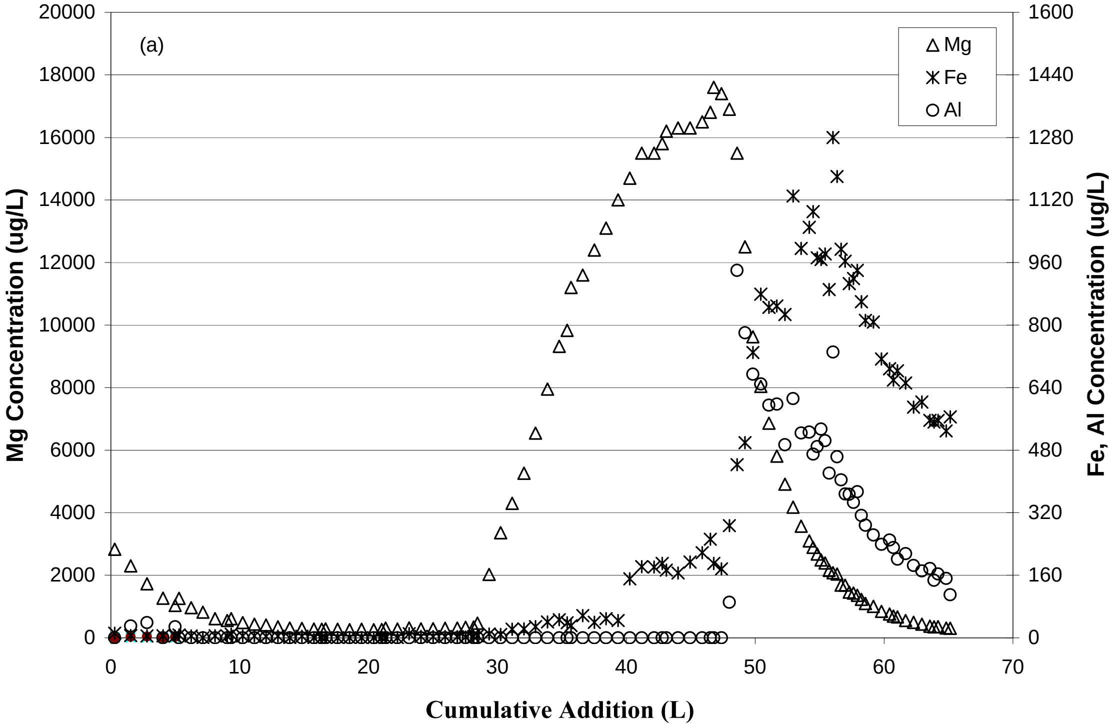

Figure 5a. Concentration of Mg, Fe and Al with cumulative addition of eluant: Plant A.

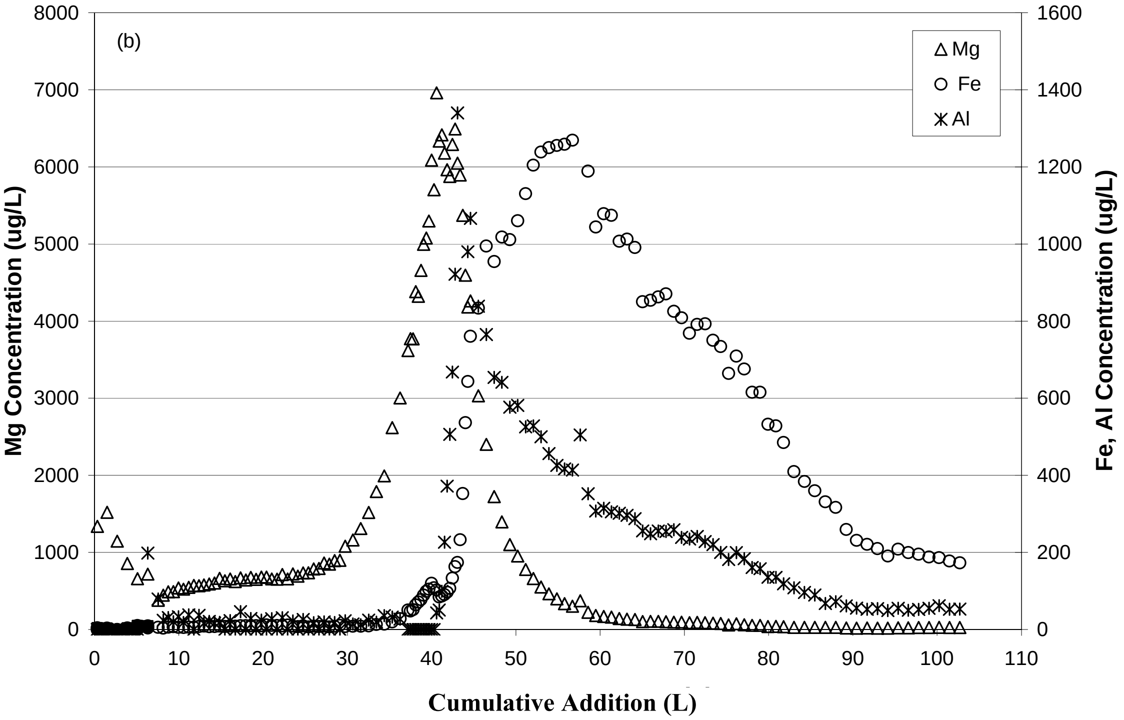

Figure 5b. Concentration of Mg, Fe and Al with cumulative addition of eluant: Plant B.

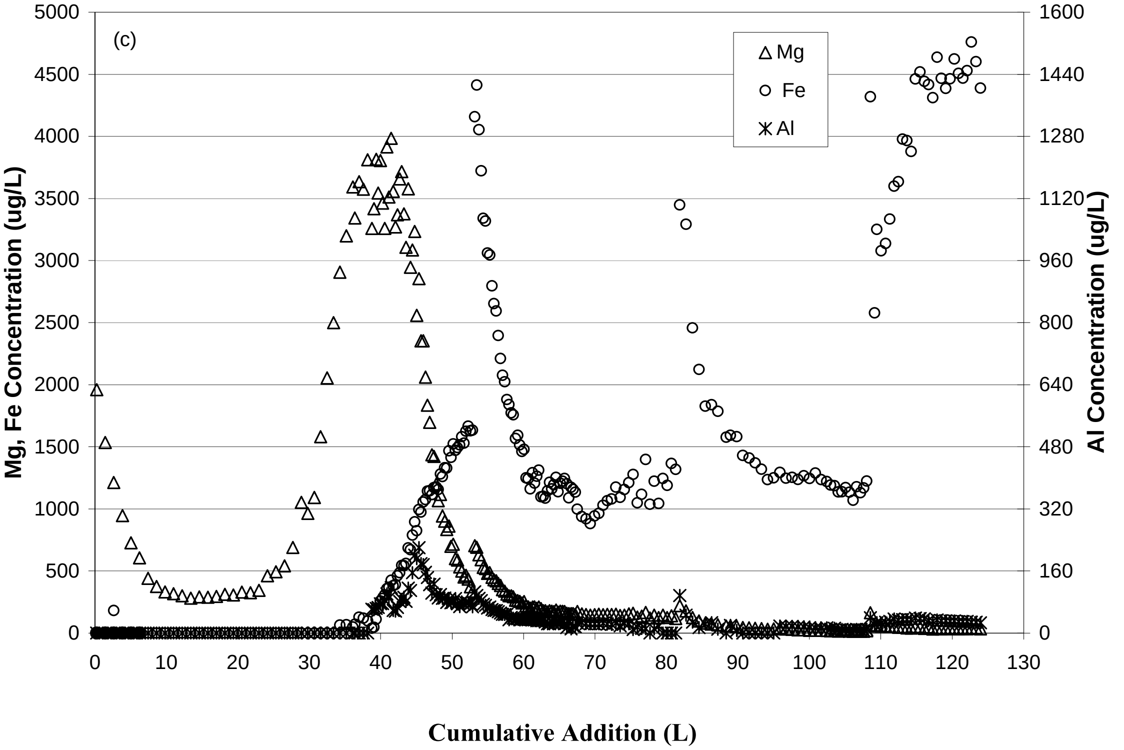

Figure 5c. Concentration of Mg, Fe and Al with cumulative addition of eluant: Plant D.

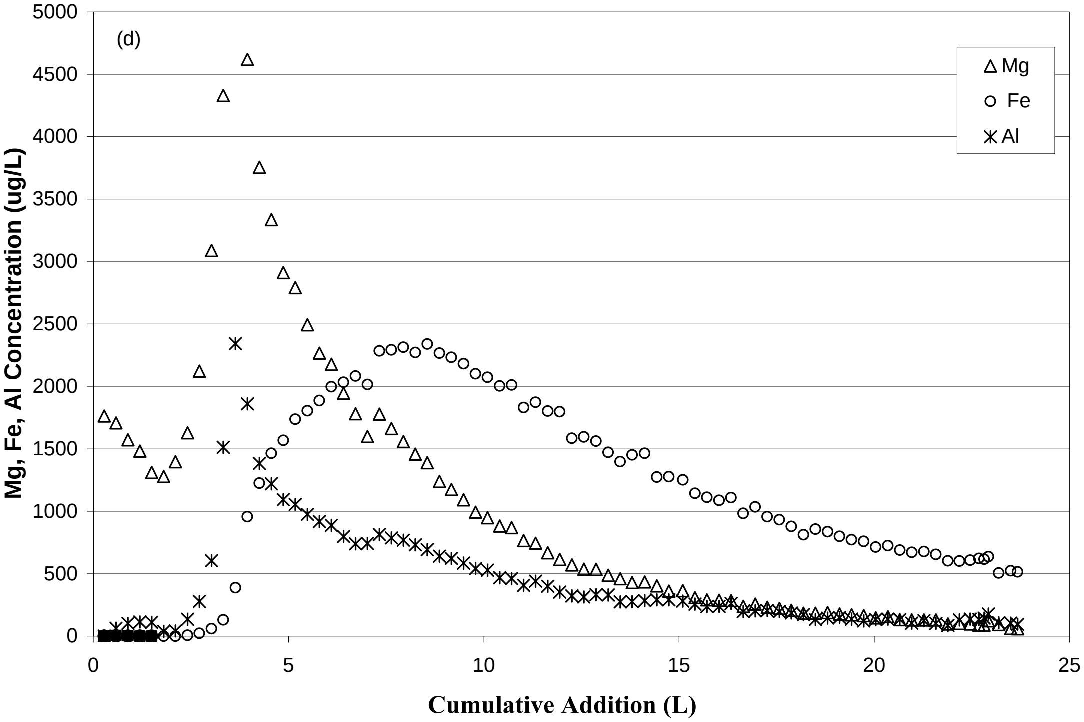

Figure 5d. Concentration of Mg, Fe and Al with cumulative addition of eluant: Plant E.

Comparing the actual elution concentrations of aluminum with predictions based on a simple washing of soluble material from the extractor (Figures 6 a - d) shows similar behavior for all four materials. Although the FGD gypsums came from different wallboard plants and in spite of the different acid strengths used in the leaching experiments, all four profiles show Al being released slowly causing significant tailing of the elution peak. The extent of tailing is not due to the flow rate, which was constant at approximately 300 mL/hr in these experiments. The pH corresponding to the maximum Al concentration varied from 2.9 to 4.1 for the four gypsums but was not related to the extent of tailing. Maximum Al concentrations from Plants B and E gypsums occurred at pH 2.9 and 3.1 respectively yet did not tail less than the aluminum from Plants A and D for which the maximums occurred at pH 3.4 and 4.1, respectively. Thus, the rate of dissolution of the Al-bearing mineral is sufficiently slow in the pH range of 3 to 4 that it continues to appear hours after it might otherwise be expected if it were rapidly solubilized. For example, Al continued to elute from Plant B gypsum after 100 L of eluant has passed when only a little over 60 L would have been the volume corresponding to the wash-out of a fully solubilized element. This corresponds to an additional “reaction time” of over 5 days.

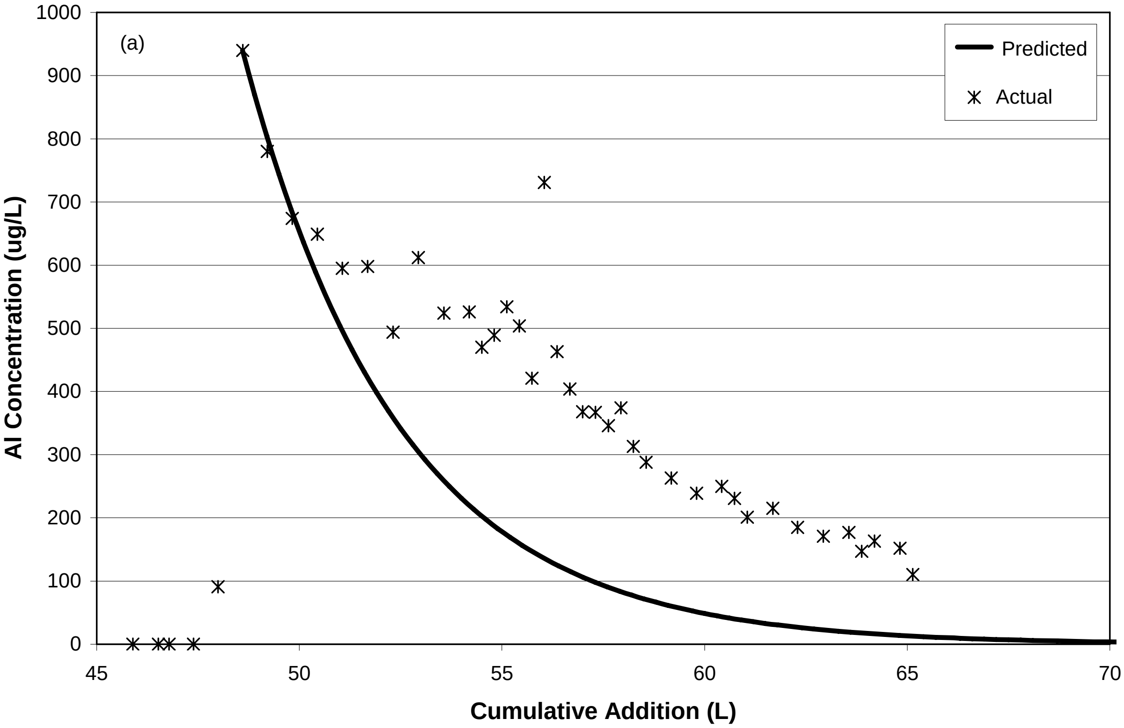

Figure 6a. Concentration of Al with cumulative addition of eluant: Plant A.

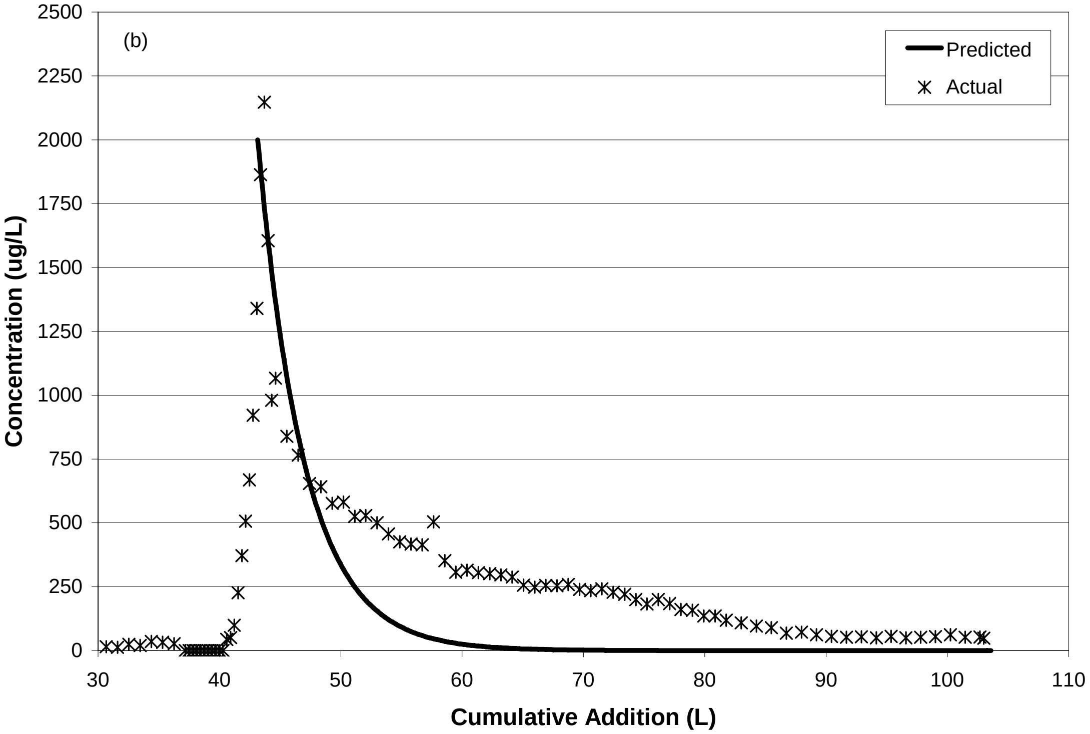

Figure 6b. Concentration of Al with cumulative addition of eluant: Plant B.

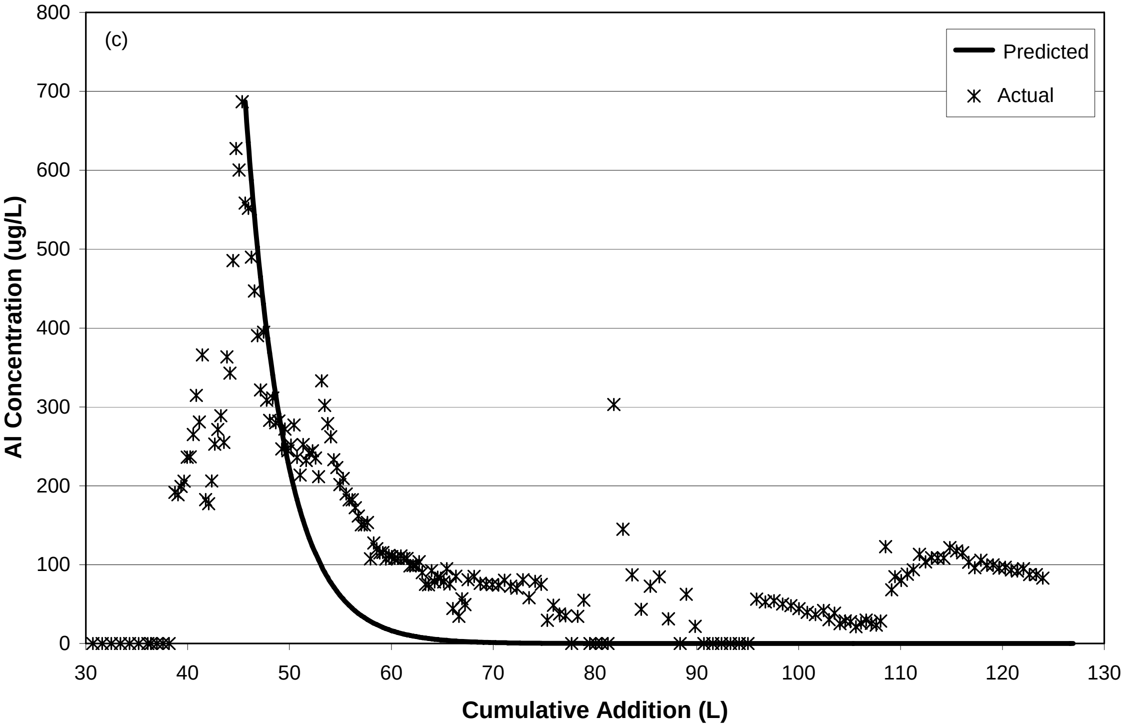

Figure 6c. Concentration of Al with cumulative addition of eluant: Plant D.

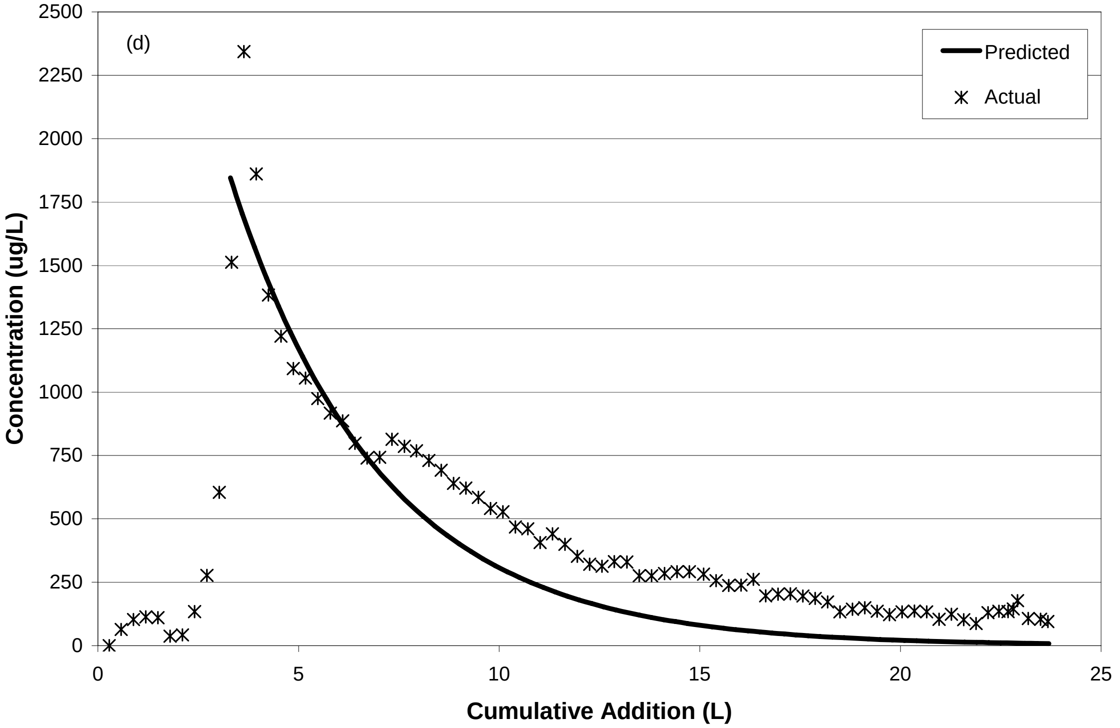

Figure 6d. Concentration of Al with cumulative addition of eluant: Plant E.

The leaching profiles of Fe in these samples are even more complex than those of Al. It is not possible to fit any of the elution profiles to that predicted by the sequential dilution model (Figure 7a - d). At the leading edge of the elution peak, Fe concentrations increase at a more gradual rate than seen for Al. For plants A, B, and D, (Figure 7a, b, and c), the Fe concentrations increase in at least two steps before reaching a maximum, indicating the dissolution of more than one species. This is followed by a slower than predicted decrease. As with Al, the slow elution rate could indicate slow, continuous dissolution or desorption reactions occurring in the tank. Because of the operating problems encountered during the leaching of the Plant D gypsum, interpretation is difficult, but the onset of the Fe peak around 110 L that corresponds to a switch to more concentrated HCl had an obvious effect. As stated earlier, either the increase in reaction rate due to the availability of additional protons or the dissolution of separate phases is responsible.

Overall, the behavior of the Al and Fe during the leaching of the samples does not follow a pattern of rapid dissolution, release, or neutralization followed by continuous dilution in a back-mixed system. The more complex chemistry could indicate the presence of multiple Al and Fe phases, the involvement of surface sorbed Fe and/or Al, and/or mixed Fe and Al phases such as clay minerals. The multiple phases dissolve at different pH and/or rates.

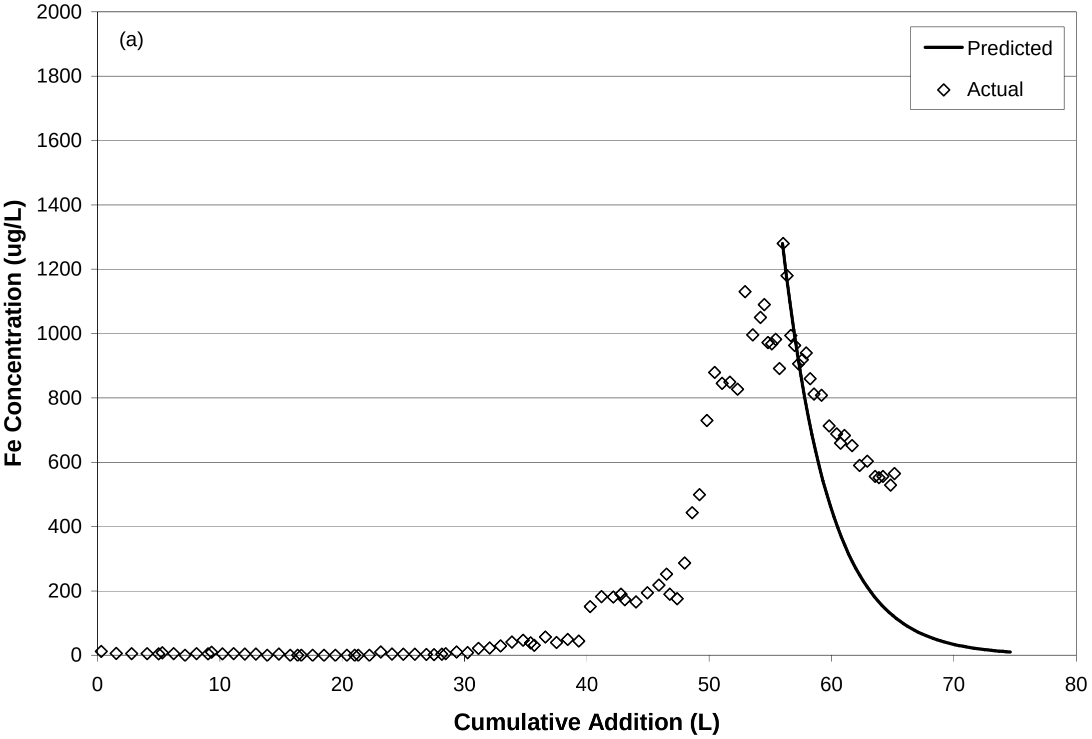

Figure 7a. Concentration of Fe with cumulative addition of eluant: Plant A.

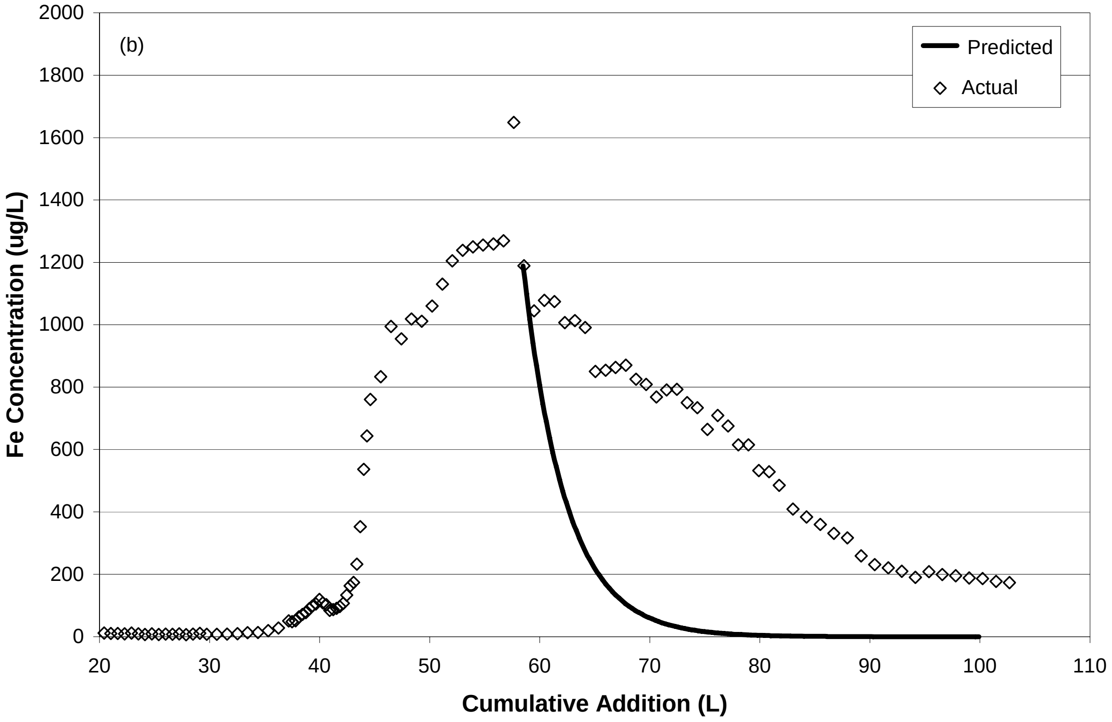

Figure 7b. Concentration of Fe with cumulative addition of eluant: Plant B.

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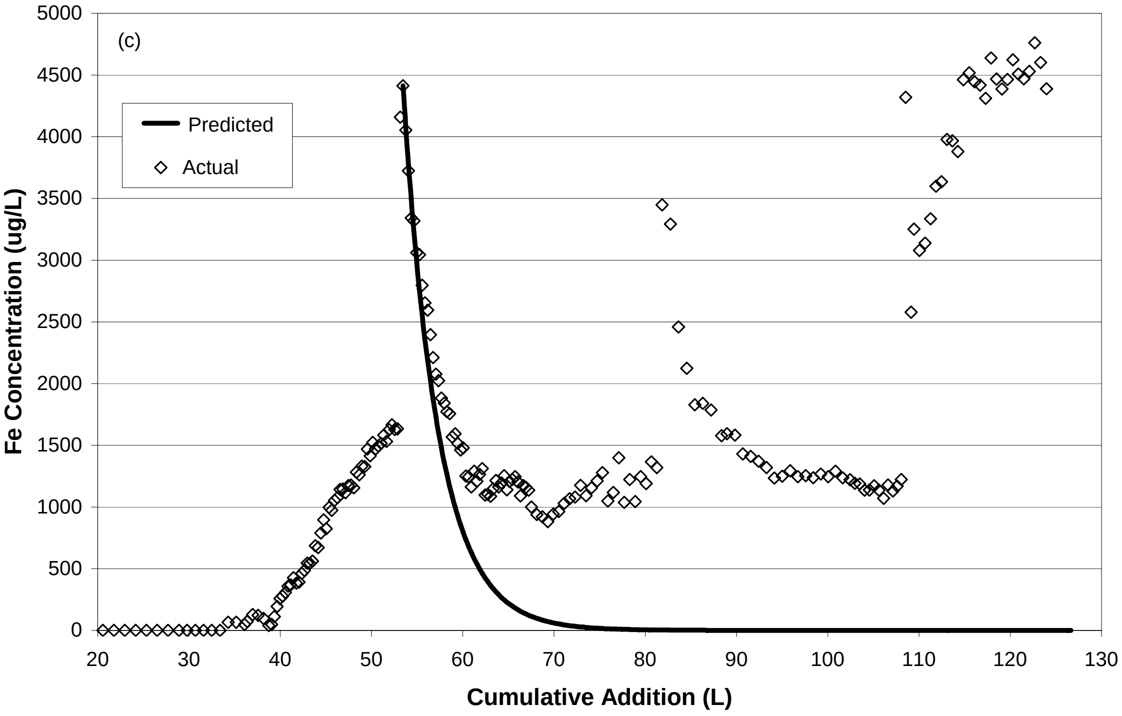

Figure 7c. Concentration of Fe with cumulative addition of eluant: Plant D.

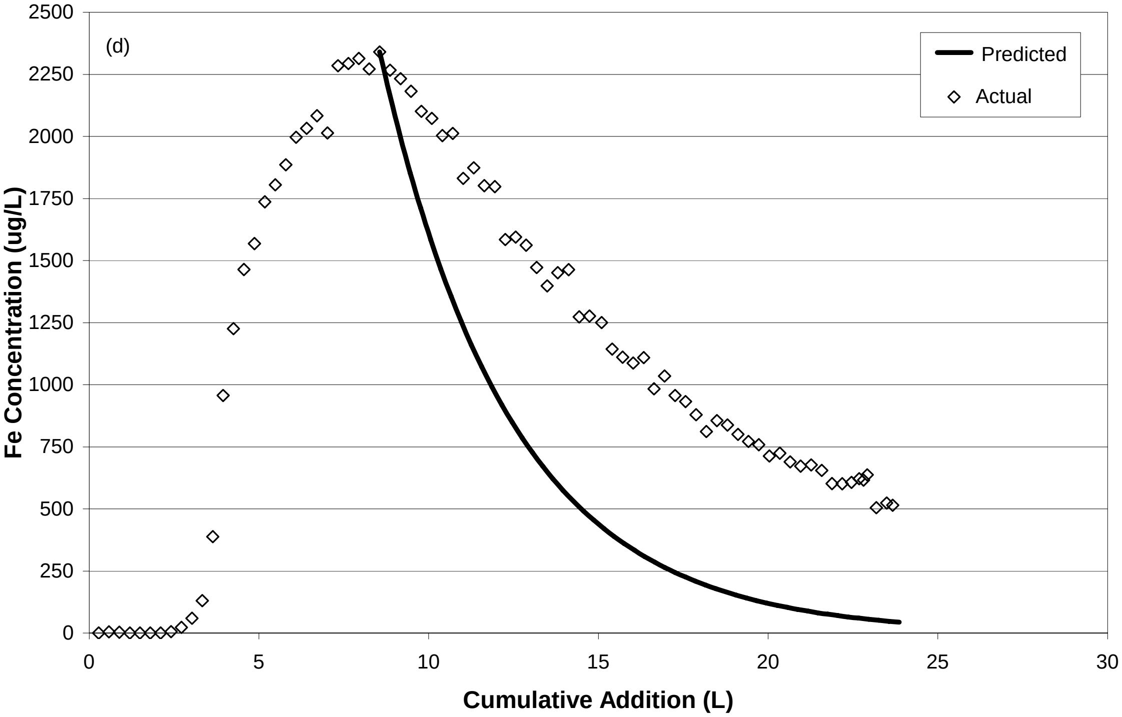

Figure 7d. Concentration of Fe with cumulative addition of eluant: Plant E.

Patterns produced by several elements (Cd for Plant A, Pb for Plants D and E, and Ni for Plants B, D, and E) suggest they are released during the leaching process only to be re-adsorbed by the material remaining in the tank. Using the elution pattern for Cd in the gypsum from Plant A as an example (Figure 8), a spike in concentration followed by a sudden decrease is evident. This post-release behavior is not consistent with the predicted sequential dilution behavior (indicated by solid line on graph). Its disappearance from solution is much faster than expected, indicating a possible release followed by rapid adsorption onto another phase present in the tank. The detection limit of Cd is 2 ppb, so the concentrations < 2 ppb would not be measured. It is unlikely that re-adsorption behavior such as this would be seen in the typical batch or fixed-column leaching tests.

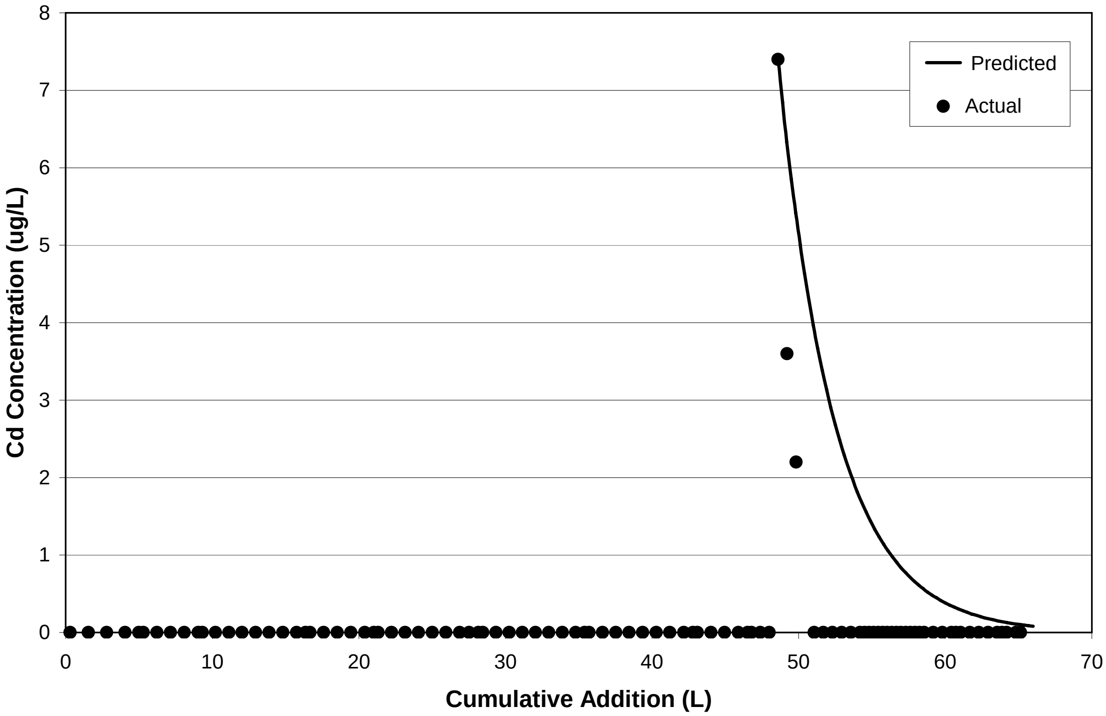

Figure 8. Concentration of Cd with cumulative addition of eluant for Plant A.

Residue

The post-leaching residues accounted for less than 2% of the original gypsum samples with only traces of remaining gypsum, but concentrated amounts of Fe, Al, As, Cd, Cr, Hg, Pb, Se, and Zn. It appears that the phase responsible for retention of these metals is not the calcium sulfate, but more likely an Fe or mixed Fe-Al phase. For some samples, certain elements, including As, Cd, Pb, and Se were not detectable in the starting solid but became concentrated in the residue (Table 2). Release could have occurred at concentrations below the detection limits of the analytical instruments. If release at these levels did occur, the possibility also exists that release was followed by adsorption onto the solid material remaining in the tank. The rate of re-sorption would need to be faster than the rate of release. Leaching of the FGD gypsum samples mobilize little Hg under the pH conditions (~8.5 – 2.5) of the experiments. A significant finding of this experiment is the presence of the insoluble residue that appears to be responsible for retention and sequestration of several potentially hazardous elements. The insoluble residue could be the result of clays and other impurities in the limestone reagent used in the FGD process.

Conclusion

The use of a CSTX is a highly effective approach to the leaching of fine-grained and cementitious materials and allows the chemistry of the leaching process to be studied at a level unachievable through more traditional batch and column techniques. It would not be possible to separate patterns of metals release to the degree presented here using other leaching approaches. The behavior of individual elements depends on a number of factors, including, but not limited to: (1) solubility of the mineral phases present; (2) sorption properties of these phases; (3) behavior of the solubilized material in the tank; (4) the type of species in solution; and (5) the neutralization capacity of the minerals. Metal release behavior over a wide pH range can be obtained and used to evaluate the stability of various elements in the material under investigation. Understanding the fundamental mechanisms operating during the leaching process provides a basis for evaluating the safety of FGD By-products and ensuring these materials are used and disposed of in an appropriate manner.

The chemistry of mine environments can vary significantly between sites, depending on the geology, minerals present in any remaining coal and overburden material and interaction with surface and groundwater environments. Consequently, the behavior of FGD gypsum at mine sites will also vary. From the results presented here, it can be expected that Ca and S will be released continuously during any post-placement leaching process until the gypsum is consumed, regardless of pH. Other metals, including Al and Fe will not be released until the buffering capacity of the FGD product is consumed. In our work, this corresponded to the depletion of a Mg-containing phase, probably the carbonate. The data here indicate that below a pH of about 4, Fe and Al will begin to dissolve, providing the potential for the mobilization of any elements bound to them. However, because of the slower rate of dissolution, the maximum concentrations attained by Al, Fe, and elements bound to them will depend on the flow rate to a greater extent than do the concentration of Ca and S that arise from the easily solubilized gypsum itself.

Disclaimer: The mention of specific product names is to facilitate understanding and does not imply an endorsement by the US government.

Acknowledgements

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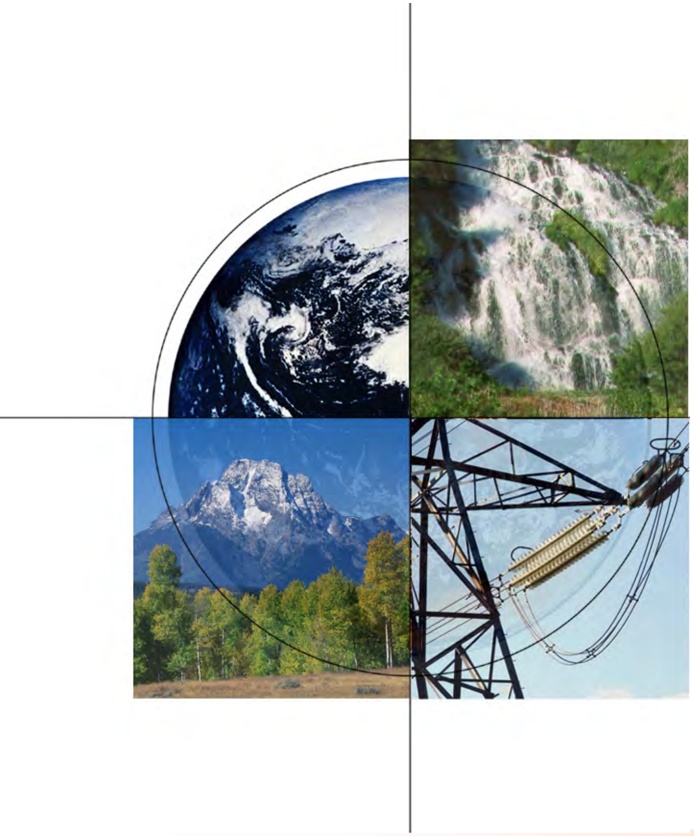
Dr. Candace L. Kairies is currently a visiting assistant professor at Denison University and a Faculty ORISE researcher with the Coal Utilization By-products group at DOE's National Energy Technology Laboratory (NETL) in Pittsburgh, Pennsylvania. Her research with NETL focuses on the stability of and the mechanisms behind the capture and retention of mercury and other metals in FGD materials. She holds a BS in Environmental Science (Westminster College), a MS in Environmental Science and Management (Duquesne University), and a Ph.D. in Geology (University of Pittsburgh).

Solubility of FGD Gypsum Using a Continuously Stirred Tank Extractor



Candace Kairies, Karl Schroeder, Robert Thompson, Carol Cardone and Paul Rohar

FGD Byproducts at Coal Mines

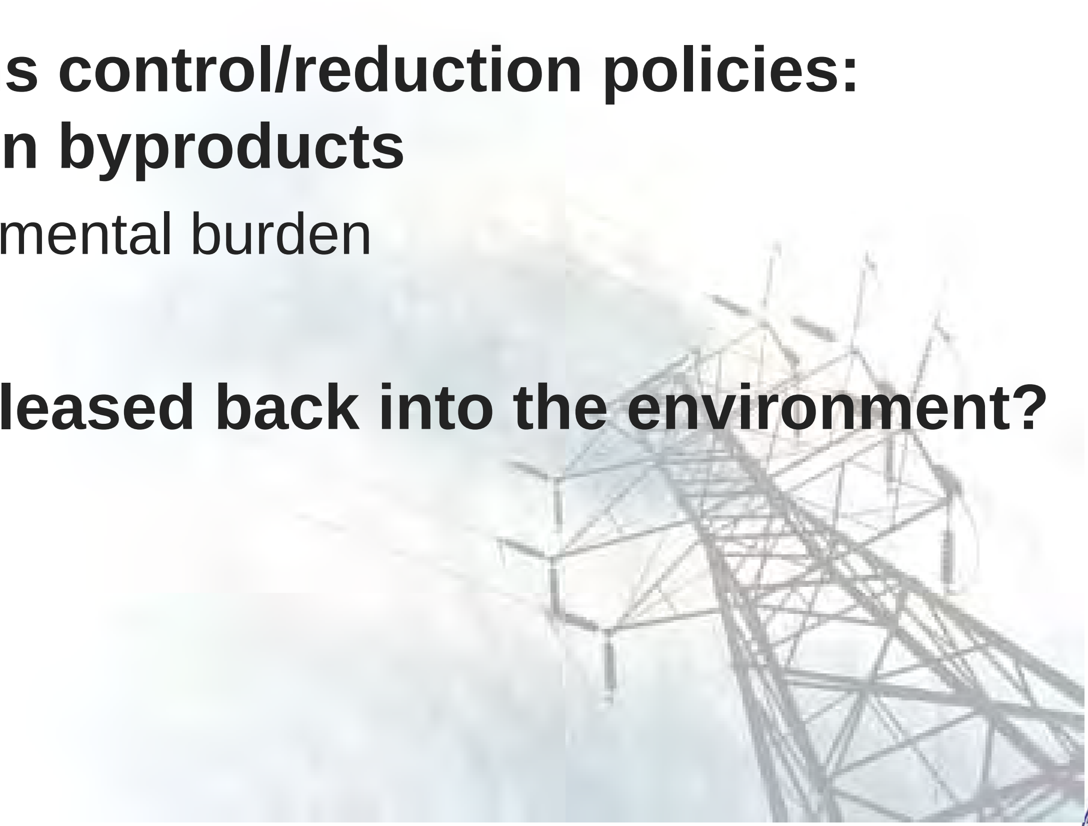
November 14 - 16, 2006

NETL

DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA

Introduction

- **Coal contains trace metals**
  - CUBs - low concentrations
- **Stricter emissions control/reduction policies: Increase metals in byproducts**
  - Transfer environmental burden
- **Can metals be released back into the environment?**
  - Reuse
  - Disposal



Leaching

- **Evaluate potential heavy metal release**
  - Batch or fixed column techniques

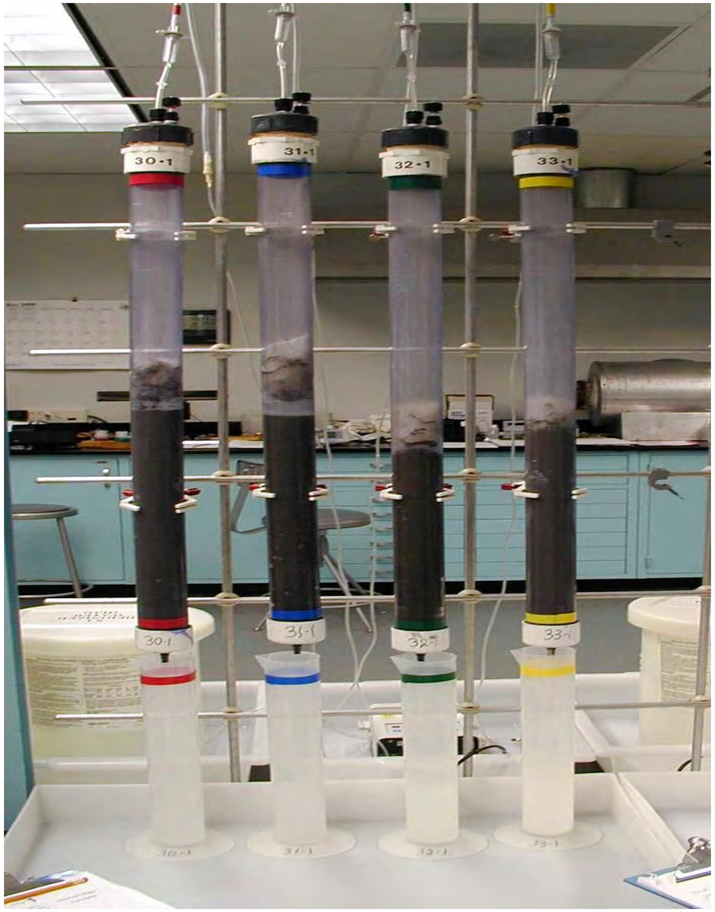
Batch Leaching

- Metals release at set pH

Column Leaching

- **Elution profiles with changing elution volume and pH**
  - Continuous flow of eluant

- **Impermeability issues**
  - Cementitious properties
    - FBC ash
  - Precipitate formation
    - High Ca ash subjected to sulfate containing leachates
      - $CaSO_4$ ppt.
  - Too fine-grained
    - FGD gypsum



Alternative!

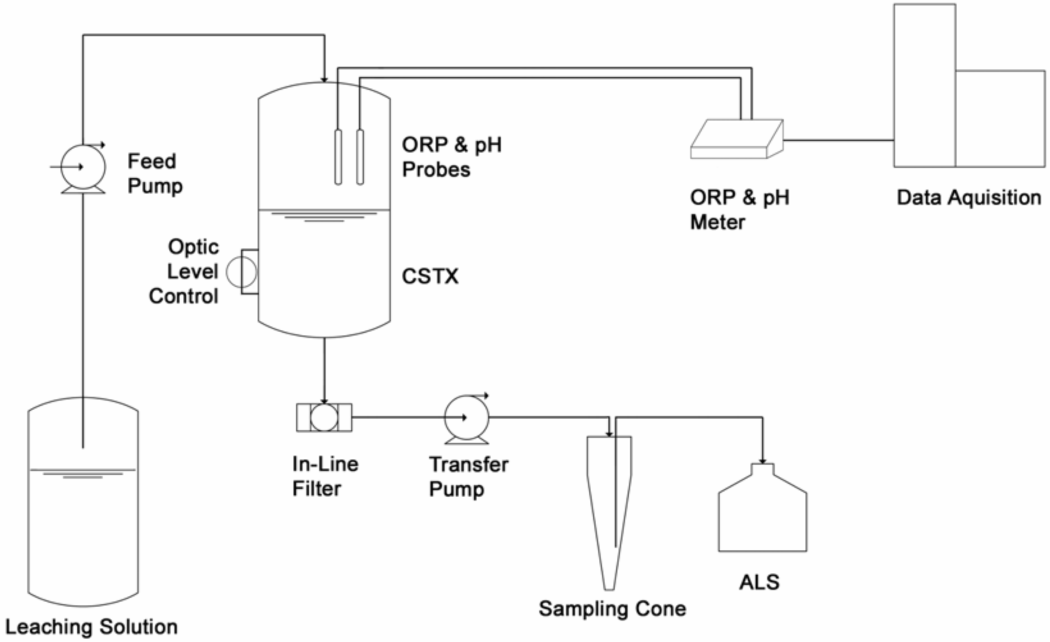
- **Continuously stirred tank extractor (CSTX)**
- **Advantages**
  - – Elution profile w/o clogging issues
  - – Exit stream same composition as tank
  - – Obtain fundamental chemical information
    - Reaction rates
    - Equilibrium constants
    - Effective solubility products
    - Effect of pH changes
  - – Data used in geochemical models

Objectives

- **Develop CSTX method for continuous leaching of difficult materials**
  - Cementitious, precipitate-forming, and/or fine-grained
  - PRB fly ash, FBC, other high-Ca, FGD

- **Apply to FGD materials to determine**
  - What elements are released
  - How much is released
  - Under what conditions
    - Liquid / solid ratio
    - Effect of pH (slightly alkaline to acidic)

Methods - CSTX Setup



Methods

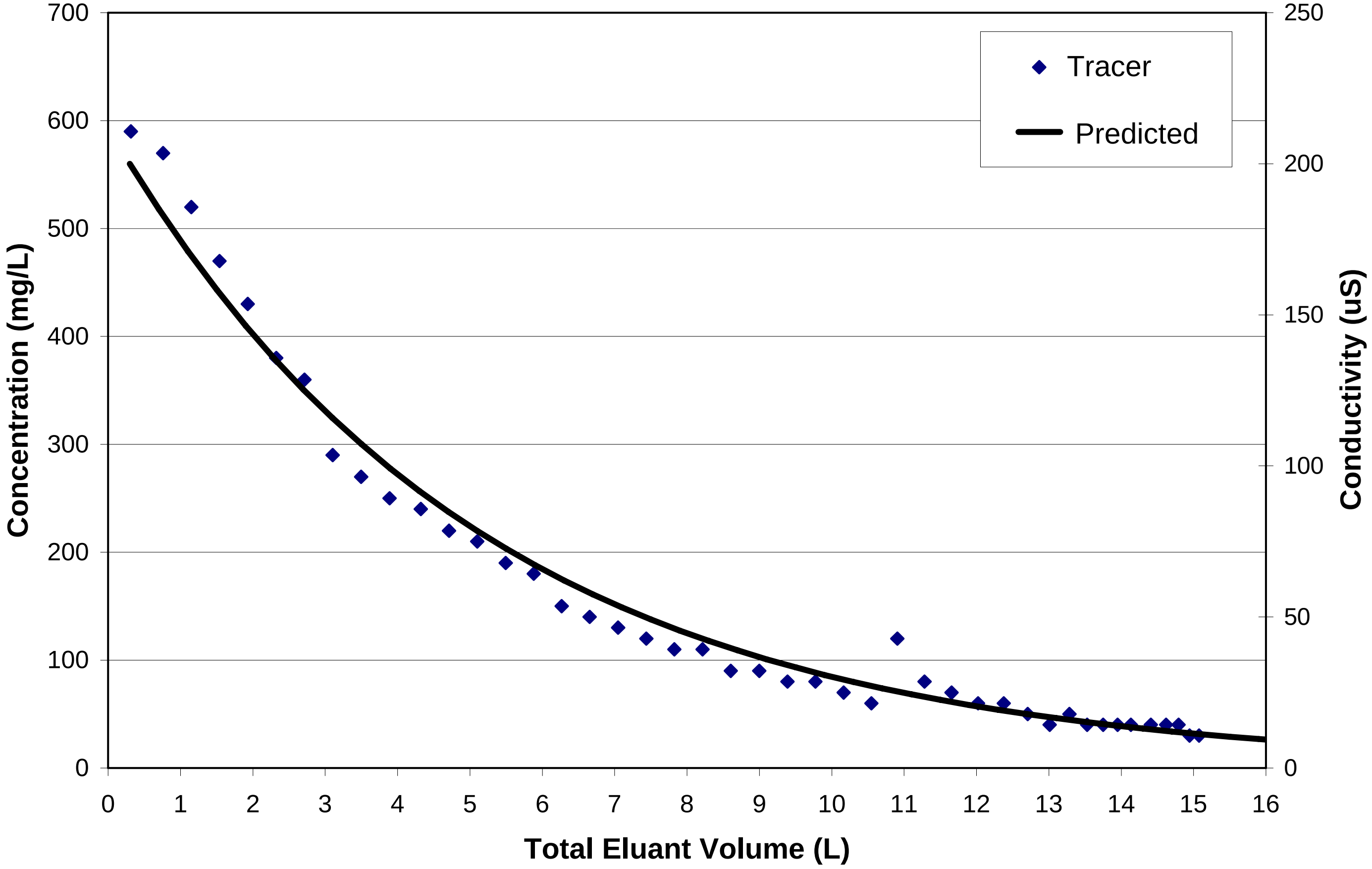
- **4 L MQW**
- **Four FGD gypsum samples**
  - A, B, D: 200 g
  - E: 60 g
- **MQW followed by HCl**
- **Leachate analysis**
  - ICP-OES, ICP-MS
  - CVAA
  - Solids analysis of separate splits
    - Digestion, ICP-OES, ICP-MS
    - DMA-80, CVAA, CVAF
- **Remaining material removed, filtered**

Table 1. Concentration of HCl used in leaching

	Acid Concentration (N)
Plant A	0.00036/0.0036
Plant B	0.004
Plant D	0.001/0.01
Plant E	0.01

Methods -Tracer Experiment

- **Ammonium chloride**
  - 0.8 g + 4 L MQW
  - Removal monitored
    - Conductivity
- **Establish elution behavior of material**
  - Compared to calculated removal
- **Aid interpretation**



Results and Discussion

- **Material balances**
  - **Ca, S: ~100%**
  - **Metals with low balances**
    - Leaching at levels < DL

- **Residue**
  - Preferential partitioning of most elements

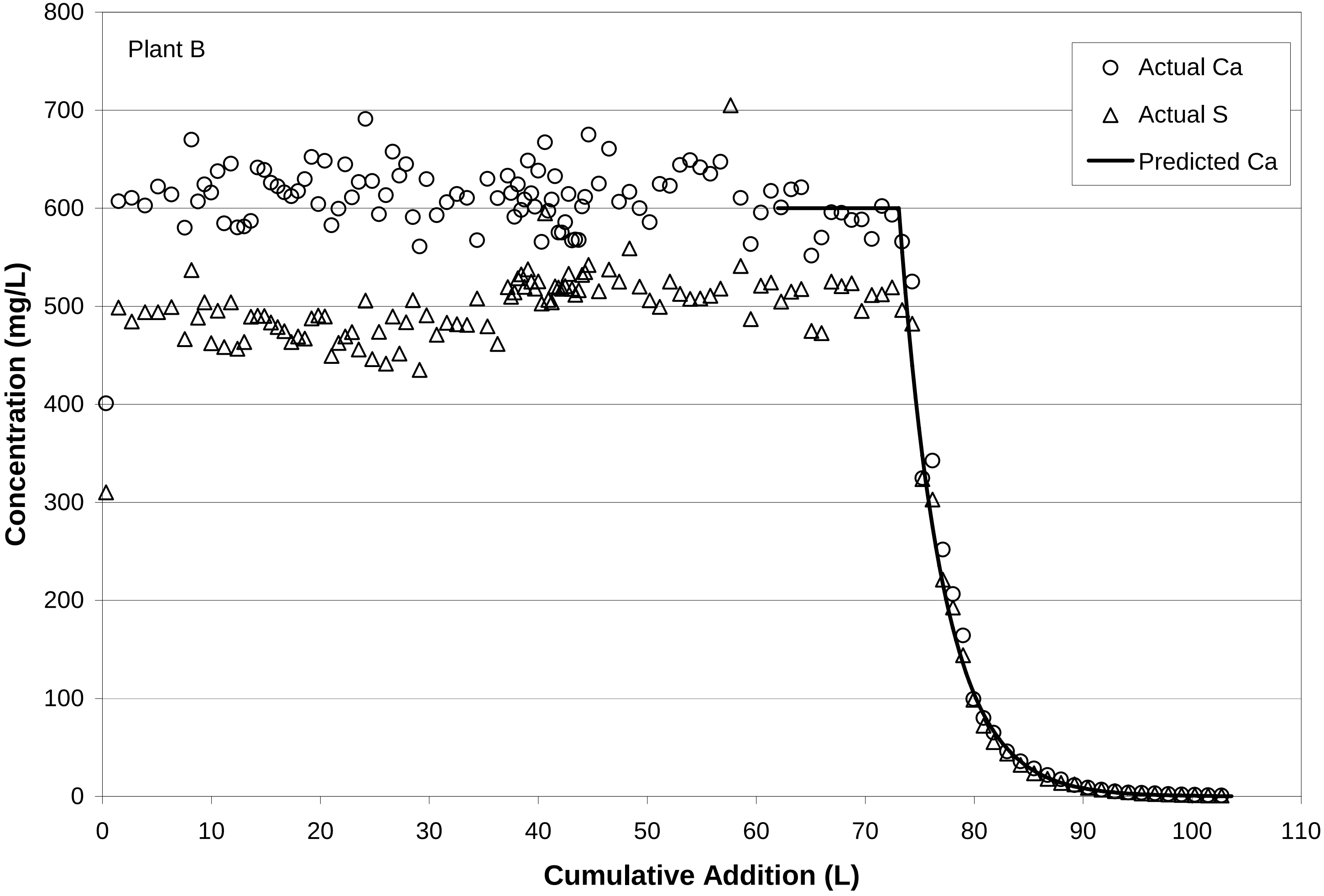
Results and Discussion

- **Metal release patterns**
  - Identify and interpret different processes occurring in the CSTX

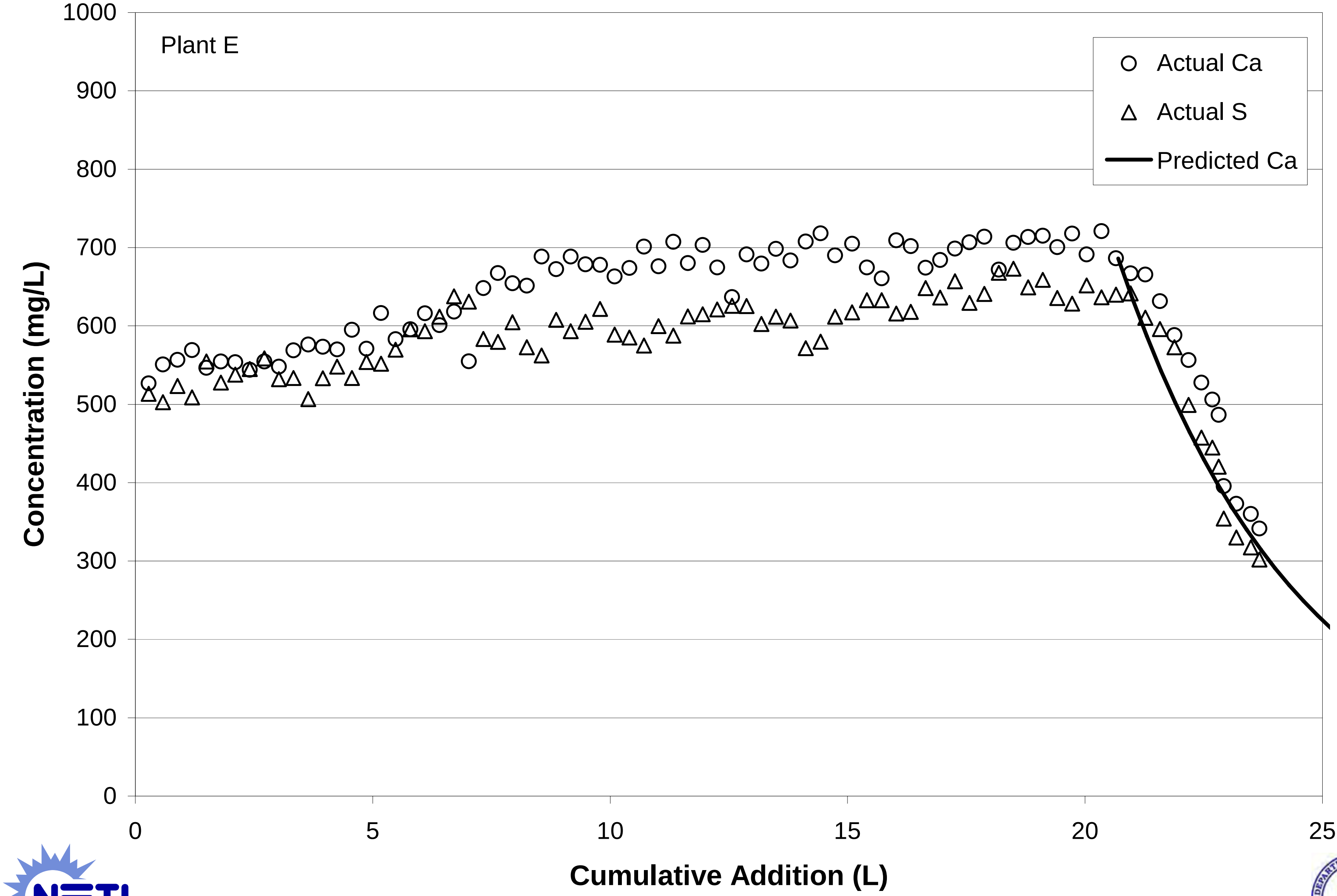
1. **Solubility driven release**
2. **Neutralization reaction driven release**
3. **Complex behavior**
   - Not explained by a single process
4. **Release/Readsorption**

Solubility Driven Release: Ca, S

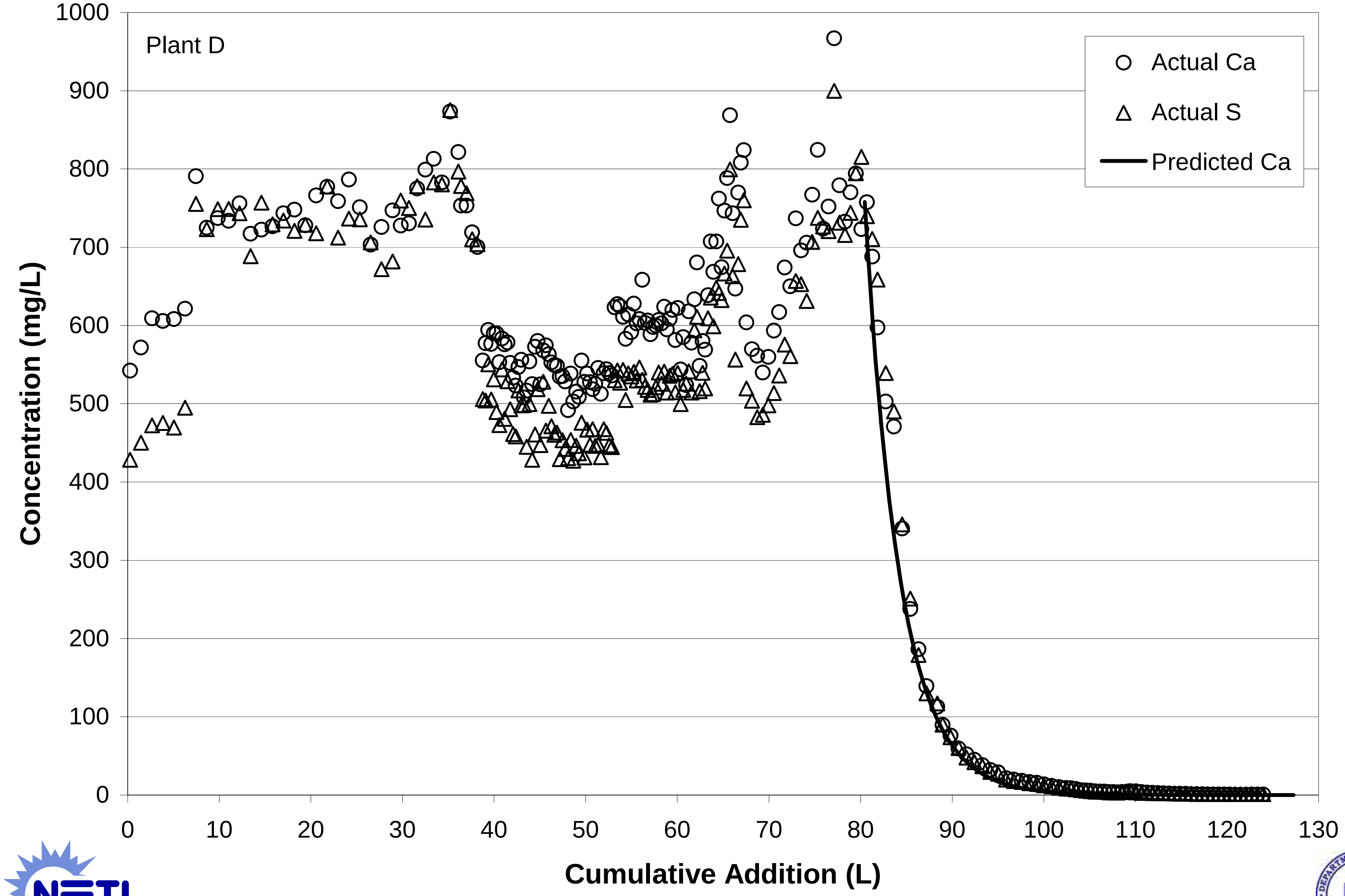
- **Relatively constant concentrations**
  - Steady state dissolution; controlled by K_{sp}



Solubility Driven Release: Ca, S



Solubility Driven Release: Ca, S

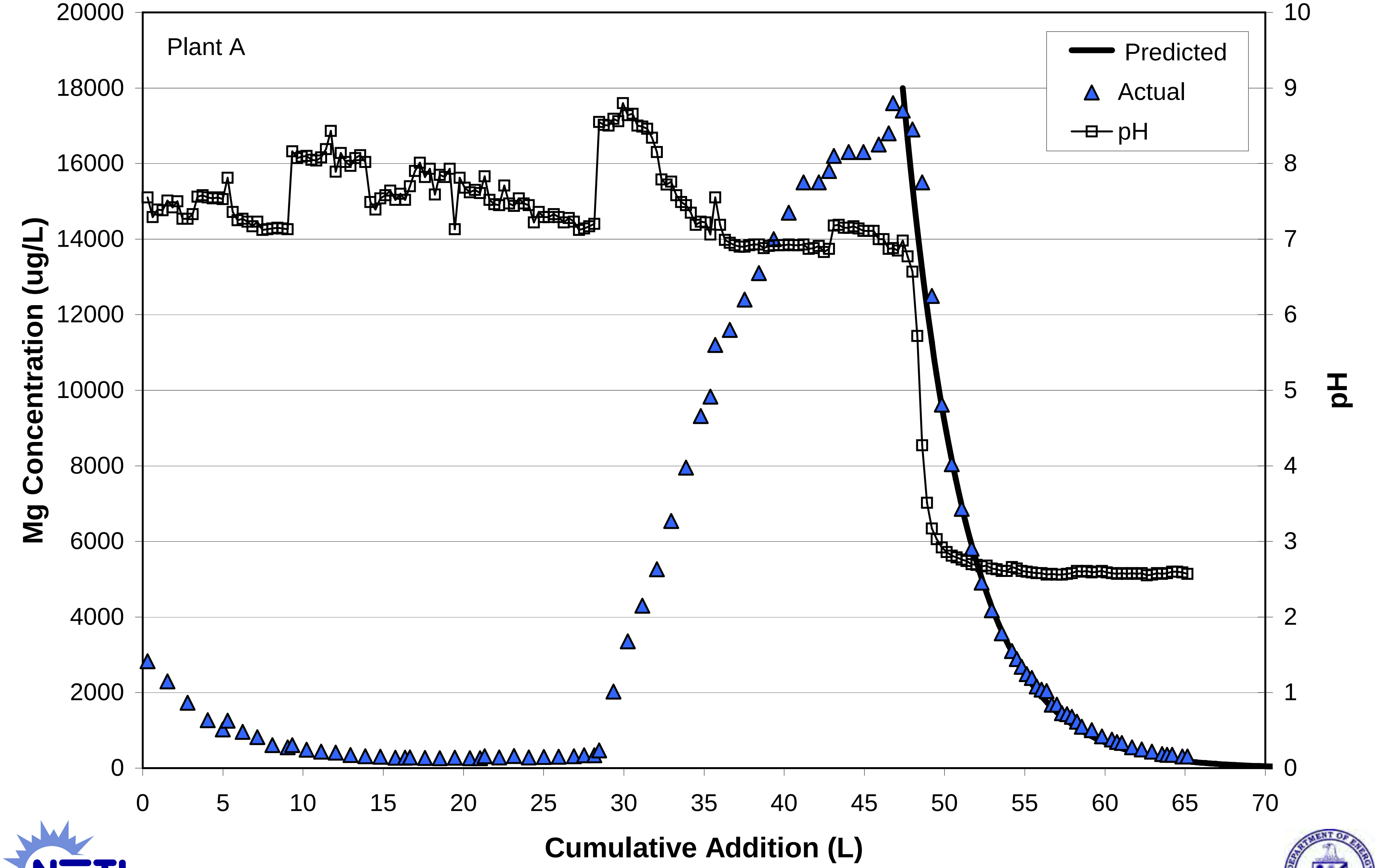


Solubility Driven Release: Ca, S

- **Molar solubilities**
  - **Ideal = 5.01 x 10^{-3} mol/L**
  - **Actual = 15.6 x 10^{-3} mol/L**

  - **Difference indicates liquid in tank is supersaturated compared to ideal behavior**
    - Material amorphous?
      - Higher solubility
    - Fine $CaSO_4$ rather than excess of ions

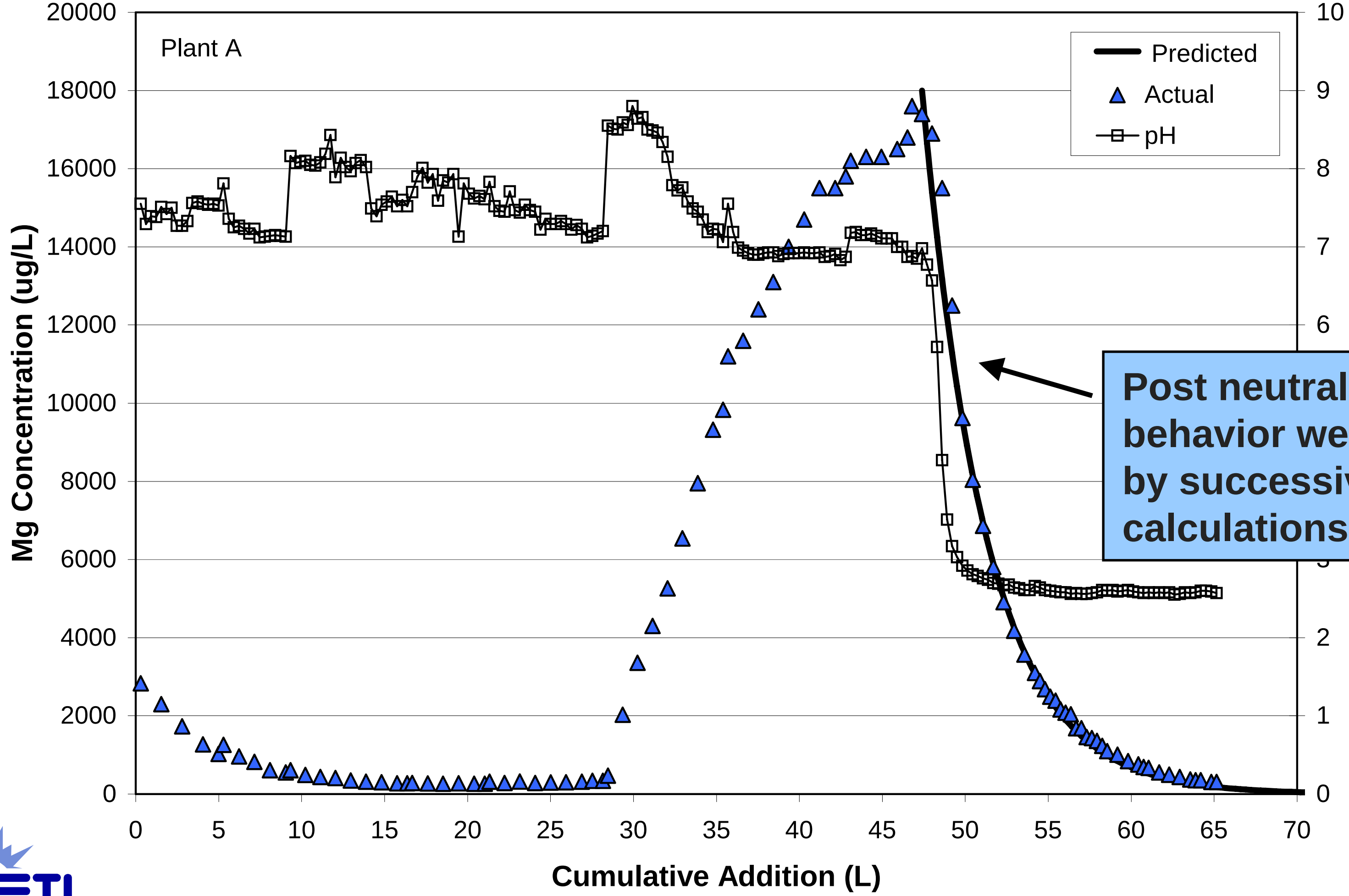
Neutralization Reaction Driven Release: Mg



Neutralization Reaction Driven Release: Mg

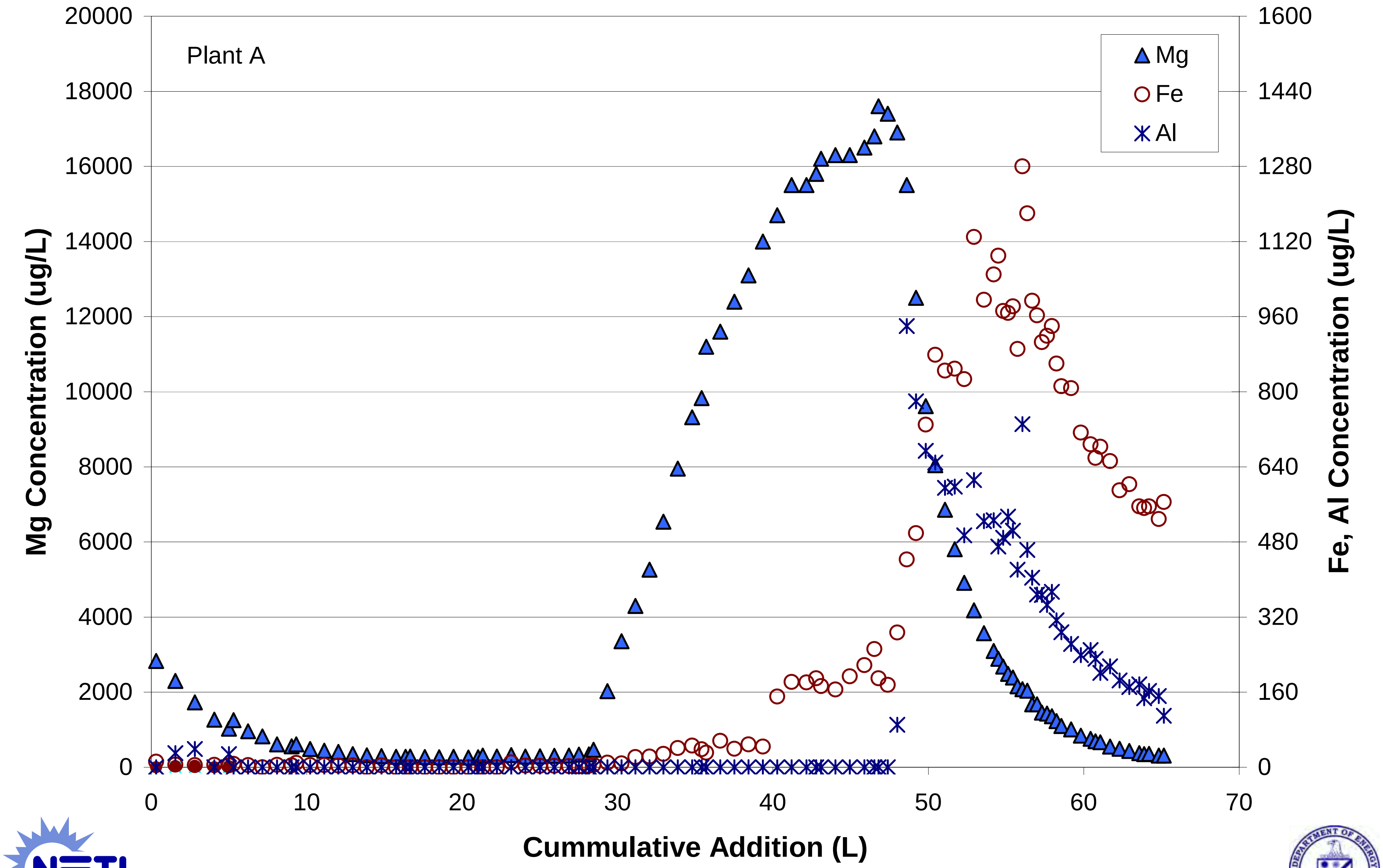
- **Elution indicative of acid neutralizing capacity**

- **Mg present as carbonate?**
  - $MgCO_3 + H^+ \rightarrow Mg^{2+} + HCO_3^-$
  - $HCO_3^- + H^+ \rightarrow H_2O + CO_{2\,(g)}$

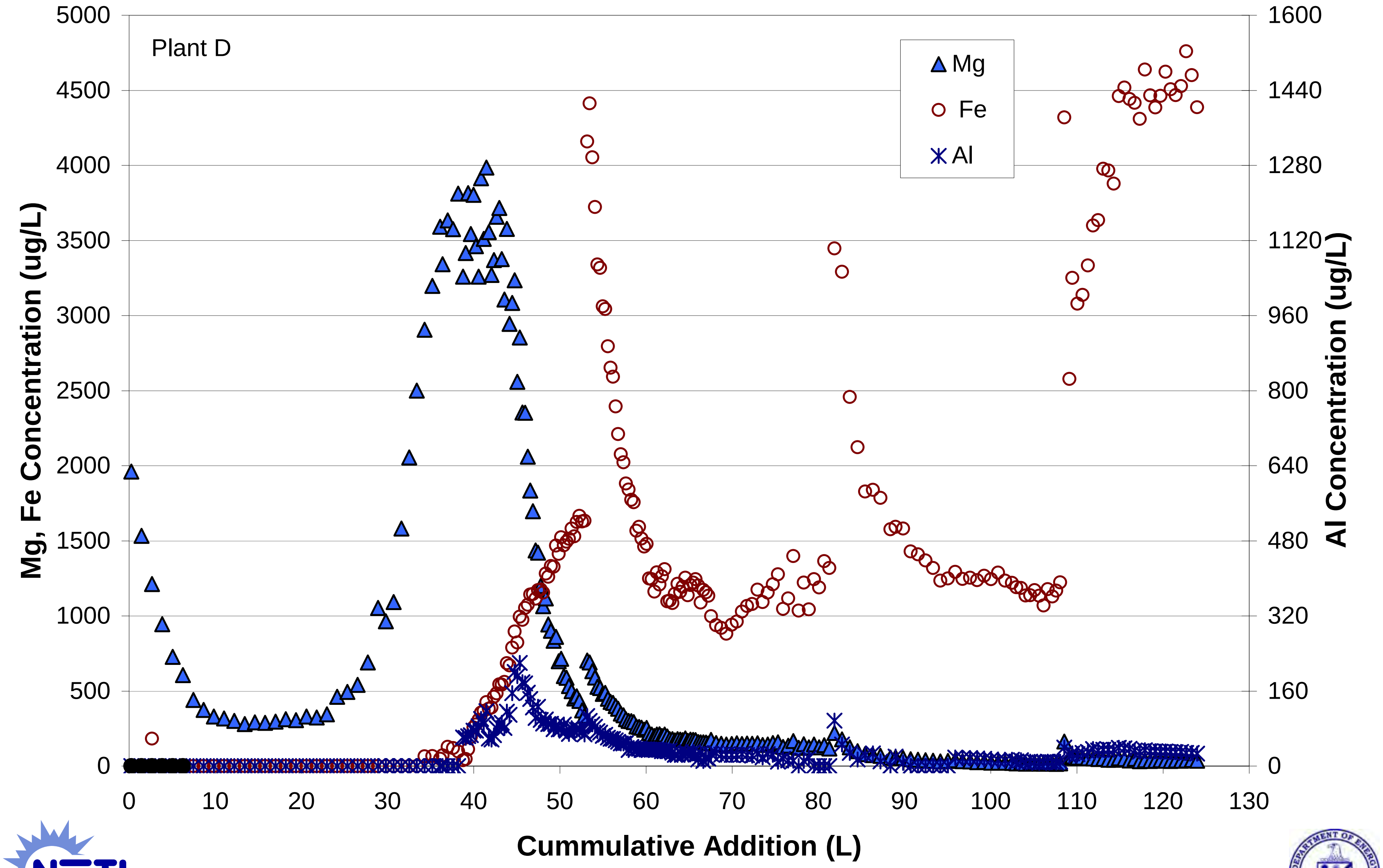


Post neutralization behavior well modeled by successive dilution calculations

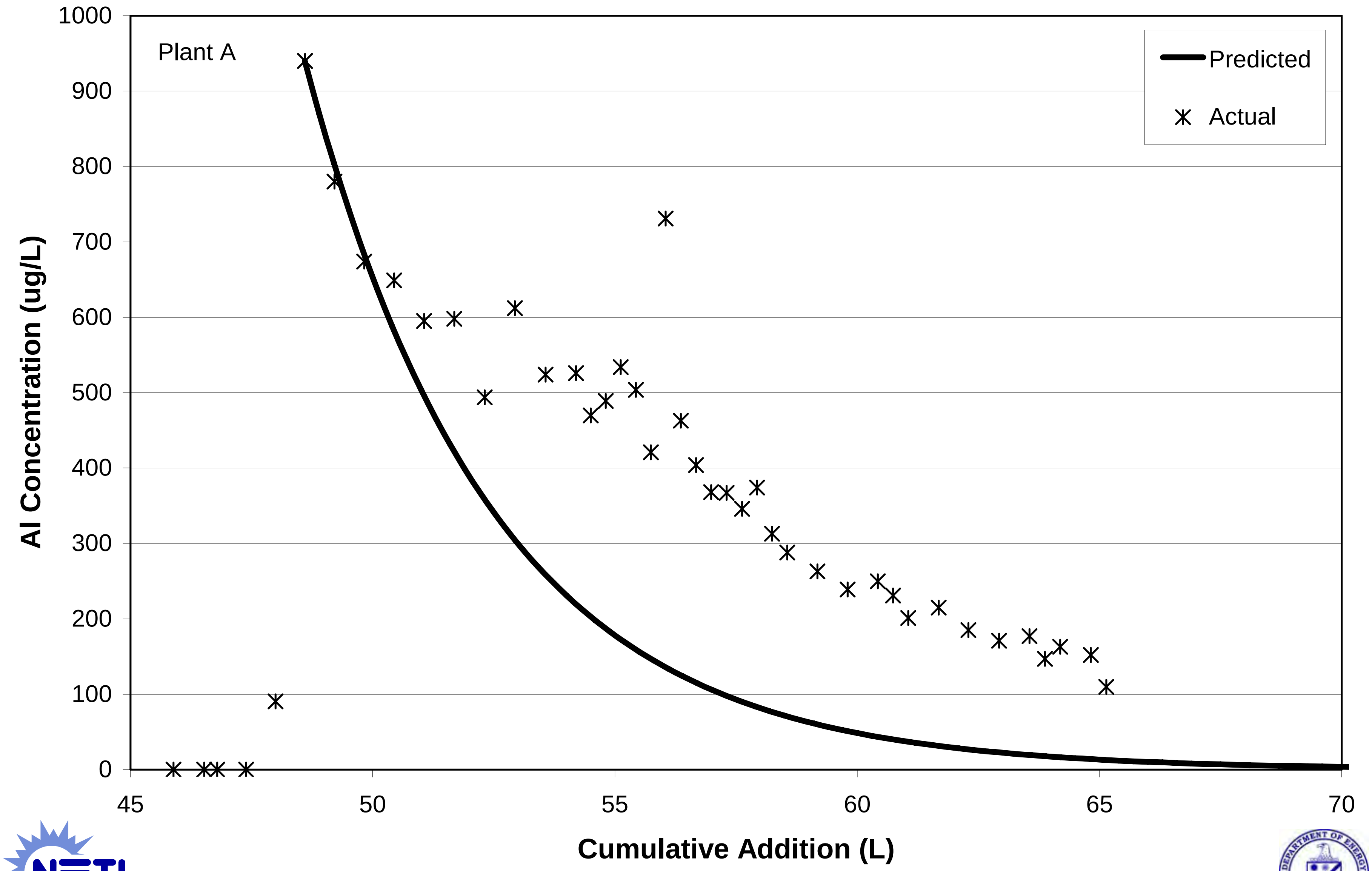
Neutralization Reaction Driven Release: Mg



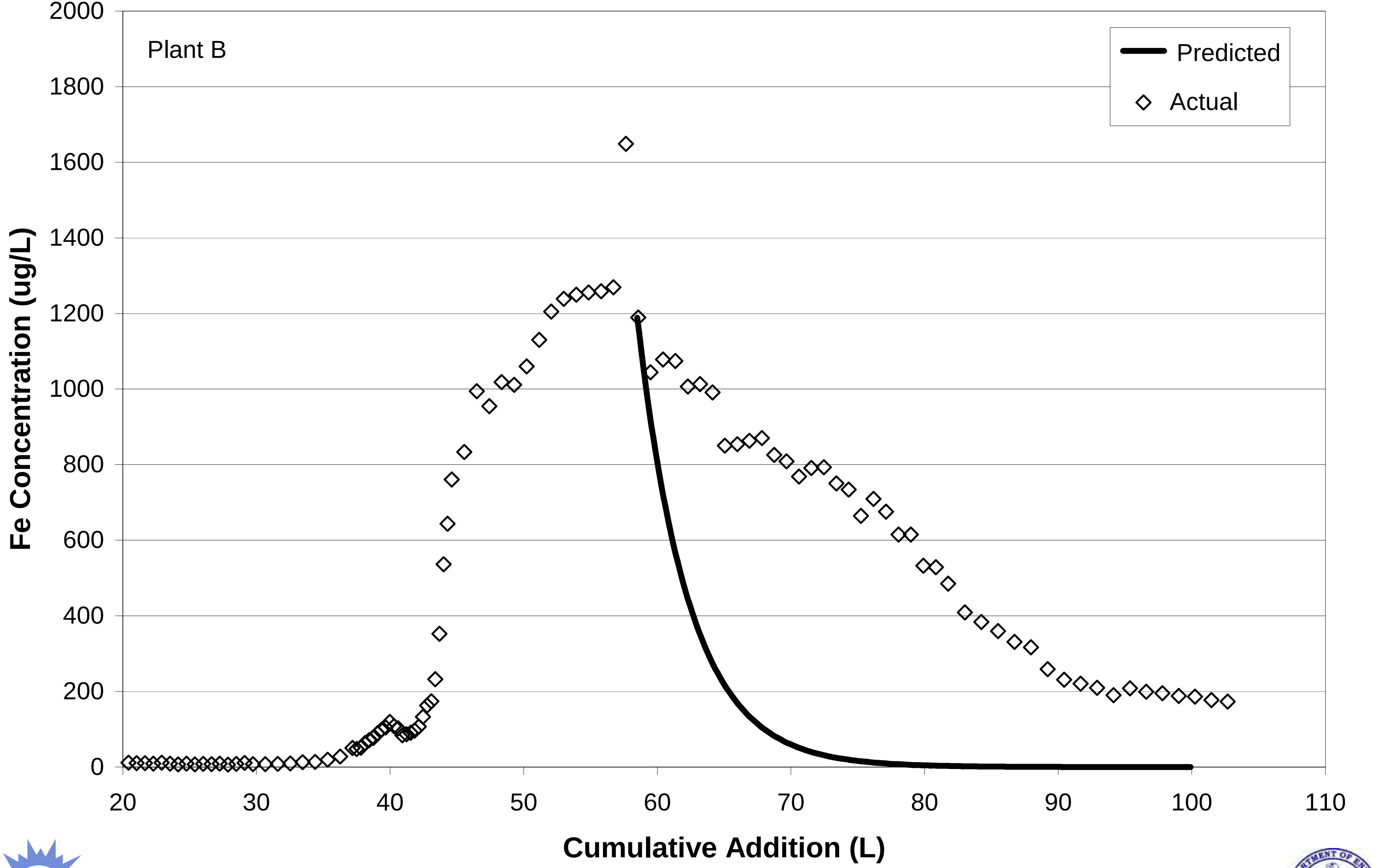
Neutralization Reaction Driven Release: Mg



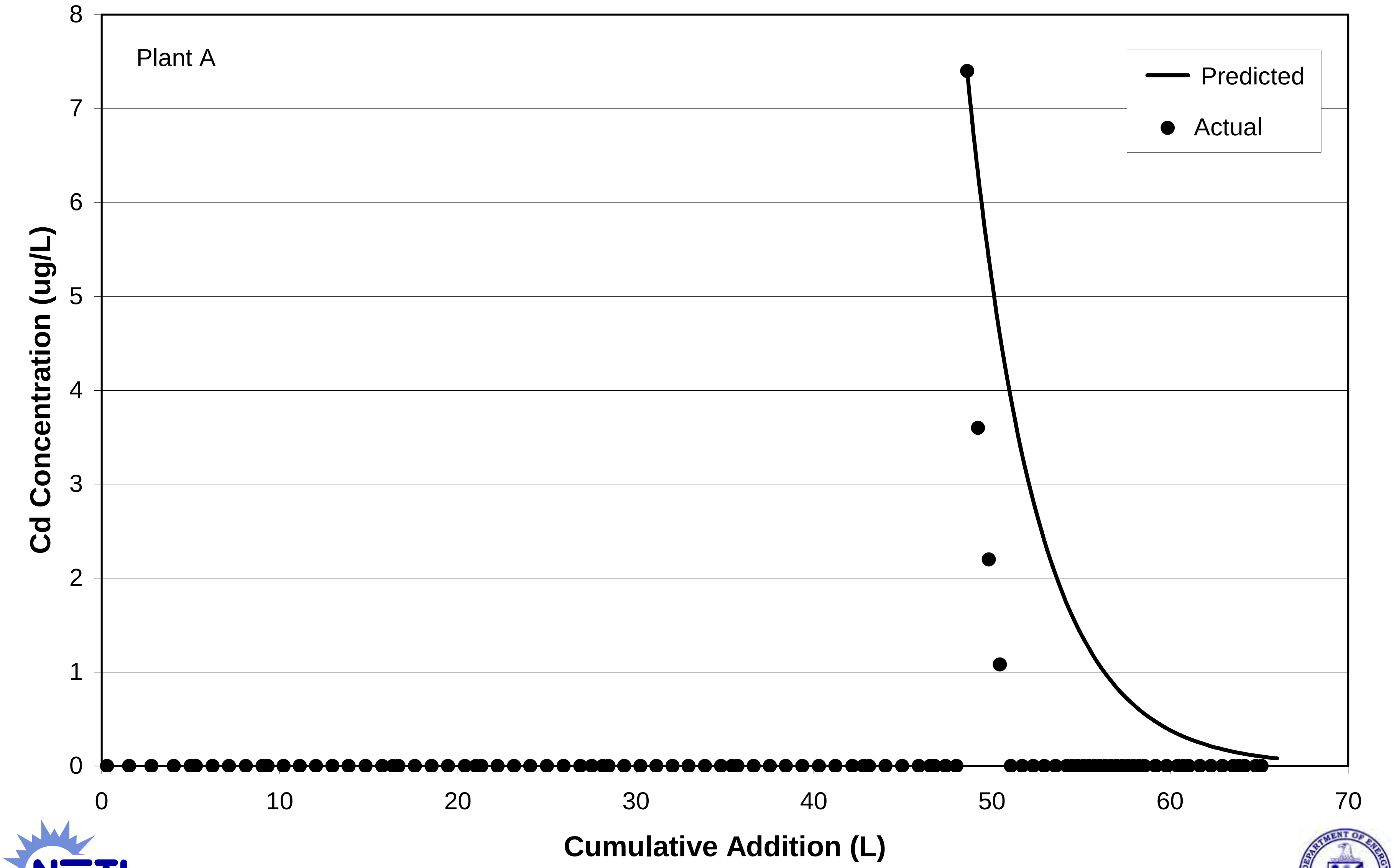
Complex Behavior: Al



Complex Behavior: Fe



Release/Readsorption



Post-leaching Residue

- **Accounted for < 2% of the original material**
  - Traces of remaining Ca, S
  - Fe, Al
  - Cd, Cr, Hg, Pb, Se, Zn
    - Phase responsible for retention is not gypsum
      - Fe or mixed Fe-Al phase
- **Possible release at concentrations below detection limit**
  - Followed by readsorption?

Conclusion

- **CSTX allows chemistry of leaching processes to be studied at a level unachievable through batch and fixed bed leaching techniques**

- **Behavior of individual elements depends on a variety of factors:**
  - Mineral phases
    - Solubility
    - Sorption properties
    - Neutralization capacity
  - Behavior and type of solubilized material in tank

- **Understand fundamental mechanisms: basis for evaluating safety**

AN INTEGRATED FRAMEWORK FOR EVALUATING LEACHING IN WASTE MANAGEMENT AND UTILIZATION OF SECONDARY MATERIALS

David S. Kosson[1], Hans A. van der Sloot[2], Florence Sanchez[1],
Andrew C. Garrabrants[1], Rob Keeney[3], Susan Thorneloe[4]
[1]Vanderbilt University, Nashville, Tennessee
[2] ECN, Petten, The Netherlands
[3]ARCADIS
[4]U.S. EPA Office of Research & Development, Research Triangle Park, North Carolina

The authors declined to provide either an abstract or paper for their presentation.

View Presentation

Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials

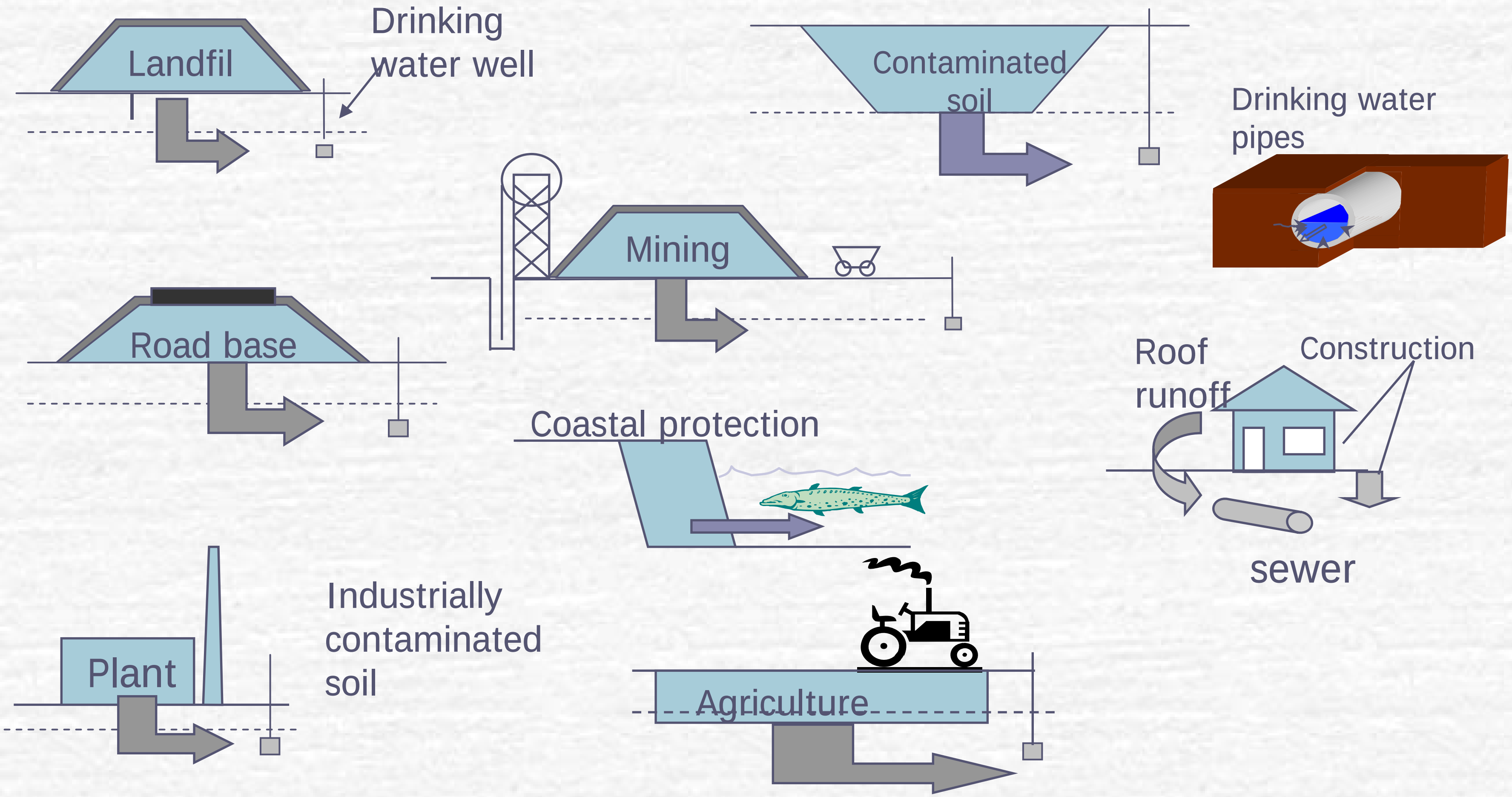
David S. Kosson[1], Hans A. van der Sloot[2], Florence Sanchez[1], Andrew C. Garrabrants[1], Rob Keeney[3], Susan Thorneloe[4]

[1]Vanderbilt University, Nashville, USA
[2] ECN, Petten, The Netherlands
[3]ARCADIS
[4]U.S. EPA-ORD

Technical Interactive Forum on Flue Gas Desulfurization By-Products at Coal Mines
Columbus, OH, 15 November 2006

Different Impact Scenarios........

16 Dec. 2003
DG ENV



Landfil

Drinking water well

Contaminated soil

Drinking water pipes

Mining

Road base

Roof runoff

Construction

Coastal protection

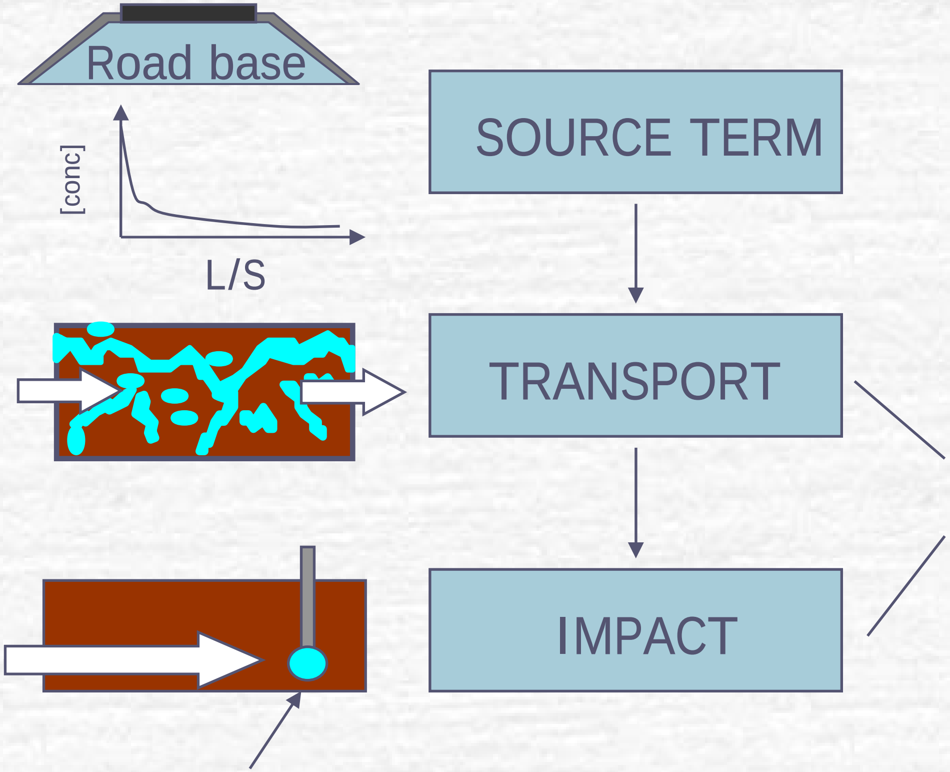
sewer

Plant

Industrially contaminated soil

Agriculture

………. Similar Problem



SOURCE TERM

TRANSPORT

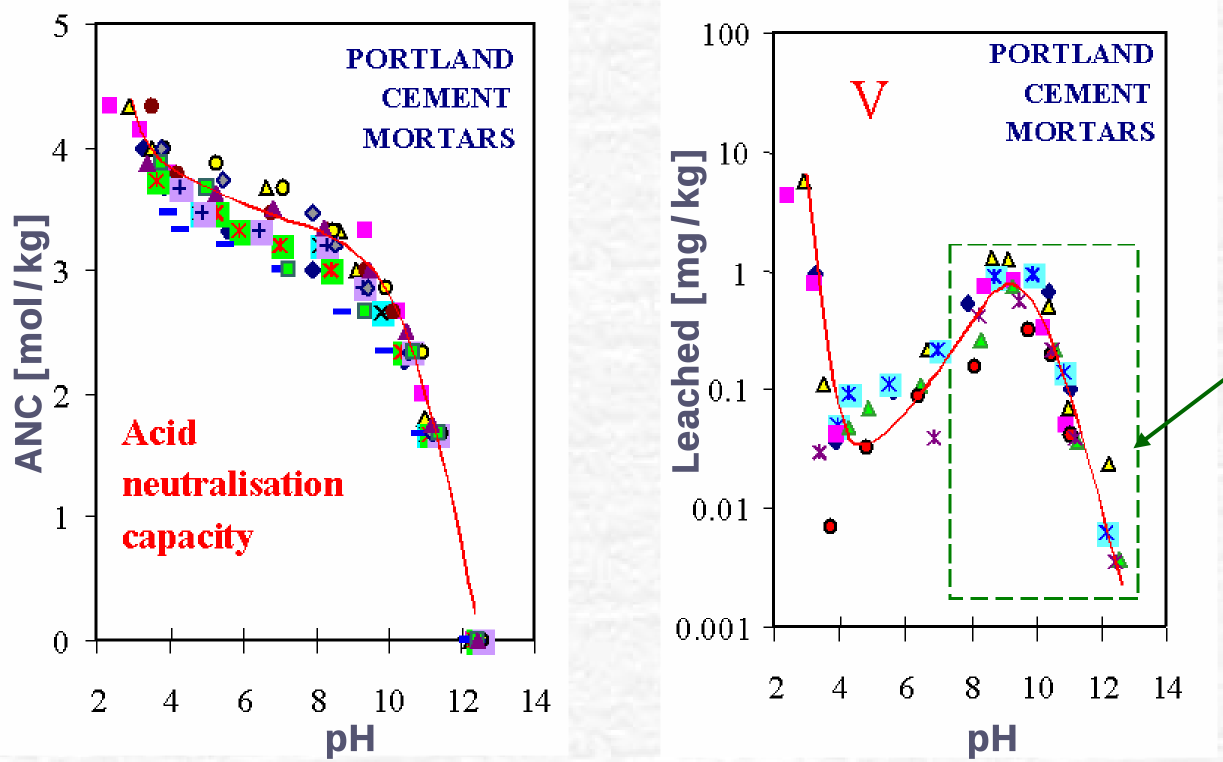
IMPACT

Point of compliance

Different for each scenario - material, changes over time (carbonation, redox), etc.

Transport in unsaturated zone and saturated zone to point of compliance - Similar for each scenario

Consistent Leaching Behavior

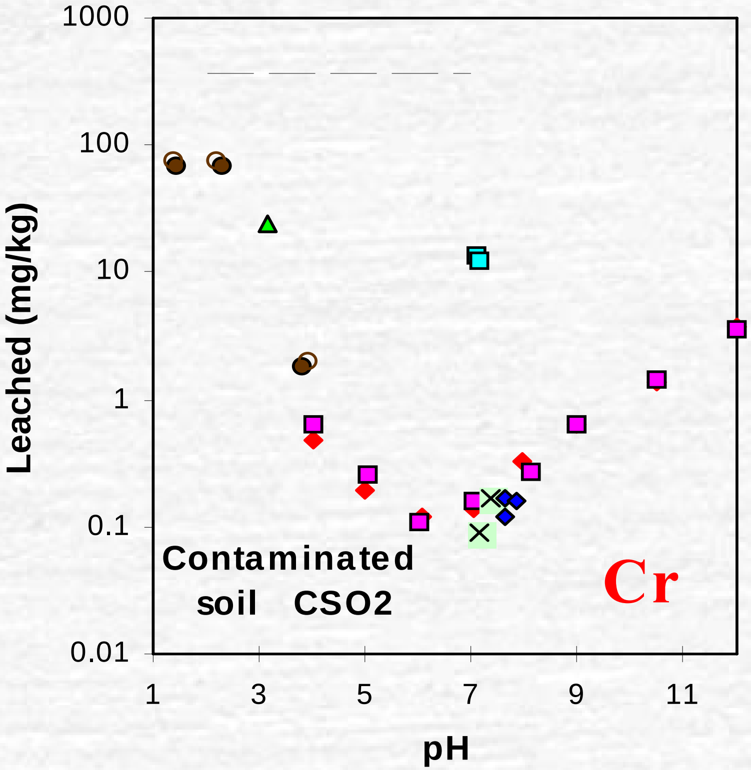


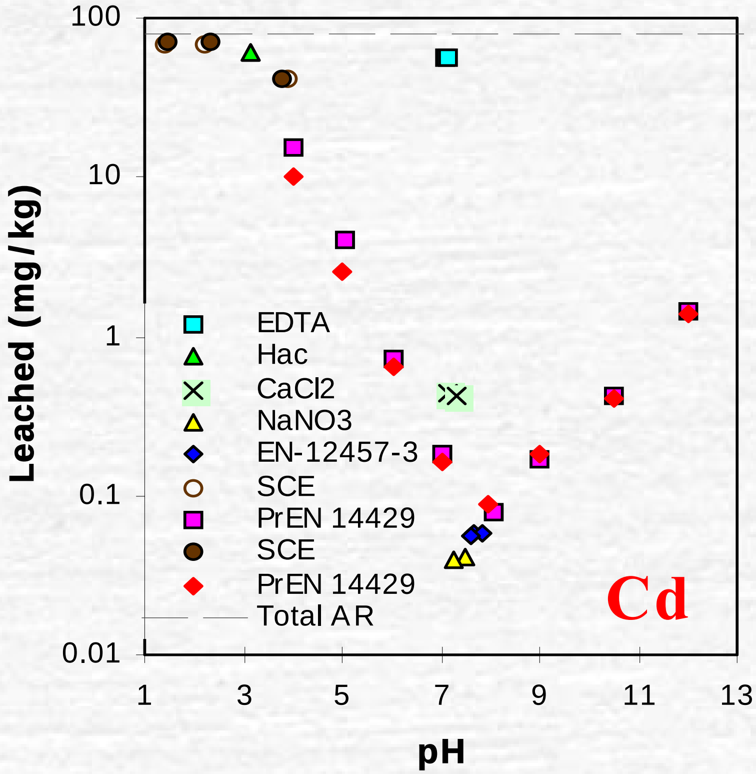
Most relevant pH range for cement-bound materials

A class of materials behaves consistently according to controlling chemistry

Comparison of Different Leaching Tests

Contaminated Soil

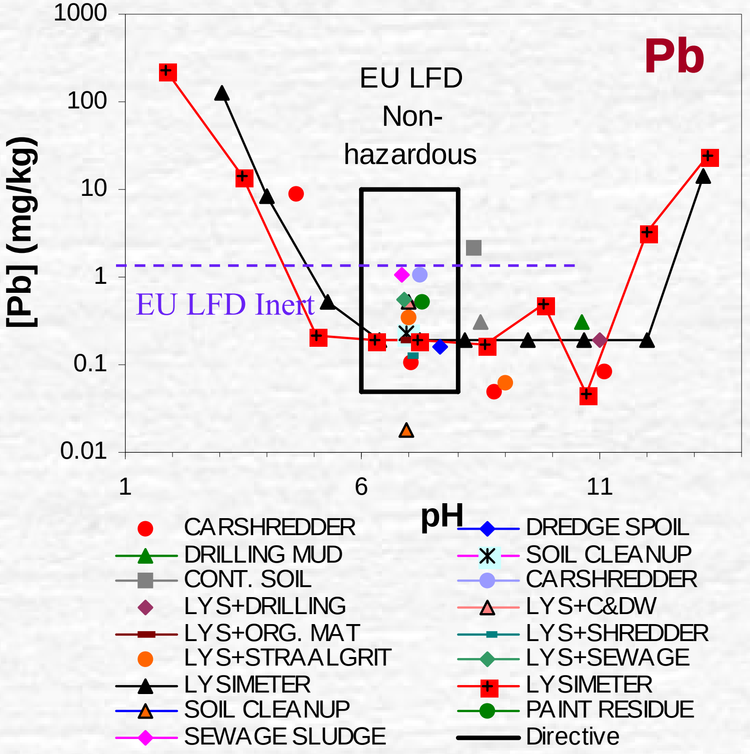


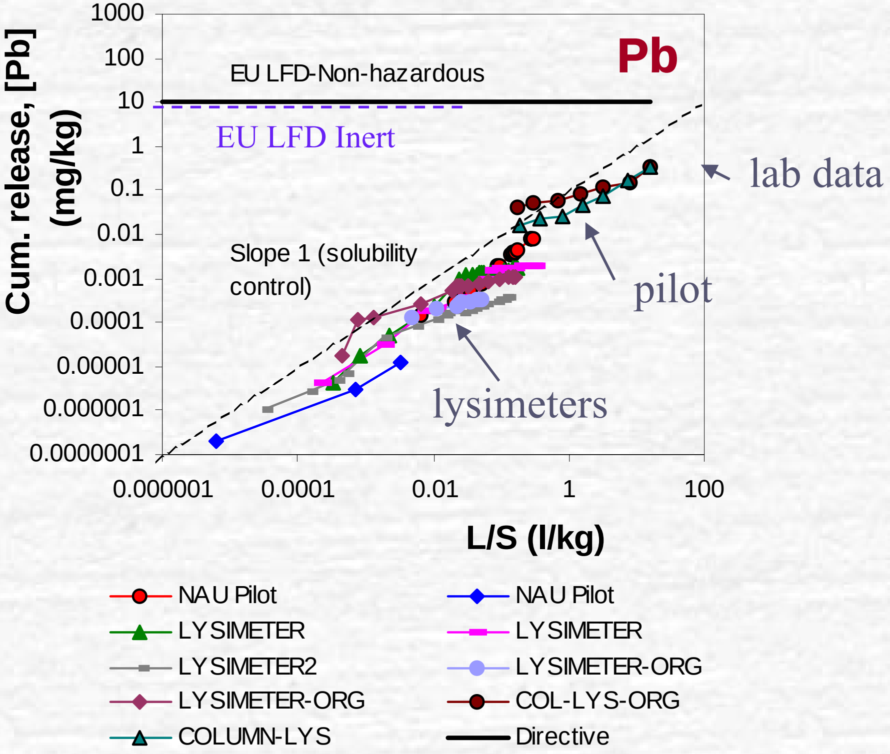


pH dependence test as reference basis

Comparison of Test Results

Lab, Lysimeter and Field Scales





- Lead leaching behaviour of mixed waste very systematic.
- Testing at different scales consistent and indicative of solubility control.

Framework Approach

Kosson, van der Sloot, Sanchez and Garrabrants, 2002,
Environmental Engineering Science, 19, 159-203

Measure intrinsic characteristics

- Solubility and Release as function of pH (redox, DOC)
- Solubility and Release as function of LS
- Mass transfer rate (monolith and compacted granular)

Evaluate release in context of field scenario

- External influencing factors such as carbonation, oxidation
- Hydrology
- Mineralogical changes

Tiered approach

- Characterization – detailed, full range of data
- Compliance – concise testing, limited range
- On-site verification – short, single point

Main Types of Leaching Tests

Equilibrium-based leaching tests

- Particle-size reduced material
- Aim to measure contaminant release related to specific chemical conditions (pH, LS ratio)

Mass transfer-based leaching tests

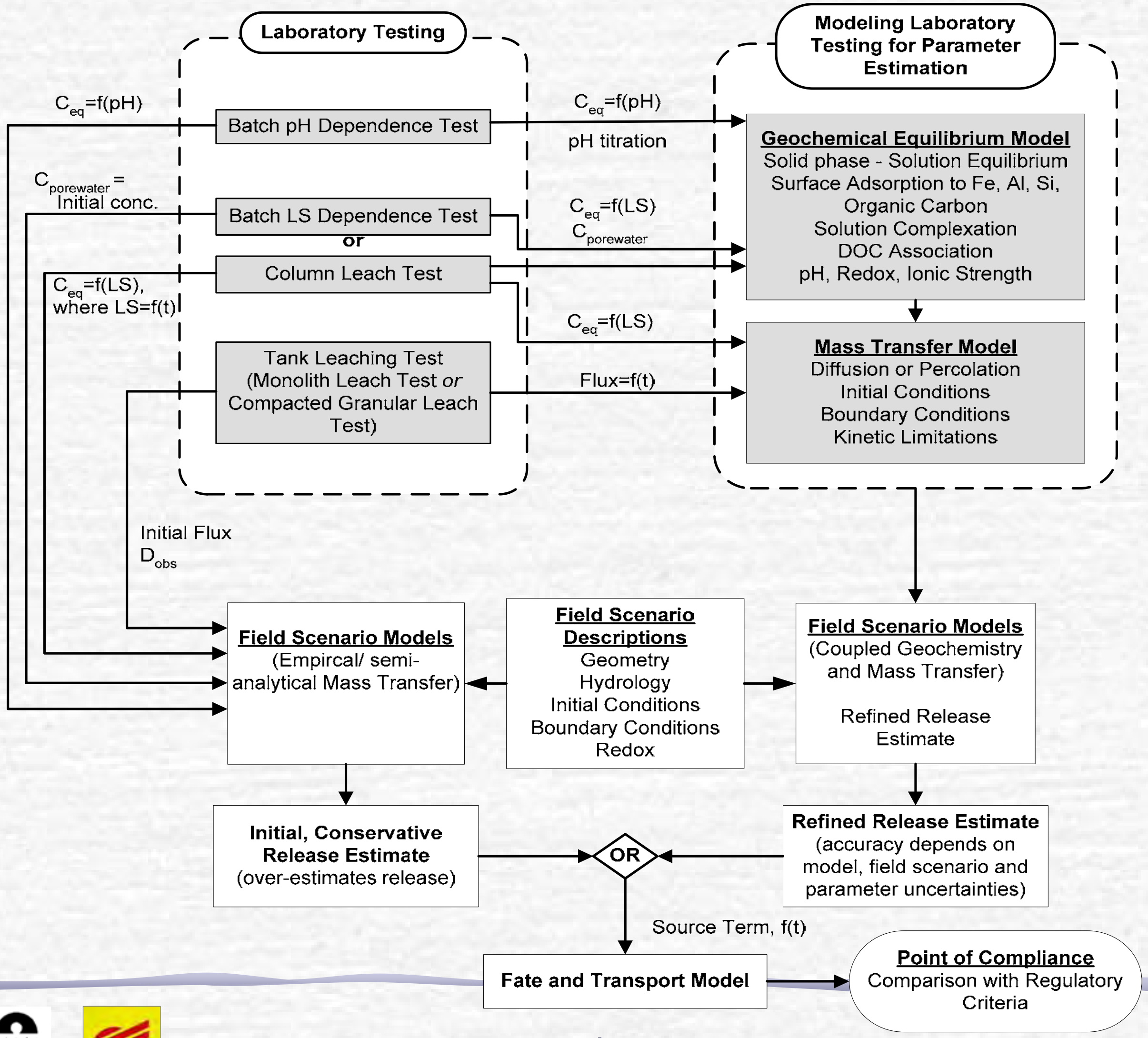
- Monolithic material or compacted granular material
- Aim to determine contaminant release rates by accounting for both chemical and physical properties of the material

Percolation (column) leaching tests

- Field compacted or loose aggregate material
- Aim may be either equilibrium or mass transfer rate characterization

15 November 2006

Integrated Use of Testing and Simulation



Laboratory Testing

Batch pH Dependence Test

Batch LS Dependence Test

or

Column Leach Test

Tank Leaching Test (Monolith Leach Test *or* Compacted Granular Leach Test)

Modeling Laboratory Testing for Parameter Estimation

Geochemical Equilibrium Model
Solid phase - Solution Equilibrium
Surface Adsorption to Fe, Al, Si, Organic Carbon
Solution Complexation
DOC Association
pH, Redox, Ionic Strength

Mass Transfer Model
Diffusion or Percolation
Initial Conditions
Boundary Conditions
Kinetic Limitations

C_{eq}=f(pH)

pH titration

C_{eq}=f(LS)
$C_{porewater}$

C_{eq}=f(LS)

Flux=f(t)

C_{eq}=f(pH)

$C_{porewater}$ = Initial conc.

C_{eq}=f(LS), where LS=f(t)

Initial Flux
D_{obs}

Field Scenario Models
(Empircal/ semi-analytical Mass Transfer)

Field Scenario Descriptions
Geometry
Hydrology
Initial Conditions
Boundary Conditions
Redox

Field Scenario Models
(Coupled Geochemistry and Mass Transfer)

Refined Release Estimate

Initial, Conservative Release Estimate
(over-estimates release)

OR

Refined Release Estimate
(accuracy depends on model, field scenario and parameter uncertainties)

Source Term, f(t)

Fate and Transport Model

Point of Compliance
Comparison with Regulatory Criteria

Coal Combustion Residues (CCRs)

Regulatory Environment

1990 - Clean Air Act Amendments

- Required EPA to evaluate mercury and other hazardous air pollutants from anthropogenic sources

1997 - Coal-fired power plants identified as largest source of mercury (EPA Report to Congress).

2000 - EPA announced intent to regulate mercury from coal-fired power plants.

2005 - EPA announced a multi-pollutant approach for reducing air emissions from power plants.

- Clean Air Interstate Rule (CAIR) and the Clean Air Mercury Rule (CAMR) will implement a cap and trade approach to reduce emissions

USEPA Evaluation of CCRs

Air pollution control (APC) to meet regulations

- Contaminants transferred from the flue gas to fly ash and other APC residues.

ORD was charged with evaluating potential cross-media transfers of contaminants from coal combustion residue (CCR) management (disposal and beneficial use)

- Primary focus on mercury but also interest in arsenic, selenium, and other constituents of concern.
- Key release route for land-managed CCRs is leaching to groundwater. Concern also for release to surface waters and avoiding bioaccumulation and re-emission of mercury.
- Need for reliable inputs to ground water transport and risk assessment models including use in 3MRA risk assessment model.

ORD-VU Project Objectives

(EPA/600/R-06/008, January 2006)

Evaluate the potential for leaching to groundwater of constituents retained in CCRs after removal by air pollution control technology

- Mercury
- Arsenic
- Selenium

Provide the foundation for assessing the impact of enhanced mercury and multi-pollutant control technology on leaching of constituents of potential concern from CCRs during the lifecycle of CCR management, including storage, beneficial use and disposal

Perform assessments using the most appropriate evaluation methods currently available

- Laboratory leach testing approach developed by Kosson, et al. (2002)
- Development of a quality assurance/quality control (QA/QC) framework
- Technology transfer to the U.S. EPA National Risk Management Laboratory

Wet Scrubber Facilities Providing Residues for Testing

Facility Code	Coal Rank	Oxidation Type	NOx Control	Particulate Control
O,N	Bit	Forced	SCR	ESP-CS
O,N	Bit	Forced	SCR-BP*	ESP-CS
B	Bit	Natural	SCR	ESP-CS
K	Sub-Bit	Natural	SCR	ESP-CS
B	Bit	Natural	SCR-BP	ESP-CS
M	Bit	Inhibited	SCR	ESP-CS
M	Bit	Inhibited	SCR-BP	ESP-CS
A	Bit	Natural	SNCR	Fabric Filter
A	Bit	Natural	SNCR-BP	Fabric Filter
Q	Sub-Bit	Forced	SCR	ESP-CS

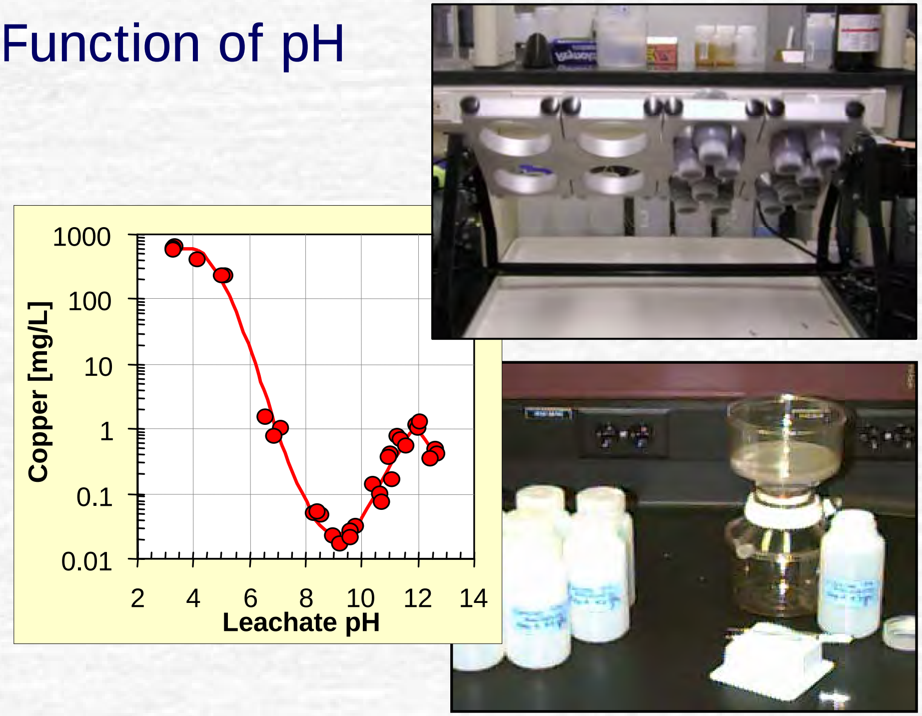
* BP = By-passed during winter months

Last update-10-18-06

Equilibrium Characterization

SR002.1 - Solubility and Release as a Function of pH

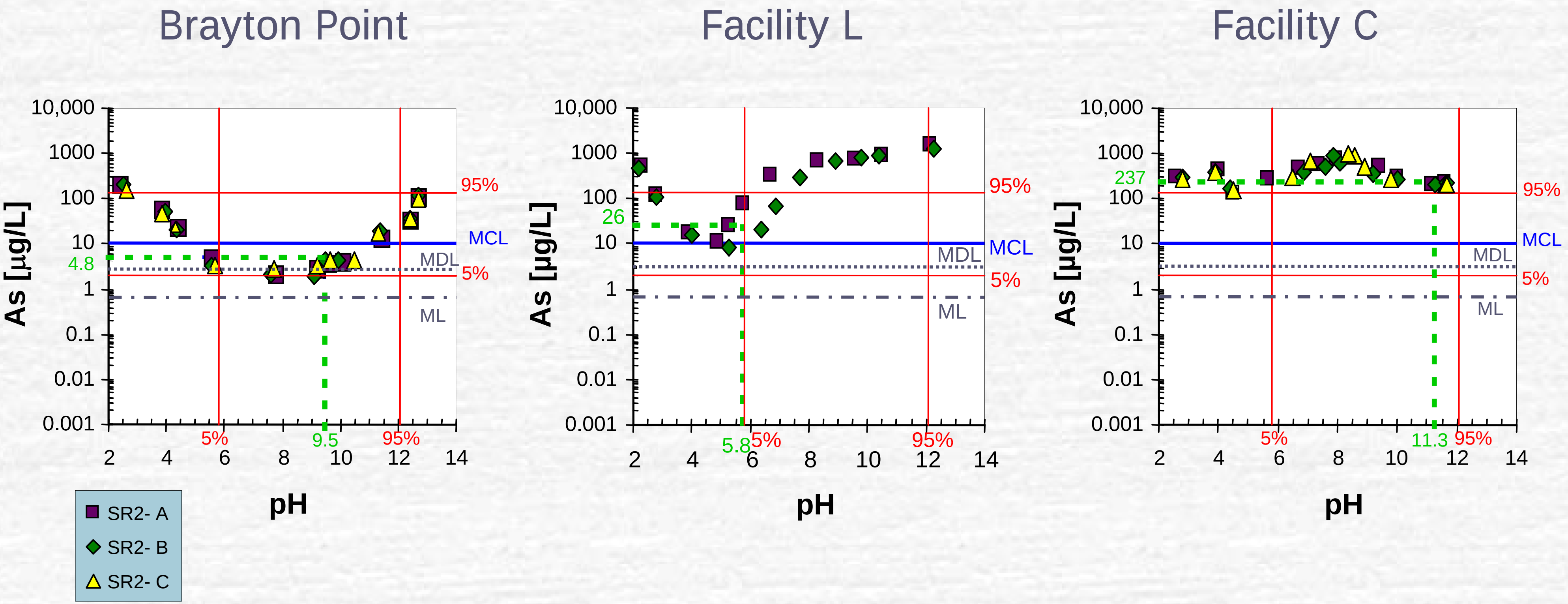
- Size-reduced material
- 11 parallel batch extractions
- Liquid-to-Solid Ratio of 10 mL/g
- DI water
    - HNO_3 to lower pH
    - NaOH to raise pH
- Contact time based on particle size
- Measure/Record
    - Acid added
    - pH and conductivity
    - Constituent concentrations



Titration curve and constituent solubility or release curves

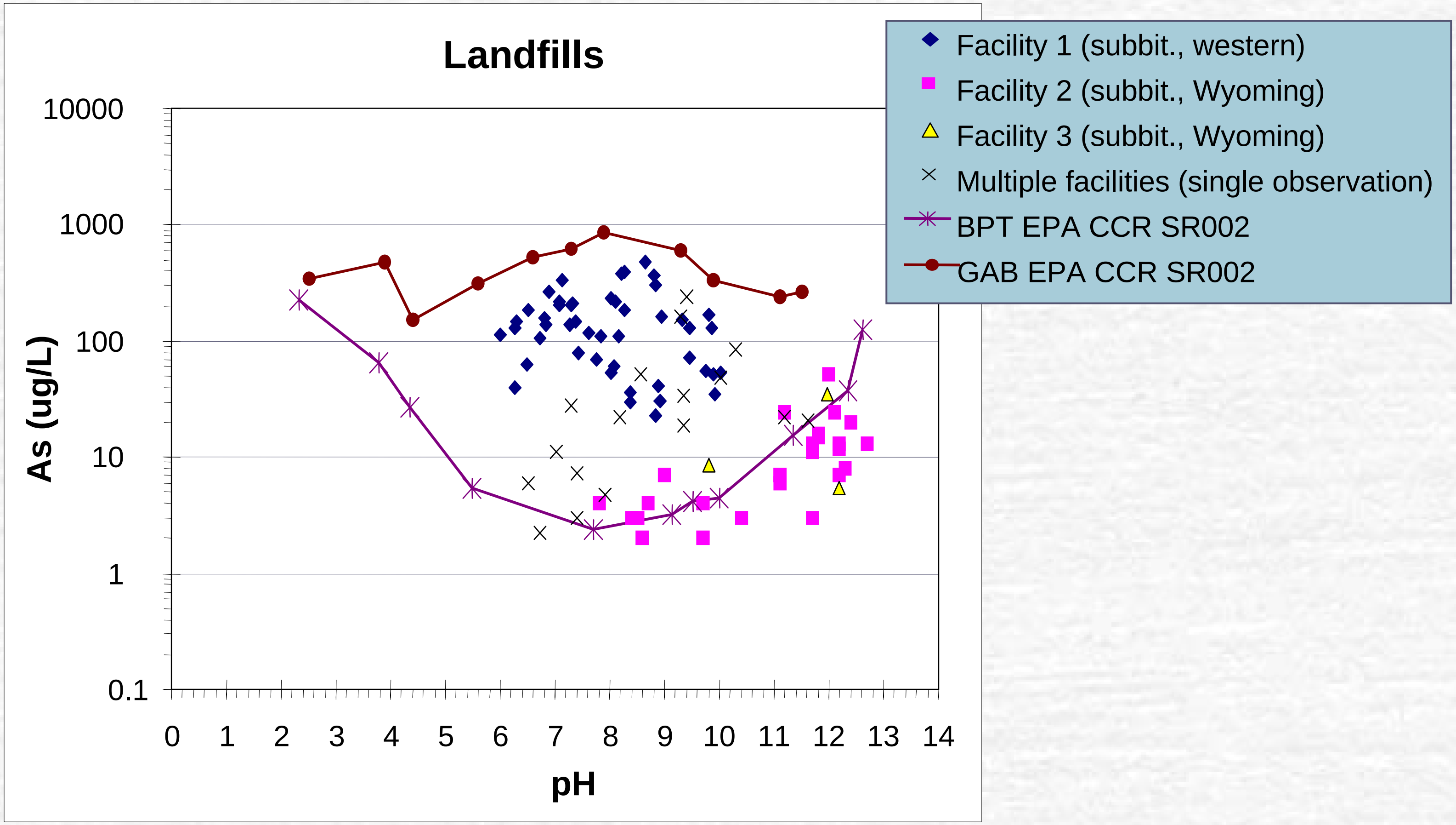
Particle size	Contact time
< 0.3 mm	18 hr
< 2 mm	48 hr
< 5 mm	168 hr

Arsenic Leaching as a Function of pH

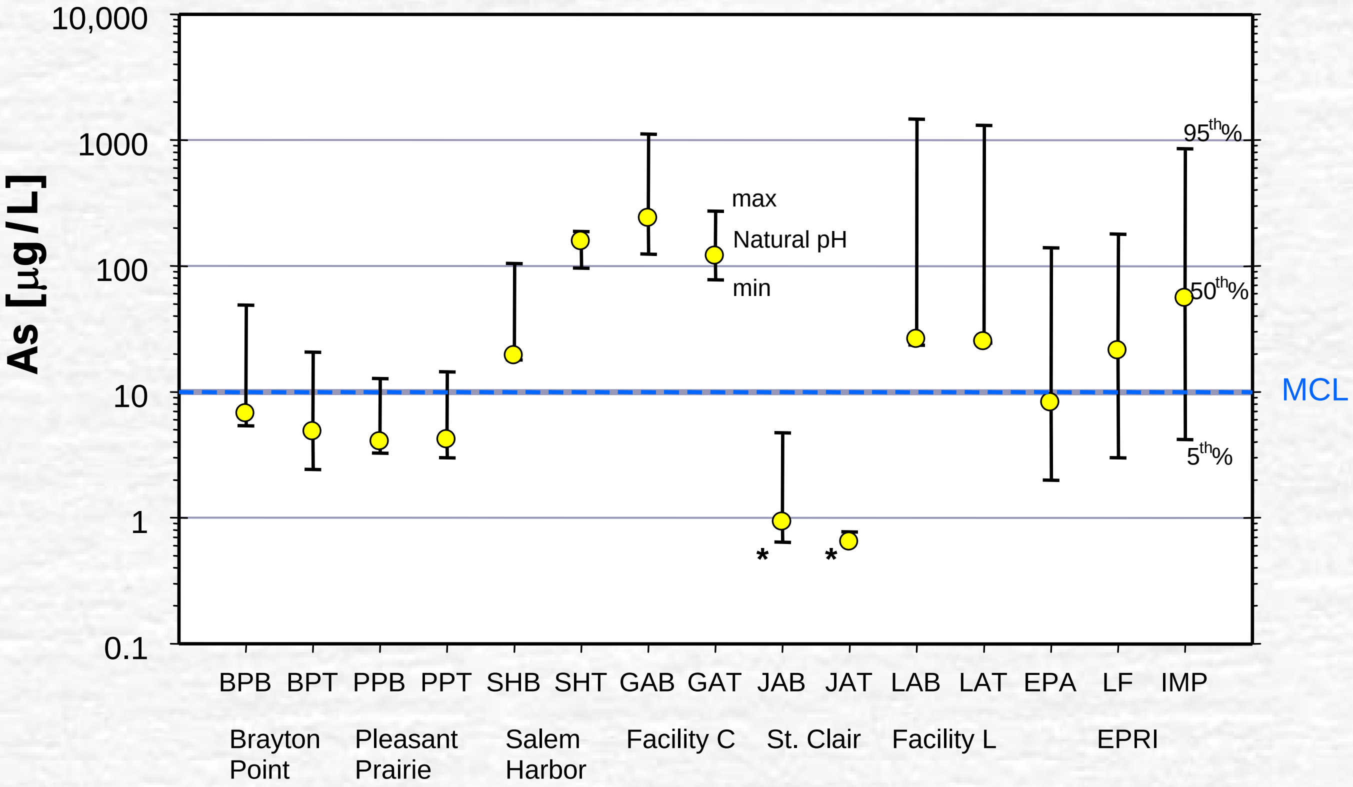


Field Leaching Data for Landfills (As)

EPRI data in comparison with EPA SR002 Lab data

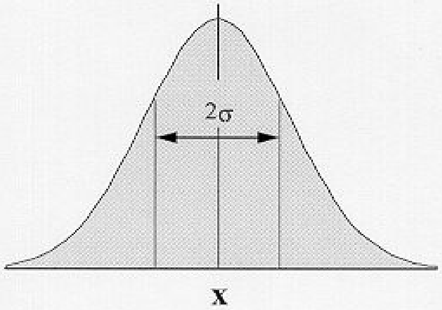


Expected Range of Field Leaching Concentrations (As)



Applying Probabilistic Analysis to Release Models

Inputs



Distribution of inputs

- LS ratio
- Field pH

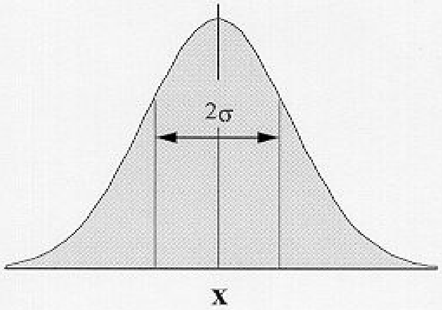
Use of experimental solubility curves

Percolation / Equilibrium Model

$$M^{t_{year}}_{mass} = LS_{site} \times S_{field\ pH}$$

Monte Carlo technique

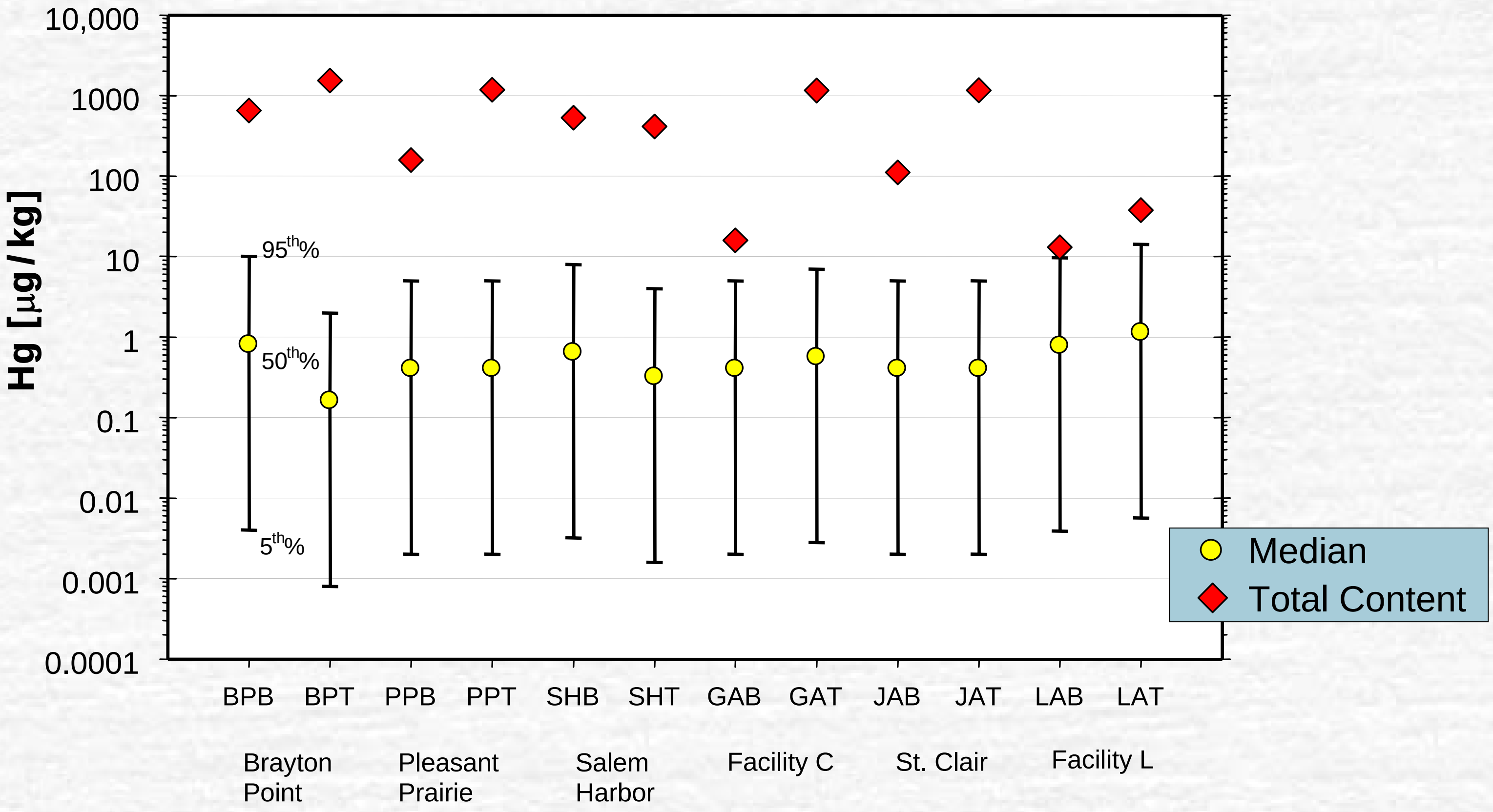
Outputs



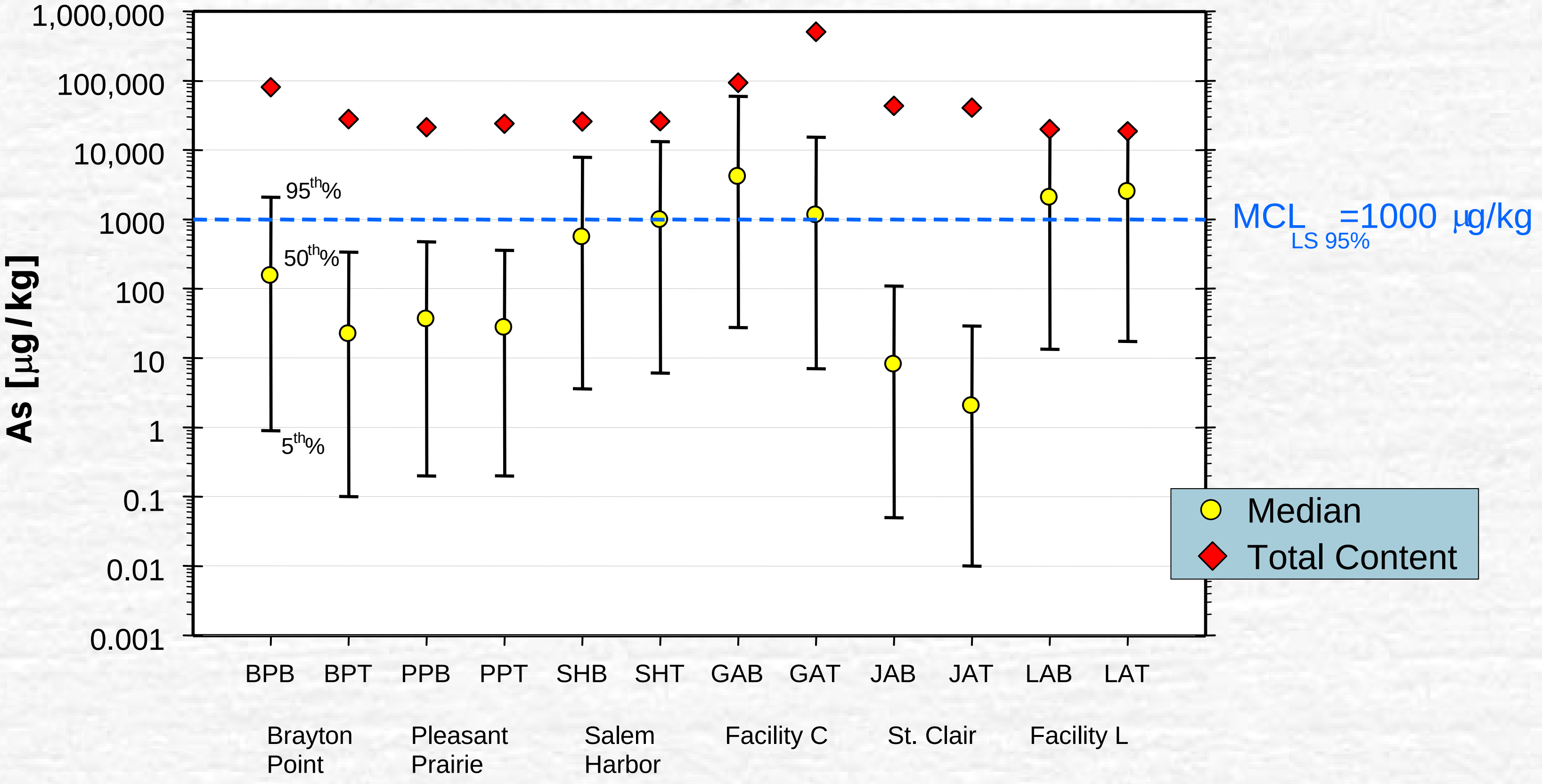
Distribution of outputs

- Release estimates

Comparison of 100-Yr Release Estimates (Hg)



Comparison of 100-Yr Release Estimates (As)



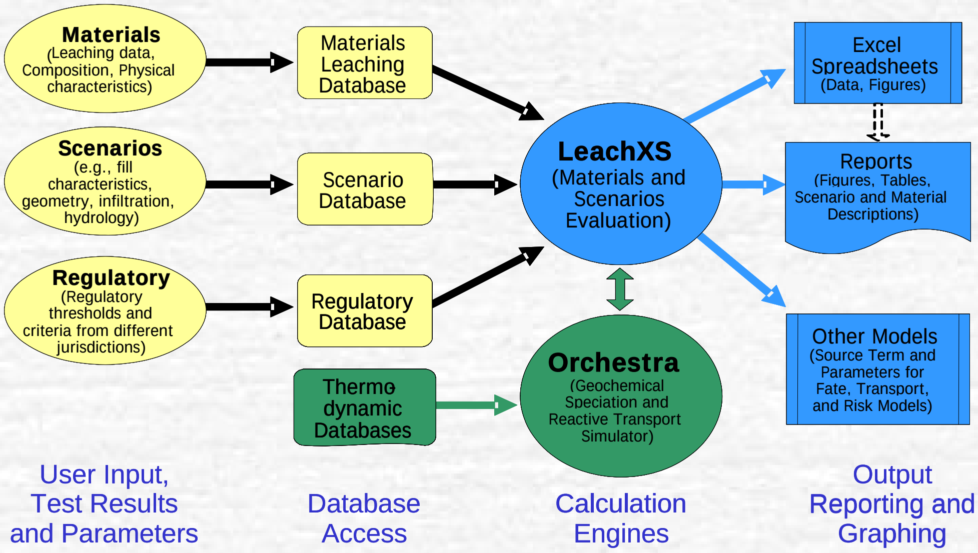
LeachXS System

A set of integrated software tools to provide:

- Applicability to a wide range of materials (granular, monolithic, mixtures) and constituents (inorganic, organic, radionuclide)
- Guidance on the selection of test methods
- Data management, evaluation and presentation
- Database of leaching characteristics, lysimeter and field data
  - Performance comparison
  - Compliance testing
- Geochemical speciation modeling
- Coupled reaction/transfer models
  - Reducing conditions
  - Gas interaction (O_2 and CO_2)
- Quality control protocols
  - Data enhancement
  - Materials production

XS
EACH

http://www.leaching.net



Materials (Leaching data, Composition, Physical characteristics)

Scenarios (e.g., fill characteristics, geometry, infiltration, hydrology)

Regulatory (Regulatory thresholds and criteria from different jurisdictions)

Materials Leaching Database

Scenario Database

Regulatory Database

Thermo dynamic Databases

LeachXS (Materials and Scenarios Evaluation)

Orchestra (Geochemical Speciation and Reactive Transport Simulator)

Excel Spreadsheets (Data, Figures)

Reports (Figures, Tables, Scenario and Material Descriptions)

Other Models (Source Term and Parameters for Fate, Transport, and Risk Models)

User Input, Test Results and Parameters

Database Access

Calculation Engines

Output Reporting and Graphing

ORD-VU Observations

Activated carbon injection impacts content in CCRs

- Increased the total mercury (5 of 6 facilities)
- Increased arsenic and selenium (1 facility w/ COHPAC fabric filter)
  - Adsorption of arsenic and selenium onto CCR while retained in the fabric filters

Mercury is strongly retained by the resulting CCR and unlikely to be leached at levels of environmental concern.

- Observed leaching not dependent on total Hg content, leachate pH, nor liquid to solid ratio.
- Mercury concentrations in lab extracts between 0.01 µg/L (MDL) and 0.2 µg/L appeared to be controlled by non-linear adsorption equilibrium.

Arsenic and selenium may leach at levels of potential concern from CCRs generated at some facilities.

- With and without enhanced mercury control technology
- Further evaluation of leaching of arsenic and selenium from CCRs that considers site specific conditions is warranted.

ORD-VU Observations (cont'd.)

Leachate concentrations of mercury, arsenic and selenium

- Do not correlate with total content.
- Function of final pH over range of field conditions.

Use of linear partition coefficients (Kd) in modeling release phenomena does not reflect the underlying processes for source term evaluation.

- Applicability of K_d approach for some cases (leaching of some trace constituents; groundwater modeling); but not source-term release for many constituents.

100 Year Release Estimates

- Majority of cases: The amount of mercury, arsenic and selenium estimated to be released over a 100 year interval is a small fraction (< 0.1% -5%) of the total content.
- Selenium release observed from less <5% to the total content can be anticipated over the 100 year period in some cases.

Conclusions

Management conditions (e.g., controlled infiltration and pH) may be applied to result in reduction of arsenic and selenium release by as much as two orders of magnitude below upper bound estimated releases.

Landfill management decisions should not be based on total content of constituents in CCRs since total content does not consistently relate to quantity released.

Leaching framework facilitated the understanding of the variations in anticipated leaching behavior under the field landfill disposal conditions:

- Expected ranges of constituent concentrations in leachates
- Cumulative release over a defined time interval

The obtained insights into the mechanisms controlling constituent release represents a depth of understanding not possible using leaching approaches that focus on single extract condition (e.g., TCLP or SPLP).

Current and Future Directions

USEPA Program

- Evaluation of Scrubber Residues
  - Blended Scrubber Residues (e.g., FGD residue, fly ash, lime) as disposed in on-site landfills
  - Range of air pollution control configurations and coal types
- Evaluation of Synthetic Gypsum
  - Use in gypsum wall board and subsequent disposal
  - Use as soil amendment
- Inclusion of Framework Methodology in SW-846

Session 3

PEER REVIEW OF NATIONAL ACADEMY OF SCIENCES CCB & MINING REPORT

Session Chairperson:
Peter Michael
Office of Surface Mining
Pittsburgh, Pennsylvania

Managing Coal Combustion Residues in Mines: A Report of the National Academy of Sciences
Dr. Richard Sweigard, University of Kentucky, Lexington, Kentucky

Technical Comments on the National Research Council Report on Managing Coal Combustion Residues at Mines
Dr. Ishwar P. Murarka, ISH Inc., Raleigh, North Carolina

National Academy of Sciences (NAS) Final Report "Managing Coal Combustion Residues in Mines": A Review
Dr. Yoginder Paul Chugh, Southern Illinois University, Carbondale, Illinois

Comments on Managing Coal Combustion Residues in Coal Mines
Dr. Harold W. Walker, The Ohio State University, Columbus, Ohio

A Review of the National Research Council Report on "Managing Coal Combustion Residues in Mines"
David J. Hassett, University of North Dakota, Energy and Environment Research Laboratory, Grand Forks, North Dakota

National Academy of Sciences Mine Fill Report: Critical Evaluation of Recommendations for Future Research
Dr. Paul Ziemkiewicz, National Mined Land Reclamation Center, University of West Virginia, Morgantown, West Virginia

A Technical Review of the Final Report of the National Academy of Sciences "Managing Coal Combustion Residues in Mines"

Kimery C. Vories, Office of Surface Mining, Alton, Illinois

MANAGING COAL COMBUSTION RESIDUES IN MINES: A REPORT OF THE NATIONAL ACADEMY OF SCIENCES

Dr. Richard Sweigard
University of Kentucky
Lexington, Kentucky

View Presentation

Abstract

The Committee on Mine Placement of Coal Combustion Wastes was appointed by the National Research Council (NRC) and given the charge of investigating the practice of placing coal combustion residue (CCR) in coal mines. The eleven-point Statement of Task required the committee to examine the health, safety, and environmental risks associated with using CCR for reclamation in active and abandoned coal mines. The study considered all major coal basins. The committee focused on CCR from utility power plants and independent power producers, rather than small business, industries, and institutions.

The committee consisted of 14 members representing a broad spectrum of expertise and experience. The process involved six public testimony sessions from October 2004 to August 2005 held in Washington, D.C.; Farmington, NM; the Navajo Nation, NM; Austin, TX; Evansville, IN; and Harrisburg, PA. During the information gathering meetings, the committee, subgroups of the committee, and individual committee members also visited several mine sites that were currently using or had previously used CCR for mine filling.

The report consists of eight chapters. In addition to an introductory chapter, subsequent chapters address: CCR production, characteristics, reuse, and placement technologies; the behavior of CCR in the environment; potential environmental impacts, considerations for human health, and reasons for concerns regarding placement of CCR in mines; an overview of the regulatory framework governing the placement of CCR in mines; the risk management framework for CCR disposal including material and site characterization and prediction methodologies; site management strategies including reclamation and monitoring practices; and a summary of the committee's overall management approach. The committee concluded that "placement of CCR in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material. In such situations, however, an integrated process of CCR characterization, site characterization, management and engineering design of placement activities, and design and implementation of monitoring is required to reduce the risk of contamination moving from the mine site to the ambient environment. Enforceable federal standards are needed for the disposal of CCR in mine fills to ensure that states have specific authority and that states implement adequate safeguards."

Background

The coal combustion residue study was my second experience serving on a National Research Council study committee. About six years ago there was a breakthrough at a coal slurry impoundment in Martin County, Kentucky. The NRC formed a panel to study coal slurry impoundments. The committee focused its study more on the design standards for such impoundments and alternative disposal methods rather than that incident in particular. From this experience, I learned a lot about the process of how such a study is conducted. During that study, which followed the same process, many people came and gave statements during public meetings. It took much give and take on the part of the panel to reach a consensus report. I was surprised, however, that the level of public concern with the coal slurry impoundment study was less compared to what I found with the CCR study. I believe the difference is that the coal slurry impoundment issue is a primarily a central Appalachian issue, while the CCR issue potentially affects people all across the country. It turned out this issue was very hotly debated.

Based on my experience with these studies, I would describe the reports as "middle-of-the-road." It is a given that the NRC wants a consensus report. The NRC prefers not to have a minority report on some issues that differs from the majority opinion of the committee. This means that the more extreme viewpoints of the committee members on either side of an issue do not get included in the report. The conclusions of the report are those that all of the committee members can accept. Therefore, the final report tends to be something that everyone can quote but few really like.

Coal Combustion Residues (CCRs) are produced at the rate of >120 million tons/yr. The major concern is that they concentrate the trace elements from coal. The management options available include alternative products or placement in landfills, surface impoundments, or mines. Mine placement represents only a small percentage. During the study, it was interesting to learn how small the amount (apx. 5-7%) of CCRs that are currently being placed in mines. This amount is expected to increase due to the current disfavor with utility impoundments and the current increase in coal utilization.

The study was mandated by Congress. The committee was asked to examine the health, safety, and environmental risks from use of coal combustion residues (CCRs) for reclamation in coal mines. We were instructed to consider placement in abandoned and active, surface and underground coal mines in all major coal basins. We considered coal mines receiving large quantities of CCRs; however, that quantity was never defined precisely. The focus was on CCRs from utility power plants and independent power producers, rather than small business, industries, and institutions. Although the committee covered all issues requested by Congress, not all issues were covered in the same level of detail. This means more time was spent looking at surface mines than underground mines because a much higher volume of CCRs is going into surface mines.

Specifically, the committee addressed: adequacy of data collection, impacts on aquatic life, responses of mine operators and regulators to adverse impacts, whether CCRs and the mines are adequately characterized, whether clear performances standards are set for “beneficial uses,” status of isolation requirements, adequacy of monitoring programs, ability to achieve economically productive post-mine land uses, the need for upgraded bonding, provisions for public involvement, and evaluation of the risks in the context of RCRA and SMCRA.

The committee was made up of the following members: Perry R. Hagenstein, *Chair*, Institute for Forest Analysis, Planning, and Policy; George R. Hallberg, The Cadmus Group, Inc.; William A. Hopkins, Virginia Polytechnic Institute; Thomas J. O’Neil, Cleveland Cliffs, Inc. (retired); Charles L. Poole, University of North Carolina; Carol J. Ptacek, University of Waterloo, Canada; Robin M. Ridgway, Purdue University; Larry Robinson, Florida A & M University; Madan M. Singh, Department of Mines and Mineral Resources, State of Arizona; Mark S. Squillace, University of Colorado School of Law; Richard J. Sweigard, University of Kentucky; Baulus Walker, Jr., Howard University; John J. Warwick, Desert Research Institute; and Jeffery J. Wong, California Environmental Protection Agency. There were clearly different areas of expertise but everyone’s input was weighted the same. For instance, although I am a surface mining engineer by background, I was not the only one who could comment on surface mining and reclamation issues. The whole committee discusses and must come to consensus on each recommendation in the report. The makeup of the committee is a matter of public record and resulted in some controversy. At the beginning of the study, there was a provisional list of members. There were numerous objections to some members of the committee by citizens groups. After lengthy consideration, three of the provisional committee members were replaced.

The study process consisted of seven meetings, (six were information gathering) including public sessions and site visits that included: Washington, DC, Farmington, New Mexico, Austin, Texas, Evansville, Indiana, Harrisburg, Pennsylvania, and Santa Barbara, California. All of the meetings with the exception of Washington, DC, and Santa Barbara, California involved field trips to sites where CCRs were being or had been placed in coal mines. More than 120 individuals gave testimony/presentations at these meetings. The result of the process was a peer reviewed consensus report.

Findings of the Committee

The overarching conclusion of the committee was that putting CCRs in coal mines as part of reclamation process is a viable management option as long as: (1) CCR placement is properly planned and carried out in a manner that avoids significant adverse environmental and health impacts; (2) the regulatory process for issuing permits includes clear provisions for public involvement; and (3) mine placement avoids creating new landfills and surface impoundments and assists in meeting reclamation goals. The committee was impressed by the reality that CCRS are a high volume material that will be placed somewhere. They were very concerned about the continued placement in utility surface impoundments. They felt that the creation of landfills involved the disturbance of green field sites. The committee had a lot of sympathy with the idea of using coal mines for CCR disposal for these reasons. The committee still has reservations about the issue because they felt that not enough is known about potential for mine filling to degrade groundwater and/or surface water quality. They also felt that data limitations suggest that absence of EPA damage cases should not be taken as conclusive evidence of no effects.

Permitting and Planning

The steps involved in planning for CCR management should include: (1) the consideration of CCR disposal and use options; (2) full characterization of mine site placement options; and (3) development of a long-term management plan for the mine. Whenever mine fill is chosen as the disposal/use option there should be consideration of: (1) the costs of CCR placement, use options, and local regulatory requirements; the potential effects on human health and the environment; (2) secondary uses of CCRs should be strongly encouraged, realizing this is going to be market driven; and (3) that many CCRs are not suitable for reuse and must be placed in landfills, impoundments, and mines.

Concerning CCR characterization, the committee found that: (1) routine analysis of CCRs should be required to identify potentially toxic materials and to ensure that CCRs are properly emplaced and managed; (2) CCR characterization should include identification of volume of material, physical and chemical characteristics, trace element leaching potential, and cementitious properties; and (3) that improved methods for characterizing leaching potential are still needed. Leachate test methods that are commonly used are not totally adequate for determining leaching potential.

Concerning information needs for site characterization, the committee found that such information needs to be site specific for placement at the mine. The committee felt that comprehensive site characterization *specific* to CCR placement at all mine sites is needed prior to significant placement of CCRs. This site characterization should include: (1) the hydrogeological setting; (2) water quality and geochemistry; and (3) proximity to sensitive receptors.

Integration of CCR and site characterization provides an estimate of risk that guides engineering design, permitting decisions, and development of effective monitoring programs. The planning for CCR placement in mines should be designed to minimize interaction of CCRs and water. This should be determined on a site specific basis.

Management During Active Coal Mining and Reclamation Operations

The committee concluded that some current groundwater monitoring programs were insufficient. In some cases, the committee found that a mine was using a monitoring program that was designed for basic monitoring of surface mining and reclamation without modification to address potential CCR disposal impacts. The extent of monitoring should be customized to address the estimated level of risk. The monitoring system should be designed to detect problems early (i.e. during the performance bonding period). Groundwater monitoring linked to performance standards is essential.

The issue of future land use restrictions was debated. The committee agreed that: (1) the deed should be recorded and (2) the deed discloses that CCRs were used in site reclamation to guard against future inappropriate land uses.

There was no consensus that land use restrictions should be required. The committee found that mines reclaimed with large amounts of CCRs can achieve economically productive post-mine land use.

Management of Abandoned Mine Land and Remining Sites

Since most of the CCRs used in reclamation currently are being placed in abandoned mine lands, this is a very important issue. The placement of CCRs in abandoned and remining sites should be subject to same characterization and management standards recommended for active coal mines. However, when developing performance standards, adequate consideration should be given to differences among active mines versus abandoned mines and remining of previously abandoned mine sites due to their degraded conditions.

Research Issues

The committee recommended that additional research be conducted on: (1) long-term environmental behavior of CCRs at mine sites; (2) potential ecological and human health effects of placing CCRs in coal mines; and (3) improvements and field validation of leaching tests to better predict mobilization of constituents from CCRs after placement in the mine setting.

Public Participation

The committee heard many public concerns about the potential for adverse environmental and public health impacts from improper CCR disposal. One of the concerns that they heard often was that any addition of CCR to a mine after the permit has been approved should be treated as a "significant alteration of reclamation plan." This would trigger the opportunity for public involvement in the decision making process.

Regulatory Authority

One of the biggest issues that the committee had to consider was who the responsible regulatory authority should be. The committee found that the scope of SMCRA was sufficiently broad to cover regulation of CCRs at coal mines. However, they also found that neither SMCRA nor its implementing regulations explicitly address CCRs and that the States vary in approach and rigor. The committee found that EPA should propose regulations for CCRs in utility landfills and impoundments. They also found that: (1) disposal of CCRs in coal mines should be subject to reasonable site-specific performance standards; (2) regulatory gaps exist that create opportunities for unnecessary risks; (3) regulatory guidance is insufficient; and (4) enforceable Federal standards should be established for use of CCRs in mine fills.

Regulatory alternatives for federal enforcement include: (1) changes to SMCRA regulations to address CCRs specifically; (2) joint OSM-EPA rules pursuant to the authority of SMCRA and RCRA; or (3) RCRA Subtitle D (Solid Waste) rules that are enforceable through a SMCRA permit. The committee did not make a recommendation as to which alternative should be followed.

Summary

Placement of CCR in mines as part of reclamation is a viable disposal option. An integrated process of CCR characterization, site characterization, management and design of placement activities, and design and implementation of groundwater monitoring is required to reduce the risk of contamination moving from the mine site to the ambient environment.

Dr. Richard J. Sweigard is chairman and professor in the Department of Mining Engineering at the University of Kentucky. Prior to his academic positions, he was an engineer for Betz-Converse-Murdoch and a consulting engineering geologist. Dr. Sweigard's research falls under the category of environmental impacts of mining including alleviation of excessive compaction of reconstructed soil, post-mining land use, slope stabilization on abandoned mine lands, and disposal of coal combustion by-products. He is a registered engineer in Pennsylvania and his professional activities include the Society for Mining, Metallurgy, and Exploration; the American Society for Surface Mining and Reclamation; and the American Society of Civil Engineers. Dr. Sweigard served as a member of the National Academies Committee for the Study on Preventing Coal Waste Impoundment Failures and Breakthroughs. He received his Ph.D. in Mining Engineering from the Pennsylvania State University.

Managing Coal Combustion Residues in Mines

Committee on Mine Placement of Coal Combustion Wastes

National Research Council

Background

- Coal Combustion Residues (CCRs)
  - >120 million tons/yr produced
  - Concentrates trace elements from coal
- Management options include:
  - Alternative products
  - Disposal in landfills, surface impoundments, or mines
  - Mine placement small percentage, but increasing

The Study

- Congressionally mandated study
- Examine health, safety, and environmental risks from use of coal combustion residues (CCRs) for reclamation in coal mines
- Consider placement in abandoned and active, surface and underground coal mines in all major coal basins
- Consider coal mines receiving large quantities of coal combustion wastes
- Focus on CCRs from utility power plants and independent power producers, rather than small business, industries, and institutions

Statement of Task

Specifically, the committee addressed:

- Adequacy of data collection
- Impacts on aquatic life
- Responses of mine operators and regulators to adverse impacts
- Whether CCRs and the mines are adequately characterized
- Whether clear performances standards are set for “beneficial uses”

Statement of Task (cont.)

- Status of isolation requirements
- Adequacy of monitoring programs
- Ability to achieve economically productive post-mine land uses
- Need for upgraded bonding
- Provisions for public involvement
- Evaluate the risks in the context of RCRA and SMCRA

Committee Membership

- **PERRY R. HAGENSTEIN, *Chair*, Institute for Forest Analysis, Planning, and Policy**
- **GEORGE R. HALLBERG, The Cadmus Group, Inc.**
- **WILLIAM A. HOPKINS, Virginia Polytechnic Institute**
- **THOMAS J. O’NEIL, Cleveland Cliffs, Inc. (retired)**
- **CHARLES L. POOLE, University of North Carolina**
- **CAROL J. PTACEK, University of Waterloo, Canada**
- **ROBIN M. RIDGWAY, Purdue University**
- **LARRY ROBINSON, Florida A & M University**
- **MADAN M. SINGH, Department of Mines and Mineral Resources, State of Arizona**
- **MARK S. SQUILLACE, University of Colorado School of Law**
- **RICHARD J. SWEIGARD, University of Kentucky**
- **BAILUS WALKER, Jr., Howard University**
- **JOHN J. WARWICK, Desert Research Institute**
- **JEFFREY J. WONG, California Environmental Protection Agency**

Study Process

- 7 meetings (6 information gathering) including public sessions and site visits
  - Washington, DC
  - Farmington, NM
  - Austin, TX
  - Evansville, IN
  - Harrisburg, PA
  - Santa Barbara, CA
- Testimony/presentations from ~120 individuals
- Peer reviewed consensus report

Overarching Conclusion

- Putting CCRs in coal mines as part of reclamation process is a viable management option as long as
  - CCR placement is properly planned and carried out in a manner that avoids significant adverse environmental and health impacts and
  - The regulatory process for issuing permits includes clear provisions for public involvement
- Mine placement avoids creating new landfills and surface impoundments and assists in meeting reclamation goals

Caveats

- Comparatively little is known about potential for minefilling to degrade groundwater and/or surface water quality

- Data limitations suggest that absence of EPA damage cases should not be taken as conclusive evidence of no effects

Planning for CCR Management

- Considering CCR Disposal and Use Options

- Characterizing a Mine Site Disposal Option

- Developing a Long-Term Management Plan for CCRs

CCR Disposal/Use Options

- Consider costs of CCR disposal, use options, and local regulatory requirements
- Consider potential effects on human health and the environment
- The secondary uses of CCRs should be strongly encouraged
- Many CCRs are not suitable for reuse and must be disposed in landfills, impoundments, and mines

CCR Characterization

- Routine analysis of CCRs needed to identify potentially toxic materials and to ensure that CCRs are properly emplaced and managed
- CCR characterization includes identification of volume of material, physical and chemical characteristics, trace element leaching potential, and cementitious properties
- Improved methods for characterizing leaching potential are needed

Site Characterization

- Comprehensive site characterization *specific* to CCR placement at all mine sites is needed prior to significant placement of CCRs
- Site characterization should include
  - – hydrogeological setting
  - – water quality, geochemistry
  - – proximity to sensitive receptors

Management During Active Coal Mining and Reclamation Operations

- Integration of CCR and site characterization provides an estimate of risk that guides engineering design, permitting decisions, and development of effective monitoring programs
- CCR placement in mines should be designed to minimize interaction of CCRs and water

Monitoring

- Current monitoring programs insufficient
- Extent of monitoring should be customized to address estimated level of risk
- Should design monitoring systems to detect problems early (i.e. during bonding period)
- Groundwater monitoring linked to performance standards is essential

Future Land-Use Restrictions

- Mines reclaimed with large amounts of CCRs can achieve economically productive post-mine land use

- Deeds should record and disclose that CCRs were used in site reclamation to guard against future inappropriate land uses

AML and Remining Sites

- The placement of CCRs in abandoned and remining sites should be subject to same characterization and management standards recommended for active coal mines
- When developing performance standards, adequate consideration should be given to differences among active mines, abandoned mines, and remining of previously abandoned mine sites

Overarching Issues: Research

- The committee recommends additional research is needed on:
  - Long-term environmental behavior of CCRs at mine sites
  - Potential ecological and human health effects of placing CCRs in coal mines
  - Improvements and field validation of leaching tests to better predict mobilization of constituents from CCRs

Public Participation

- Heard concerns about the potential for adverse environmental and public health impacts from improper CCR disposal
- Any proposal to dispose of substantial quantities of CCRs in coal mines should be treated as a “significant alteration of reclamation plan”

Regulatory Authority

- Scope of SMCRA sufficiently broad to cover regulation of CCRs at mine sites
- But neither SMCRA nor its implementing regulations explicitly address CCRs
  - States vary in approach and rigor
- EPA proposed to regulate CCRs in landfills, impoundments

Regulatory Authority

- Disposal of CCRs in coal mines should be subject to reasonable site-specific performance standards
- Regulatory gaps exist that create opportunities for unnecessary risks
- Guidance is insufficient
- Enforceable federal standards should be established for use of CCRs in minefills

Alternatives for Regulatory Authority

- SMCRA is broad enough to encompass regulation during reclamation activities
- Primary regulatory mechanisms that could be used to develop enforceable standards
  - Changes to SMCRA regulations to address CCRs specifically;
  - Joint OSM-EPA rules pursuant to the authority of SMCRA and RCRA; or
  - RCRA-D rules that are enforceable through a SMCRA permit.

Summary

- Placement of CCR in mines as part reclamation is a viable disposal option
- An integrated process of CCR characterization, site characterization, management and design of placement activities, and design and implementation of monitoring is required to reduce the risk of contamination moving from mine site to ambient environment

TECHNICAL COMMENTS ON THE NATIONAL RESEARCH COUNCIL REPORT ON MANAGING COAL COMBUSTION RESIDUES AT MINES

Dr. Ishwar P. Murarka
ISH Inc.
Raleigh, North Carolina

View Presentation

Observations on NAS Recommendations

The first thing I would like to do is offer my personal opinion about some of the more important findings by the National Academy of Sciences (NAS) in its report. I will do this by first citing the NAS recommendation in italics and then follow with my observations.

The NAS Committee recommends that secondary uses of Coal Combustion Residues (CCR) that pose minimal risks to human health and the environment be strongly encouraged. The Committee then states that there are three major disposal practices for CCR – namely landfills, surface impoundment, and mine filling.

> I do not believe that mine filling should be called "disposal." Mine filling is not disposal but it is a beneficial use of Coal Combustion By-Products (CCBs) when and where appropriate. Mine filling of CCBs should support a beneficial land reclamation/land use purpose. Not every mine should be receiving CCBs because every mine is not suitable and not every CCB is suitable for every mine. Disposal of CCBs should be discouraged at utility landfills and impoundments because of economic and environmental issues. Beneficial and wise use of CCBs should be encouraged. Labeling mine filling of CCBs as a disposal practice creates a big stigma and public perception of negative concern.

The NAS Committee concludes that while potential advantages should not be ignored, the full characterization of possible risks should not be cut short in the name of beneficial use. The Committee specifically recommends that CCR placement in mines be designed to minimize reactions with water and the flow of water through the CCR.

> Beneficial use of CCBs for neutralization of acid mine drainage in abandoned surface or underground mines does require that the maximum amount of chemical reaction occur so that the abatement of acid mine water is accomplished. If chemical reactions are minimized then the benefits will not be derived and there is no need to fully characterize risks from a water free environment in which the CCBs are entombed. One question raised by this recommendation is, if it is required that the CCBs not be allowed to react with water or have contact with water, why then do we need to have a full characterization of CCBs?
>
> Further, it is ambiguous as to what is meant by "full characterization of possible risks." I have no idea what this means. We should characterize the CCBs and know if significant risks are present and should abate them or not use CCBs in those cases.

The Committee recommends additional research to examine long-term (>10 years) environmental behavior of CCR at mine sites, including differing climatic and geologic settings, so that the type of mine settings, CCRs and placement techniques most protective of human and ecological health can be identified.

> This is a very tall order that I am not sure whether it is even possible. Even if this research could be done and everyone could agree on the design and results (a very unlikely probability), it would not be completed in my lifetime. This could effect a moratorium on current mine placement for the foreseeable future.

Long-Term Monitoring of Ash Placement at a Coal Mine

I think that the most productive contribution that I can make to this discussion would be to give an account of the long term (16 year) water quality monitoring study that I have been doing at the Universal Coal Mine in Indiana. The Universal Mine was an open pit with a pool of acid water and was a waste land prior to reclamation with coal ash. Cinergy filled the mine-pit with coal ash from its nearby power plant over a 12 year period. About 1.5 million tons of CCBs were used to completely fill the mine pit. Five feet of soil completed the final cover which was vegetated as wildlife habitat. The mine-pit now is a reclaimed land permanently dedicated to wildlife use. Groundwater quality and surface water quality at the site have been improved greatly. Risks to humans and the ecosystem are now negligible. I have reached this conclusion based on my analysis of the following groundwater quality data. The field pH values of the ash (Figure 1) are around pH 9 which provides the alkalinity that was necessary to neutralize the acid mine drainage from the mine pit. The mine water prior to reclamation was very acid with a pH of 2-3. Currently, the water produced at groundwater seeps down gradient from the reclaimed pit is near neutral with a pH of around 7 (Figure 2).

Figures 3 and 4 provide the field trend data for alkalinity in the ash and in the ground water at the mine. The ash is saturated in the ground water for the bottom 15 feet of the fill. Alkalinity from the ash is imparted to the ground water which is required to neutralize the acidic ground water from historic mining.

Figures 5 and 6 provide the field trend data for boron in the ash and in the groundwater at the mine. In this case, the ash contained significant amounts of boron which is shown by the concentrations of boron in the leachate samples (between 30-80 ppm). Boron concentrations in the groundwater at the mine seep is much lower (around 7 ppm) and is about 30-35 ppm in the nearby groundwater. Boron is the only constituent in the ground water leaving the ash filled former pit area that is higher than it was prior to filling the pit with ash.

Sulfate in the leachate is about 1,600 ppm (Figure 7) which is very typical in this case. Sulfate concentration in the mine seep water is about the same at about 1,600 ppm (Figure 8) and is around 800-900 ppm in the ground water. Prior to placement of the coal ash in the pit, the groundwater had 3,000 to 4,000 ppm of sulfate. Because of the calcium sulfate in the ash, the solubility of the calcium sulfate is controlling the level of sulfate in the groundwater. We can not distinguish between the sulfate from the ash and the sulfate from acid mine drainage.

Arsenic levels in the leachate from the ash are fairly consistent although it varies by location to location within the ash fill (Figure 9). At the mine seep (Figure 10), arsenic levels are showing up at 0.01 mg/L. Once the water is exposed to air at the seep, even this arsenic co-precipitates with iron about 5 feet downstream of the exit point. Within 30 feet downstream of the exit point, no arsenic remains in the water.

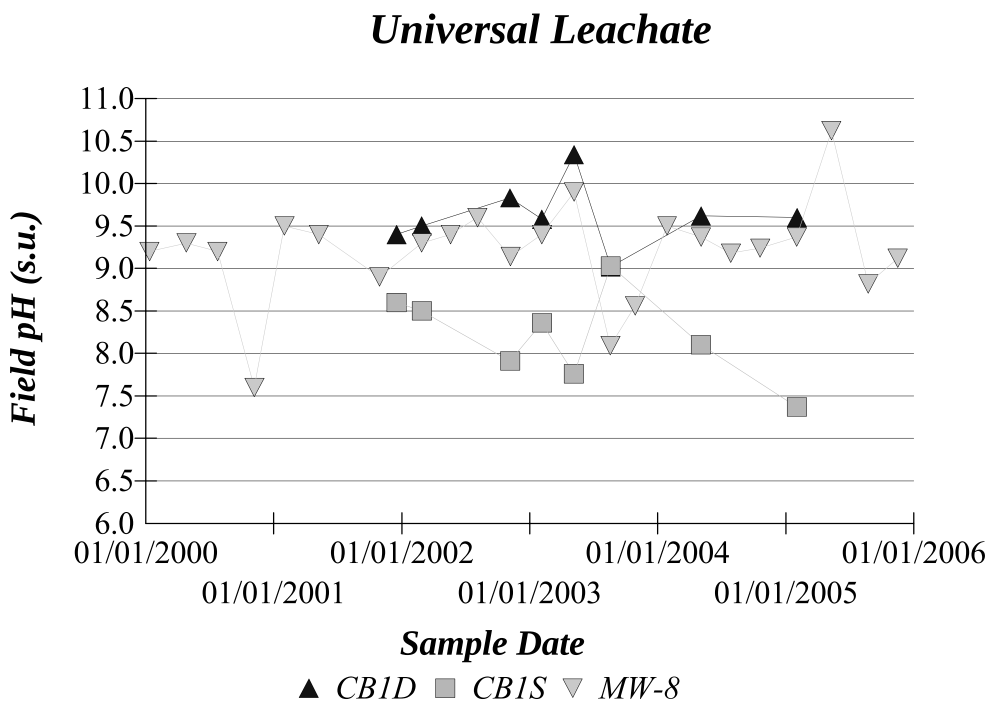


Figure 1. Field pH values over time from fly ash within the reclaimed mine pit at the Universal Mine.

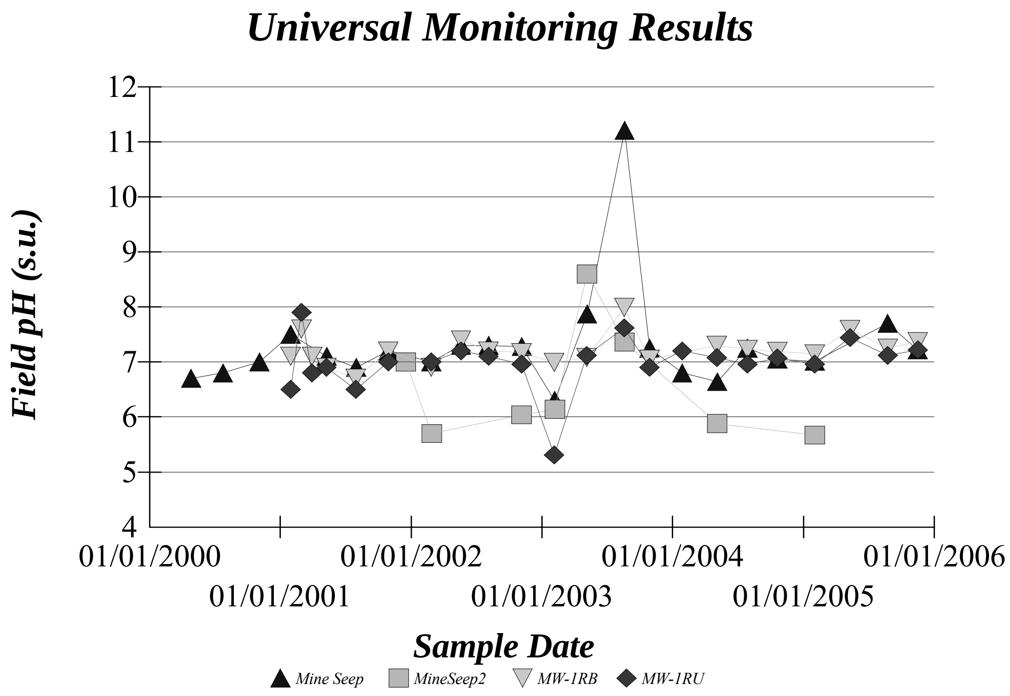


Figure 2. Field pH values over time from down gradient groundwater seeps at the Universal Mine.

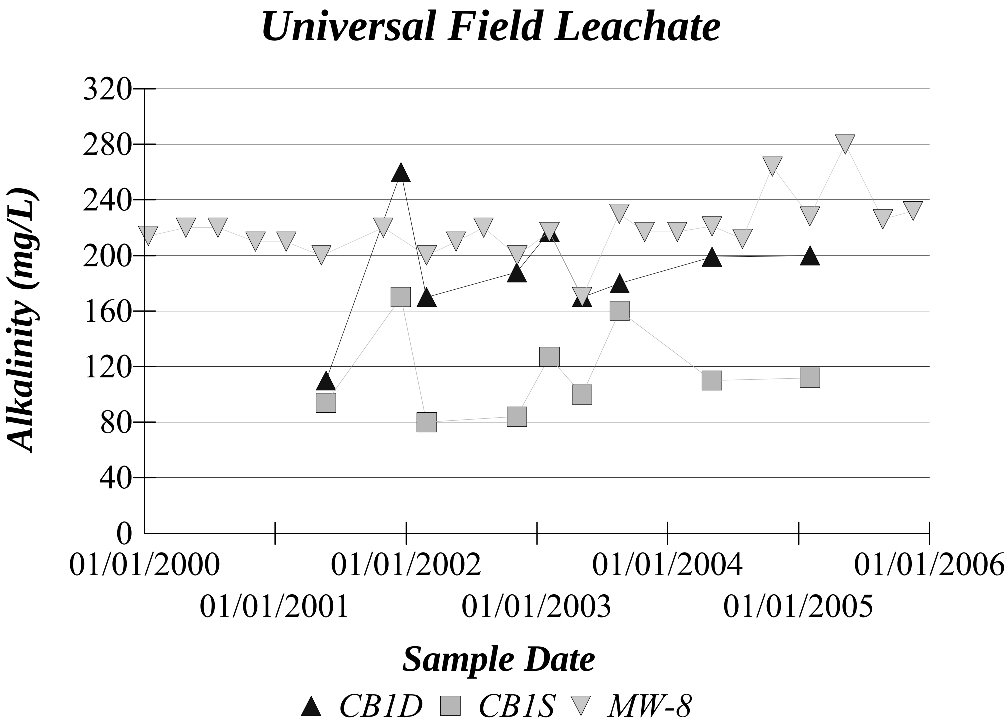


Figure 3. Field alkalinity values over time from fly ash leachate at the Universal Mine.

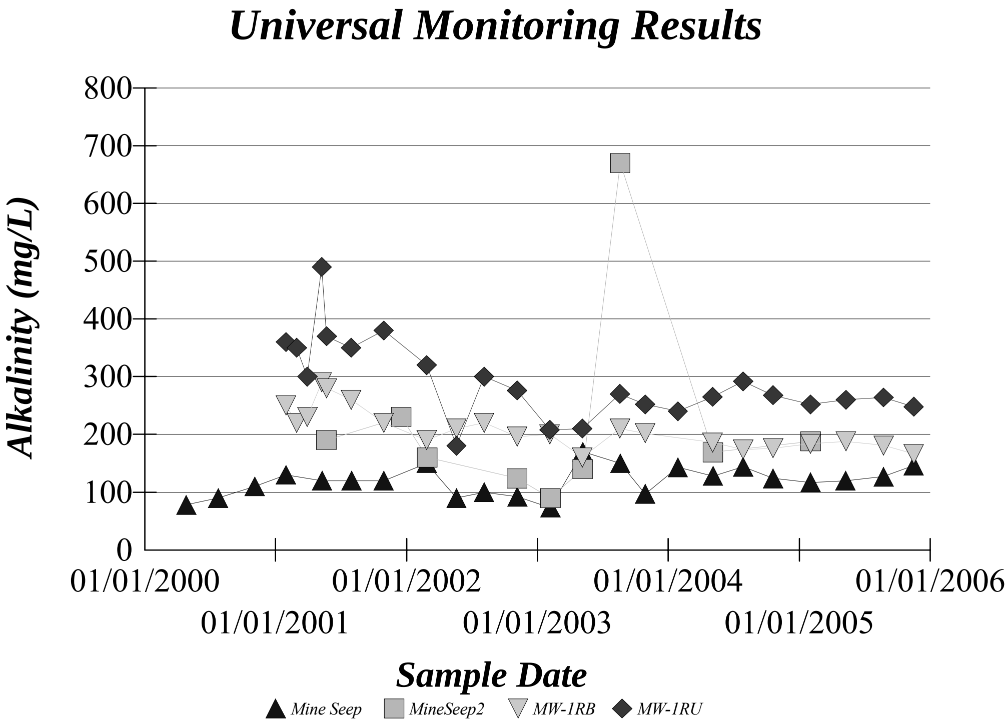


Figure 4. Field alkalinity values over time for groundwater monitoring at the Universal Mine.

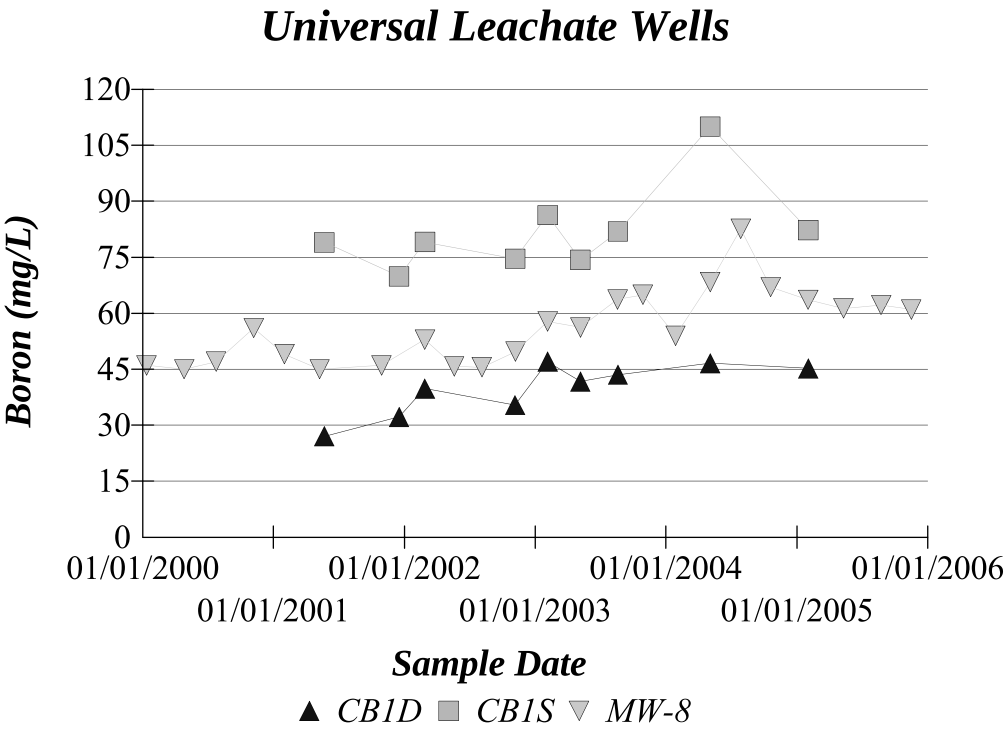


Figure 5. Field boron values over time from fly ash leachate at the Universal Mine.

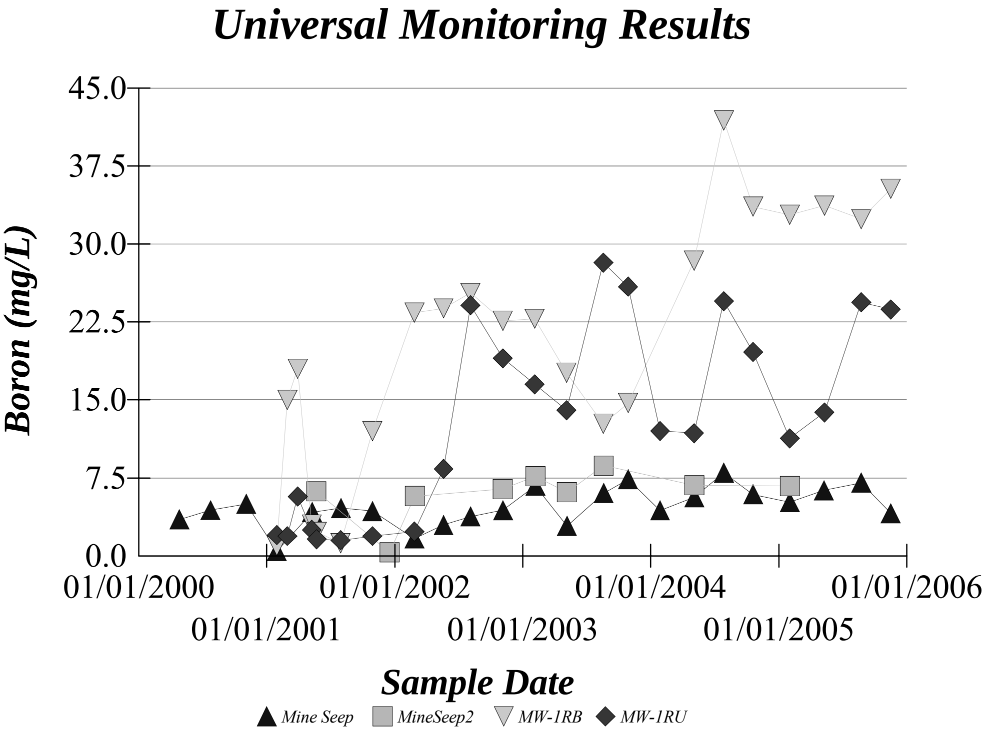


Figure 6. Field boron values over time for groundwater monitoring at the Universal Mine.

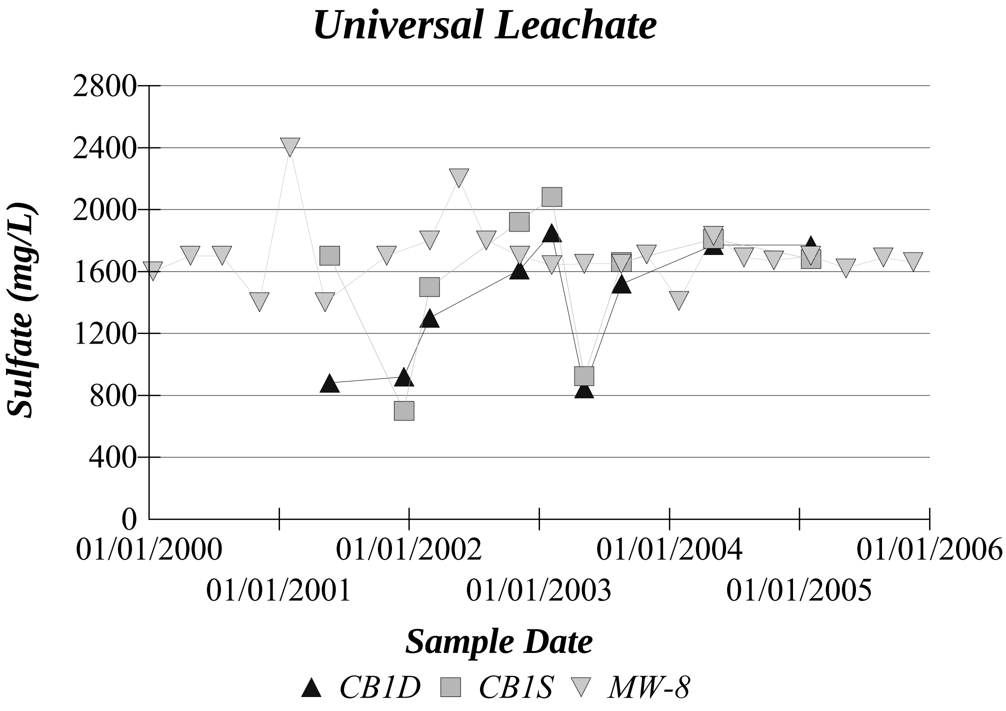


Figure 7. Field sulfate values over time from fly ash leachate at the Universal Mine.

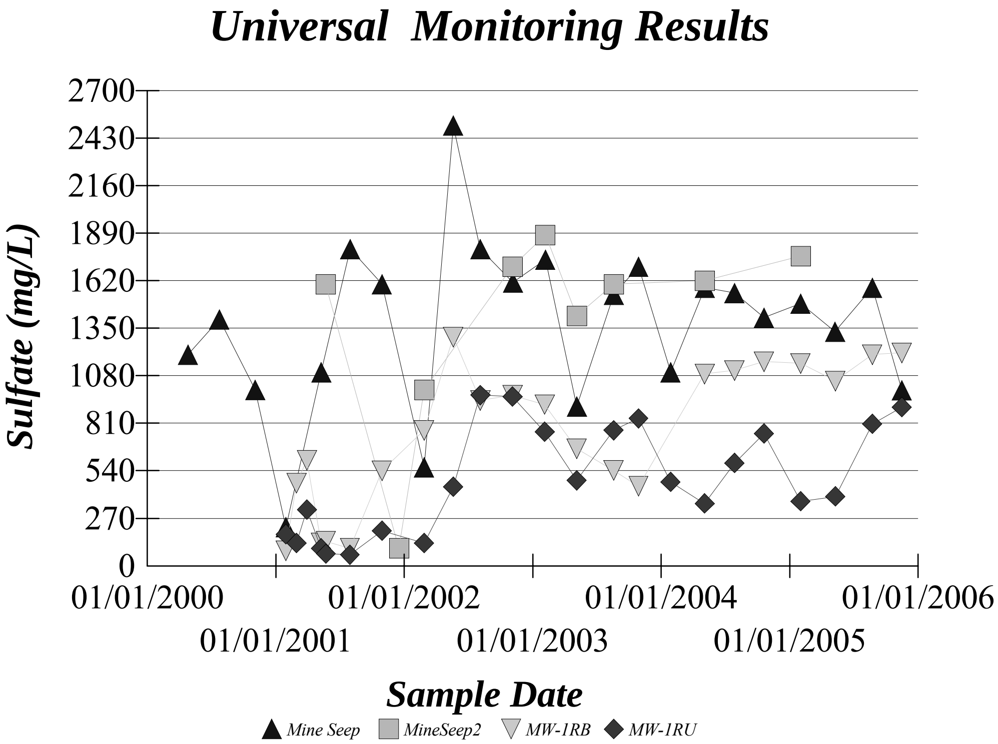


Figure 8. Field sulfate values over time for groundwater monitoring at the Universal Mine.

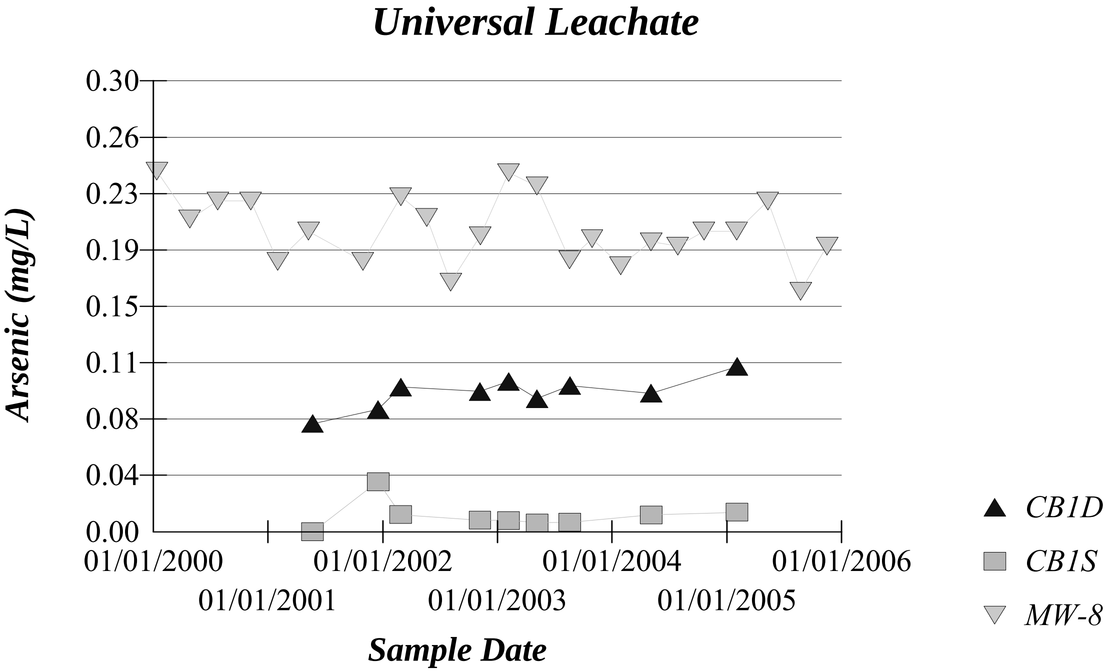


Figure 9. Field arsenic values over time from fly ash leachate at the Universal Mine.

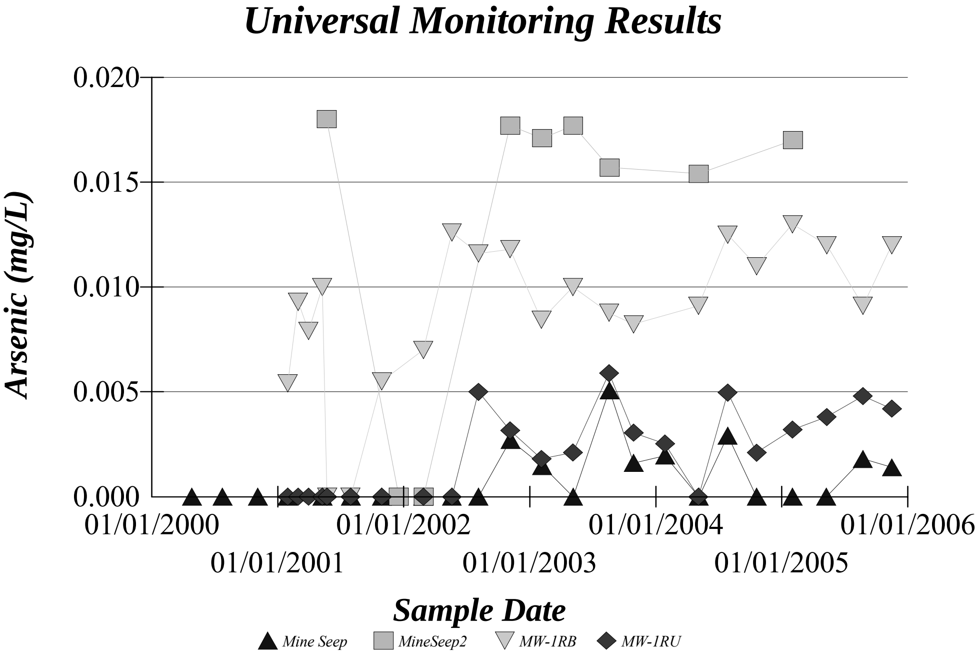


Figure 10. Field arsenic values over time for groundwater monitoring at the Universal Mine.

Conclusion

The Universal site long-term monitoring (greater than 15 years) provides an assessment on beneficial use of CCBs for a surface mine pit that was unsafe and hazardous. The mine pit is now returned to wildlife land use which has enhanced the ecology of the area. Acid water quality conditions have vanished. However, boron is the only leached constituent and has migrated in the groundwater but not outside the property boundary. Boron is not evident in the surface water of the receiving stream.

The NRC report has missed an opportunity by not providing clear scientific and policy directions for balancing and resolving the beneficial reuse of CCBs in mines. They should have provided a chapter on how to conduct a balanced risk assessment for abandoned mine land scenarios that are already degraded. The NRC report through its recommendation on research has essentially declared a moratorium on beneficial use of CCBs in mine.

Dr. Ishwar Murarka is the Executive Scientist and President of Ish Inc. that he created in 1998 as an environmental consulting company specializing in investigating, evaluating, and developing strategies for the remediation of soils, groundwater, and sediments contaminated with metals and organics. His current research interests include: leaching, attenuation, transport and fate of metals and organic compounds in soil, groundwater, surface water, and sediments, and investigation and remediation of contaminated sites containing non-aqueous liquids (NAPL), cyanide, petroleum products, and metals from various sources, etc. He has been addressing Land and Water Environmental Issues for over 25 years. He has worked as an Environmental professional for Texas Instruments, Argonne National Laboratory, and Electric Power Research Institute (EPRI). He continues to offer consulting services to address environmental issues associated with the disposal and utilization of fossil-fuel combustion byproducts. He has served on the U.S. EPA's Science Advisory Board (SAB) from 1988 through 2001 in various capacities and continues to be a consultant to the SAB. He is most experienced with the scientific and regulatory deliberations on the management of fossil fuel combustion wastes and the former manufactured gas plant sites. He continues to perform research on leaching, attenuation, and environmental fate of metals and organic constituents. He holds a Ph.D. in Soil Science and Statistics from Oregon State University and an MBA from the University of Chicago. He was an NIH postdoctoral fellow in Biomathematics at North Carolina State University.

Technical Comments on the NRC report on Managing Coal Combustion Residues In Mines

By
Ishwar P. Murarka, Ph.D.,
Ish Inc.
November 2006

Recommendation of the NRC

- The Committee recommends that secondary uses of CCR that pose minimal risks to human health and the environment be strongly encouraged. The Committee then states that there are three major disposal practices for CCR – namely Landfills, Surface impoundment and Mine Filling.

Comments on the Specific Recommendation

- Mine filling is not a disposal but is a beneficial use of CCR when appropriate
- Not every mine is to receive CCR
- Disposal of CCR should be discouraged
- Use of CCR should be encouraged
- Labeling it as disposal creates a big stigma and bad public perception

Recommendation of the NRC

- The NRC Committee concludes that while potential advantages should not be ignored, the full characterization of possible risks should not be cut short in the name of beneficial use. The Committee specifically recommends that CCR placement in mines be designed to minimize reactions with water and the flow of water through the CCR.

Comments on the Specific Recommendation

- Beneficial use of CCR for neutralization of acid mine drainage does require that maximum amount of chemical reactions occur so that the abatement of acid mine water is accomplished. If chemical reactions are minimized then the benefits will not be derived and there is no need to fully characterize risks from a water free environment in which the CCR are entombed.

Comments on the Specific Recommendation

- Further, it is ambiguous as to what is meant by “full characterization of possible risks”.
- We should characterize and know if significant risks are present and should abate them or not use CCR in those cases

Recommendation of the NRC

- The Committee recommends additional research to examine long-term (>10 years) environmental behavior of CCR at mine sites, including differing climatic and geologic settings, so that the type of mine settings, CCRs and placement techniques most protective of human and ecological health can be identified

Comments on the Specific Recommendation

- This is a very big order and not even possible to implement
- Even if this research could be conducted and everyone agrees with the results and interpretations, we are essentially putting a moratorium on CCRs beneficial use in mines

Comments on the Specific Recommendation

- Numerous hurdles in funding, designing and conducting such a study
- Can same source of CCR be found for beneficial use in different climatic conditions?
- Can replicated sites of same hydro-geological conditions be included in the study?

Comments on the Specific Recommendation

- I have conducted long term monitoring research of the environmental behavior of coal ash placed in Universal Mine site for more than 16 years of operations and am providing a brief picture of the benefits and limitations of the beneficial use

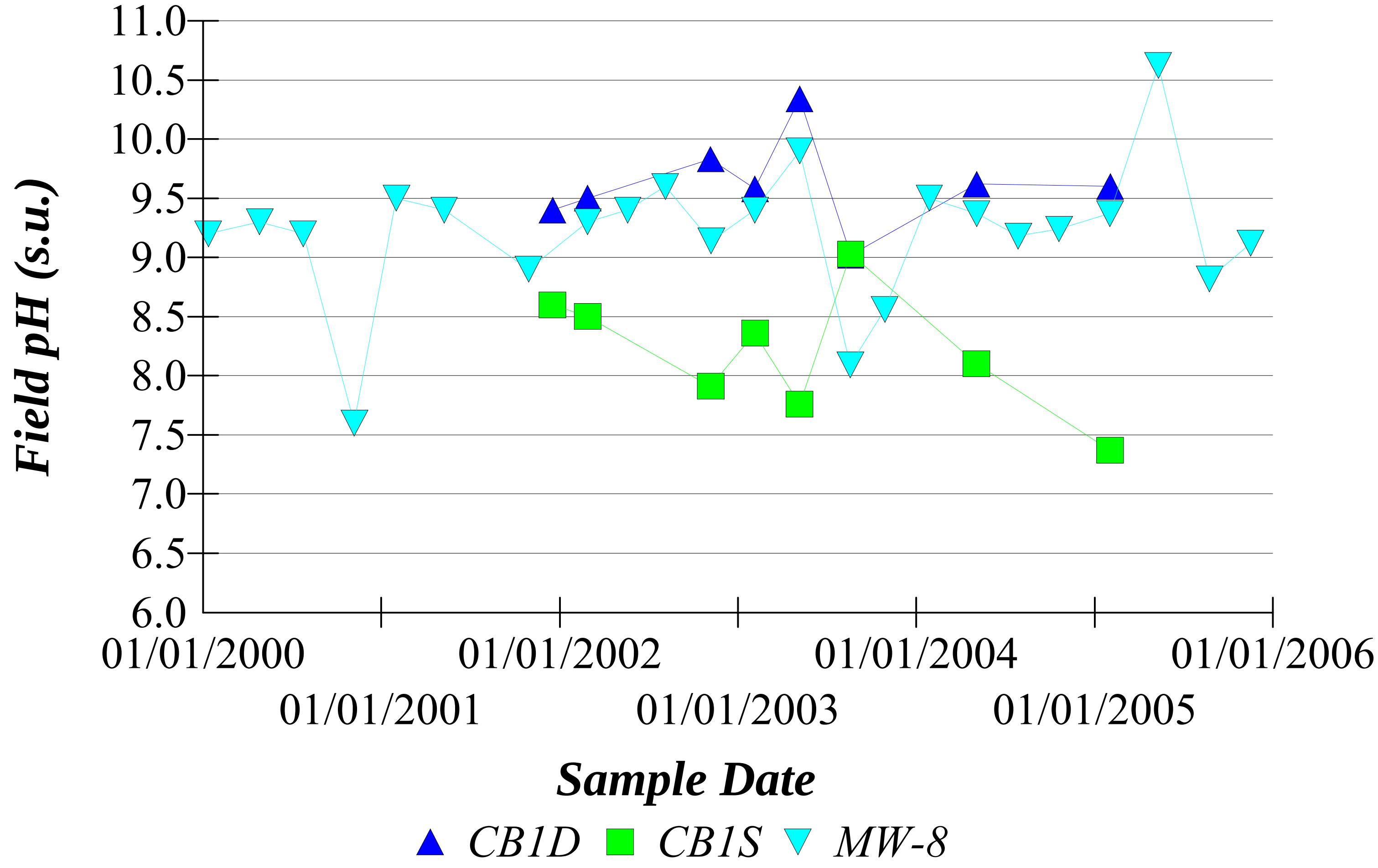
Universal Site with Coal Ash

- The Mine site was an open pit with pool of acid water and was a waste land
- Cinergy filled the mine-pit with coal ash from its nearby power plant
- About 1.5 million tons were used to completely fill the mine pit
- Five feet of soil and revegetation completed the final cover

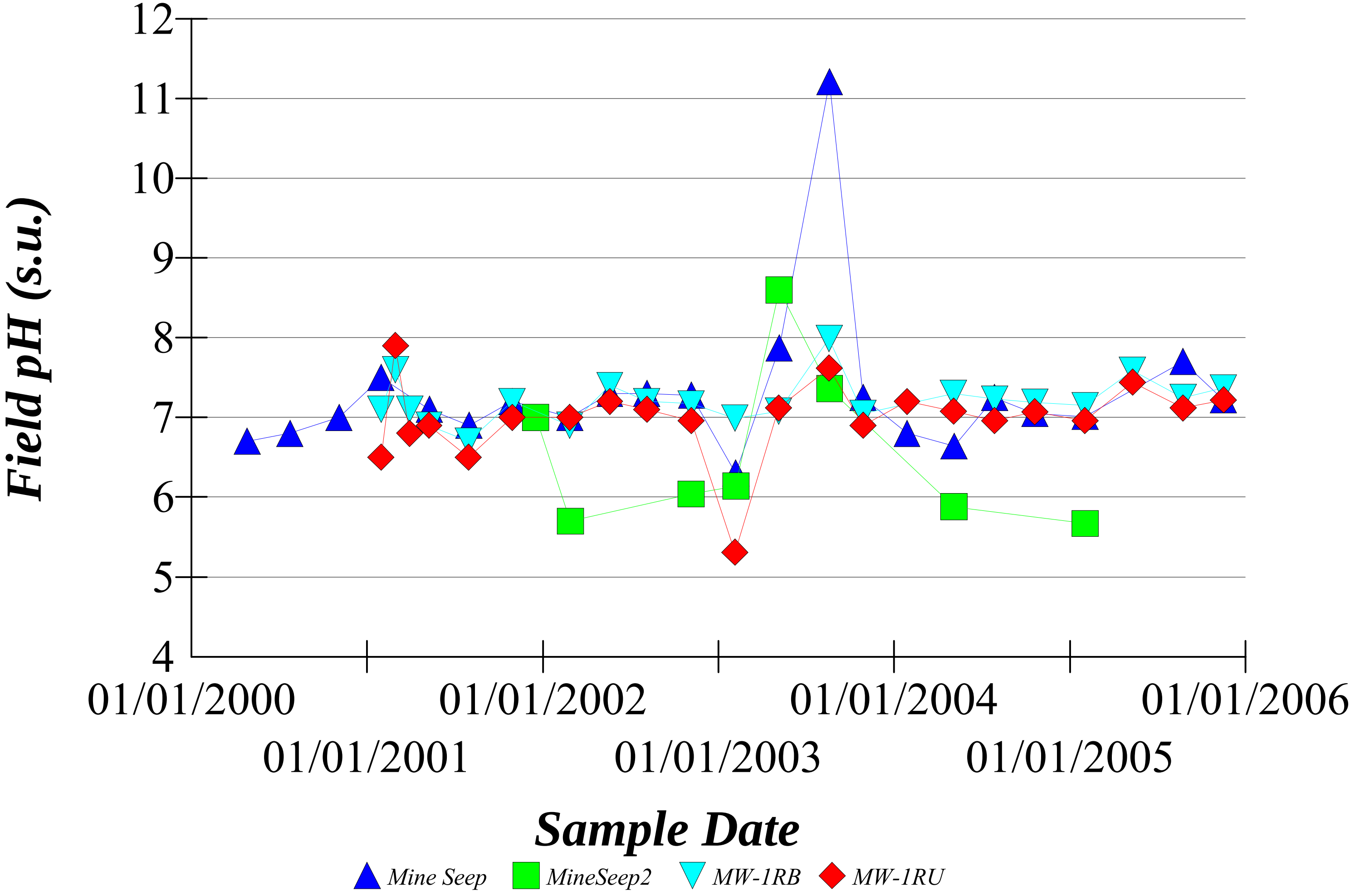
Universal Site with Coal Ash

- The mine-pit now is a reclaimed land dedicated to wild-life use
- Groundwater quality and surface water quality at the site have improved greatly
- Risks to humans and ecosystem are negligible now

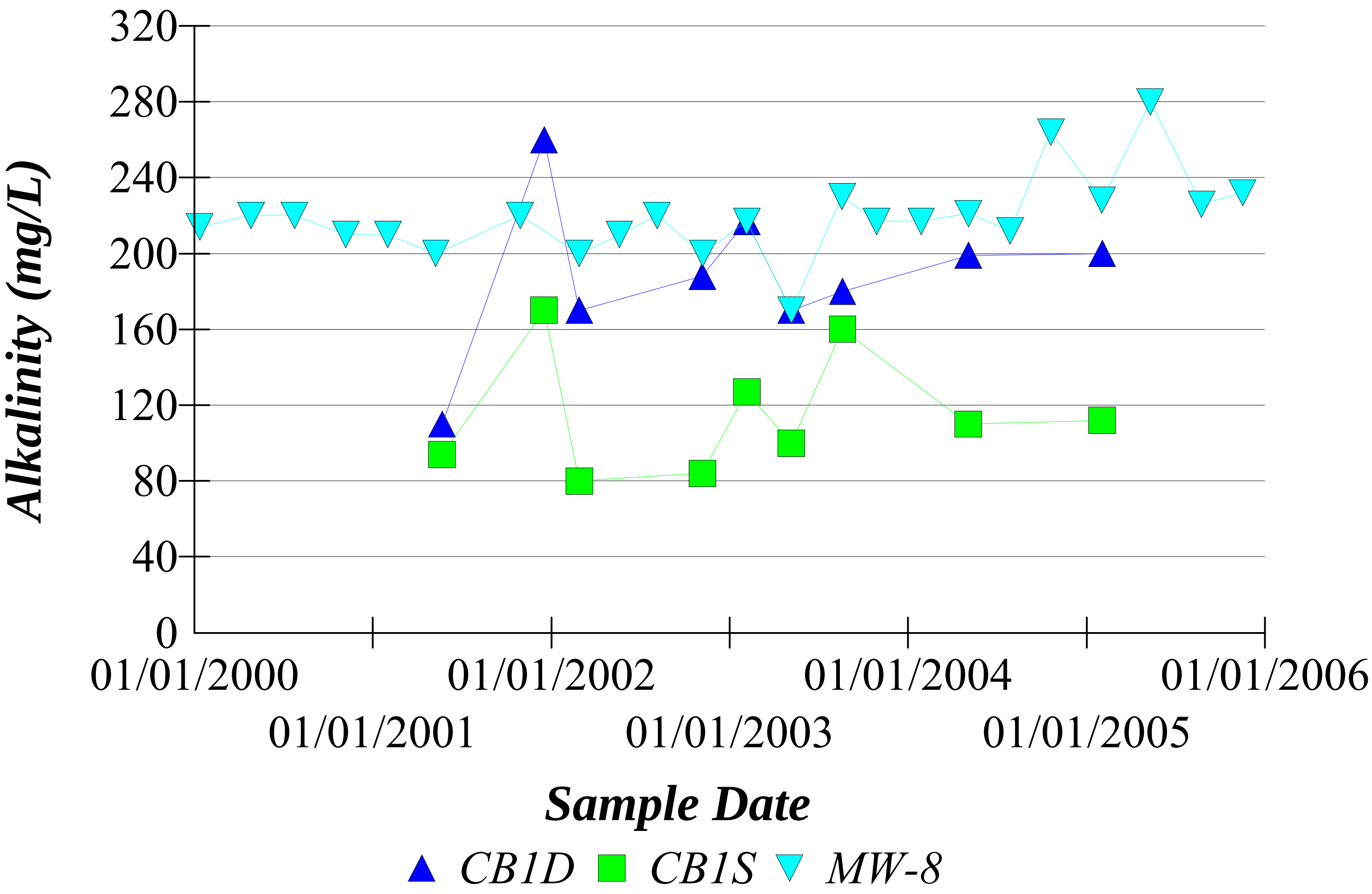
Universal leachate



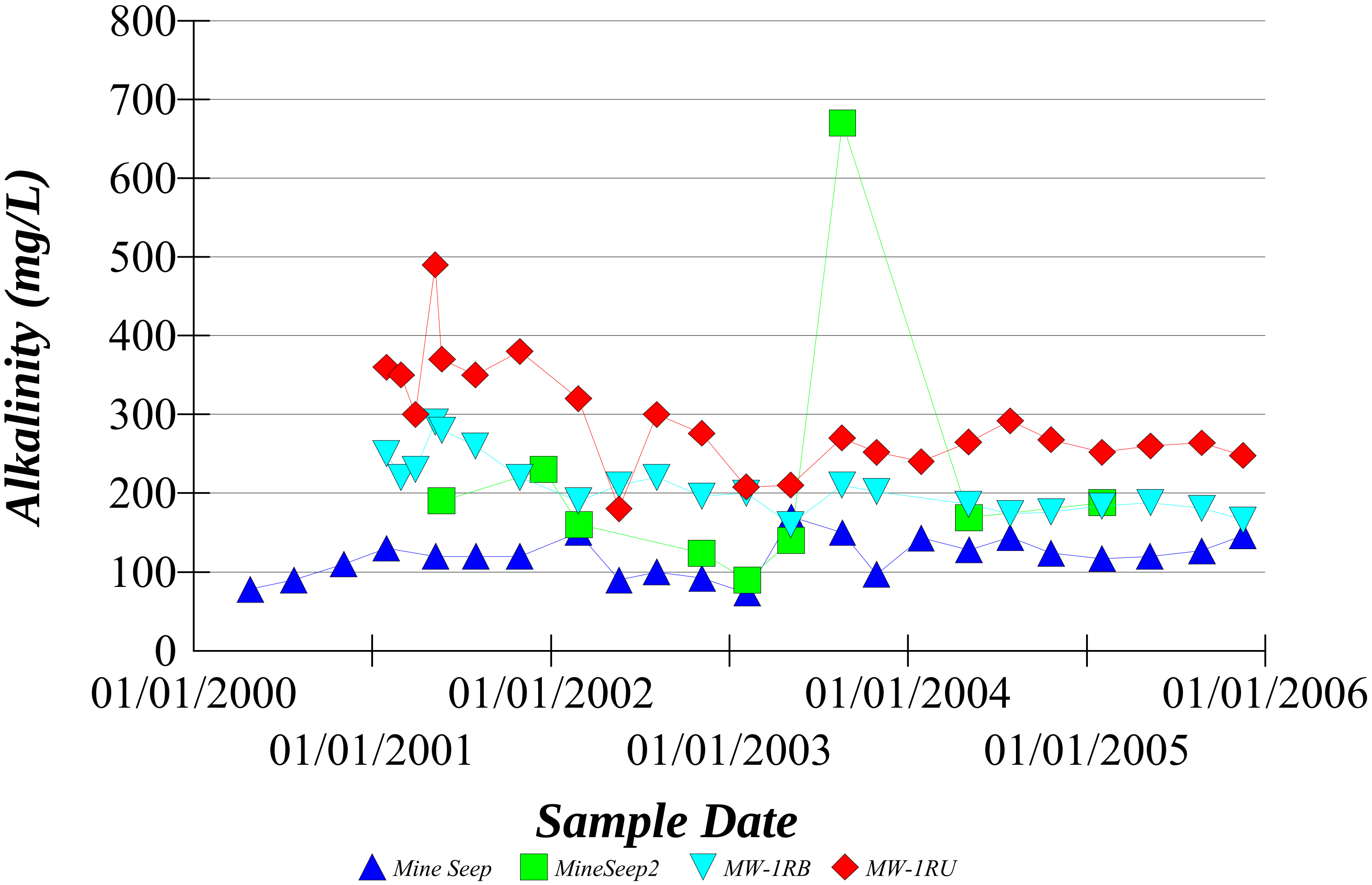
Universal Monitoring Results



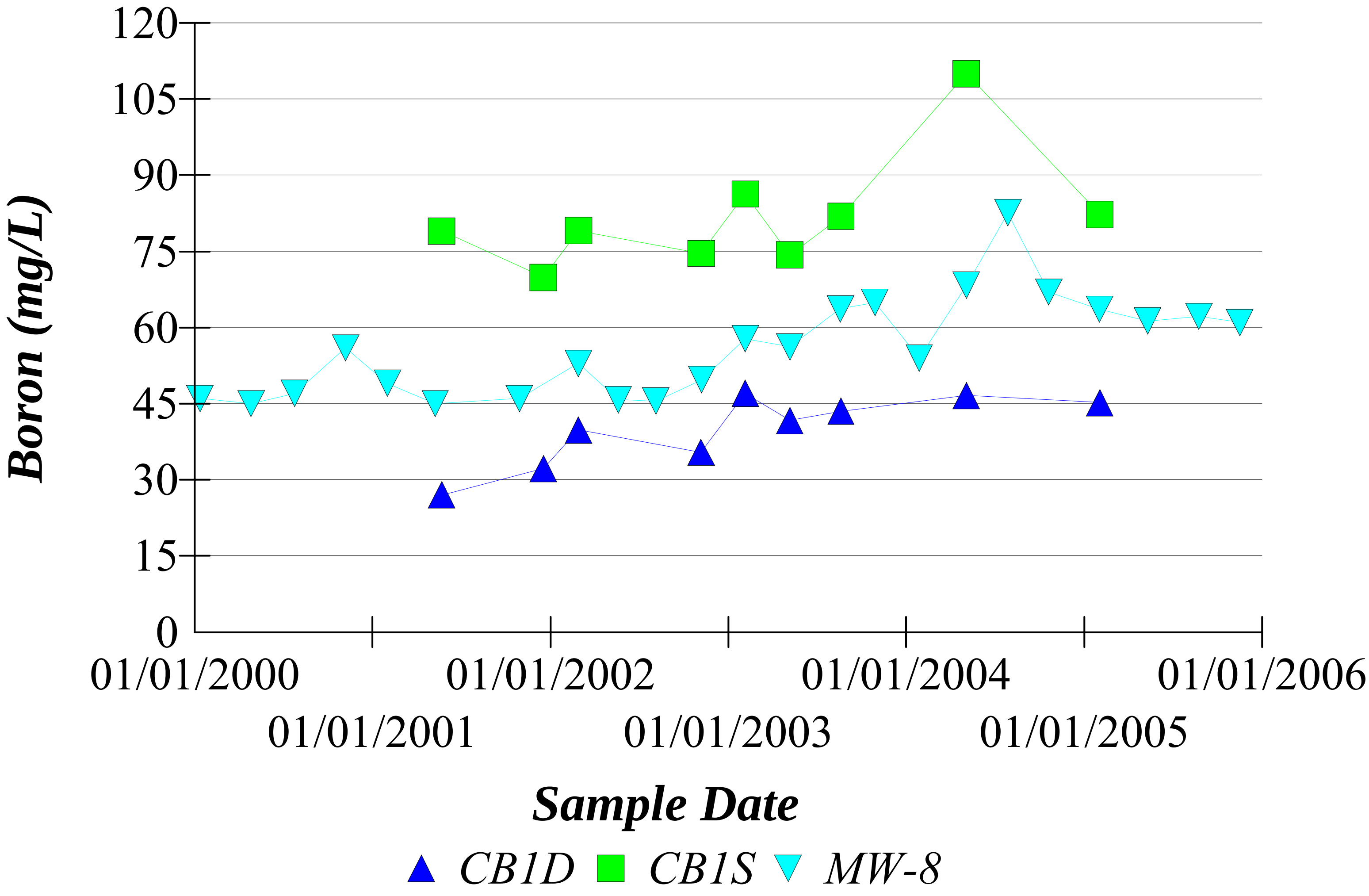
Universal Field Leachate



Universal Monitoring Results



Universal Leachate Wells



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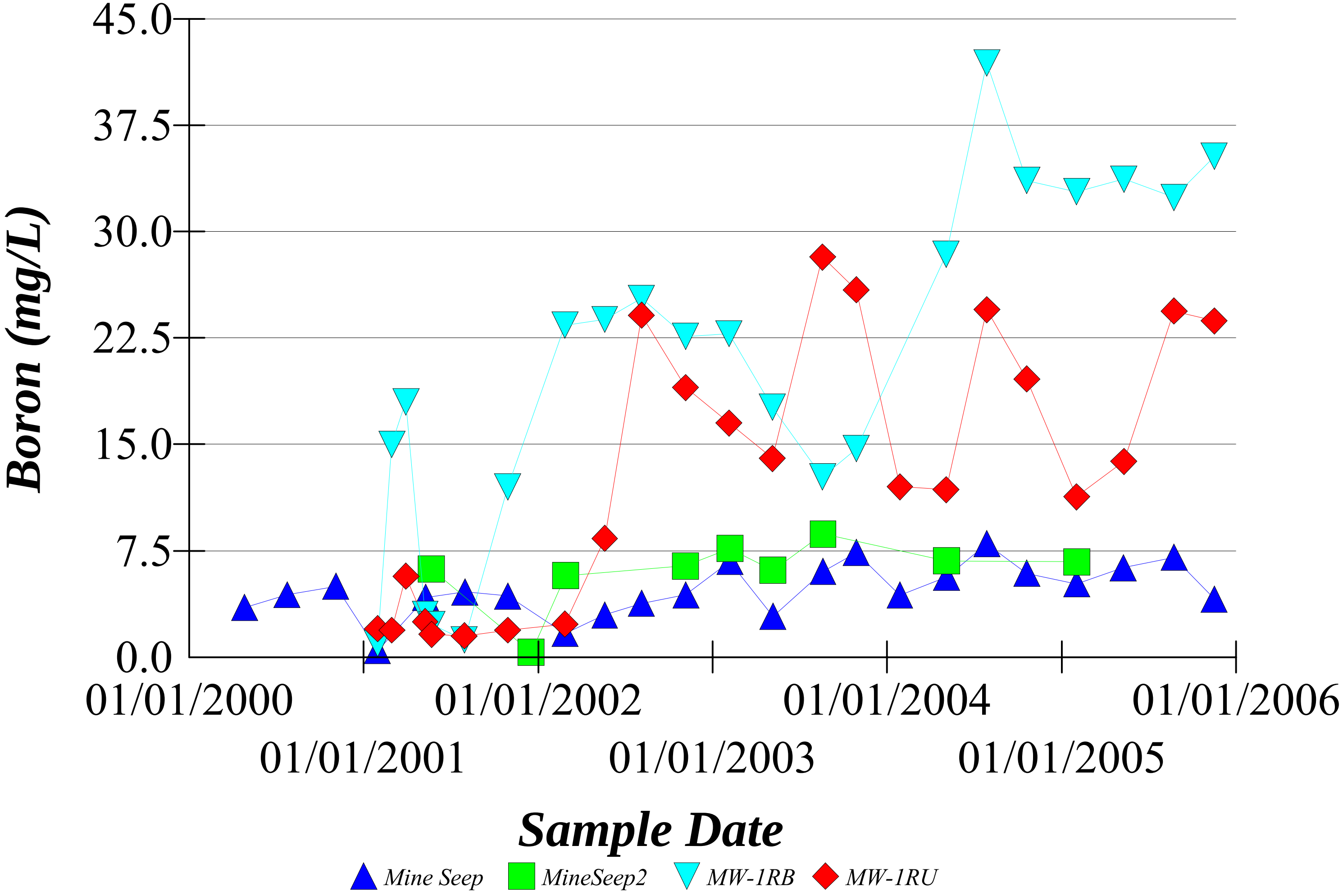

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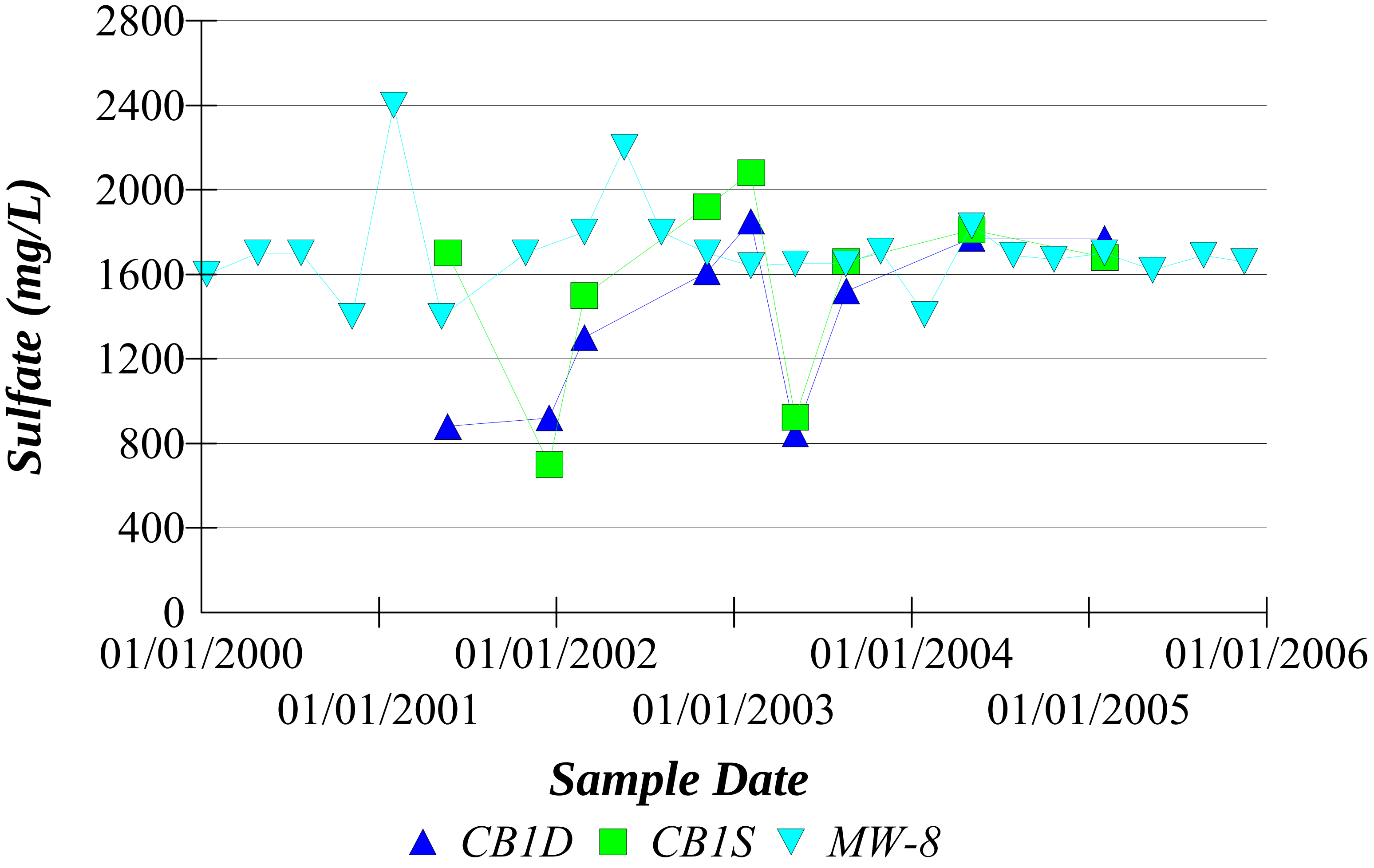

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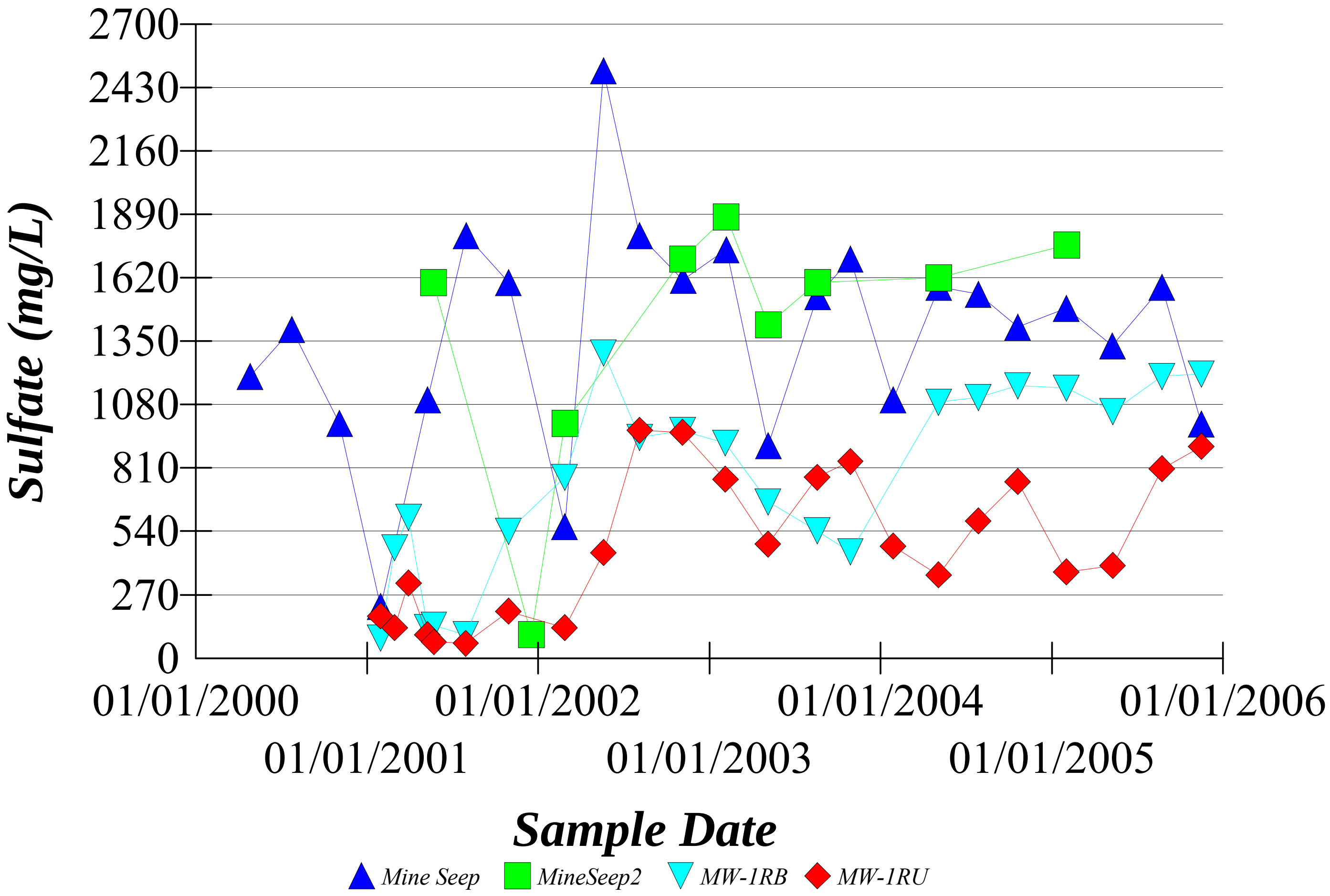

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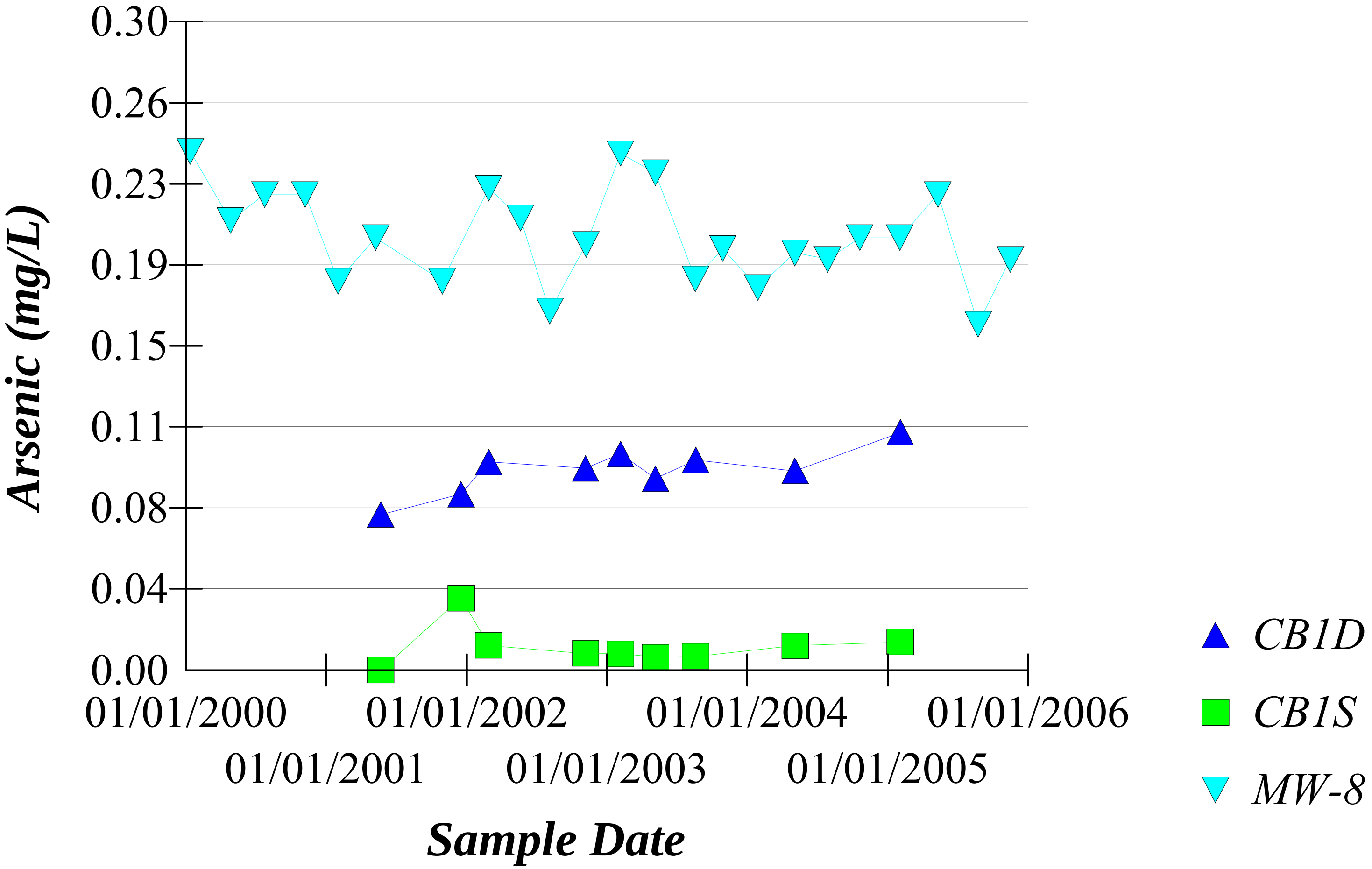
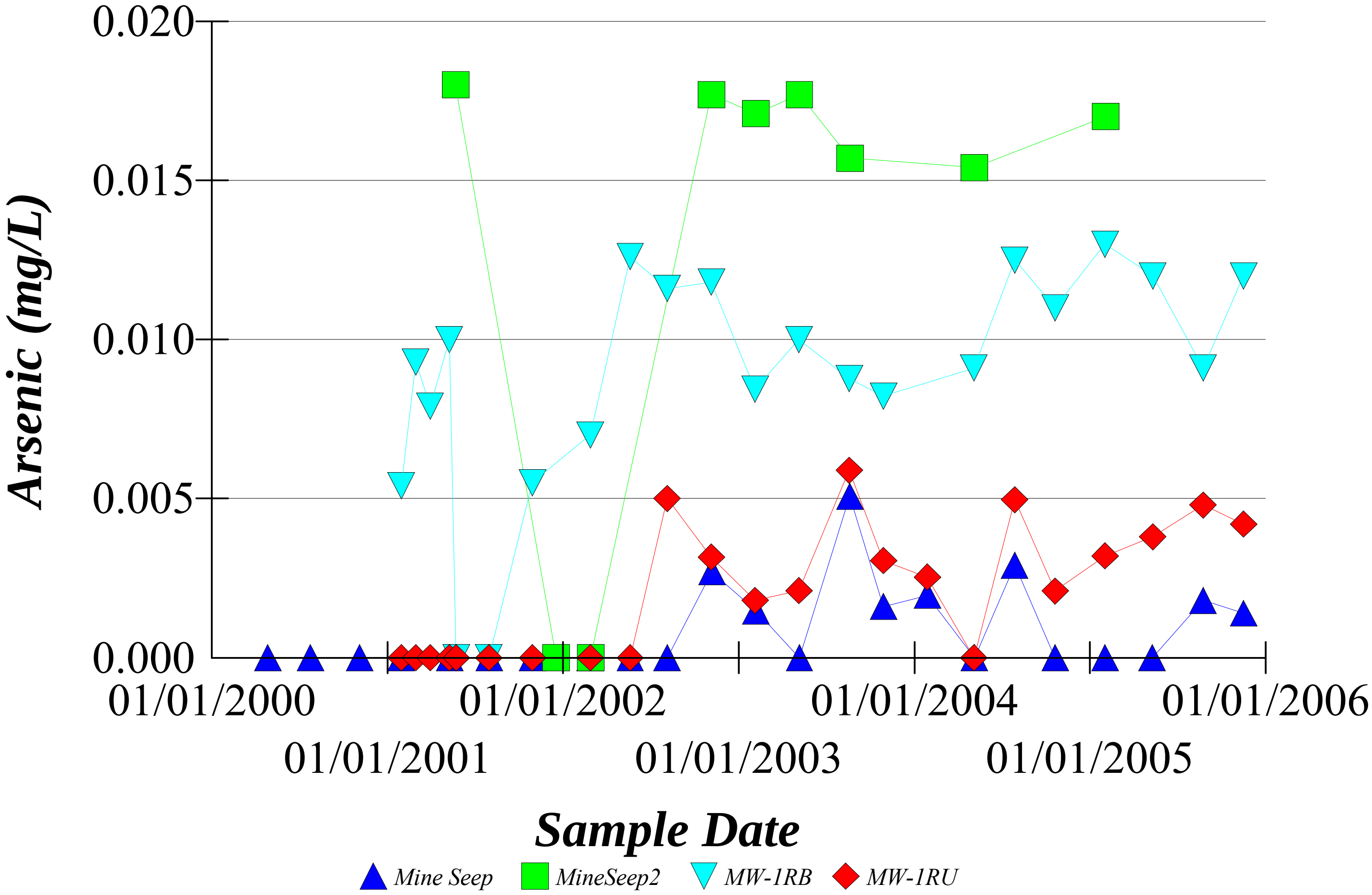


Universal Monitoring Results



Conclusions

- The Universal site long term monitoring provides an assessment on beneficial use of CCR for a surface mine-pit that was unsafe and hazardous. The mine-pit is now returned to wildlife land use.
- Acid water quality conditions have vanished. However, Boron is leached and migrated in the groundwater.

Final Comments

- The NRC report has not provided clear scientific and policy directions for balancing and resolving the beneficial reuse of CCR in mines.
- The NRC report through its recommendation on research has essentially declared a moratorium on beneficial use of CCR in mine.

NATIONAL ACADEMY OF SCIENCES (NAS) FINAL REPORT "MANAGING COAL COMBUSTION RESIDUES IN MINES": A REVIEW

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Southern Illinois University
Carbondale, Illinois

View Presentation

Abstract

The paper provides a review of the report with emphasis on: (1) evaluation of damage cases and resulting observations related to impacts of CCRs placements in mine fills; (2) physical and geochemical properties of CCRs and development of informed risk; and (3) engineering and planning related to placement of CCRs in mine settings, including underground placement. Research needs in each area are also identified.

Background

Combustion of coal results in incombustible matter residues that are commonly termed "Coal Combustion Byproducts (CCBs). The NAS report uses the term coal combustion residues (CCRs) to describe these materials. This paper uses the terms CCBs and CCRs interchangeably. These include fly ash, bottom ash, and boiler slag. When air pollution control technologies are utilized in conjunction with combustion such as fluidized bed combustion (FBC), flue gas desulphurization (FGD), Nox control, and mercury control, additional dry or wet byproducts may be produced with physical, chemical, and environmental characteristics significantly different than fly ash, bottom ash, or boiler slag. Of the current production of over 123 million tons of CCBs in the USA, only about 40% are beneficially utilized, while others are disposed of into surface impoundments, landfills, or other on-site facilities. Only about 2% of CCBs from traditional utilities and about 4% from independent power producers are currently managed (beneficial use and/or disposal in mining areas).

With expected increase in coal-based power production over the next 20 years and air emission control requirements, CCBs production is expected to increase at a more accelerated rate than before. Simultaneously, the utilization rate component of CCBs may not keep pace with the production rate since the chemical characteristics of CCBs may make them unsuitable or more expensive to use. As surface impoundments and landfill space around power plants become more expensive for CCBs management, attention to CCBs management in mining areas is drawing more attention. Surface as well as underground mining areas are natural host sites for consideration because of available void space and infrastructure for CCBs management.

CCBs management in mining areas has been under the regulatory purview of the Surface Mining Control and Reclamation Act (SMCRA) and its regulations since 1977. SMCRA has allowed states to develop, implement, and control their own regulatory programs as long as they are approved by OSM. In its decision to U.S. Congress on May 22, 2000, the U.S. Environmental Protection Agency (USEPA) indicated that when CCBs are used to fill surface or underground mines, national regulations under Subtitle D (solid waste) and/or possible modifications to regulations under SMCRA were warranted. This was considered important to ensure consistent management for all wastes. Since 2000, the office of Surface Mining (OSM), USEPA and the states have been reviewing information on placement of CCBs in mining areas. The debate between OSM, USEPA, the public, and environment groups with concerns about long-term environmental safety assurance of CCBs managed in mining areas led to the NAS study. Its findings were reported in a final report in March, 2006.

Goal and Specific Objectives

This paper discusses the NAS report findings in three (3) areas.

- Evaluation of damage cases and resulting observations.
- Physical and geochemical properties of CCBs and development of informed risk.

- Engineering and planning for CCBs placement in mining areas.

A few recommendations for additional research are also included in each area.

Evaluation of Damage Cases and Resulting Observations

NAS study states "… the committee's review of literature and damage cases recognized by EPA supports the EPA's concerns about proper management of CCBs." The study uses this conclusion to support their statements regarding potential for negative impacts in mine settings and suggestions for mine placement to minimize such risk. The following comments are relevant to the above statements.

1. The report and USEPA recognize that identified damage cases are not at mine sites currently. The report does not allege that CCBs placement at mines is poorly regulated.
2. The NAS committee (Committee) made their statements based on a review of:(a) literature, damage cases and associated geologic and hydro-geologic environments for surface impoundments and landfills; and (b) long-term environmental performance data from mine fills.

Since long-term environmental performance data for mine fills were limited and potential for development of conditions that might result in such damage existed, the Committee decided to make recommendations related to CCBs management in mines such as:

- *a. "The two most common CCR disposal options surface impoundments and landfills, provide insights into the types of issues that can emerge when the soluble constituents of CCBs are not contained with the waste management system."*
- *b. "Although disposal conditions may differ substantially from mine settings, landfills and surface impoundments are useful for understanding the specific conditions under which CCRs can potentially impact humans and ecosystems."*
- *c. "The EPA has identified numerous cases of water contamination related to CCR landfills and surface impoundments that, in many cases, has caused considerable environmental damage. In some landfill settings, groundwater has been degraded to the point that drinking water standards were exceeded off-site. In other landfills and surface impoundments, contamination of surface waters has resulted in considerable environmental damage; in the most extreme cases, multiple impacts can be clearly related to CCR disposal, and they help guide the selection of mining environments for CCR placement that are most protective of human and ecological health.."*
- *d. "---the committee's review of literature and damage cases recognized by EPA supports the EPA's concerns about proper management of CCRs.*

1. The Committee has not provided references to specific data and analysis results that led them to make the statement (d) above. Thus, the above statement can not be justified.
2. Although most mine fills, when established, are not in contact with water, potential exists for changes in water table – over a longer term and associated leaching and contaminant transport issues.
3. Although most groundwater in mine settings is not of high quality, potential exists to degrade it further short-term soon after placement of CCBs.
4. Water movements through mine fills may occur at a very small rate that could negatively impact long-term environmental health and safety.
5. The report recognizes the significant differences in typical geological and hydrological characteristics of mine fills and surface impoundments and landfills. However, appropriate comments were not included to account for all possible conditions.
6. The report also recognizes that data from USEPA damage cases may not be relevant to SMCRA regulated mine fills.
7. Other report comments that support author's statements above are given below.
    - *a. "Comparatively little is known about the potential for mine-filling to degrade the quality of groundwater and/or surface waters particularly over longer time periods."*
    - *b. "…there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessment difficult."*
    - *c. "Currently, there are very few data available to directly indicate that placement of CCRs in abandoned or active coal mines is either safe or detrimental."*

d. *"The committee concludes that the presence of high contaminant levels in many CCR lactates may create human health and ecological concerns at or near some mine sites over the long term."*

8. The Committee recognizes that some of the practices and findings of data analyses from SMCRA mine fills could be transferred to CCBs management in surface impoundment and landfills.

Research Recommendations

1. Identify appropriate existing mine fill sites throughout USA in different geologic and hydro-geologic and climatic settings where long-term monitoring could be continued or initiated. In identifying these sites, factors to be considered should include availability of characterization data for CCBs, time periods and volumes disposed, spatial distribution of monitoring wells and times of their installation, recharge water quality data, etc.
2. Adsorption characteristics of different RCRA trace elements in soils and rocks around mining sites should be compiled and/or analyzed and considered in assessing environmental risk.
3. Additional new research mine fill sites should be developed for long-term monitoring in different parts of the USA with specific goals to establish validity of different CCBs characterization methods and long-term environmental monitoring. Such sites should include both surface and underground sites.

Characterization and Development of Informed Risk

NAS committee did a very good job in developing this chapter and the author agrees with most of the comments in regard to: (1) Development of informed risk and for it to guide additional characterization; (2) Need for mine-specific leaching tests and studies; and (3) Concepts for site characterization. However, some comments which require additional discussion and need for research and development are given below.

1. Given the variability of CCBs physical and chemical properties, site characterization data, CCBs placement technologies, and current QA/QC controls in implementation, can we develop "informed risk" that is acceptable to public and/or the environmental groups at most sites amenable to CCBs placement? Can we benchmark "informed risk" based on an analysis of data from existing sites?

2. The statement in the report "*In order to contribute to evaluation of the risk of placing CCRs at mine sites, the committee recommends that CCRs be characterized prior to significant mine placement and with each new source of CCRs. CCR characterization should continue periodically throughout the mine placement process to assess any changes in CCR composition and behavior."* is currently practiced under SMCRA permitting requirements.

3. The statement below should be discussed further.

   "The committee suggests some simple improvement to current leaching protocols. In particular, the CCR characterization methods used should provide contaminate leaching information for the range of geochemical conditions that will occur at the CCR placement site and in the surrounding area, both during and after placement. Samples that exceed pre-determined leaching criteria should be rejected for mine placement, although samples that meet the criteria may still need additional evaluation depending on the potential risks of CCR placement determined from the site characterization."

The author agrees with the first part of the statement. The second part of the statement requires clarification. All CCBs proposed for management should be evaluated as part of the total geochemical-hydrogeological system/model to assess if there is potential for environmental or health risk. For example, a CCB not meeting pre-determined leaching criteria may be suitable for management in highly adsorptive soils/rock environment or in an underground mine well below the ground water and encapsulated by impermeable shales above and below. The goal should be for the permit holder to develop "informed risk" that is defensible and acceptable to regulatory agencies.

4. The statement below requires additional discussion.

   "*The committee recommends comprehensive site characterization specific to CCR placement at all mine sites prior to substantial placement of CCRs. Site characterization is a dynamic process of developing and continually refining a 'site conceptual model' that captures the relevant aspects affecting the behavior of CCRs in the mining environment.*"

   The author believes that the first statement is already mandated by SMCRA rules since the permittee is required to demonstrate site-specifically that management of CCBs will not pose environmental or health risk.

   The author agrees that site characterization is a dynamic process. However, the possible dynamic scenarios should be evaluated as part of the permitting process for a set period. The permittee should be allowed to plan for their operations for that period unless "significant changes in environmental and health risk are encountered." The report did not address what would be considered a "significant change" in environmental and health risk.

5. The committee recommends "*additional research to apply existing reactive transport models to real field sites and to evaluate whether the transport and reaction processes included in the model adequately describe the processes taking place at CCR mine disposal sites, including those processes that occur over protracted time scales*".

   This is an extremely worthwhile (but difficult and frustrating!!) area of research to assess developing and/or developed leaching tests, site characterization, and geochemical models. It may take us a decade to develop confidence into developed models. The author suggests that several field demonstration projects should be developed for long-term monitoring studies. These should be located in different areas of the country with high projected potential for mine placement. The goals of these demonstration projects should be to assess appropriateness of : (1) CCBs characterization methods; (2) Site characterization techniques; (3) Groundwater flow models; (4) Reactive geochemical models; (5) Contaminant transport models; and (6) Integrated model/s to predict water quality over protracted periods of time. The reactive geochemical models should incorporate adsorption characteristics of host soils and rocks for RCRA trace elements.

Engineering and Planning Related to Placement of CCBs

NAS report has a good discussion of the issues involved and their recommendations in chapters 7 and 8. Again, the author commends the Committee on the thoroughness of the content covered, sharing of their concerns, and their recommendations to deal with them. The author provides the following comments on some of the content.

1. For all practical purposes, the Committee ignored discussion of underground mine placement of CCBs in active mines where benefits related to conservation of resources could be highest while having minimal potential for negative environment or health risk. Underground placement may be carried out below good quality groundwater resources, with minimal potential for contaminant transport and low presence of receptors. In some cases, underground placement may basically imply "isolation" of CCBs from any potential for leachate generation, leachate transport, mixing with high quality groundwater resources, and also allow for acid mine drainage treatment and control.

   The author agrees with the Committee that underground placement in abandoned mines could pose higher risk since adequate characterization of associated strata, leachate flow paths, and material flows may not be possible. Even for abandoned mines, the Committee should have had some discussion since potential for beneficial use (acid mine drainage, subsidence control, and associated benefits of protecting surface and groundwater resources) is very high.

   The author believes that environment and health risks associated with surface management of CCBs are much greater than underground placement because of potential of CCBs to contact water, higher porosity, and permeability of host environment. However, the committee more or less ignored or failed to discuss this important topical area.

2. The Committee has developed a large number of prescriptive comments and recommendations. Some of these should be included in the guidance documents rather than part of regulations. It is appropriate to have uniform, broad-based SMCRA regulations to minimize differences in interpretation by different states. However, the States should have the flexibility to develop site specific plans for: CCBs management; site characterization requirements; assignment of risk tolerance for each site; placement techniques; monitoring requirements; and bonding. The agreement between OSM and USEPA to incorporate CCBs-specific regulations into SMCRA regulations is a step in the right direction. The USEPA and SMCRA should work together, in collaboration with industry representatives, to develop regulations that promote CCBs placement in mines and minimize environment and health risks.

Research Needs

1. Adsorption characteristics of typical host rocks and soils for different trace elements encountered in mining areas need to be developed and considered in assessing environment and health risk.
2. Data need to be developed for contaminant transport rates through different host rocks and soils

Concluding Remarks

NAS study asserts that management of CCBs in mining areas can be a viable option and should be considered on a site specific basis. That is indeed very positive. The report has also outlined a roadmap for consideration of most of the relevant topics that should minimize environmental and health risk in managing CCBs in mining areas. Now it is for scientists, engineers, industry professionals, and regulators, with expertise in CCBs management, to work together and develop guidelines that allow for development of acceptable informed health and environmental risk. This will require: (1) synthesis of previous research, with emphasis on analysis of monitored data in relation to site and CCBs characteristics, placement technologies, and monitoring program used; (2) monitoring new CCBs management field sites and analyses of water quality data; (3) development of leaching test protocols; and (4) techniques for assessment of informed health and environmental risk. Collaborative efforts between regulatory agencies, industry, and research organizations are needed to serve the industry and the public.

Dr. Y. Paul Chugh has over 15 years of experience in research and management of CCBs, with emphasis on management in mines. He developed and administered the Coal Combustion Residues Management Program (CCRM) for the State of Illinois during early 1990s. He was awarded the USDOE 4-year award on Demonstration of Underground Management of CCBs for Subsidence Control. In this project, he developed and demonstrated paste backfill technology using sulfate-rich scrubber sludge, F-ash, and small amounts of lime to backfill abandoned areas of coal mines for subsidence control. During this project, he also developed and demonstrated pneumatic backfilling technology for FBC fly ash for acid mine drainage control and subsidence control. Subsequently, he demonstrated paste backfill technology at another underground mine in Illinois using crushed coarse coal waste, and non-compliant FBC fly ash and F-fly ash. In addition to the above experience related to management in mines, he has also developed and field demonstrated CCBs-based crib and post materials for use in mines. He has developed and demonstrated structural materials using sulfite rich sludge, FBC fly ash, and F-ash that are environmentally benign. Most recently, he has successfully developed automotive brake pads that meet and exceed SAE specifications for brake materials and contain 55-60% fly ash. He currently has two patents related to CCBs management. He has disclosed the third intellectual property idea to the university administration. He has served as Director, Combustion By-products Recycling Consortium-Midwest Region since its inception. Dr. Chugh holds BS, MS, and PhD degrees in Mining Engineering, the latter two from Penn State University.

A Review of Findings of the NAS Report

“ Managing Coal Combustion Residues in mines”

Yoginder P. Chugh

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618-453-7922

Coal Combustion Residues(CCR)
vs.
Coal Combustion Byproducts(CCBs)

NAS study uses the word CCR. In the author's opinion, the term CCBs is a better description and will use this term throughout discussion.

Outline

- Background
- Evaluation of damage cases.
- Physical and geochemical properties of CCRs and development of informed risk.
- Engineering and planning related to mine placement.
- Concluding Remarks

Evaluation of Damage Cases and Resulting Observation

Statement

- NAS study states "… *the committee's review of literature and damage cases recognized by EP A supports the EPA's concerns about proper management of CCBs.*"
- The study uses this conclusion to support their statements regarding potential for negative impacts in mine settings and suggestions for mine placement to minimize such risk.

Discussion -- 1

- The report and USEPA recognize that currently recognized damage cases are not at mine sites. They do not allege that CCBs placement at mine sites is poorly regulated.

- The Committee made their statements based on a review of (i) literature, damage cases and associated geologic and hydro-geologic environments for surface impoundments and landfills, and (ii) long-term environmental performance data from mine fills.

Discussion -- 2

- Since long-term environmental performance data for mine fills were not available and potential for development of conditions that might result in such damage existed, the committee decided to make recommendations such as:
  - “The two most common CCR disposal options surface impoundments and landfills, provide insights into the types of issues that can emerge when the soluble constituents of CCBs are not contained with the waste management system.”
  - Although disposal conditions may differ substantially from mine settings, landfills, and surface impoundments are useful for understanding the specific conditions under which CCRs can potentially impact humans and ecosystems.

Discussion – 3

- The EPA has identified numerous cases of water contamination related to CCR landfills and surface impoundments that, in many cases, has caused considerable environmental damage.
- In some landfill settings, groundwater has been degraded to the point that drinking water standards were exceeded off-site. In other landfills and surface impoundments, contamination of surface waters has resulted in considerable environmental damage.
- In the most extreme cases, multiple impacts can be clearly related to CCR disposal, and they help guide the selection of mining environments for CCR placement that are most protective of human and ecological health..”
- “---the committee’s review of literature and damage cases recognized by EPA supports the EPA’s concerns about proper management of CCRs.

Discussion -- 4

- Although most mine fills, when established, are not in contact with water, potential exists for changes in water table over longer term and leaching and contaminant transport.
- Although most ground water in mine settings is not of high quality, potential exists to degrade it short-term soon after placement of CCBs.
- Water movements through mine fills may occur slowly that could negatively impact environmental health and safety long term.

Discussion -5

- The report recognizes significant differences in l geological and hydrological characteristics of mine fills and surface impoundments and landfills. However, appropriate comments were included to account for all possible conditions.

- The report also recognizes that data from USEPA damage cases may not be relevant to SMCRA regulated mine fills.

Discussion -- 6

- Other report comments that support author’s statements above are given below.
  - Comparatively little is known about the potential for mine-filling to degrade the quality of groundwater and/or surface waters particularly over longer time periods.
  - …there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessment difficult.
  - Currently, there are very few data available to directly indicate that placement of CCRs in abandoned or active coal mines is either safe or detrimental

Discussion – 7

- Of the three methods currently available for disposal of CCRs (surface impoundments, land filling, and mine filling), comparatively little is known about he potential for mine filling to degrade the quality of ground water and/or surface waters particularly over longer periods. Additionally, there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessments difficult.

- The committee concludes that the presence of high contaminant levels in many CCR lactates may create human health and ecological concerns at or near some mine sites over the long term.

Research Recommendations

- Identify appropriate existing sites throughout USA in different geologic and hydro-geologic and climatic settings where long-term monitoring could be continued or initiated.
- Factors to be considered should include availability of characterization data for CCBs, time periods and volumes disposed, spatial distribution of monitoring wells and times of their installation, and water quality data.
- Adsorption characteristics for different RCRA trace elements in soils and rocks around mining sites should be compiled and considered in assessing environmental risk.

Research Recommendations (contd.)

- Additional research mine fill sites should be developed for long-term monitoring in different parts of the USA with specific goals to establish validity of different CCBs characterization methods and long-term environmental monitoring. Such sites should include both surface and underground sites.

Characterization and Development of Informed Risk

- NAS committee did a very good job in developing this chapter and agrees with most of the comments in regard to:

1) Development of informed risk and for it to guide additional characterization.
2) Need for mine-specific leaching test and studies,
3) Concepts for site characterization.
4) However, below are some comments which require additional discussion.

Comments Requiring Additional Discussion

- Given the variability of different parameters of CCBs, sites, placement technologies, and QA/QC controls in implementation, can we develop “informed risk” that is acceptable to public and/or the environmental groups?

- Should we perform an exercise with data available from existing sites permits if acceptable risk can be achieved?

- The committee recommendation that CCRs be characterized prior to significant mine placement and with each new source of CCRs, and it should continue periodically throughout the mine placement process is currently required under SMCRA permitting.

Statement

- “The committee suggests some simple improvement to current leaching protocols. In particular, the CCR characterization methods used should provide contaminant leaching information for the range of geochemical conditions that will occur at the CCR placement site and in the surrounding area, both during and after placement.

- Sample that exceeds pre-determined leaching criteria should be rejected for mine placement, although samples that meet the criteria may still need additional evaluation depending on the potential risks of CCR placement determined from the site characterization.”

Discussion

- Agree with the first part of the statement. The second part of the statement requires clarification.
- All CCBs proposed for management should be evaluated as part of the total geochemical-hydro geological system/model to assess if there is potential for environmental or health risk.
- A CCB not meeting pre-determined leaching criteria may be suitable for management in highly adsorptive soils/rock environment or in an underground mine well below the ground water and encapsulated by impermeable shale’s above and below.
- The goal should be to develop “informed risk” that is acceptable to regulatory agencies.

Statement

- “The committee recommends comprehensive site characterization specific to CCR placement at all mine sites prior to substantial placement of CCRs.”
- Site characterization is a dynamic process of developing and continually refining a “site conceptual model” that captures the relevant aspects affecting the behavior of CCRs in the mining environment.

Discussion

- The first statement is already mandated by SMCRA rules since the permit requires to demonstrate site-specifically that management of CCBs will not pose environmental or health risk.

- Site characterization is a dynamic process. The possible dynamic scenarios should be evaluated as part of the permitting process for a set period.

- Permit should be allowed to plan for their operations for that period unless "significant changes in environmental and health risk occur.

- What would be considered a "significant change" in environmental and health risk needs to be discussed.

Statement

- The committee recommends “additional research to apply existing reactive transport models to real field sites and to evaluate whether the transport and reaction processes included in the model adequately describe the processes taking place at CCR mine disposal sites, including those processes that occur over protracted time scales”

Discussion

- This is extremely worthwhile (but difficult and frustrating!!) to assess developing and/or developed leaching tests, site characterization and geochemical models. I suggest that several field demonstration projects should be developed for long-term monitoring studies.

- These should be located in different areas of the country with high projected potential for mine placement.

Discussion (contd.)

- The goals of these demonstration projects should be to assess appropriateness of

1) CCBs characterization methods
2) Site characterization techniques
3) Ground water flow models
4) Reactive geochemical models
5) Contaminant transport models
6) Integrated model/s to predict water quality over protracted periods of time.

Engineering and Planning Related to Placement of CCBs (Overview)

- NAS has a good discussion of the issues involved and their recommendations in chapters 7 and 8. The author would offer the following comments.

Discussion-1

- The committee ignored discussion of underground mine placement of CCBs in active mines where benefits related to conservation of resources could be highest while having minimal potential for negative environment or health risk.
- Underground placement may be carried out below good quality groundwater resources, with minimal potential for contaminant transport and low presence of receptors.
- In some cases, underground placement may basically imply “isolation” of CCBs from any potential for leachate generation, leachate transport, mixing with high quality groundwater resources, and also allow for acid mine drainage treatment and control.

Discussion-2

- The author agrees with the committee that underground placement in abandoned mines could pose higher risk since adequate characterization of associated strata, leachate flow paths, and material flows may not be possible.

- Even for abandoned mines, the committee should have had some discussion since potential for beneficial use (acid mine drainage, subsidence control and associated benefits of protecting surface and groundwater resources) is very high.

Discussion-3

- The author believes that environment and health risks associated with surface management of CCBs are much greater than underground placement because of potential of CCBs to contact water, and higher porosity and permeability of host environment. However the committee more or less ignored to discuss this important topical area.

Discussion-4

- There are large number of prescriptive comments and recommendations. Some should be included in the guidance documents rather than part of regulations.
- It is appropriate to have uniform, broad-based SMCRA regulations to minimize differences in interpretation. However, the States should have the flexibility to develop site specific plans and requirements for each permit.
- The agreement between OSM and USEPA to incorporate CCBs-specific regulations into SMCRA regulations is a step in the right direction.
- The USEPA and SMCRA should work with industry to develop regulations that promote CCBs placement in mines and minimize environment and health risks.

Research Needs

- Adsorption characteristics of typical host rocks and soils for different trace elements in mining areas need to be developed and considered in assessing environment and health risk.
- Some of these data need to be incorporated into reactive models.
- Data need to be developed for contaminant transport rates through different host rocks and soils.

Concluding Remarks

- NAS study asserts that management of CCBs in mining areas can be a viable option and should be considered on a site specific basis. That is indeed positive.
- The study has outlined a roadmap for consideration of most of the relevant topics to minimize environmental and health risk in managing CCBs in mining areas.
- There is need now for a team of scientists, engineers, industry professionals and regulators with expertise in CCBs management to develop guidelines for CCBs and site characterization, placement techniques, monitoring and QA/QC that allow for development of acceptable informed health and environmental risk.

Concluding Remarks (contd.)

- Research and development efforts must continue with strong interdisciplinary teams to develop meaningful tools and protocols in different US regions.
- Underground placement of CCBs should be encouraged and guidance for management developed.
- Collaborative efforts between regulatory agencies, industry and research organizations are needed to serve the industry and public.

COMMENTS ON MANAGING COAL COMBUSTION RESIDUES IN COAL MINES

View Presentation

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Columbus, Ohio

Abstract

This paper comments on the recent report by the National Academy of Sciences (NAS) "Managing Coal Combustion Residues in Mines." The report reviewed information on the basic properties of coal combustion residues, transport and possible impacts in the environment, and current regulations and management options with particular reference to placement of CCRs at mine sites. The major overarching conclusion of the report was that "placement of CCR in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material," however, the committee indicated that additional research is needed. With respect to the potential for leaching, the report recommended additional research for developing new laboratory leaching protocols. Lessons learned from the Roberts Dawson project, a full-scale demonstration of the injection of fixated flue gas desulfurization (FGD) into a deep mine, provides insight into the appropriateness of the NAS recommendations. For example, experience with placement of fixated FGD material at the Roberts Dawson mine suggested it may be difficult to develop a predictive leaching methodology for this type of application. The development of numerical models was also recommended in the NAS report, but again the development of such models, especially for abandoned mine sites may be problematic given the extent of hydrologic and chemical data needed to develop truly predictive models. The NAS report also indicated that neutralization may not reduce the concentration of all elements. This latter conclusion was consistent with data obtained at the Roberts Dawson site where the potential for armoring of CCR or mobilization of elements from CCR at very high pH was observed.

Summary of Report

The goal of the National Academy of Science report "Managing Coal Combustion Residues in Mines" report was to examine "the health, safety, and environmental risks associated with using coal combustion wastes (CCW) for reclamation in active and abandoned coal mines." The report covers general information on coal combustion residues (CCRs), behavior of CCRs in the environment, potential impacts from contaminates derived from CCRs, the current regulatory framework, characterization approaches for facilitating the management of CCRs, management of CCRs in reclamation activities, and the use of planning for CCR placement at mine sites. The major overarching conclusion of the report was that "placement of CCR in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material." However, the committee indicated that additional research is needed to "provide more information on the potential ecological and human health effects of placing CCRs in coal mines." The report also notes that enforceable federal standards are needed to regulate the process of CCR placement in mines.

The NAS Report and Lessons Learned from the Roberts Dawson Project

The goal of this paper is to carry out a case study and examine some of the conclusions in the NAS report in light of findings from the Roberts Dawson project (Whitlatch et al. 1999, 2002; Lamminen et al. 2001; Taerakul et al. 2004). At the Roberts Dawson site, fixated flue gas desulfurization material (FGD) was injected into the down-dip portions of an underground mine to seal major seeps exiting the mine and to coat exposed pyretic surfaces. Before and after grouting, extensive groundwater and surface water monitoring was conducted, as well as hydrological data collection and modeling.

A major conclusion of the NAS report was that current leaching methods may not be appropriate to predict the behavior of CCRs in mine environments and that new leaching methods are needed. On page 9, the report states

“The continuous improvement and field validation of leaching tests to better predict the mobilization of constituents from CCR’s in mine settings—specifically, post-placement field studies should be conducted that would allow the comparison of leaching results to detailed water quality monitoring.” The committee also “recommends additional research to continually improve and field-validate leaching tests to better predict the mobilization of constituents from CCRs in mine settings.”

During the Roberts Dawson project, a series of both short-term and long-term laboratory batch leaching tests were carried out to examine the interactions between the fixated FGD and mine drainage water. These studies indicated the potential for the formation of both amorphous and crystalline iron oxide phases on the fixated FGD material. The presence of these solids decreased the neutralization capacity of the material. Over extended leaching periods, it was found that significant weathering of the fixated FGD material occurred, thereby increasing the complexity of the interactions.

Field monitoring data from the site and geochemical speciation calculations demonstrated that significant re-routing of mine drainage waters occurred upon injection of the fixated FGD material. As a result, some areas of the site with accumulated metal salts were exposed to water resulting in the wash out of these materials. Thus, considering the complex precipitation and weathering reactions, as well as the influence of existing solids in the mine voids, it would be extremely difficult to develop a laboratory leaching protocol that would be useful for predictive purposes. However, leaching methods may be useful in understanding particular aspects of the chemistry controlling interactions at a given site.

The NAS committee also made specific comments regarding the role of acid neutralization during the mine placement of CCRs. “The committee concludes that acid neutralization will not reduce the mobility of all contaminants of concern from the CCR.” At the Roberts Dawson site, a number of groundwater wells were installed directly within the fixated FGD material grout. The pH was measured at these different wells and showed various amount of acid neutralization, with pH values ranging from 4.1 to 10.2. For wells with near neutral pH values, significant reductions in most elements was observed. Reduced levels of Fe and Al in these wells suggested that precipitation may have been a major mechanism reducing the levels of elements in these wells. However, one monitoring well showed an increase in pH up to 10.2. In this well, significantly higher levels of arsenic were observed, compared to the levels found in wells with near-neutral pH values. We suspected that at the higher pH, the solubility of arsenic was higher and that metal oxides provided a less effective sink for arsenic. Thus, the NAS conclusion about the role of neutralization is consistent with the findings at the Roberts Dawson site.

In the NAS report, the committee states that “a number of computer models are available for integrating water flow, oxygen transport, and a broad range of geochemical interactions …” but that “these models have not been applied to coal mine sites containing CCRs.” Apparently, the NAS was not aware of the work done as part of the Roberts Dawson project. In addition to water quality monitoring at the Roberts Dawson site, an extensive hydrogeologic model was developed. Numerical models were constructed with three hydrologic layers representing two perched aquifers and water table to predict water movement and chemical fate and transport. The model was calibrated with water levels and chemical data from the site. While the modeling effort provided useful insight into the physical and chemical factors controlling the movement of water and chemical elements at the site, the process of model construction and validation was very time consuming and costly, requiring a large data collection effort. In addition, for abandoned mines, like the Roberts Dawson mine, many areas were not accurately mapped making it difficult to develop a realistic model for the site. Thus, short of a research project, the application of off-the-shelf computer modeling codes for the prediction of chemical transport at CCR mine sites would appear to be unrealistic for many sites where specific site data may be difficult to obtain.

References

Lamminen, M., Wood, J., Walker, H. W., Y.-P. Chin, Y. He, and S. Traina (2001) "Effect of Flue Gas Desulfurization (FGD) By-Product on Water Quality at an Underground Coal Mine", *J. Env. Quality*, 30, 1371-1381.

Taerakul, P., Lamminen, M., He, Y., Walker, H. W., Traina, S. J., and E. Whitlatch (2004) "Long-Term Behavior of Fixated FGD Material Grout in Mine Drainage Environments," *Journal of Environmental Engineering ASCE*, 130(7), 816-823.

Whitlatch, E. E., Bair, E. S., Chin, Y.-P., Traina, S. J., Walker, H. W., and W. E. Wolfe, "Injection of FGD Grout to Mitigate Acid Mine Drainage at the Roberts-Dawson Underground Coal Mine, Coshocton and Muskingum Counties, Ohio: Volume 1: Public Abstract and Executive Summary", Final Technical Report submitted to the Ohio Coal Development Office, State of Ohio, May 3, 1999.

Whitlatch, E. E., Bair, E. S., Chin, Y.-P., Traina, S. J., Walker, H. W., and W. E. Wolfe, "Injection of FGD Grout to Mitigate Acid Mine Drainage at the Roberts-Dawson Underground Coal Mine, Coshocton and Muskingum Counties, Ohio: Volume 10: Public Abstract and Executive Summary, Phase II", Final Technical Report submitted to the Ohio Coal Development Office, State of Ohio, February 15, 2002.

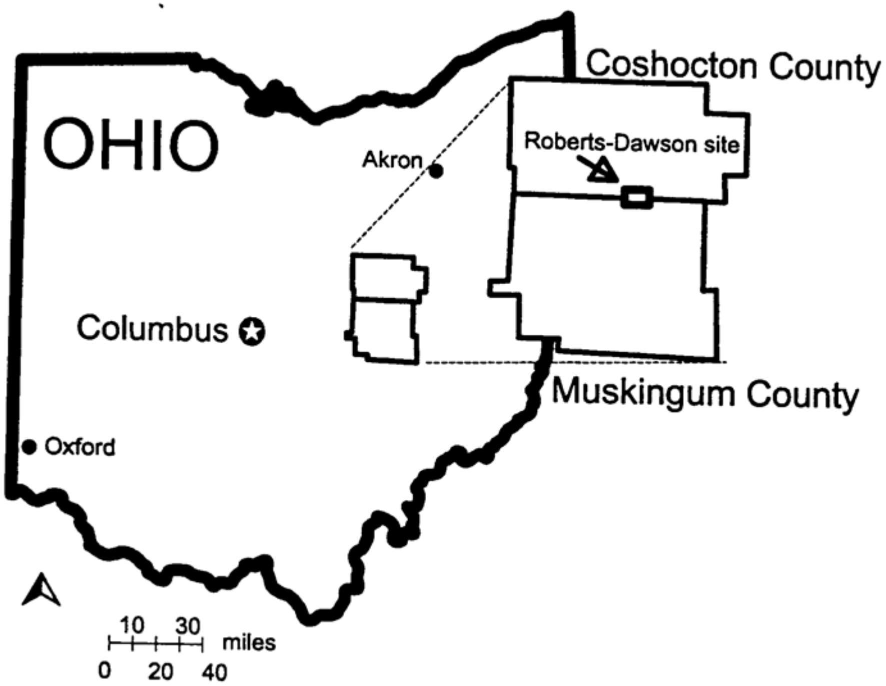
Dr. Harold Walker is an Associate Professor in the Department of Civil and Environmental Engineering and Geodetic Science at Ohio State University. He has spent the last 10 years working on a variety of research projects, from the lab-scale to full-scale, examining the beneficial re-use of coal combustion by-products in a variety of settings. He received his MS and Ph.D. degrees in Environmental Engineering from the University of California, Irvine. He is a registered professional engineer in the state of Ohio.

Comments on *Managing Coal Combustion Residues in Mines*

Harold Walker, Ph.D., P.E.

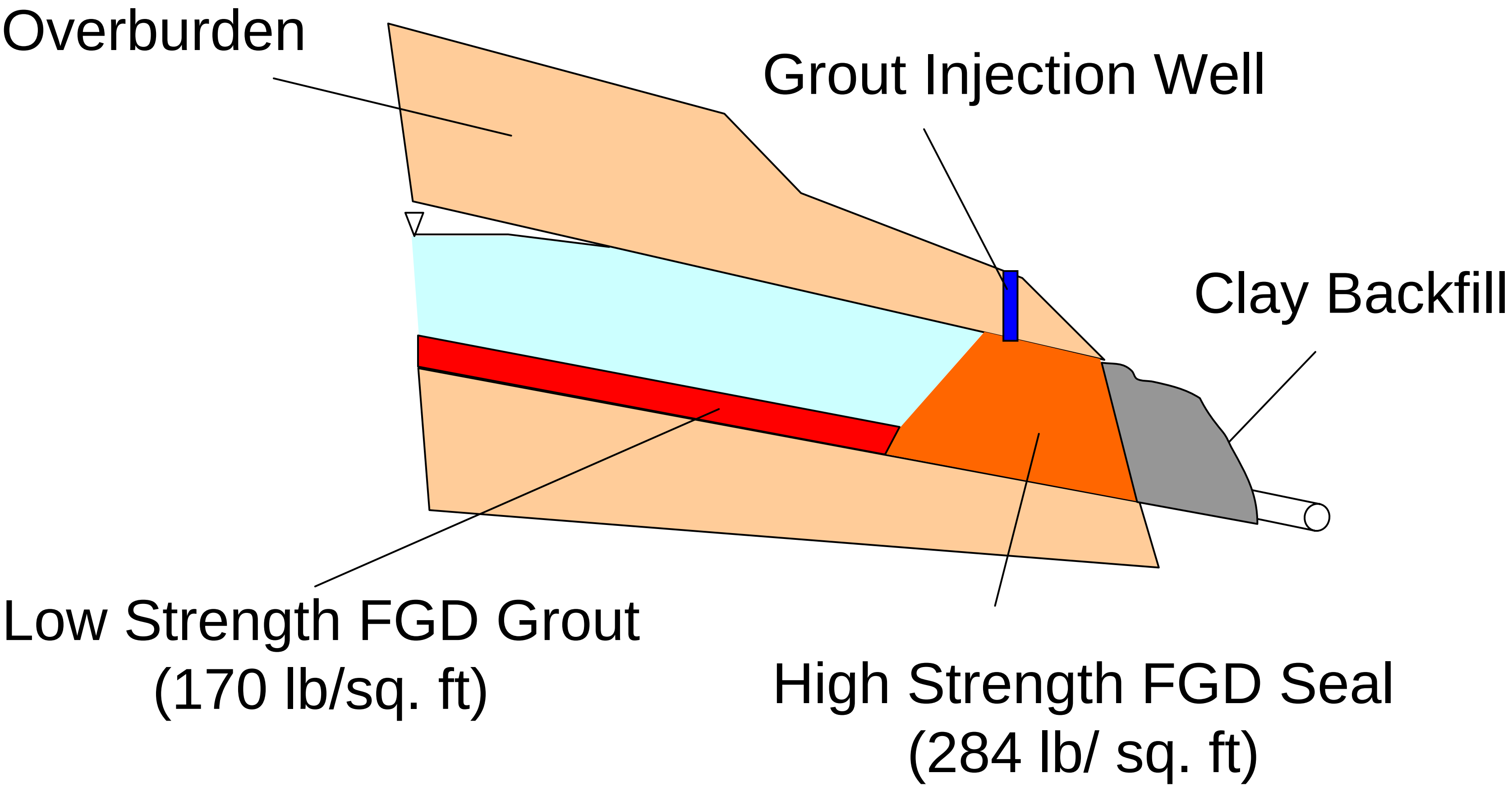
Ohio State University

CCRs at the Roberts Dawson Mine



- 14 acres
- #6 Kittanning Coal
  - 4-7 ft thick
- Closed 1950s
- 2 million cubic feet of coal removed

Fixated FGD Grouting Strategy



Overburden

Grout Injection Well

Clay Backfill

Low Strength FGD Grout
(170 lb/sq. ft)

High Strength FGD Seal
(284 lb/ sq. ft)

FGD Grout Injection

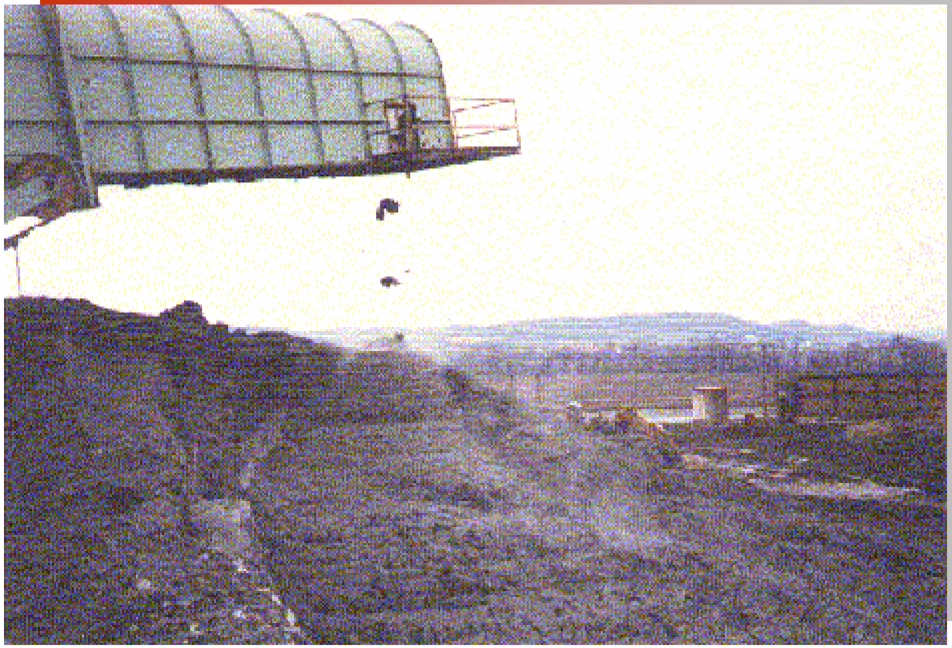
- 109 days of grouting
- 318 vertical grout holes
- ~ 200 took 10 cubic yards or less
- 23,778 cubic yards of FGD grout used
- Pressure grouting of 20 holes in unmapped area

Damian, M. and S. Mafi, Injection and FGD grout to mitigate acid mine drainage at the Roberts Dawson underground coal mine, Coshocton and Muskingum County, Ohio, Volume 5: Grouting operations. Final Technical report, Ohio Coal Development Office, Columbus, Ohio.

Ch. 2. Coal Combustion Residues

- "*The committee concludes that understanding both the characteristics of CCRs and the options for their disposal and use are critical to sound CCR management and that such characteristics and options are highly specific.*"

Fixated FGD Grout Mix



- 1:1.25 FC:FA, ~ 5% Lime
- AEP Conesville
- Coshocton, Ohio
- 1-2 Miles from Mine Project

Laperche, v. and S. Traina, Flue gas desulfurization by-product weathering by acid mine drainage, J. Env. Quality, 28, 1733-1734, 1999.

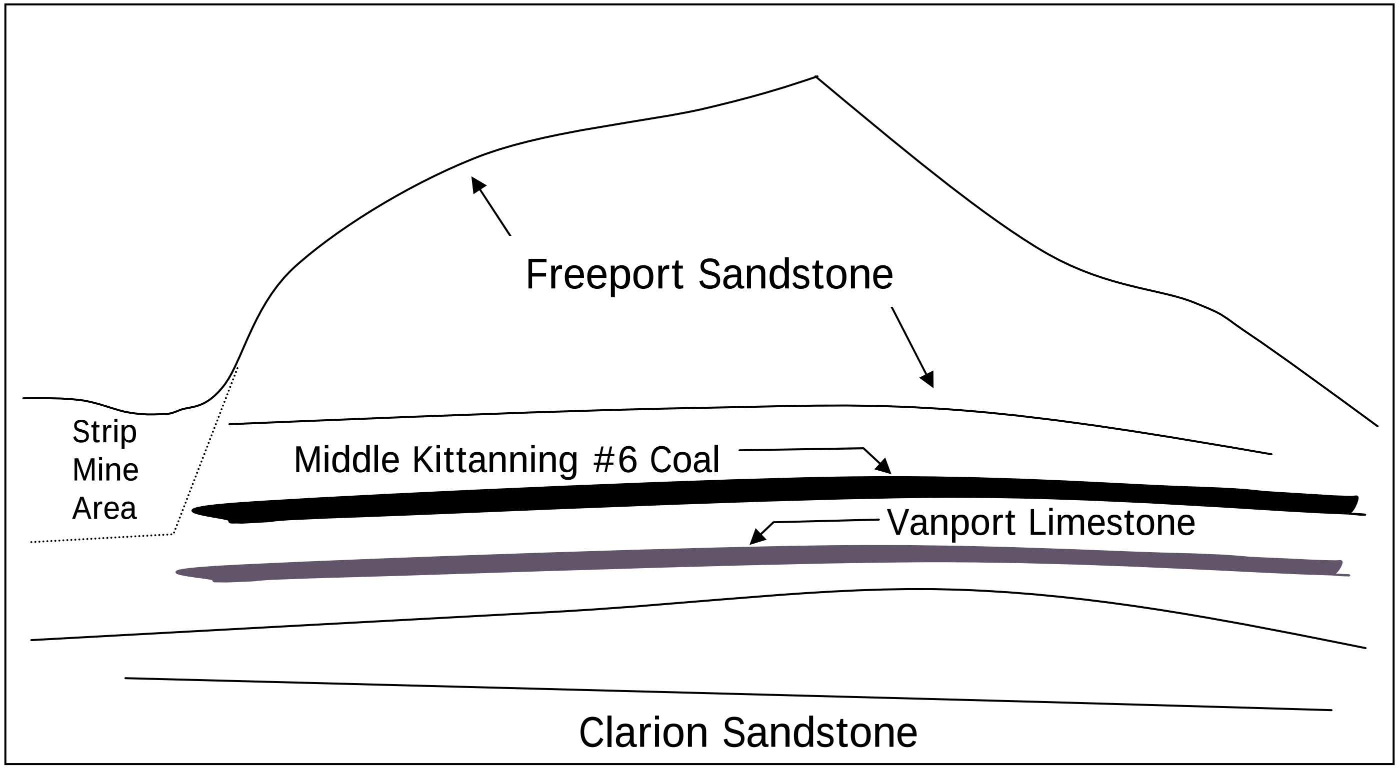
Grout Strength

- High Strength Grout
  - Strength need based on a “blow out” force analysis
  - Design strength need: 145 psi
  - Actual strength was 284 psi
- Lower Strength Grout
  - Design strength needed: 75 psi
  - Actual strength was 171 psi
- Core samples showed strengths significantly above the design strength

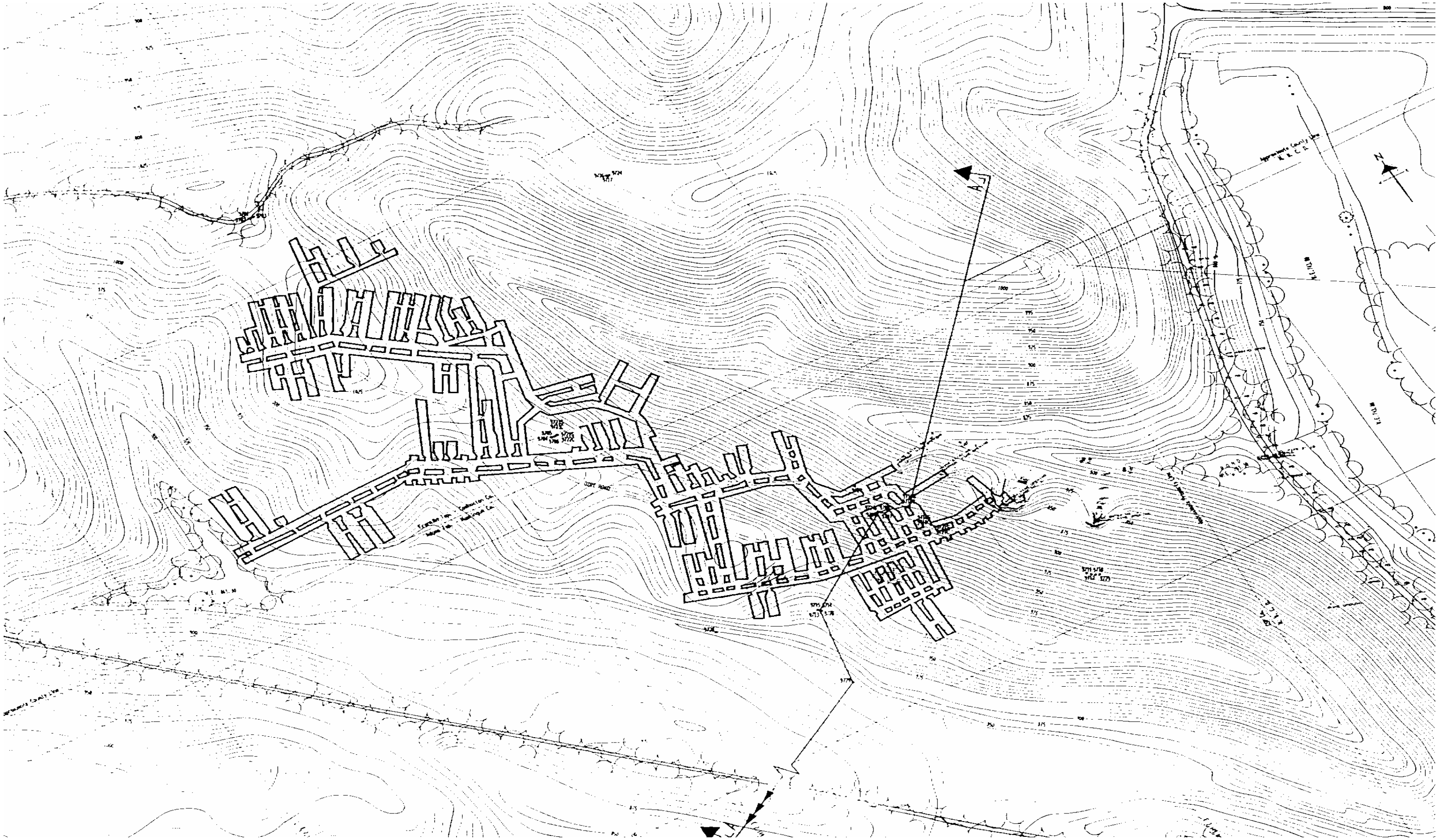
Ch.3. Behavior of CCRs in the Environment

- "*Successful prediction of CCR behavoir in the mine environment requires a thorough understanding of the complex physical and biogeochemical processes that control the release and transport of CCR-derived constituents.*"

Site Geology

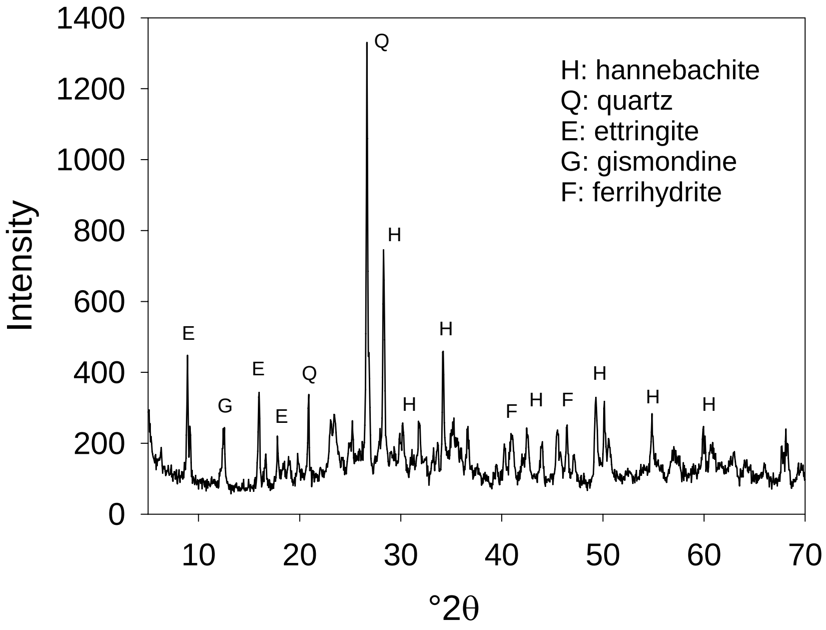


Mapped and Un-Mapped Regions of the Mine

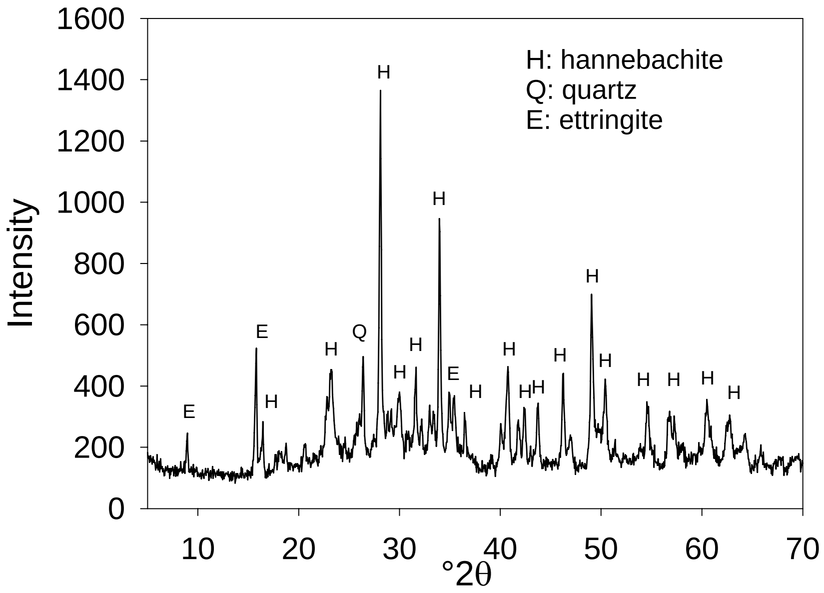


XRD of Grout Core Samples

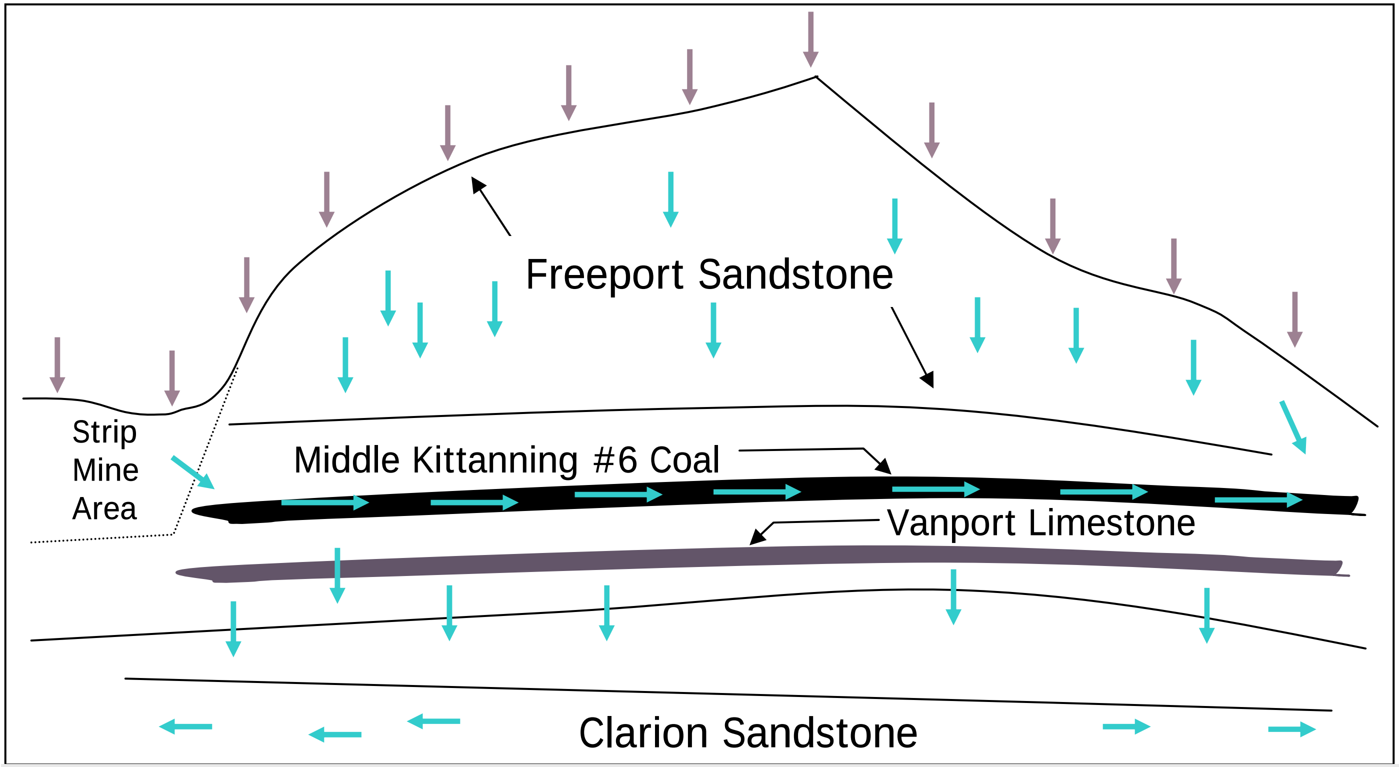
Core 9906



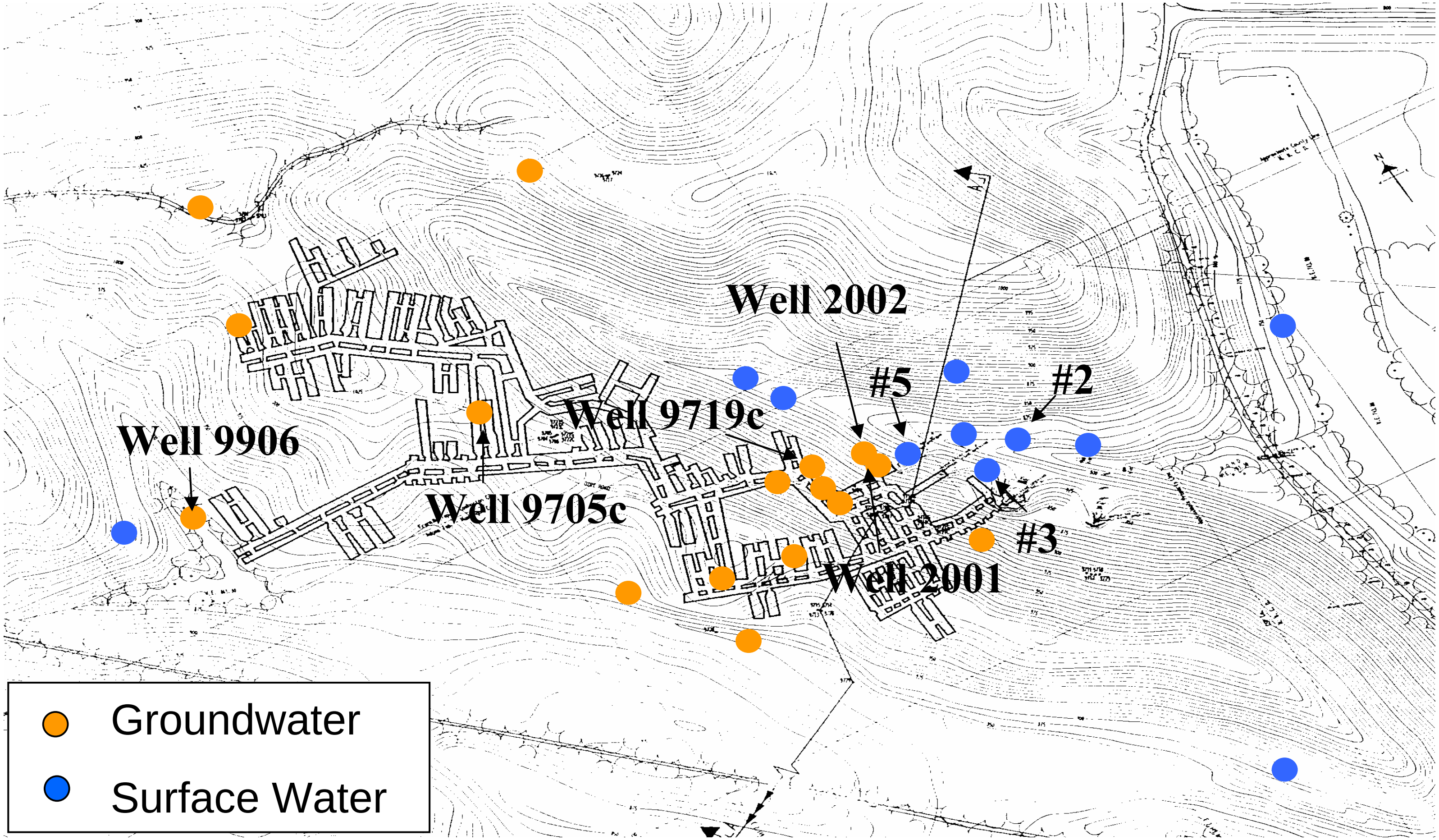
Core 2002



Conceptual Hydrologic Model



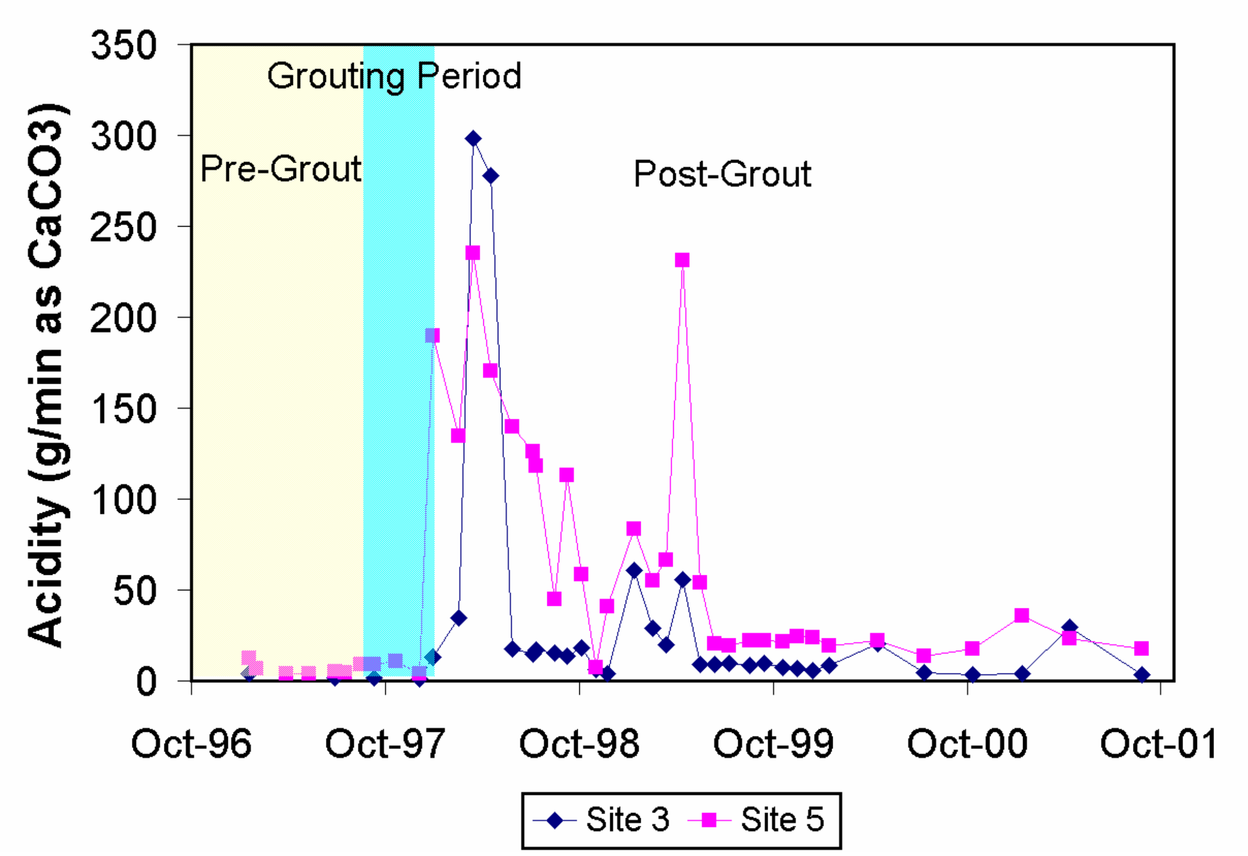
Surface and Groundwater Monitoring Locations



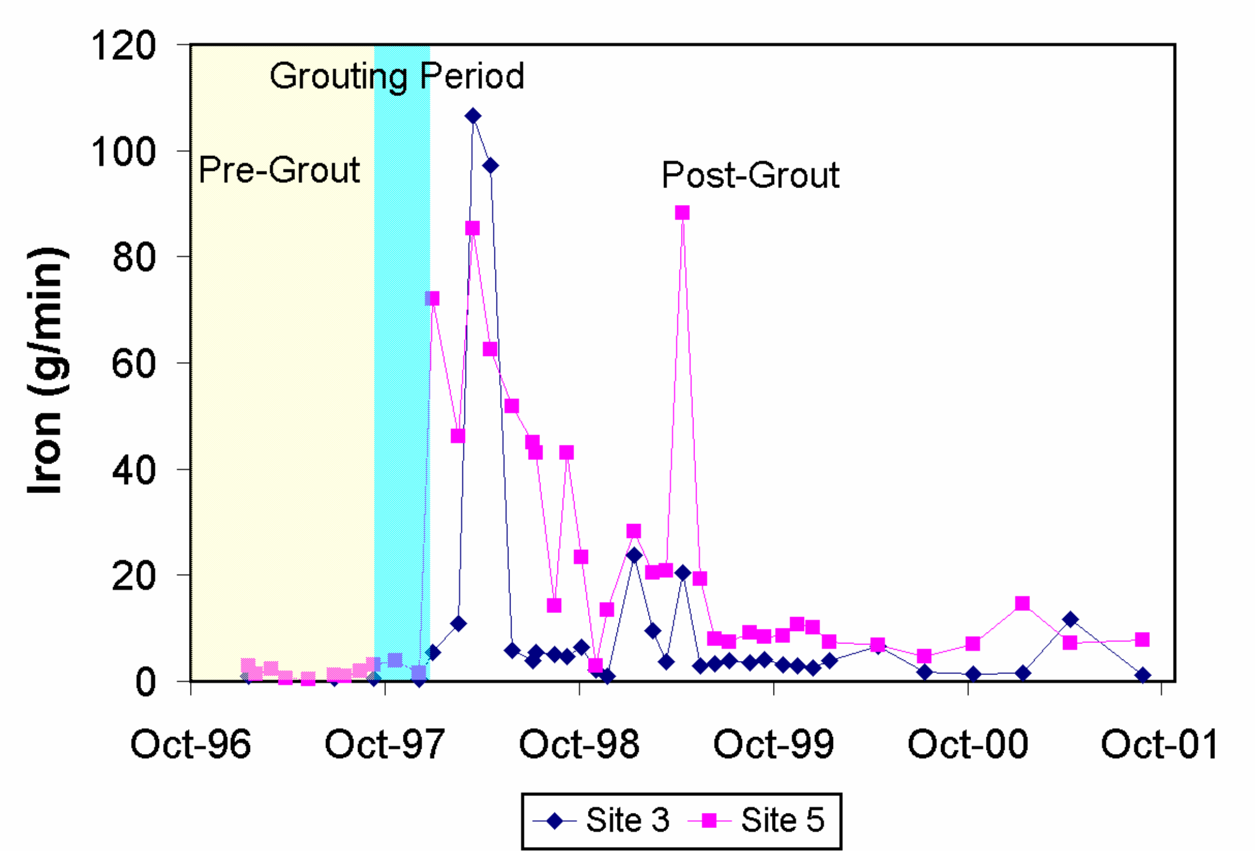
Water Quality Parameters

- Surface water flow rate, groundwater elevation
- pH, Alkalinity, Sulfates, Chloride, Conductivity, TDS
- Metals (Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe,K, Li, Mn, Mg, Na, Ni, P, Pb, Si, Sr, Zn)

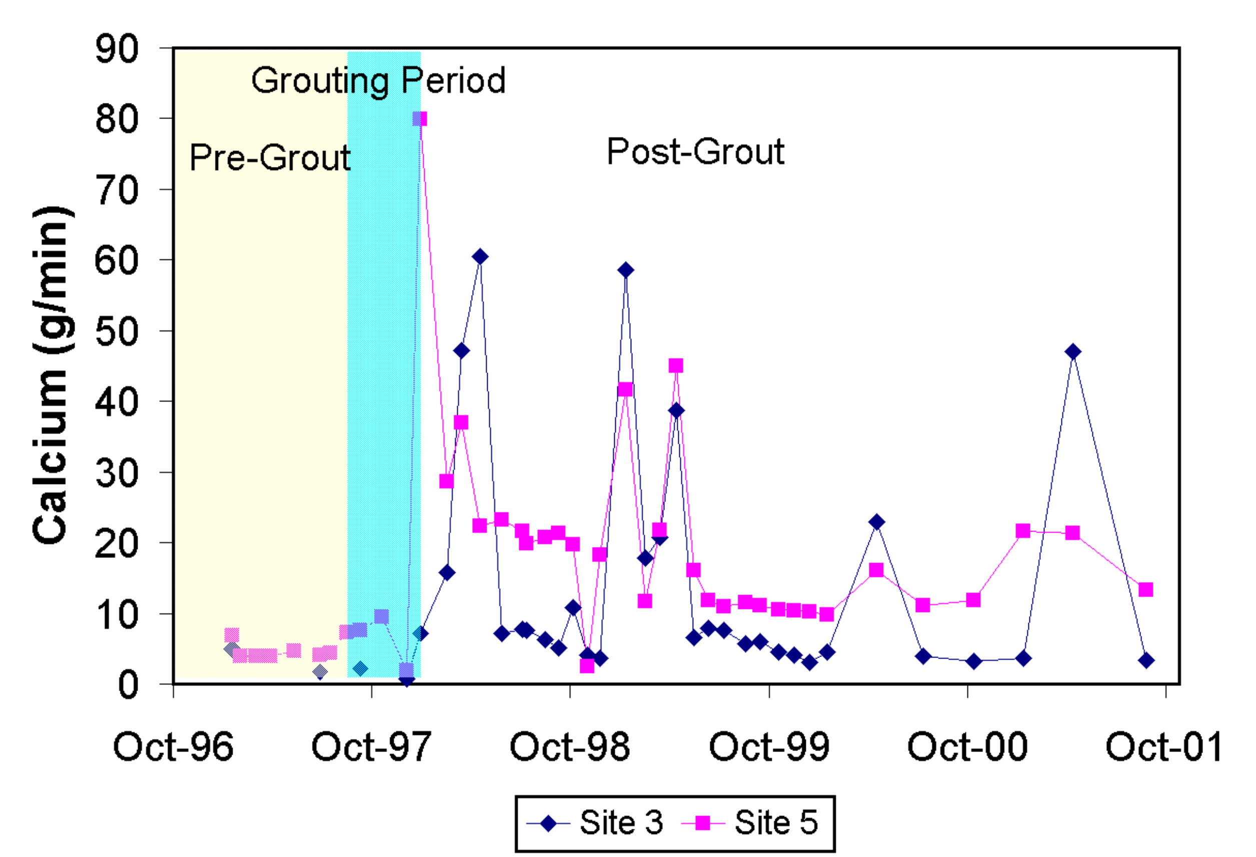
Flux of AMD Constituents, Acidity



Flux of AMD Constituents, Iron



Flux of Grout Constituents, Calcium



Ch.3. Behavior of CCRs in the Environment

- “*The committee concludes that acid neutralization will not reduce the mobility of all contaminants of concern.*”

Water Quality in New Well, 9906

Sampling Date	Apr-00	Jul-00	Oct-00	Jan-01	Apr-01	Sep-01
pH	10.28	9.7	10.4	10.81	10.76	10.57
Alkalinity (mg/L as CaCO3)	163.1	123.4	265.5	360.0	347.8	309.9
TDS (mg/L)	960	1151	1248	1297	1245	1262
Aluminum (mg/L)	1.486	<0.001	1.174	2.167	2.435	1.743
Iron (mg/L)	1.312	0.142	0.024	<0.007	<0.007	<0.007
Calcium (mg/L)	64.0	175.9	70.6	46.8	62.5	58.3
Sulfur (mg/L)	47.2	99.8	77.2	63.1	68.3	67.9
Arsenic (µg/L)	61.0	27.9	63.3	71.6	78.7	64.7

Water Quality in New Well, 2001

Sampling Date	Oct-00	Jan-01	Apr-01	Sep-01
pH	4.82	4.75	4.70	4.40
Alkalinity (mg/L as CaCO3)	2.8	0.0	3.9	0.0
TDS (mg/L)	1224.0	1202.0	731.0	1013.0
Aluminum (mg/L)	4.1	4.4	4.5	8.2
Iron (mg/L)	186.9	189.8	94.2	151.4
Calcium (mg/L)	268.2	214.4	129.8	176.7
Sulfur (mg/L)	451.7	398.4	212.0	340.2
Arsenic (µg/L)	<1	2.1	<1	<1

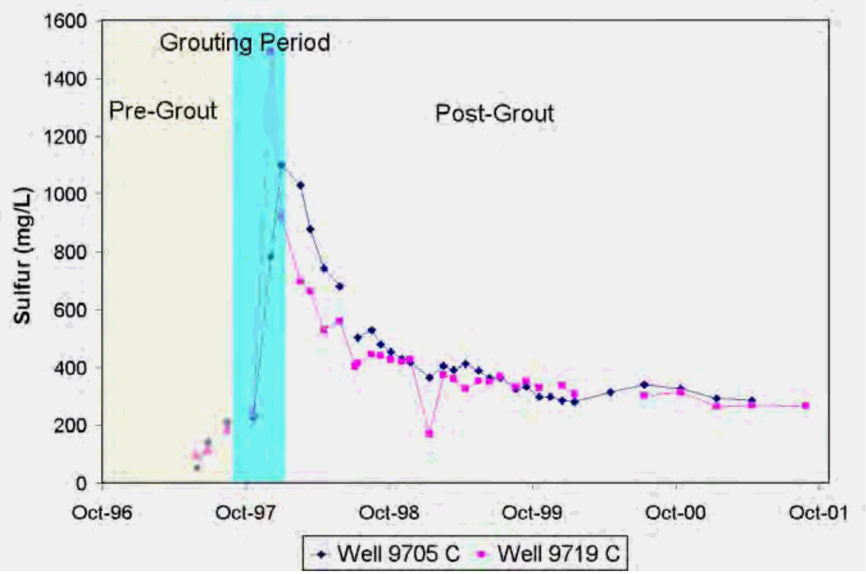
Water Quality in New Well, 2002

Sampling Date	Oct-00	Jan-01	Apr-01	Sep-01
pH	6.30	6.44	5.41	6.67
Alkalinity (mg/L as CaCO3)	12.6	8.1	5.0	9.3
TDS (mg/L)	210	179	327	153
Aluminum (mg/L)	0.0	0.0	0.8	<0.001
Iron (mg/L)	2.4	0.0	25.5	<0.007
Calcium (mg/L)	38.7	24.6	52.2	27.8
Sulfur (mg/L)	42.6	26.4	77.7	29.0
Arsenic (µg/L)	<1	<1	<1	<1

Ch.6. Characterization for CCR Management

- “*The committee concludes that information on the applicability of laboratory leaching test methods to predict CCR leaching behavior in the field is lacking.*”

Solids Controlling the Release of Sulfur



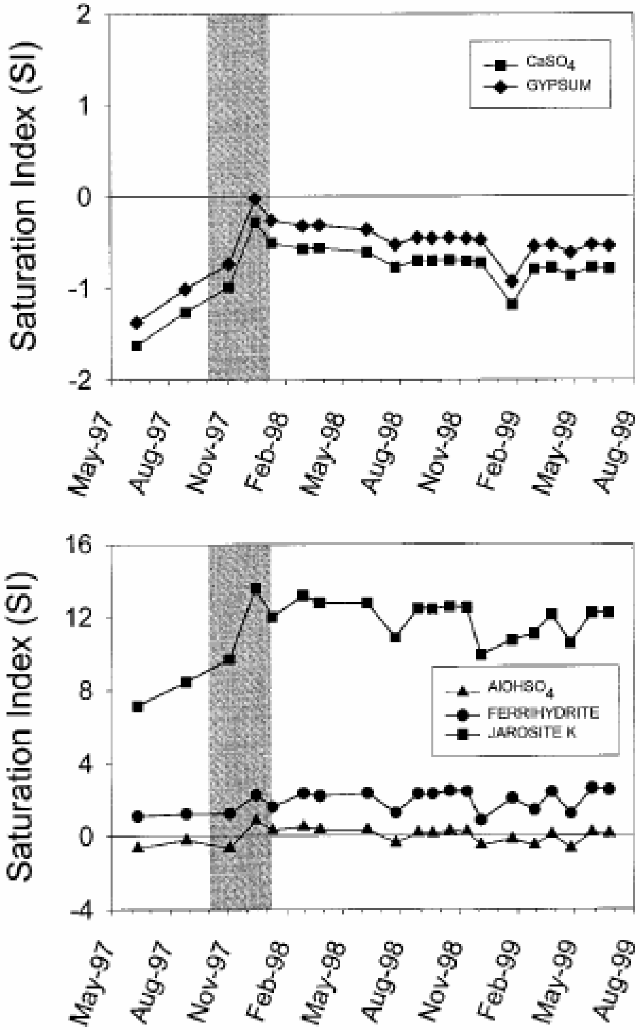


Fig. 6. Saturation indices for $CaSO_4$, gypsum [$CaSO_4 \cdot 2H_2O$], ferrihydrite [$Fe(OH)_3$], jarosite [$KFe_3(OH)_6(SO_4)_2$], and $Al(OH)SO_4$ as a function of sampling date for Well 9719. All calculations were performed using MinteqA2 Version 4.0.

Ch.6. Characterization for CCR Management

- "*Site characterization and CCR characterization data should be thoroughly integrated into a site conceptual model, perhaps supplemented by numerical modeling tools, to predict contaminant transport and assess the potential impacts of CCR disposal at a mine site.*"

Ch.7. Management of CCR in Reclamation Activities

- “*Boron or selenium may be viewed as a good indicator of the presence of CCR-related contaminants in both groundwater and associated downgradient surface water bodies*.”

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- The Ohio State University
- Department of Energy
- Ohio Dept. of Natural Resources
- Dravo Lime Company
- US Army Corps of Engineers
- Office of Surface Mining

Ohio State 24 Michigan 13

A REVIEW OF THE NATIONAL RESEARCH COUNCIL REPORT ON "MANAGING COAL COMBUSTION RESIDUES IN MINES"

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Energy & Environmental Research Center
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View Presentation

Introduction

A review of the National Research Council's (NRC's) report on the management of coal combustion by-products (CCBs) in coal mines (referred to as the NAS Report throughout this document) by industry professionals was undertaken in order to aid industry and the regulatory community in understanding the basis of the findings and conclusions stated in the NAS Report. The technical and scientific areas of the author include ash hydration reactions, ash characterization through chemical means to include leaching and modeling of leaching results to determine the potential for environmental impacts. The author has long been part of a research team that supports the responsible placement of CCBs in appropriate mine settings.

Summary of Key Information in the NAS Report

The NAS Report summarized coal use and CCB production, characteristics, and utilization in order to provide background to the NAS review team.

The NAS Report also summarized information on the behavior of CCBs in the environment including leaching (laboratory studies) and mobility of CCB constituents in the mine setting. These topics are more complex than those of CCB utilization, and the committee indicated that additional research and/or information was needed to better understand the behavior of CCBs in the mine environment. The NAS Report also recommended additional research to provide information on the ecological and human health effects of placement of CCBs in mine settings.

In a review of the regulatory framework, the NAS Report indicated that the Surface Mine Control and Reclamation Act (SMCRA) is broad enough to encompass regulation of CCB placement in mine settings. It is this author's opinion that SMCRA, under the Office of Surface Mining, brings the best knowledge base from which to regulate CCB mine placement.

The NAS Report recommended that leaching procedures be improved to include the use of leaching solutions that take into account the geochemical impacts on water that might contact the CCB in a mine setting, that low-pH solutions and multiple liquid-to-solid ratios and long-term leaching be employed. The NAS Report further suggests that laboratory leaching results be compared to some predetermined criterion, although that criterion or the means to develop it were not suggested. It is also suggested that CCB samples for which leachate data do not meet the predetermined criterion would require additional evaluation. Field validation of leaching tests was also recommended to allow better prediction of the mobilization of constituents from CCBs in mine settings. Additional research on transport models was also recommended.

The NAS Report also addressed items associated with CCBs in reclamation activities, including monitoring, and discussed issues associated with planning for and regulation of CCB mine placement.

Review and Discussion of the NAS Report

Reviewer's Background

A research project to evaluate the appropriateness of placement of fly ash and flue gas desulfurization (FGD) materials in a surface mine setting was performed by the Energy & Environmental Research Center (EERC) from 1978–1986 (Beaver et al. 1987). The conclusions drawn from this study were:

- Utilization of fly ash and FGD material is preferable to disposal, as these materials are valuable resources.
- No exotic elemental species are introduced into the hydrogeologic system associated with the site if the materials are replaced in the approximate same geologic and hydrogeologic setting from which they came.
- In North Dakota, the postmining groundwater in the reestablished aquifer exhibited mineralization that was not associated with the placement of fly ash or FGD materials.
- In North Dakota, natural pH buffering and sediment attenuation resulted in insignificant levels of trace elements measured in sediments adjacent to the location where fly ash and FGD materials were placed.
- It is important to appropriately characterize the site and to design the placement to minimize contact with surface or groundwater.

During the 8-year study, the EERC developed an understanding of the hydration of moderate- to high-calcium fly ash and the impacts of hydration on the mobility of trace elements from fly ash. The EERC has performed numerous studies of the environmental performance of CCBs in the past 25 years, and as a result, has facilitated implementation of improved CCB management practices (Butler et al. 1992; Hassett et al. 2001; Pflughoeft-Hassett et al. 2004).

This background knowledge provides the basis for the reviewer's comments on the NAS Report.

Reviewer's Comments

This reviewer found it unfortunate that the NAS Report guidelines for selecting experts to prepare the report actually precluded the inclusion of any of the individuals who have worked in the area of CCB research and especially CCB placement in mine settings. While the expertise of the NAS panel was broad and included many areas associated with mining and environmental and health risk assessment, many of the individuals that this reviewer and others considered to have the best qualifications on CCBs were not included on the panel because of a potential for a conflict of interest. It is unfortunate that those types of guidelines were imposed. The lack of CCB expertise on the panel was noted in some information included in the NAS report. One example of inadequacy of information in the report was in the brief discussion of CCB utilization, where erroneous statements, including an indication that use of fly ash in cement rather than concrete production was a leading utilization application.

This reviewer suggests that the information in the NAS Report should not be used or cited as sources of information on CCB utilization, and industry should be cautioned to provide more accurate and detailed information to any stakeholders who use this report as a source of information on CCB utilization options.

The NAS Report incorporated a wide range and inclusive set of information appropriate in evaluating the status of CCB management and especially placement in mine settings. However, this author, with his experience in general CCB production, characterization and utilization, and mine placement, noted that many reputable sources of information were not cited in the NAS Report. Many of these documents apparently fell outside the "peer review" process and were not considered for that reason. While this selection process for citations may be applied under guidelines from the NRC and NAS, it is important to note that a peer review is not always a reliable indicator of the validity of technical papers or reports. The formal peer review process does by no means ensure the quality or accuracy of data but provides a prepublication editorial format by persons that may or may not have a personal bias. Additionally, a number of publications that were not used in the NAS Report information summaries were reviewed by qualified individuals even though it may not have been under the formal peer review process. The panel may have drawn some of its conclusions about the level of research that still needs to be performed in order to accomplish placement of CCBs in mine settings in an environmentally appropriate manner in part because the information available to them was limited by the criteria that required only the inclusion of peer review documents.

Conclusions

The NAS Report findings were consistent with previous EERC research conclusions regarding placement of CCBs in mine settings, and the conclusions overall indicated that mine placement of CCBs requires caution but can likely be used as one means of managing CCBs. Unfortunately, even though the NAS report drew conclusions similar to those drawn from an early EERC mine placement study, it did not provide any guidance about placement of CCBs in mine sites as an approved beneficial use. This reviewer believes that the scientific evidence supports the conclusion that CCB placement in mine sites should generally be considered as beneficial use.

References

Beaver, F.W., Groenewold, G.H., Manz, O.E., Hassett, D.J. *The Effects of Fly Ash and Flue Gas Desulfurization Wastes on Groundwater Quality in a Reclaimed Lignite Strip Mine*; Final Report for U.S. Department of Energy Contract Nos. DE-AC21-80FC10230 and DE-AC21-80FC10120; Energy & Environmental Research Center: Grand Forks, ND, 1987.

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Pflughoeft-Hassett, D.F., Dockter, B.A., Hassett, D.J., Heebink, L.V.; Solc, J., Buckley, T.D. *Demonstration of Coal Ash for Feedlot Surfaces*; Final Report; EERC Publication 2004-EERC-02-10; Energy & Environmental Research Center: Grand Forks, ND, Feb 2004.

David J. Hassett is a Senior Research Advisor at the Energy & Environmental Research Center (EERC) of the University of North Dakota. He also serves as the Fuels Analyst for the State of North Dakota. Mr. Hassett's principal areas of interest and expertise include the application of analytical chemistry to address environmental issues associated with trace element occurrence, transport, and fate; coal combustion by-product (CCB) management; groundwater quality; and air quality. Additional areas of expertise include interaction between groundwater and CCBs as related to the leachability of trace elements and hydration reactions of CCBs. He has extensive laboratory experience, is a member of several professional organizations, has authored or coauthored over 300 publications, and holds a patent entitled "Enhanced Ettringite Formation for the Treatment of Hazardous Liquid Wastes." He received his BS in Chemistry and Mathematics from Winona State University in Winona, Minnesota, in 1966 and continued with graduate studies in Chemistry from 1970 to 1975.

EERC

EERC Technology… Putting Research into Practice

Thoughts on the NRC Report

Office of Surface Mining Responses
to the National Academy of Sciences
Final Report: A Technical Interactive
Forum

November 15, 2006

David Hassett

NAS Review Process vs. OSM Review Panel

NAS Review	OSM Review Panel
14 members	7 members
Varying environmental expertise/credentials	Varying environmental expertise/credentials
Limited CCB expertise	Extensive CCB expertise
Months of work	Years of work

Discussion on Trace Elements

- Most trace elements were described in terms of their toxicity rather than noting the essential nature of key trace elements associated with CCBs.

Discussion on Trace Elements

- Most of the text dealing with trace elements imposes traditional thinking regarding fate and transport. The trouble with this, is that in the case of alkaline ash, hydration reactions may go on for more than a year and can affect trace element solubility through secondary hydrated phase formation. This must be considered.

Leaching

- There still is a belief among the committee members that a leaching test can be developed that will mimic the environment.
- They got the need for long term leaching right but for the wrong reasons and with no understanding of ash hydration reactions.

Summary

- CCB’s placed at mine sites should not be considered disposal unless that’s what it is.
- Caution needs to be used in looking at literature as the state of knowledge is changing.

Summary

- Long-term research on CCB placement and associated impacts is needed to compliment what is already underway.
- Regulatory guidance is also needed to avoid the potential to make every mine placement project a research project.
- OSM is the appropriate authority to develop guidance.

EERC
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NATIONAL ACADEMY OF SCIENCES MINE FILL REPORT: CRITICAL EVALUATION OF RECOMMENDATIONS FOR FUTURE RESEARCH

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View Presentation

Abstract

All scientific effort should be judged against expectations and resources consumed in their production. The National Research Council (NRC) report was well endowed with both. The NRC report dated March 2006 took roughly a year and over one million dollars to prepare. From this, one would expect an exceptionally thorough report both with respect to acquisition of data and quality of analysis. However, the committee quickly came upon several serious problems that stem from the lack of a strong research base:

- Un-systematic characterization of Coal Combustion By-Products (CCB),
- Spotty monitoring of CCB application sites,
- Inconsistent, if any, analysis of monitoring results,
- Little understanding of the interactions among CCB, mine spoil, and groundwater,
- Effects of CCB on improvement or further degradation to existing, polluted mine water.

Thus, the committee was limited by historic data shortfalls. There has been very little funding available to undertake research into the environmenal effects of CCB minefills. Much of the research was initiated in response to the Environmental Protection Agency's (EPA) 2000 Report to Congress and much of that research is still in the early stages. It is likely that the committee has spent several times over in one year what has been invested in CCB minefill research over the past ten years. It is not surprising, therefore, that we have a very expensive report that identifies a lack of fundamental understanding of the interactions among groundwater, CCBs, and mine spoil and then repeats a well-known list of research needs.

Lacking direct evidence, the committee then refers to non-analogous CCB disposal sites in flood plain gravels, impoundments and other non-mine settings. As a result, the report consists of a superficial appreciation of the issue, generalities, and obvious conclusions. Nevertheless, the conclusions, while obvious, would find agreement among most knowledgeable practitioners.

Key findings of the report:

- Many damage cases involving non-mining CCB landfills or impoundments were identified.
- Not a single damage case related to CCB minefills was found.
- Regulation of CCB minefills should remain with OSM, not EPA through EPA/Resource Conservation and Recycling Act (RCRA) as subtitle C or D wastes.
- OSM should develop national standards that mainly focus on pre-CCB placement site characterization, better leaching tests, post placement monitoring and environmental performance standards.
- Main contaminants of concern (based on CCB landfills and impoundments) are boron, selenium, and arsenic.
- Environmental risks would be mitigated by disposal above the groundwater table, decreasing the permeability of the CCB mass and better characterization of its leaching potential.

The paper will evaluate the key conclusions as they relate to the techical appreciation of the CCB minefill issue, risk reduction, and research needs.

Current Status of CCB Issues

Although the report brings out the lack of compelling evidence that CCB mine filling is safe, there is also no evidence that it is unsafe. I would agree with the report's findings that there is inconsistent and incomplete performance documentation. There are some mining situations that are very well monitored and understood and others that aren't. There certainly seems to be a lack of criteria and standards. I don't know how many times I have heard testimony that a certain substance has increased by 200%. When on closer investigation, it was found to have changed from an insignificant level to an insignificant level times two. That a substance has increased by 200% is not the standard but it is the sort of language that gets the attention of the politicians and the press.

Although most states require TCLP/SPLP screening of the CCB materials for the potential to produce toxic leachate, the shortcominings of these tests for accurately predicting leachate potential in the field are well known. Mines are required to perform routine water monitoring but it is not readily available or in the scientific literature. For the last several decades, the impact of CCB placement at mines has not been a priority for research. The Department of Energy Combustion Byproducts Recyling Consortium (CBRC) has funded a number of projects that are part of the scientific literature. The Office of Surface Mining has initiated its applied science funding support beginning in 2005. There has never been developed, however, a national reseach and development strategy for this issue. In the absence of strong scientific literature, anecdotal or inferential evidence is used by both sides.

NAS Research Recommendations

NAS suggested a research initiative, identified topic areas, and suggested improved monitoring and monitoring protocols that I would agree with.

The NAS identified three research needs:

- document the effects of placement method and geologic setting on improving or degrading groundwater;
- predict soluble contaminant transport through the environment (i.e.groundwater and surface waters); and
- develop improved laboratory methods that will predict environmental performance.

Specific NAS research recommendation included *(in italics)*:

- *The committee recommends that research be conducted to provide more information on the potential ecological and human health effects of placing CCRs in coal mines.*
- *Specific attention in such a research program should be directed at improved understanding of the following:*
  - *The environmental behavior of CCR at mine sites, including differing climatic and geologic settings, so that the types of mine settings, CCRs, and placement techniques most protective of human and ecological health can be identified.*
  - *This research should include studies to determine under what conditions CCRs can effectively ameliorate the adverse effects of acid mine drainage (AMD) in surface waters, particularly over protracted time scales.*
  - *This research should also include the application of existing* ***reactive transport models*** *to CCR mine placement sites to evaluate whether the transport and reaction processes in the model adequately describe the processes taking place at CCR mine disposal sites, including those processes that occur over protracted time scales.* Many mine sites and particularly the surrounding strata have heterogenous flow paths. Heterogenous flow paths make it extraordinarily difficult if not impossible to resolve critical parameters such as residence time, solid/liquid contact and ultimately chemical equillibria. You might do a reasonably good job when looking at flow through a fairly homogenous spoil with a shallow gradient as illustrated by Dr. Murarka at the Universal mine in Indiana. However, many spoils promote channelling and as the hydraulic gradients increase, there will be a relatively thin saturated zone along the pit floor with the bulk of the spoil subject to vadose zone hydraulics. So, we must make sure that any proposed water quality modeling is grounded in reality or we are going to waste huge amounts of money developing models that are not useful.

- *The potential ecological and human health effects of placing CCR in coal mines. This program should include studies to clarify the fate and transport of contaminants from CCRs and the potential for human exposure from contaminated drinking water.*
- *Include studies to determine the effects (or lack thereof) on biological communities over protracted time scales in mine placement sites where nearby streams or wetlands are likely to be connected to groundwater.*
- *The continuous improvement and field validation of leaching tests to better predict the mobilization of constituents from CCRs in mine settings*
- *Specifically, post-placement field studies should be conducted that would allow the comparison of leaching test results to detailed water quality monitoring.*

CBRC Research Recommendations

The CBRC has been working on a national research strategy since the summer of 2006. The CBRC believes a strategic research effort is needed to address the outstanding technical questions related to mine fills. In addition, we need a technically capable body to manage the research program and to interpret the results and make sure that the results get to the right regulatory agencies.

Capabilities and Role of the Combustion By-Products Recycling Consortium

The Combustion Byproducts Recycling Consortium (CBRC) is the logical organization to lead this research effort. The consortium has a strong record of managing CCB research through a partnership consisting of state, industry, and federal participation. Following is a summary of CBRC's organization and capabilities.

The mission of the Combustion Byproducts Recycling Consortium (CBRC) is to develop and demonstrate technologies to address issues related to the recycling of these byproducts. By 2010, the CBRC hopes to:

- increase the overall ash utilization rate from the current 34% to 50%,
- increase the current rate of flue gas desulfurization by-products use,
- increase the number of uses considered allowable under state regulations, and
- examine the environmental impact of by-product use and disposal.

To meet these goals, the CBRC provides seed money to researchers to develop innovative applications for coal combustion by-products while ensuring their economic and environmental viability.

The Combustion Byproducts Recycling Consortium (CBRC) was initiated in 1998 to provide national focus for development of beneficial uses for the products of coal combustion. CBRC promotes and supports the commercially viable and environmentally sound recycling of coal combustion byproducts for productive uses through scientific research, development, and field testing. The CBRC is funded by the U.S. Department of Energy–National Energy Technology Laboratory (DOE-NETL) and collaborating companies. Over the past eight years, $5,973,861 in U.S. DOE-NETL funds have been matched by $4,775,313 industry dollars in 52 projects.

CBRC is managed by the West Virginia Water Research Institute at West Virginia University with regional management by Southern Illinois University, the University of North Dakota, and the University of Kentucky. Within each region, teams of technical experts from industry and government have developed research priorities and, annually, rank proposals for funding. A national steering committee consisting of senior federal, state, and industry representatives provides program direction and project selection.

Thirty-seven of the fifty-two funded projects have been completed and project final reports containing project results can be found on the CBRC web page at: http://wvwri.nrcce.wvu.edu/programs/cbrc.

Program Goals

Develop analytical tools that will provide agencies, the public and the industry the assurance that CCB mine fills will be conducted economically and in such a way as to benefit ground and surface water while protecting the public health.

Specific goals include:

1. Identification of CCB placement methods that minimize risks and maximize benefits.
2. Development of tools that will predict the transport of contaminants via groundwater.
3. Development of predictive tools that will identify high and low risk CCB applications for specific geologic settings.

Program Strategy

Oversight:	USDOE/NETL
Management:	CBRC model for topic identification, procurement, program management, accountability.
Governance:	Subcommittee of the CBRC National Steering Committee.
Project Selection:	Requests for pre-proposals would be issued by CBRC based on the priority topics identified by NAS and refined by CBRC. Selection would be per the existing CBRC process and managed in conjunction with the regional CBRC centers.
Cost Share:	A minimum 25% non-federal cost share would be required.

Tasks:

1. Identification of CCB placement methods that minimize risks and maximize benefits. Identify key controlling variables:
   a. CCB source and type
   b. Water flux rate: CCB permeability
   c. Geologic setting: spoil and surrounding rock permeability, sorption capacity
   d. Contaminant leaching rate from CCB: from leaching test
   e. Groundwater setting: Pre-placement groundwater quality, saturated/fluctuating/unsaturated
   f. Receptor proximity
   g. Develop criteria for field validation trials
2. Development of tools that will predict the transport of contaminants through groundwater.
   a. Evaluate and select contaminant transport model
   b. Quantify effect of flux rate
   c. Quantify effect of retardation rate
   d. Quantify sorption/precipitation chemistries
   e. Develop criteria for field validation trials
3. Leaching tests: development of predictive tools that will identify high and low risk CCB applications for specific geologic settings. How will a specific CCB react with a specific groundwater?
   a. Characterization data needs from a leaching test
   b. Evaluate existing leaching tests
   c. Select subset for further development, standardization and field validation
4. Field validation.
5. Develop conclusions.

Schedule:

Year	Task 1	Task 2	Task 3	Task 4	Task 5
1	1a,b,c,d,e,f,	2a	3a		
2	1g	2b,c,d,e	3b,c		
3				4	
4				4	
5					5

Funding: $1.5m/year for five years.

Output

The program would provide the lead regulatory agency, OSMRE as well as USEPA and the states with the technical information to evaluate and develop mine filling policy options that will be responsive to environmental, health, and safety issues. The results would be available to the public via web site as well as in the form of written reports. Workshops would be held annually to update stakeholders on progress and to gain input on ongoing research direction.

What This Might Look Like

Hypothetical Risk Categories

Risk Factor	High (5)	Medium (3)	Low (1)
GW velocity (V)	V >10-3 cm/sec	10-6<V<10-3 cm/sec	V<10-6 cm/sec
Saturation (s)	saturated	fluctuating	unsaturated
CCB hyd cond (k) (cm/sec)	k>10-3	10-6<k<10-3	k<10-6
GW pH (pH)	pH > 6	4 < pH < 6	pH < 4
CCB buffering (NNP)	NNP < 1%	1%< NNP < 5%	NNP >5%

Risk = R(V) + R(s) + R(K) + R(pH) + R(NNP)

Hypothetical Risk Values

greater than or equal to:	Risk Value	less than
5	low	11
12	medium	18
19	high	25

Dr. Paul Ziemkiewicz is the Director, National Mine Land Reclamation Center, West Virginia University and the West Virginia Water Research Institute since 1988 and 1991 respectively. Previously he directed the reclamation research program in coal and oil sand mining for the Alberta Government's Department of Energy. He also served on Alberta's regulatory review committee and served as the research manager of the Province's coal technology research program. Dr. Ziemkiewicz has over 80 publications on the topic of mine land reclamation, acid mine drainage, and coal ash application in mines. He received a BS and MS from Utah State University in Biology and Range Ecology respectively. He then received a Ph.D. from the University of British Columbia in Forest Ecology in 1979.

NAS Mine Fill Report:

Critical Evaluation of Recommendations for Future Research

Paul Ziemkiewicz, Director

Combustion Byproducts Recycling Consortium
West Virginia University

Today’s Situation

- Concerned citizens and politicians
- Lack of compelling evidence that CCB mine filling is safe
- No evidence that it is unsafe
- Inconsistent/incomplete performance documentation
- Lack of criteria and standards

How Did We Get Here? Uncertainty

- TCLP/SPLP screening
- Routine monitoring
- Not a priority for research
- In the absence of strong scientific literature, anecdotal or inferential evidence is used by both sides

Available Options

- NAS suggested a research initiative
- Identified topic areas
- Also suggested improved monitoring

CBRC's Recommendation

- A strategic research effort is needed to address the outstanding technical questions related to mine fills

- In addition, we need a technically capable body to manage the research program and to interpret the results

NAS Indicated Three Research Needs:

1. Document the effects of placement method and geologic setting on improving or degrading groundwater.
2. Predict soluble contaminant transport through the environment: groundwater and surface waters.
3. Develop improved laboratory methods that will predict environmental performance.

Specific Recommendations

- *The committee recommends that research be conducted to provide more information on the potential ecological and human health effects of placing CCRs in coal mines.*
- *Specific attention in such a research program should be directed at improved understanding of the following:*

NAS Recommendation #1

- *The environmental behavior of CCR at mine sites, including differing climatic and geologic settings, so that the types of mine settings, CCRs, and placement techniques most protective of human and ecological health can be identified.*

- *Excellent!*

NAS Recommendation #1 (cont.)

- *This research should include studies to determine under what conditions CCRs can effectively ameliorate the adverse effects of acid mine drainage (AMD) in surface waters, particularly over protracted time scales.*

- *Excellent!*

NAS Recommendation #1 (cont.)

- *This research should also include the application of existing reactive transport models to CCR mine placement sites to evaluate whether the transport and reaction processes in the model adequately describe the processes taking place at CCR mine disposal sites, including those processes that occur over protracted time scales.*
- *These systems are dominated by heterogenous flow pathways.*
- *Unless grounded in reality this is an excellent way to waste another couple million dollars.*

NAS Recommendation #2

- *The potential ecological and human health effects of placing CCR in coal mines*

- *We already have MCLs for all of the potential contaminants from CCBs.*
- *Use or adapt RCRA risk-based approach to compare pre and post-CCB placement human health and environmental risks.*
- *Requires prediction of contaminant concentrations and exposure pathways.*

NAS Recommendation #2 (cont.)

- *This program should include studies to clarify the fate and transport of contaminants from CCRs and the potential for human exposure from contaminated drinking water.*

- *Use RCRA risk-based approach*
- *We already discussed fate and transport modeling*

NAS Recommendation #2 (cont.)

- *Include studies to determine the effects (or lack thereof) on biological communities over protracted time scales in mine placement sites where nearby streams or wetlands are likely to be connected to groundwater.*

- *Use RCRA risk-based approach. It includes human health risk and ecological risk.*

The RCRA Approach: Equations for the Derivation of Benchmarks for Groundwater

$$GwSTL=(Dr/Tr) \times ATV$$

- Where:
  - – GwSTL = Mean groundwater screening threshold limit (mg/L)
  - – Dr = Groundwater discharge rate (L/day)
  - – Tr^1 = Surface water turnover rate (L/day)
  - – ATV^2 = Aquatic Toxicity Value (mg/L)

1. If the surface water body is a creek or river, then substitute the mean flow volume (l/day) for the turnover rate.
2. If available, use the appropriate ecological ambient water quality criteria. Otherwise, use the lowest TRV for all aquatic receptors of concern associated with the site.

NAS Recommendation #3

- *The continuous improvement and field validation of leaching tests to better predict the mobilization of constituents from CCRs in mine settings*

- *Specifically, post-placement field studies should be conducted that would allow the comparison of leaching test results to detailed water quality monitoring.*

- *10-4!!*

A Research Program to Address Outstanding Questions:

The Combustion Byproducts Recycling Consortium's Suggestion

Program Goals

- Develop analytical tools that will provide agencies, the public and the industry assurance that CCB mine fills will be conducted economically and in such a way as to benefit ground and surface water while protecting the public health.

Developing an R&D program:

- Outcome: Technical guidance for regulatory agencies and industry that will lower the risk and improve the environmental performance of CCB mine fills

Developing an R&D program:

Objectives:

1. Identify ecological and human health effects
2. Improved site characterization
3. Improved monitoring protocols
4. Improved prediction methods
    1. Long-term leaching behavior
    2. Movement of contaminants through groundwater

Strategy:

1. Identification of CCB placement methods that minimize risks and maximize benefits.
2. Development of tools that will predict the transport of contaminants via groundwater.
3. Development of predictive tools that will identify high and low risk CCB applications for specific geologic settings.

Task 1: Identify best practices and quantify key controlling variables:

1. Classify CCBs according to their chemical and physical properties,
2. Classify placement methods
3. Classify site characteristics
4. Identify how they interact so that managers can minimize risk and maximize benefits.

Task 1 (cont.): Identify best practices and quantify key controlling variables:

1. CCB source and type
2. Water flux rate: CCB permeability
3. Geologic setting: spoil and surrounding rock permeability, sorption capacity
4. Contaminant leaching rate from CCB: from leaching test
5. Groundwater setting: Pre-placement groundwater quality, saturated, fluctuating or unsaturated
6. Receptor proximity

Task 2: Develop tools that will predict the transport of contaminants through groundwater.

1. Identify what data a model should provide
2. Identify and evaluate existing models
3. Identify chemical interactions with groundwater
4. Quantify effect of groundwater flux rate
5. Quantify effect of spoil retardation rate
6. Quantify sorption/precipitation chemistries
7. Develop criteria for field validation trials

Task 3: Identification of leaching tests that will predict high and low risk CCB applications in specific hydro-geologic settings.

1. Identify what data a leaching test should provide
2. Evaluate existing leaching tests
3. Select subset for further development, standardization and field validation

Task 4: Field Validation

1. Develop monitoring protocol
2. Develop evaluation criteria
3. Select candidate sites/time scales
4. Monitor and evaluate
5. Translation of laboratory leaching results to field results

Task 5: Final Report

- Documentation
- Develop conclusions
- Develop recommendations for regulatory agencies
- Technology transfer

How this Might Ultimately Look:

Remember MRAM?

Risk Factor	high (5)	medium (3)	low (1)
GW velocity (V)	$V > 10^{-3}$ cm/sec	$10^{-6} < V < 10^{-3}$ cm/sec	$V < 10^{-6}$ cm/sec
Saturation (s)	saturated	fluctuating	unsaturated
CCB hyd cond (k) (cm/sec)	$k > 10^{-3}$	$10^{-6} < k < 10^{-3}$	$k < 10^{-6}$
GW pH (pH)	$pH > 6$	$4 < pH < 6$	$pH < 4$
CCB buffering (NNP)	NNP < 1%	1%< NNP < 5%	NNP >5%

$$Risk = R(V) + R(s) + R(K) + R(pH) + R(NNP)$$

Hypothetical Risk Categories

Risk = R(V) + R(s) + R(K) + R(pH) + R(NNP)

greater than or equal to:	and	less than:
5	low	11
12	medium	18
19	high	25

Questions?

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A TECHNICAL REVIEW OF THE FINAL REPORT OF THE NATIONAL ACADEMY OF SCIENCES "MANAGING COAL COMBUSTION RESIDUES IN MINES"

View Presentation

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Abstract

On March 1, 2006, the National Research Council released to the public its final report by the National Academy of Sciences "Managing Coal Combustion Residues (CCRs) in Mines." Based on the news release of the National Academy of Sciences (NAS), putting coal ash back into mines for reclamation is a viable option for disposal, as long as precautions are taken to protect the environment and public health. The report also acknowledged that CCRs could serve a useful purpose in mine reclamation, lessen the need for new landfills, and potentially neutralize acid mine drainage. The report recommends development of enforceable federal standards that give the states authority to permit the use of CCRs at mines but allows them to adopt requirements for local conditions.

The report lists 40 findings or recommendations under 12 categories. This paper addresses these findings on a case by case basis to evaluate their merits against the extensive record of data and scientific studies on the subject. The NAS has chosen to use the term "Coal Combustion Residues" where OSM has historically used the term "Coal Combustion By-Products." The terms are interchangeable. The author is in agreement with the NAS findings that support: (1) the use of these materials in mine reclamation; (2) the need for specific federal regulations under the Surface Mining Control and Reclamation Act of 1977 (SMCRA) that spells out the minimum permitting, bonding, and environmental performance standard requirements when they are placed on active coal mines; (3) the research priorities to specifically address the hydrogeologic fate of CCBs and any leachate generated by those CCBs in relation to public health and environmental quality; and (4) to develop mining appropriate leachate tests. A limitation of the report is in its inability to: (1) acknowledge the profound differences between regulatory environments that control placement of CCBs at mines; (2) evaluate available ground water monitoring data and scientific research within the context of the applicable regulatory environments; and (3) acknowledge the volumes of scientific studies and state regulatory data that shows no degradation of water quality due to placement of CCBs at SMCRA mines for the last 29 years. The following review is strictly the opinion of the author and carries no institutional endorsement.

Introduction

On March 1, 2006, the National Research Council released to the public its final report by the National Academy of Sciences "Managing Coal Combustion Residues in Mines." The study was in response to a request from Congress and was initiated in June of 2004. The study was to determine whether CCRs were placed and disposed of in coal mines with inadequate safeguards and whether this activity is degrading water supplies in coal mines in contravention of SMCRA. The study was sponsored by the Environmental Protection Agency (EPA). The NAS committee looked at the placement of coal combustion residue (CCR) in abandoned and active, surface and underground coal mines in all major coal basins. A profile of the utility industry was taken into consideration in designing the study to focus on the sources producing the greatest quantities of coal combustion wastes.

The committee's efforts focused on coal combustion residue from utility power plants and independent power producers, rather than small business, industries, and institutions. The committee examined regulatory structures and the interaction of programs under EPA's jurisdiction and the Surface Mining Control and Reclamation Act (SMCRA) implemented by the Office of Surface Mining (OSM) in partnership with States. The committee held six public meetings around the country between October 2004 and August 2005, and visited field sites related to their inquiry.

NAS Statement of Task

Specifically, the committee addressed the following points:

1. The adequacy of data collection from surface water and groundwater monitoring points established at Coal Combustion Residue (CCR) sites in mines.
2. The impacts to aquatic life in streams draining CCR placement areas and the wetlands, lakes, and rivers receiving these drainages.
3. The responses of mine operators and regulators to adverse or unintended impacts such as the contamination of ground water and pollution of surface waters.
4. Whether CCRs and the mine they are being put in are adequately characterized for such placement to ensure that monitoring programs are effective and groundwater and surface waters are not degraded. (This item is not explicitly in the NAS statement of task but is there implicitly.)
5. Whether there are clear performance standards set and regularly assessed for projects that use CCR for "beneficial purposes" in mines.
6. The status of isolation requirements and whether they are needed.
7. The adequacy of monitoring programs including:
   a. The status of long-term monitoring and the need for this monitoring after CCR is placed in abandoned mines and active mines when placement is completed and bonds released.
   b. Whether monitoring is occurring from enough locations;
   c. Whether monitoring occurs for relevant constituents in CCR as determined by characterization of the CCR; and
   d. Whether there are clear, enforceable corrective actions standards regularly required in the monitoring.
8. The ability of mines receiving large amounts of CCR to achieve economically-productive post mine land uses.
9. The need for upgraded bonding or other mechanisms to assure that adequate resources are available for adequate periods to perform monitoring and address impacts after CCR placement or disposal operations are completed in coal mines;
10. The provisions for public involvement in these questions at the permitting and policy-making levels and any results of that involvement;
11. Evaluate the risks associated with contamination of water supplies and the environment from the disposal or placement of coal combustion residues in coal mines in the context of the requirements for protection of those resources by Resource Conservation and Recovery Act (RCRA) and SMCRA.

A Technical Analysis of the NAS Findings and Recommendations (NRC, 2006)

The following analysis follows the format of the NAS findings *(in italics)* as they appear in the final report followed by a discussion of the technical merit of those findings.

1. <u>Conclusion</u>
   a. *The committee believes that placement of CCR in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material.*

      Agree.

2. <u>Value of existing CCR data and information</u>
   a. *The two most common CCR disposal options, surface impoundments and landfills, provide insights into the types of issues that can emerge when the soluble constituents of CCRs are not contained within the waste management system.*
   b. *Although disposal conditions may differ substantially from mine settings, landfills and surface impoundments are useful for understanding the specific conditions under which CCRs can potentially impact humans and ecosystems. The EPA has identified numerous cases of water contamination related to CCR landfills and surface impoundments that, in many cases, have caused considerable environmental damage. In some landfill settings, groundwater has been degraded to the point that drinking water standards were exceeded off-site. In other landfills and surface impoundments, contamination of surface waters has resulted in considerable environmental damage; in the most extreme cases, multiple species have*

experienced local extinctions. Such cases are instructive because these impacts can be clearly related to CCR disposal, and they help guide the selection of mining environments for CCR placement that are most protective of human and ecological health.

c. *… the committee's review of literature and damage cases recognized by EPA supports the EPA's concerns about proper management of CCRs.*

d. *As of 2005, EPA had recognized 24 proven damage cases involving CCR landfills and surface impoundments. One CCR coal minefill is under investigation as a potential damage case by EPA.*

The following comments address findings 2.a. through d.

The author would disagree with the NAS' use of data from landfills and impoundments as an indicator of CCB leachate characteristics of a SMCRA mine. Conditions at SMCRA mines are substantially different (See pp. 7-9 in Vories, 2002).

Electric Utility CCB Disposal Facility

Electric utility disposal sites where toxic leachates have occurred are typically characterized by:

- geographic placement in a floodplain;
- a geologic setting of alluvial sand and gravel usually close to a river;
- ground water that is plentiful and of high quality;
- all types of fossil fuel wastes are placed in these facilities in a wet slurry without any chemical characterization of the material;
- reclamation is accomplished with a shallow layer of fill over the area and revegetated; and
- the Clean Water Act usually covers the area during operation and State Solid Waste regulations at disposal (Figure 1).

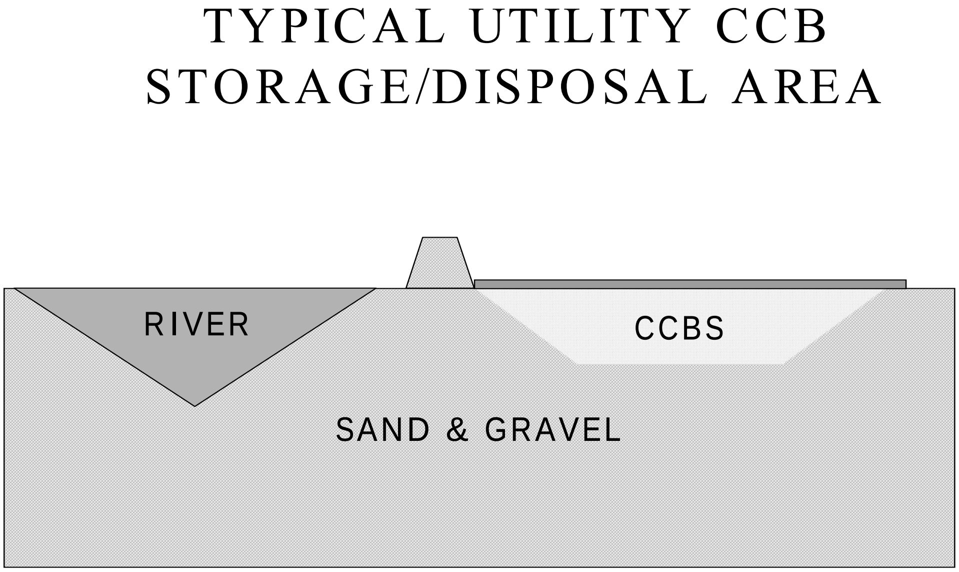

Figure 1. Typical cross-section of an electric utility disposal site where toxic leachate has occurred.

SMRCA Mine Site CCB Placement

CCB placement at mine sites typically is characterized by:

- a geographic placement in an upland position;
- a geologic setting of bedrock sandstone, shale, and limestone underlain by an impermeable fire clay below

the lowest coal seam that was mined;

- groundwater is limited and of poor quality;
- only those CCBs that are leachate tested and approved in the SMCRA permit are allowed for placement on the mine site;
- reclamation is accomplished with a deep layer of spoil over the area followed by topsoil and then revegetated; and
- at all phases, the placement is regulated by the environmental protection permitting and performance standards of SMCRA (see discussion under 5.a.), which include the requirements of the Clean Water Act and applicable State Solid Waste Programs requirements (Figure 2).

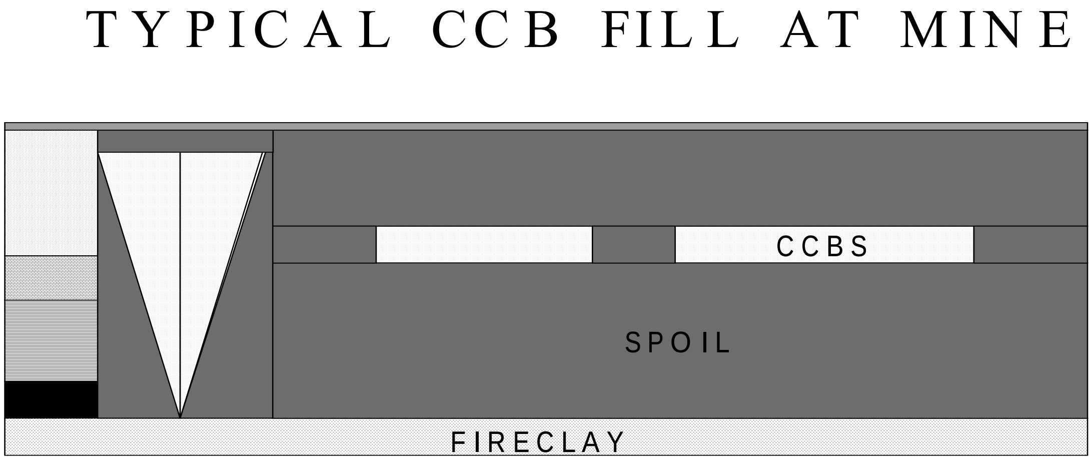

Figure 2. Typical cross-section of CCB placement at a reclaimed coalmine site.

The data from EPA damage cases associated with leachate into ground water from historic landfills where disposal was unregulated is not relevant to SMCRA mines. Data from these sites are characterized by the lack of: (1) knowledge of all of the types and quantities of wastes that were disposed in addition to coal ash; and (2) a permitting process to require (a) characterization of the wastes, (b) characterization of the site; (c) determination of impact to the hydrology, and (d) establishment of a waste specific water quality monitoring program.

In any scientific investigation, it is essential that you establish how a set of data is representative of a given population. If the NAS is to use data from non-SMCRA landfills and impoundments as a substitute for water quality data from SMCRA mines then it is up to NAS to demonstrate how this data is representative of leachate characteristics of CCB placement on SMCRA mines.

e. *….comparatively little is known about the potential for mine-filling to degrade the quality of groundwater and/or surface waters particularly over longer time periods.*

f. *…there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessment difficult.*

g. *Currently, there are very few data available to directly indicate that placement of CCRs in abandoned or active coal mines is either safe or detrimental.*

The author has found that there is a substantial body of evidence that CCB placement at active coal mines permitted under SMCRA have not caused detrimental effects to the environment or public health as evidenced by extensive research done by: (1) the U.S. Department of Energy's (DOE) Combustion By-Products Recycling Consortium; (2) the DOE researchers at the National Energy Technology Laboratory; (3) the Energy and Environment Research Center at the University of North Dakota; (4) the Center of Applied Energy Research at University of Kentucky; (5) The University of Ohio; (6) Southern Illinois University Carbondale; (7) Penn State University; (8)West Virginia University; and (9) CCB scientists and mining experts who wrote 134 articles published in six technical interactive forum proceedings by the Office of Surface Mining over the period 1996 to 2005.

2. Potential Impacts
   a. *Of the three methods currently available for disposal of CCRs (surface impoundments, landfilling, and minefilling), comparatively little is known about the potential for minefilling to degrade the quality of groundwater and/or surface waters particularly over longer periods. Additionally, there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessments difficult.*

      All SMCRA permitted mines are required to conduct ground and surface water quality monitoring to protect the hydrologic balance, the existing water users, and to comply with all state and federal water laws and regulations as stated earlier. In the 29 years of SMCRA, there has been no documentation of proven EPA damage cases on SMCRA mines. The author is unaware of any State Regulatory Authority quarterly water monitoring data recording damage to a drinking water supply or damage to a surface aquatic ecosystem. All of this data has been reviewed by EPA and was offered to the NAS. This represents a substantial quantity of data that shows no degradation of water quality.

   b. *The committee concludes that the presence of high contaminant levels in many CCR leachates may create human health and ecological concerns at or near some mine sites over the long term.*

      These concerns could be addressed by the research priorities identified by the NAS.

3. CCR Disposal and Use Options
   a. *The committee recommends that secondary uses of CCRs that pose minimal risks to human health and the environment be strongly encouraged.*

   Agree.

   b. *With regard to CCR placement in minefills, the committee concludes that while potential advantages (beneficial use) should not be ignored, the full characterization of possible risks should not be cut short in the name of beneficial use.*

4. CCR Characterization
   a. *In order to contribute to evaluation of the risk of placing CCRs at mine sites, the committee recommends that CCRs be characterized prior to significant mine placement and with each new source of CCRs. CCR characterization should continue periodically throughout the mine placement process to assess any changes in CCR composition and behavior.*

      In order to address the concern for uniformity among the states to maintain minimum environmental protection standards for placement of CCBs at SMCRA mines, the Office of Surface Mining has committed to writing specific federal rules that would address the minimum permitting, environmental performance requirements, and bonding of CCB placement at SMCRA mines.

   b. *The committee suggests some simple improvements to current leaching protocols. In particular, the CCR characterization methods used should provide contaminant leaching information for the range of geochemical conditions that will occur at the CCR placement site and in the surrounding area, both during and after placement. Samples that exceed pre-determined leaching criteria should be rejected for mine placement, although samples that meet the criteria may still need additional evaluation depending on the potential risks of CCR placement determined from the site characterization.*

      The author agrees that there is a need for mining appropriate leachate tests standardized and endorsed by either EPA or a third party technical institution like the American Society of Testing Methods (ASTM). It is the responsibility of the permit applicant to demonstrate that the operational handling plan, reclamation plan, and monitoring program provide sufficient technical support so that the State Regulatory Authority can make the finding that all SMCRA water quality performance standards will be met. The State Regulatory Authority must determine whether certain leachate criteria must be met in order to ensure that the SMCRA water quality performance standards can be met. Because of the broad range of climatic and geologic settings and mining technologies where these materials are placed, the author believes that general statements like "*Samples that exceed pre-determined leaching criteria should be rejected for mine placement"* ignore the need for state specific expertise and responsibility for determining the measures necessary to meet SMCRA performance standards.

5. Site Characterization
   a. *Current site characterization requirements of SMCRA focus on assessing the potential impacts of coal mining and reclamation but do not specifically address the impacts of CCR placement. The committee recommends that comprehensive site characterization specific to CCR placement be conducted at all mine sites prior to substantial placement of CCRs.*

Neither SMCRA nor the OSM regulations, specifically address the use or disposal of the by-products of electric power generation at surface coal mines. However, when the use or disposal of coal combustion by-products happens at surface coal mines, state coal mining regulators are involved to the extent that SMCRA requires:

1. the mine operator to ensure that all toxic materials are treated, buried, and compacted, or otherwise disposed of, in a manner designed to prevent contamination of the ground or surface water;
2. making sure the proposed land use does not present any actual or probable threat of water pollution; and
3. ensuring the permit application contains a detailed description of the measures to be taken during mining and reclamation to assure the protection of the quality and quantify of surface and groundwater systems, both on and off-sites, from adverse effects of the mining and reclamation process also to assure that rights of present users of such water are protected (Henry 1996).

All SMCRA permits are required to demonstrate how all aspects of mining and reclamation (including any associated CCB placement) will meet SMCRA environmental performance standards. A separate impact assessment for CCB placement is not required, because it can not be excluded from the comprehensive site specific characterization, operations plan, reclamation plan, and water quality monitoring plan already required by SMCRA. Each permit application must include a description of the existing, pre-mining environmental resources within the proposed permit area and adjacent areas that may be affected or impacted by the proposed surface mining activities. The permit application must include the following information upon which the mining and reclamation plan must be based:

- General Environmental Resources Information including the cultural, historic, and archeological resources, 30 CFR §779.12. (2005)
- Climatic Information, 30 CFR §779.18.
- Vegetation Information, 30 CFR §779.19.
- Soils Resource Information, 30 CFR §779.21.
- Maps: General Requirements, 30 CFR §779.24.
- Cross sections, maps and plans, 30 CFR §779.25.
- Fish and Wildlife Resources, 30 CFR §779.16.
- Hydrologic Information, 30 CFR §780.21, (including flood plains, critical receptors such as water wells, dams, streams, water intake structures, and wetlands) including:
  - Sampling and Analysis methodology
  - Groundwater and surface water baseline information
  - Cumulative impact area information
  - Modeling or statistical analysis may be required
  - Alternate water sources
  - Probable Hydrologic Consequences (PHC)
  - Cumulative Hydrologic Impact Assessment (CHIA)
  - Hydrologic reclamation plan
  - Surface and Groundwater monitoring plan

- Geologic Information, 30 CFR §780.22, including:
  - All potential acid and toxic forming strata to just below coal seam
  - Description of the geology (Detailed guidance is given in the OSM Permitting Hydrology reference including structural geologic features such as folding and faulting, strike and dip, and joints and fractures related to fault areas, seismic impact zones, and unstable areas) in the proposed permit and adjacent areas down to just below the coal seam or any lower aquifer impacted by mining. The description shall include the area and structural geology of the permit and adjacent areas, and other parameters which influence the required reclamation and the occurrence, availability, movement, quantity, and quality of potentially impacted surface and ground water based on information collected in 30 CFR 779 and:
    - Geologic literature. The geologic information is based on the following:
    - Analysis of samples collected from test borings and drill cores down to just below the coal seam or to the lowest aquifer affected by mining.
    - Logs showing the lithologic characteristics of each stratum and related ground water.
    - Chemical analysis of any acid, alkaline, or toxic strata including total and pyretic sulfur.
    - The regulatory authority may require additional information necessary to protect the hydrologic balance or meet the performance standards.

6. <u>CCR Use in Reclamation</u>

a. *The disposal of CCRs in coal mines occurs under highly variable conditions, ranging from small quantities to massive minefills, from arid to wet regions, from remote to semiurban locations, from surface to underground mines, and from active to abandoned mines. Thus, the committee endorses the concept of site-specific management plans, including site-specific performance standards.*

Concerning the recommendation for "*site-specific management plans, including site-specific performance standards,"* the author agrees that this is important. All SMCRA permits require site-specific operations plans, reclamation plans, revegetation plans, and water quality monitoring plans. Incorporation of specific CCB regulations into the SMCRA regulations as committed to by OSM will reinforce the existing protections of SMCRA.

b. *Given the known impacts that can occur when CCRs react with water in surface impoundments and landfills, special attention should be paid in reclamation operations to the interactions of water with CCRs. Specifically, the committee recommends that CCR placement in mines be designed to minimize reactions with water and the flow of water through CCRs. Such methods include:*
(1) placement well above the water table
(2) compaction (in lifts)
(3) cement ation (cement addition)
(4) use of impermeable liners, and
(5) use of low-permeability covers.

As stated in 2.d. above, the author has demonstrated the non-representative nature of data from surface impoundments and landfills.

The report recommends methods "*designed to minimize reactions with water and the flow of water through CCRs"* of "*(1) placement well above the water table; (2) compaction (in lifts); (3) cementation (cement addition); (4) use of impermeable liners; and (5) use of low-permeability covers.*" These methods are RCRA requirements for solid waste land fills and may or may not have applicability to SMCRA permits. Under SMCRA, it is the responsibility of the permit applicant to demonstrate that the operational mining and spoil handling plan, reclamation plan, and water quality monitoring program provide sufficient technical support so that the State Regulatory Authority can make the finding that all SMCRA water quality performance standards will be met. In each SMCRA permit, the regulatory authority will have to assess the physical/chemical characteristics of the CCBs to be placed, the hydrogeologic setting of the mine, the mining and reclamation plan, and the water quality monitoring plan in order to determine the safety and appropriateness of the application.

7. *Post Reclamation Water Quality Monitoring*
   a. *Based on its reviews of CCR post-placement monitoring at many sites visited during the course of the study, the committee concludes that the number of monitoring wells, the spatial coverage of wells, and the duration of monitoring at CCR minefills are generally insufficient to accurately assess the migration of contaminants.*
   b. *The committee found quality assurance and control and information management procedures for water quality data at CCR mine placement sites to be inadequate.*
   c. *The committee believes that a more robust and consistent monitoring program is needed in situations involving CCR mine placement. The committee recommends that the number and location of monitoring wells, the frequency and duration of sampling, and the water quality parameters selected for analysis be carefully determined for each site, in order to accurately assess the present and potential movement of CCR-associated contaminants.*
   d. *Although monitoring plans should be site-specific, downgradient wells should be sited with an understanding of the travel times for contaminants to reach these monitoring points.*
   e. *Depending on the individual site characteristics and the distances to downgradient wells, a longer duration of groundwater monitoring may be necessary at some sites to adequately assess the temporal release of contaminants, which can occur over several decades. To address these concerns, several monitoring points should be established along predicted flow paths that will yield early (prior to bond release) information that can be used to confirm predicted CCR leachate transport.*
   f. *At least one well or lysimeter, and preferably two, should be placed directly in the CCR to assess the field leaching behavior and confirm predicted contaminant flux.*
   g. *As part of the monitoring plan, quality assurance and control plans should be developed prior to CCR placement with clearly defined protocols for sampling and analysis, for data validation, and for managing systematic errors in analytical procedures.*

The post reclamation water quality monitoring concerns cited in the report make no distinction as to the regulatory program of the sites visited under the course of the NAS study. These sites included: (1) active coal mines (SMCRA Title V); (2) abandoned coal mines (SMCRA Title IV); (3) disposal in a coal mine final pit that has been released from SMCRA as an industrial area and is regulated under a State RCRA program; (4) abandoned coal mines under a State Regulatory Program other than SMCRA; and (5) unregulated waste dumps that were not in coal mines.

Under SMCRA, a groundwater monitoring program should be done against a backdrop of site-specific background data. For that reason, extensive information is required on the hydrologic and geologic conditions of a proposed permit site. This information involves existing wells, seasonal rainfall amounts, stream flows, groundwater levels and other items that can be used in modeling and predicting impacts to the permit area and adjacent areas during and after mining. This is the (PHC) part of the permit document. The regulatory authority, as part of the process, is then required to develop a cumulative hydrologic impact assessment (CHIA).

The information collected allows determination of a site-specific monitoring plan for ground water and surface waters. Rather than using a “one size fits all” approach that may under sample one permit while over sampling another, the monitoring program can fit the site and the situation as known.

All known factors are required to be included in the PHC determination and the CHIA. Therefore, CCB placement as minefill is required in the analysis with adjustments to ground water monitoring on a site-specific basis.

SMCRA References: 30 CFR (2005)
Part 777.15 – Completeness of Application
Parts 779.11, 783.11 – Environmental Resources
Parts 779.18, 783.18 – Climatological Information
Parts 779.21(a), 783.21(a) – Soil Resources
Parts 779.24, 783.24 – General Features
Parts 779.24(g), 786.24(g) – Surface Water Movement

Parts 779.25(a)(6), 783.25(a)(6) – Ground Water
Parts 779.25(a)(7), 783.25(a)(7) – Surface Water Bodies And Structures
Parts 779.25(a)(9), 783.25(a)(9) – Identification Of Placement Areas
Parts 780.21, 784.14 – Hydrologic Information
Parts 780.22, 784.22 – Geologic Information
Parts 780.21(f) & 784.14(e) – Probable Hydrologic Consequences
Parts 780.21(g) & 784.14(f) – Cumulative Hydrologic Impact Assessment

Water Quality Monitoring: The required ground water monitoring (**including well design, location, installation, sampling, and maintenance**) is permit specific. A ground water monitoring plan is required that is based on the PHC determination and the analysis of **all** (**all includes all coal combustion material (CCB) placement**) hydrologic, geologic, and other information in the permit application. The plan shall provide for the monitoring of parameters (**including parameters necessary to evaluate the impact of CCB placement**) that relate to the suitability of the ground water for current and approved post-mining land uses and to the objectives for protection of the hydrologic balance. It will identify the quantity and quality parameters to be monitored, sampling frequency, and site locations. It shall describe how the data may be used to determine the impacts of the operation upon the hydrologic balance. The data is to be submitted to the RA at least every 3 months for each monitoring location. All water quality analysis must be conducted according to the methodology of the 15th edition of "Standard Methods for the Examination of Water and Wastewater," or the methodology of 40 CFR Parts 136 and 434. The RA may require additional monitoring [30 CFR 780.21 and 816.41(c)].

SMCRA References: 30 CFR
Part 780.21 Hydrologic Information
Parts 780.21(i), 784.14(h) – Ground Water Monitoring Plan
Parts 816.41(c), 817.41(a) – Ground Water Monitoring
Parts 780.23(b), 784.15(b) – Post-Mining Land Use

Parameters: The required ground water monitoring (including identification of parameters) is permit specific. The plan must provide for the monitoring of parameters that relate to the suitability of the ground water for current and approved post-mining uses. The plan shall provide for the monitoring of parameters (**including parameters necessary to evaluate the impact of CCB placement**) that relate to the suitability of the ground water for current and approved post-mining land uses and to the objectives for protection of the hydrologic balance. Based on the PHC, it must identify the quantity and quality parameters to be monitored, sampling frequency, and site locations (**including the parameters necessary to evaluate the impact of CCB placement)**. It shall describe how the data may be used to determine the impacts (**including the potential toxicity levels of any CCB specific parameters that would impact the use of the ground water)** of the operation upon the hydrologic balance. The data is to be submitted to the RA at least every 3 months for each monitoring location. The RA may require additional monitoring [30 CFR 780.21 and 816.41(c)].

SMCRA References: 30 CFR
Parts 780.21(i), 784.14(h) – Ground Water Monitoring Plan
Parts 816.41(c), 817.41(a) – Ground Water Monitoring
Part 780.21 – Hydrologic Information
Parts 780.23(b), 784.15(b) – Post-Mining Land Use

Frequency: The required ground water monitoring (including frequency of sampling) is permit specific. The ground water monitoring plan will identify the quantity and quality parameters to be monitored, sampling frequency, and site locations (**including the sampling frequency necessary to evaluate the impact of CCB placement)**. It shall describe how the data may be used to determine the impacts (**including the frequency of sampling of any CCB specific parameters that would impact the use of the ground water)** of the operation upon the hydrologic balance. The data is to be submitted to the RA at least every 3 months for each monitoring location. The RA may require additional monitoring [30 CFR 780.21 and 816.41(c)].

SMCRA References: 30 CFR
Parts 780.21(i), 784.14(h) – Ground Water Monitoring Plan
Parts 816.41(c), 817.41(a) – Ground Water Monitoring

Duration: Performance bond liability will be for the duration of the surface coal mining and reclamation operation and for a period which is coincident with the operator's period of extended responsibility for successful revegetation (10 years after establishment of vegetation in areas with less than 26" precipitation;

5 years after establishment of vegetation in areas with more than 26" precipitation) or until achievement of the reclamation requirements of the Act, regulatory programs, and permit, which ever is later (this would include determination of compliance with the hydrologic performance standards at 30 CFR 816.41(a, b, and h) and 816.42. Performance standards related to the protection of ground water must include that all mining and reclamation activities shall be conducted to minimize disturbance of the hydrologic balance within the permit and adjacent areas, to prevent material damage to the hydrologic balance outside the permit area, to assure the protection or replacement of water rights, and to support the approved post-mining land uses in accordance with the terms and conditions of the approved permit. Any person who conducts surface mining activities shall replace the water supply of an owner of interest in real property who obtains all or part of his or her supply of water for domestic, agricultural, industrial, or other legitimate use from an underground or surface source, where the water supply has been adversely impacted by contamination, diminution, or interruption proximately (defined as a result that directly produces an event and without which the event would not have occurred) resulting from the surface mining activities. Discharges of water from areas disturbed by surface mining activities shall be made in compliance with **all** applicable State and Federal water quality laws and regulations and with the effluent limitations for coal mining promulgated by the U.S. EPA set forth in 40 CFR Part 434.
SMCRA References: 30 CFR
Part 800.13 – Period of Liability
Parts 816.131(2)(i) & (3)(i) – Bonding Period And Annual Precipitation
Parts 816.41(a),(b) & (h) – Hydrologic-Balance Protection
Part 816.42 – Water Quality Standards and Effluent Limitations

8. <u>Performance Assessment</u>
   a. *The committee recommends that the disposal of CCRs in coal mines be subject to reasonable site-specific performance standards that are tailored to address potential environmental problems associated with CCR disposal.*

   All SMCRA permits are required to demonstrate how all aspects of mining and reclamation (including any associated CCB placement) will meet all of the SMCRA environmental performance standards including the comprehensive site specific characterization, operations plan, reclamation plan, and water quality monitoring plan already required by SMCRA.

   b. *In areas where CCR leachate may interact with surface waters (directly or through groundwater interaction), more stringent requirements may be necessary to protect aquatic life.*
   In the 29 years of SMCRA, there has not been documentation of a negative impact to aquatic life due to surface water contamination by CCB placement at a SMCRA mine. In order to consider more stringent requirements than what currently exist, a problem needs to be identified. The report did not identify any documented problems with surface water quality related to CCB placement at SMCRA mines.

   c. *Where violations of permit requirements or exceedences of performance standards occur, authority for appropriate penalties or corrective actions must be available to mitigate the damage and prevent future violations.*

   SMCRA already has authority to assess penalties and require corrective actions for any exceedences of performance standards or other violations of SMCRA based regulations.
   SMCRA requires regular inspections and monitoring of the permit. Corrective actions may be required through notices of violation, cessation order, or required permit revision. The permittee is required to immediately notify the RA and take corrective actions as soon as a water quality non-compliance is determined. The permittee must take whatever steps are necessary to ensure that the public health and environment are protected based on compliance with applicable performance standards, permit terms and conditions.
   SMCRA References: 30 CFR (2005)
   Part 840 – State Regulatory Authority: Inspection and Enforcement
   Part 842 – Federal Inspections and Monitoring
   Part 843 – Federal Enforcement
   Part 845 – Civil Penalties

Part 846 – Individual Civil Penalties

9. *CCR Use in Abandoned Mine Lands and Re-mining Sites*
   a. *In order to assure adequate protection of ecological and human health, the committee recommends that placement of CCRs in abandoned and re-mining sites be subject to the same CCR characterization, site characterization, and management planning standards recommended for active coal mines.*

   Placement of CCBs at SMCRA abandoned mine lands is a low-volume low-risk activity where it is used to encapsulate or mitigate the effects of acid forming materials or acid mine drainage, backfill abandoned pits and eliminate highwalls, or in some cases as an agricultural amendment to encourage vegetative growth on low quality spoil materials. These sites are already environmentally degraded. In this context, it is always appropriate to physically and chemically characterize the CCBs to be used to determine if they have the appropriate characteristics for AML site mitigation. Requiring that this placement be subject to the same permitting and performance standards of active SMCRA mines, however, would result in the elimination of these materials as a low cost option. Because AML projects are done by state regulatory authorities using federal funds, they are subject to the provisions of NEPA. As such, OSM should consider issuing guidance to the states regarding the evaluation of CCB placement risk assessment at AML sites as part of the NEPA review.

10. *Research*
    a. *The committee recommends that research be conducted to provide more information on the potential ecological and human health effects of placing CCRs in coal mines.*
       (1) Environmental behavior of CCRs placed at coal mines for protracted time scales over a range of climates, hydrogeologic settings, CCR types, and mining and reclamation techniques.
       (2) Fate and transport of contaminants from CCRs placed at coal mines and the potential for exposure by humans and biological communities for protracted time scales.
       (3) Improvement and field validation of leaching tests to better predict the mobilization of constituents from CCRs in the mine settings for comparison with post reclamation water monitoring results.

    The author is in agreement with and has been an advocate of the NAS recommended research priorities for the last 15 years.

11. *Public Participation*
    a. *Government agencies responsible for regulating CCRs should ensure that the public receives adequate advance notice of any proposals to dispose of CCRs in mine sites.*

    Public Notification: The SMCRA permit applicant must publish a local newspaper notice [with minimum info listed at 30 CFR 773.13(a)(1)] of availability of the application at the country courthouse and the RA. The RA must notify Federal, State, and local agencies of the application. The RA must notify any persons submitting comment, parties involved in informal conferences, and appropriate agencies of permit issuance or renewal.
    Public Access*:* Access to all permitting files, including **inspections and monitoring reports**, by the public must be made available by the RA.
    Public Comments*:* The public may submit comments or written objections to the RA within 30 days of last newspaper notice. Any person with interest may request an informal conference with the RA.
    Enforcement*:* The RA must provide for public participation in enforcement. The public may also request a Federal inspection.
    SMCRA References: 30 CFR (2005)
    Part 773.6 – Public Participation in Permit Processing
    Part 773.6(a)(1) – Public Advertisement Of Permits
    Part 773.6, 773.9, 774.15 – Notification Requirements
    Parts 773.6, 840.14, 842.16 – Availability of Records
    Part 773.6(d) – Public Availability of Permit Applications
    Parts 840.15, 840.16, 842.11 – Public Participation in Enforcement
    Part 842.12 – Requests for Federal Inspections
    Part 842.14 – Review of Adequacy and Completeness of Inspections

For AML projects, the NEPA process is open to public participation

b. *The committee recommends that any proposal to dispose of substantial quantities of CCRs in coal mines be treated as a "significant alteration of the reclamation plan" under SMCRA.*

Currently there is no requirement in SMCRA that specifically requires CCB placement activities to be designated as significant permit revisions requiring full permit application requirements as stated in 30 CFR 774.13(b)(2). SMCRA leaves it up to each State to determine what constitutes a significant permit revision requiring full public review. Current CCB rulemaking efforts by OSM will need to address this concern.

12. <u>Alternatives for Regulatory Authority</u>

a. *Neither SMCRA nor its implementing regulations currently address the use or placement of CCRs in an explicit manner. As a consequence, States vary in their approach and in the rigor with which they address CCR use in mines.*

c. *Some States have expressed concern that they do not have the authority to impose performance standards specific to CCRs. Therefore, the committee recommends that enforceable federal standards be established for the disposal of CCRs in minefills.*

d. *The committee believes that OSM and it SMCRA State partners should take the lead in developing new national standards for CCR use in mines because the framework is in place to deal with mine related issues.*

f. *In all cases, guidance documents will also be necessary to help States implement their responsibility for managing CCR.*

Neither SMCRA nor the OSM regulations, specifically address the use or disposal of the by-products of electric power generation at surface coal mines. When the use or disposal of coal combustion by-products happens at surface coal mines, state coal mining regulators are involved to the extent that SMCRA requires:

4. the mine operator to ensure that all toxic materials are treated, buried, and compacted, or otherwise disposed of, in a manner designed to prevent contamination of the ground or surface water;
5. making sure the proposed land use does not present any actual or probable threat of water pollution; and
6. ensuring the permit application contains a detailed description of the measures to be taken during mining and reclamation to assure the protection of the quality and quantify of surface and groundwater systems, both on and off-sites, from adverse effects of the mining and reclamation process also to assure that rights of present users of such water are protected (Henry 1996).

See comment at 4.a. above.

b. *The committee concludes that although SMCRA does not specifically regulate CCR placement at mine sites, its scope is broad enough to encompass such regulation during reclamation activities.*

Agree.

e. *Regardless of the regulatory mechanism selected, coordination between OSM and EPA efforts is needed and would foster regulatory consistency with EPA's intended rulemaking proposals for CCR disposal in landfills and impoundments.*

OSM and EPA solid waste have agreed to work cooperatively to address the concern for uniformity among the states to maintain minimum environmental protection standards for placement of CCBs at SMCRA mines, the Office of Surface Mining has committed to writing specific federal rules that would address the minimum permitting, environmental performance requirements, and bonding of CCB placement at SMCRA mines.

Information Missing from the Report

Information on the adequacy of water quality monitoring, CCB material characterization, site characterization, evaluation of risk, and environmental performance standards must be determined by the regulatory environment in force at the time of mine placement. The report provides no discussion of: (1) the variety of regulatory environments under which CCB placement occurred; (2) the relative adequacy of technical data collected under that environment; and (3) how each of the NAS findings and recommendations would relate to these different environments. This information is of vital importance in understanding CCB mine placement due to the extremes in regulatory environments that are involved. At one end of the regulatory spectrum is the totally unregulated waste disposal sites where fly ash and other materials have been historically placed in mine pits without any record of the volumes, characteristics, or types of wastes involved. At the other end of the spectrum is the comprehensive environmental permitting process under SMCRA at an active coal mine. In between these extremes are: (1) RCRA permitting of a mine final pit as a solid waste landfill after the area has been released from SMCRA as an industrial solid waste landfill; (2) the National Environmental Protection Act (NEPA) process at a SMCRA (Title IV) abandoned mine project; (3) a non-SMCRA State permitted CCB fill of an abandoned mine; and (4) impoundments and landfills permitted by electric utilities on non-mined lands under RCRA or the Clean Water Act. By not addressing the specific regulatory context where CCB placement occurred so that it could be correlated to monitoring data, research data, and potential resultant environmental harm or benefit, the NAS report has not established specific guidance as to the regulatory adequacy of each of these regulatory programs to be addressed by the appropriate State of Federal regulatory authorities.

Conclusion

The report lists 40 findings or recommendations under 12 categories. This paper addresses these findings on a case by case basis to evaluate their merits against the extensive record of data and scientific studies on the subject. The NAS has chosen to use the term “Coal Combustion Residues” where OSM has historically used the term “Coal Combustion By-Products.” The terms are interchangeable. The author is in agreement with the NAS findings that support: (1) the use of these materials in mine reclamation; (2) the need for specific federal regulations under the Surface Mining Control and Reclamation Act of 1977 (SMCRA) that spells out the minimum permitting, bonding, and environmental performance standard requirements when they are placed on active coal mines; (3) the research priorities to specifically address the hydrogeologic fate of CCBs and any leachate generated by those CCBs in relation to public health and environmental quality; and (4) to develop mining appropriate leachate tests. A limitation of the report is in its inability to: (1) acknowledge the profound differences between regulatory environments that control placement of CCBs at mines; (2) evaluate available groundwater monitoring data and scientific research within the context of the applicable regulatory environments; and (3) acknowledge the volumes of scientific studies and state regulatory data that shows no degradation of water quality due to placement of CCBs at SMCRA mines for the last 29 years.

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Kimery Vories is a Natural Resource Specialist/Technology Transfer employed by the Office of Surface Mining since 1987. He is chairperson of several multi-agency, multi-interest group steering committees that hold forums, publish proceedings, and manage Internet Websites on mining and reclamation issues related to the technical aspects of Coal Combustion By-Products, Prime Farmland Reclamation, Bat Conservation and Mining, and Reforestation. He has been professionally employed in coal mining and reclamation since 1979 with over 60 related professional publications. He serves on: (1) the National Steering Committee and is the Midwestern Review Team Chair for the USDOE Combustion By-Products Recycling Consortium; (2) the Coal Combustion By-Products Working Group Chairman for the Acid Drainage Technology Initiative Coal Mining Section; and (3) is the team leader for the Office of Surface Mining National Technology Transfer Team. He holds a BA & MA in Biology/Geology from Western State College of Colorado with an additional three years post MA graduate work in Ecology and Reclamation at the University of Massachusetts and Colorado State University.

A TECHNICAL REVIEW OF THE NAS FINAL REPORT ON CCB PLACEMENT AT COAL MINES

KIMERY C VORIES

OFFICE OF SURFACE MINING

MANAGING
COAL COMBUSTION
RESIDUES IN MINES

PERSPECTIVE ON THE SCIENTIFIC APPROACH

- OSM 11 YEARS OF TECHNOLOGY DEVELOPMENT AND TRANSFER BASED ON MAXIMIZING CCB EXPERTISE AND EXPERIENCE
- NAS 1 YEAR OF INVESTIGATION BASED ON MAXIMIZING LACK OF BIAS BY EXCLUDING CCB EXPERTISE AND EXPERIENCE

IMPORTANT NAS FINDINGS THAT ARE TECHNICALLY WELL SUPPORTED BY LITERATURE

- CCB PLACEMENT AT ACTIVE COAL MINES IN SUPPORT OF RECLAMATION COULD BE AN APPROPRIATE OPTION FOR USE/DISPOSAL
- THE SCOPE OF SMCRA IS BROAD ENOUGH TO COVER CCB PLACEMENT IN SUPPORT OF RECLAMATION

IMPORTANT NAS FINDINGS THAT ARE TECHNICALLY WELL SUPPORTED BY LITERATURE

- SMCRA SHOULD BE AMENDED TO SPELL OUT SPECIFICALLY WHERE AND HOW THE EXISTING RULES APPLY TO CCB PLACEMENT ON ACTIVE COAL MINES
- OSM NEEDS TO SPECIFICALLY ADDRESS CCB PLACEMENT AT FEDERALLY FUNDED AML PROJECTS TO ADEQUATELY PROTECT THE PUBLIC AND ENVIRONMENT

IMPORTANT NAS FINDINGS THAT ARE TECHNICALLY WELL SUPPORTED BY LITERATURE

- OSM AND EPA NEED TO WORK TOGETHER ON FEDERAL RULEMAKING RELATED TO CCB PLACEMENT AT SMCRA MINES AND FEDERALLY FUNDED AML PROJECTS

IMPORTANT NAS RESEARCH RECOMMENDATIONS

- Investigate environmental behavior of CCBs placed at coal mines for protracted time scales over:
  - a range of climates,
  - hydrogeologic settings,
  - CCR types, and
  - mining and reclamation techniques.

IMPORTANT NAS RESEARCH RECOMMENDATIONS

- Investigate fate and transport of contaminants from CCBs placed at coal mines and the potential for exposure by humans and biological communities for protracted time scales.

IMPORTANT NAS RESEARCH RECOMMENDATIONS

- Investigate the improvement and field validation of leaching tests to better predict the mobilization of constituents from CCBs in the mine settings for comparison with post reclamation water monitoring results.

NAS REPORT LIMITATIONS

- DOES NOT ADDRESS DATA APPLICABILITY RELATED TO THE WIDE RANGE OF REGULATORY PROGRAMS
  - SMCRA TITLE V ACTIVE COAL MINES
  - SMCRA TITLE IV AML PROJECTS
  - COAL MINE PITS REGULATED UNDER RCRA SOLID WASTE
  - PLACEMENT REGULATED UNDER STATE MINING PROGRAM
  - UTILITY DISPOSAL IN IMPOUNDMENTS AND LANDFILLS
  - UNREGULATED DISPOSAL AREAS NOT RELATED TO COAL MINING

ACTIVE COAL MINE APPLICATIONS UNDER TITLE V SMCRA

ALKALINE SEAL TO PREVENT ACID MINE DRAINAGE

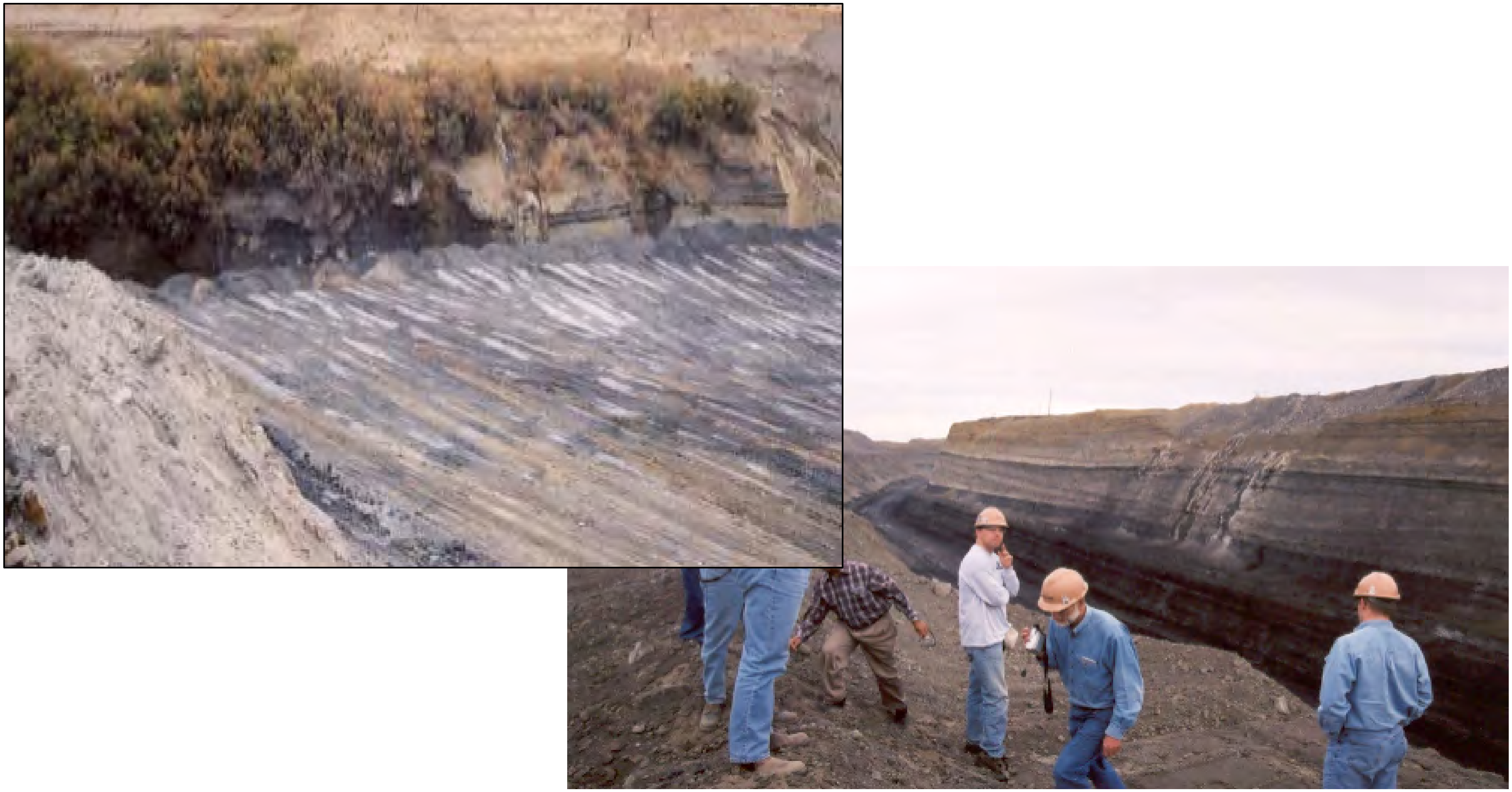
CONSTRUCTION MATERIAL AS COMPACT DURABLE BASE

Mine Road Building (Before Ash)

Mine Road Building (During)

Mine Road Building (After Ash)

NON-TOXIC FILL
TO REDUCE RECLAMATION COST



Mine Fill with Ash

ABANDONED MINE LAND APPLICATIONS EITHER SMCRA FUNDED OR STATE FUNDED

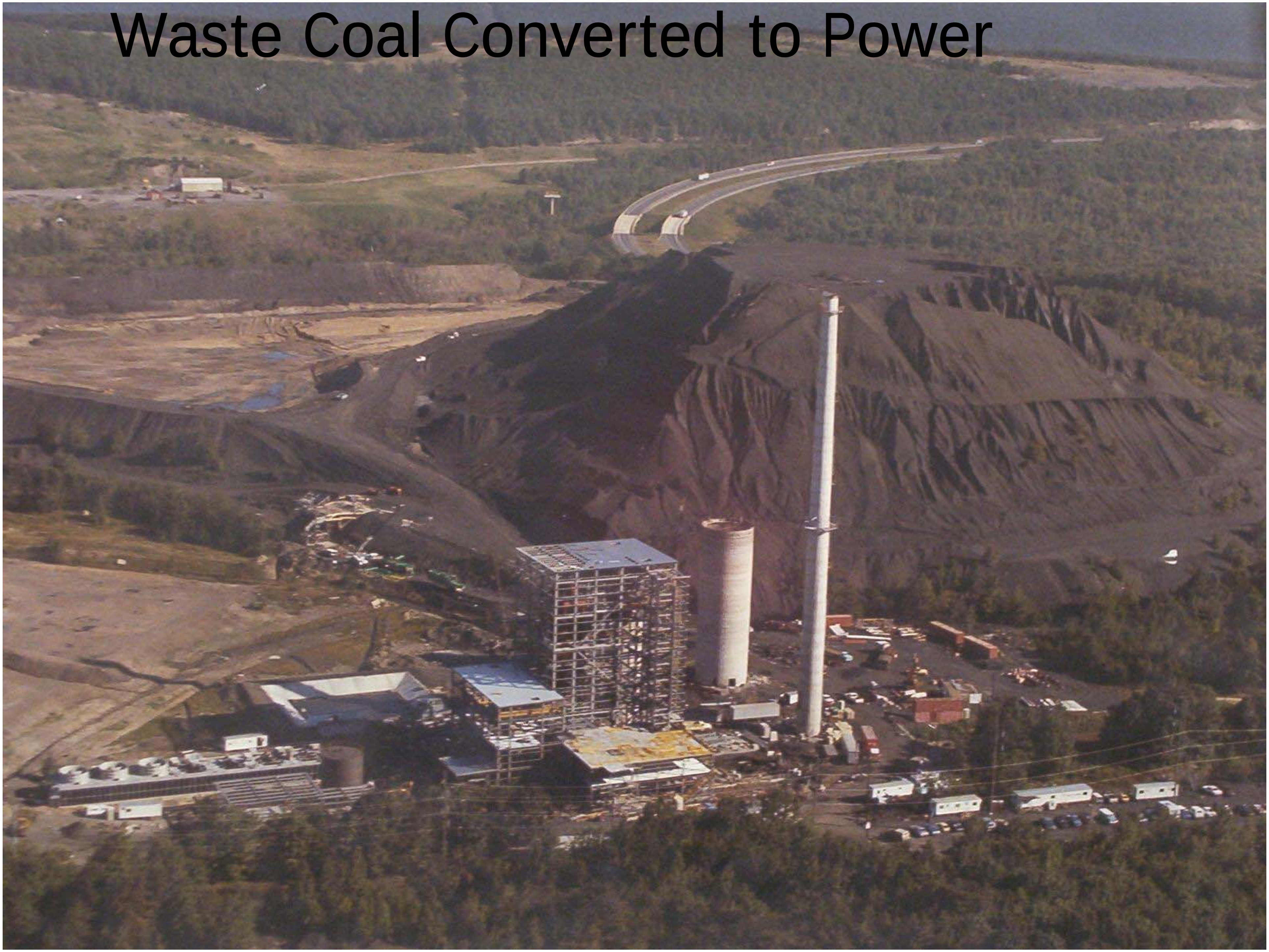
ALKALINE FILL
FOR ACID AML PIT

SOIL SUBSTITUTE FOR AML RECLAMATION

ASH GROUTING FOR AMD ABATEMENT OR SUBSIDENCE CONTROL

STATE FUNDED
AML PROJECTS

Waste Coal Converted to Power



AML Reclamation with FBC Ash

AML Ash and Harbor Dredge Fill (Before)

AML Ash & Harbor Dredge Fill (After Reclamation)

STATE RCRA PROGRAMS

- NORTH DAKOTA RELEASES FINAL PITS FROM SMCRA MINES UNDER AN INDUSTRIAL LAND USE WHERE IT IS RELEASED AS A SOLID WASTE LANDFILL REGULATED BY THE STATE SOLID WASTE PROGRAM FOR DISPOSAL OF CCBs.

NAS REPORT LIMITATIONS

- RELIANCE ON NON REPRESENTATIVE EPA DAMAGE CASE DATA WITH NO DEMONSTRATION OF APPLICABILITY TO SMCRA REGULATED MINES
- NO ADEQUATE ANALYSIS OF VOLUMES OF EXISTING STATE WATER QUALITY MONITORING DATA SHOWING NO DAMAGE ON SMCRA MINES

NAS REPORT LIMITATIONS

- NO ADEQUATE ANALYSIS OF VOLUMES OF SCIENTIFIC STUDIES SHOWING NO DEGRATION OF WATER QUALITY ON SMCRA MINES

NAS REPORT LIMITATIONS

- LACK OF ACKNOWLEDGEMENT OF DECADES OF SCIENTIFIC STUDIES RELATED TO COAL MINING BY:
  - U.S. Department of Energy’s (DOE) Combustion By-Products Recycling Consortium
  - DOE researchers at the National Energy Technology Laboratory
  - Energy and Environment Research Center at the University of North Dakota
  - Center of Applied Energy Research at University of Kentucky
  - University of Ohio
  - Southern Illinois University at Carbondale
  - Penn State University
  - West Virginia University and
  - CCB scientists and mining experts who wrote134 articles published in 6 technical interactive forum proceedings by the Office of Surface Mining over the period 1996 to 2005

CURRENT FEDERAL RULEMAKING INITIATIVES

- LATE 2006 EPA WILL PUBLISH A NOTICE OF DATA AVAILABILITY CONCERNING RULEMAKING FOR SURFACE IMPOUNDMENTS AND LANDFILLS. A VOLUNTARY ACTION PLAN SUBMITTED BY THE UTILITIES WILL BE INCLUDED.

CURRENT FEDERAL RULEMAKING INITIATIVES

- LATE 2006 OSM WILL PUBLISH A NOTICE OF PROPOSED RULEMAKING TO WRITE CCB SPECIFIC RULES FOR SMCRA REQUESTING PUBLIC COMMENT.

CURRENT FEDERAL RULEMAKING INITIATIVES

- SPRING 2007 OSM WILL PUBLISH A PROPOSED RULE FOR SMCRA TITLE IV AND V UNDER EXISTING AUTHORITY
- SPRING 2008 OSM WILL PUBLISH A FINAL RULE FOR SMCRA TITLE IV AND V UNDER EXISTING AUTHORITY

Session 4

REGULATORY STATUS

Session Chairperson:
Alfred Dalberto
Pennsylvania Department of Environmental Protection
Bureau of Mining & Reclamation
Harrisburg, Pennsylvania

Status of EPA's Regulation Development for Coal Combustion Wastes
Bonnie Robinson, Environmental Protection Agency, Washington, D.C.

Office of Surface Mining (OSM) Perspective on Responses to the NAS Report and EPA Rulemaking
John Craynon, P.E., Chief, Division of Regulatory Support, Office of Surface Mining, Washington, D.C.

State Perspective on The National Academy of Sciences Report "Managing Coal Combustion Residues in Mines" and Related OSM Rulemaking
Greg E. Conrad, Executive Director, Interstate Mining Compact Commission, Herndon, Virginia

Utility Solid Waste Activities Group (USWAG) Perspective on Mine Placement of CCPs
James Roewer, Utility Solid Waste Activities Group, Washington, D.C.

STATUS OF EPA'S REGULATION DEVELOPMENT FOR COAL COMBUSTION WASTES

Bonnie Robinson
Environmental Protection Agency
Washington, D.C.

View Presentation

Abstract

As required by the Federal Resource Conservation and Recovery Act (RCRA), EPA completed a special study and issued a Report to Congress on the effects on human health and the environment of the disposal and utilization of coal combustion waste (CCW). In May 2000, EPA issued a regulatory determination explaining its findings that CCW does not warrant regulation as RCRA Subtitle C hazardous waste, but that national RCRA Subtitle D non-hazardous waste management regulations are warranted for certain CCW management practices. The practices are management in landfills, surface impoundments, and in surface or underground mines ("minefill"). EPA has been working with the Office of Surface Mining to consider whether RCRA Subtitle D, the Surface Mining Control and Reclamation Act, or some combination of both statutes are most appropriate to ensure protection of human health and the environment. In March 2006, the National Academy of Sciences (NAS) released a report on "Managing Coal Combustion Residues in Mines." The speaker will provide an update on EPA's regulatory activity and describe plans for responding to the NAS report.

The author was unable to obtain permission to provide a paper for this talk.

Bonnie Robinson is a geologist with the U.S. Environmental Protection Agency, Office of Solid Waste, in Washington, D.C. She has 30 years of industry and government experience specializing in the management of wastes generated by the exploration and production of oil and gas, and the mining and mineral processing of ores and minerals. She has been with EPA for 16 years. Before coming to EPA, she was a petroleum geologist managing exploration and development projects throughout the western and mid-western U.S. She is a member of the Geological Society of America and the American Association of Petroleum Geologists (AAPG), and is a past Vice President of AAPG's Division of Environmental Geosciences.

Status of EPA's Regulation Development for Coal Combustion Wastes

Presentation to the U.S. Office of Surface Mining
Coal Combustion Byproducts Forum
Columbus, Ohio
November 16, 2006

Bonnie Robinson
Office of Solid Waste
U.S. Environmental Protection Agency
Washington, D.C.

Overview

- Regulatory History
- CCW Management Practices
- EPA Activities
- Progress to Date – Minefilling
- EPA Preliminary Observations
- Citizens Groups’ Concerns
- Plans for Future Action

Resource Conservation and Recovery Act (RCRA)

- An amendment to the Solid Waste Disposal Act (1965), enacted in 1976 to address the huge volumes of municipal and industrial solid waste generated nationwide. Amended several times.

RCRA (cont.)

- RCRA’s Goals:
  - To protect human health and the environment from the hazards posed by waste disposal.
  - To conserve energy and natural resources through waste recycling and recovery.
  - To reduce or eliminate, as expeditiously as possible, the amount of waste generated, including hazardous waste.
  - To ensure that wastes are managed in a manner that is protective of human health and the environment.

RCRA (cont.)

- RCRA’s Three Interrelated Programs
  - ✓Subtitle D: Solid Waste
  - ✓Subtitle C: Hazardous Waste
  - Subtitle I: Underground Storage Tanks

1980 Bevill Exemption

- Congress amended the Solid Waste Disposal Act in 1980.
- Congress treated differently a collection of wastes it characterized as “low-toxicity and high-volume,” including fossil fuel combustion (FFC) wastes.
- The Bevill amendment temporarily exempted these materials from regulation under RCRA Subtitle C as a “hazardous waste,” pending:
  - Report to Congress (RTC)
  - Regulatory Determination (RD)

Report to Congress on FFC Wastes, March 1999

- Based on a special study which focused on 8 factors identified in the statute:
  - Sources and quantities of waste generated annually
  - Present disposal practices
  - Potential danger, if any, from disposal
  - Documented cases in which danger to humans or the environment has been proved
  - Alternatives to current disposal practices
  - Costs of the alternatives
  - Impact of alternatives on use of natural resources
  - Current and potential utilization of the materials

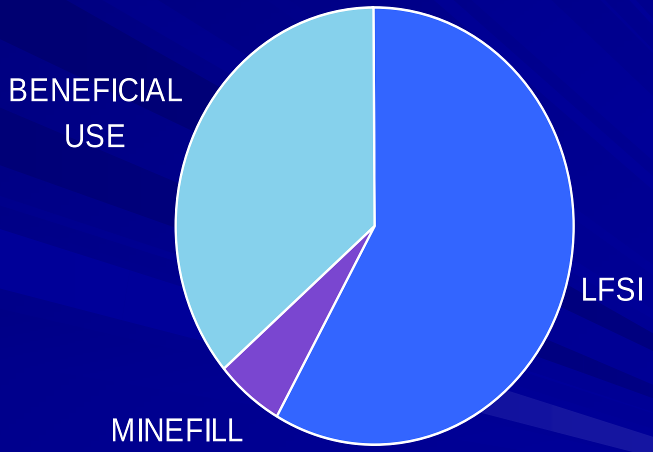
Regulatory Determination
May 22, 2000

- Key Conclusions
  - CCWs do not warrant regulation as hazardous waste under RCRA Subtitle C.
  - Beneficial uses of CCWs: No regulations are warranted other than possibly for minefilling.
  - CCWs in landfills and surface impoundments: National, non-hazardous regulations under RCRA Subtitle D are warranted.
  - Placement of CCWs in coal mines: EPA will assess whether national regulations are warranted under RCRA Subtitle D, Surface Mining Control and Reclamation Act (SMCRA), or a combination of both.

Management of CCWs

126 million tons of CCWs in 2003

- 73 million tons (58%)
  Landfills, Surface Impoundments
- 46 million tons (37%)
  Beneficial Uses
- 7 million tons (5%)
  Mine Applications
  - surface mine reclamation
  - underground mining projects
  - other mining industries (sand and gravel pits)
  - 17 States



Sources: NAS, USDOE/EIA, ACAA

EPA Activities

- For CCWs disposed in landfills or surface impoundments, we are developing RCRA Subtitle D regulations.
- For CCWs placed in coal mines: From the time of the RD (May 2000) until the start of the NAS study in October 2004, EPA assessed the environmental risks, federal and state programs, and waste management practices associated with minefilling.
  - Conducted information collection activities
  - Participated in stakeholder meetings
  - Conducted public meetings

Progress to Date - Minefilling

- Developed cooperative working relationships with state and tribal regulatory agencies through Interstate Mining Compact Commission (IMCC), Association of State and Territorial Solid Waste Management Officials (ASTSWMO); and with OSM, DOE, and other stakeholders.

Progress to Date - Minefilling (cont.)

- Gathered data to improve our understanding of minefill management practices and current federal and state regulatory controls.
  - Updated and verified our minefill operations inventory and industry profile/baseline.
  - Verified the completeness and accuracy of our compendium of existing state regulations and policy applicable to minefilling.
  - Analyzed elements of federal and state regulatory programs applicable to minefilling.
  - Identified our regulatory concerns.
  - Evaluated alleged damage cases.

Progress to Date - Minefilling (cont.)

- Participated in 4 IMCC state-federal-tribal meetings on minefilling (2001-2002).
- Visited 9 states to collect CCW minefill information and interview state and mining regulatory authorities about minefill practices and regulatory controls (2001-2002).
- Visited the Navajo Nation to discuss their concerns regarding CCW minefill practices on tribal lands (2001).

Progress to Date – Minefilling (cont.)

- Conducted session on CCW management at 2002 RCRA National Meeting.
- Coordinated with stakeholders to help IMCC conduct a facilitated stakeholders meeting on CCW minefill practices (May 2003).
- Conducted 4 public listening sessions in Pennsylvania, Indiana, and Texas, to learn more from interested parties about the management of CCWs (2004).

Progress to Date – Minefilling (cont.)

- Provided funding and information to NAS for their CCW minefill study (2004-2005).
- Met with OSM to develop an overall strategy for addressing placement of CCWs in coal mines (2006).
- Met with representatives of citizen groups to discuss their concerns and our plans for addressing minefilling (2006).

EPA Minefill Documents

- Regulation and Policy Concerning Mine Placement of CCW in Selected States
- Mine Placement of CCW: State Program Elements Analysis
- EPA Minefill Regulatory Concerns
- CCW Minefill Management Practices Discussion Guide
- State interview/Site visit reports
- Numerous working papers prepared for IMCC meetings

- Available on EPA's Fossil Fuel Combustion web site: http://www.epa.gov/epaoswer/other/fossil/index.htm

EPA Preliminary Observations

- EPA Preliminary Observations
  - We consider CCW minefilling to be an appropriate use if subject to adequate regulation and appropriate management practices.

- NAS Report
  - Placing CCRs in coal mines as part of the reclamation process is a viable management option as long as it is properly planned and carried out in a manner that avoids significant adverse environmental and health impacts.

Damage Cases

- EPA Preliminary Observations
  - We did not identify any damage cases associated with placement of CCW in coal mines.
    - Coal mine sites may exhibit damage due to historic (pre-SMCRA) mining operations so it may be difficult to attribute damage to minefilling.
- NAS Report
  - Also unable to identify any damage cases associated with minefilling.
  - Relied on the damage cases associated with landfills and surface impoundments to document the potential risks.
  - Better data are needed to fully characterize this issue.
  - Review of literature and damage cases recognized by EPA supports EPA's concerns about proper management of CCRs.

SMCRA

- EPA Preliminary Observations
  - SMCRA’s regulatory program is substantial and contains many of the features commonly incorporated into EPA regulatory programs.
    - Federal regulations for active mining operations
    - Federal permitting, inspection, and enforcement authorities
    - Authorized state programs operating in lieu of the federal program
    - Public participation in rulemaking, state program authorization and oversight, permitting, and inspections
    - Citizen suits
- NAS Report
  - Although SMCRA does not specifically regulate CCR placement at mine sites, its scope is broad enough to encompass such regulation during reclamation activities.
  - Under SMCRA, OSM and related state agencies that implement SMCRA currently have the regulatory framework in place to deal with CCRs used in mine reclamation, and have considerable expertise in review, permitting, and management of mine lands.

Key Areas of SMCRA that Need Strengthening

- EPA Preliminary Observations
  - Financial assurance for long-term monitoring and/or corrective action
- NAS Report
  - There is potential for longer-term groundwater impacts from CCRs to go undetected under the normal reclamation bonding framework.
  - Concern was expressed about the length of the liability period and the adequacy of the remaining reclamation bond to treat any groundwater impacts that may occur after the bond is released.
  - Concern was expressed that if significant contamination were detected after bond release, there would be no ready remedy available to the public.
  - NAS was unable to reach consensus on liability.

Key Areas of SMCRA that Need Strengthening (cont.)

- EPA Preliminary Observations
  - – Targeted monitoring of minefilled ash
- NAS Report
  - – The number and location of monitoring wells, the frequency and duration of sampling, and the water quality parameters selected for analysis should be carefully determined for each site, in order to accurately assess the present and potential movement of CCR-associated contaminants.

Key Areas of SMCRA that Need Strengthening (cont.)

- EPA Preliminary Observations
  - Long-term, post-mining monitoring of ground water
- NAS Report
  - Concerned about questionable adequacy of ground-water monitoring in SMCRA.
  - The number of monitoring wells, the spatial coverage of wells, and the duration of monitoring at CCR minefills are generally insufficient to accurately assess the migration of contaminants.
  - Longer duration of groundwater monitoring may be necessary at some sites to adequately assess the temporal release of contaminants, which can occur over several decades.

Key Areas of SMCRA that Need Strengthening (cont.)

- EPA Preliminary Observations
  - SMCRA ground-water performance standard
- NAS Report
  - Performance standards should be established for ground-water and surface-water monitoring points to ensure adequate protection of ground-water and surface-water quality.

Key Areas of SMCRA that Need Strengthening (cont.)

- EPA Preliminary Observations
  - – Deed recordation (for post-mining land use)
- NAS Report
  - – Deeds, or appropriate recordable instruments, should record and fully disclose that CCRs were used in the reclamation of the mine site.

Benefits

- EPA Preliminary Observations
  - Minefill practices we've seen regulated by SMCRA state programs appear to provide environmental benefits.
    - For example, each year several people in Pennsylvania die due to highwalls, water-filled abandoned pits and open mine shafts. PADEP successfully uses CCW minefilling to mitigate these hazards.
- NAS Report
  - While recognizing the potential risk of negative environmental impacts associated with CCR minefilling, it has been shown that, in some cases, benefits can accrue and should be considered in the permitting process.
  - Main advantages of CCR mine placement are:
    - Can assist in meeting reclamation goals
    - Avoids the need to disrupt undisturbed sites

Abandoned Mine Lands

- EPA Preliminary Observations
  - States tend to use procedures associated with the SMCRA regulations, but such actions are not required.
  - We are concerned about the lack of regulatory authority over minefilling at abandoned or inactive coal mines.
- NAS Report
  - Any regulatory standards for CCR use adopted under SMCRA for active coal mining would most likely apply to remining activities but would not apply directly to CCR use in the reclamation of abandoned mine lands.
  - CCR placement in abandoned and remining sites should be subject to the same CCR characterization, site characterization, and management planning standards recommended for active coal mines.

Citizen Groups' Concerns - Public Participation

- Citizen Groups
  - Concerned about access during the rulemaking process.
  - Believe that state and OSM programs are close to industry and unresponsive to public.
  - Request a federal advisory committee or structure that gives them significant participation in the regulation development process.
- NAS Report
  - Concerned about inadequate public participation in SMCRA permitting.
  - The regulatory process for issuing permits should include clear provisions for public involvement.
  - Government agencies responsible for regulating CCRs should ensure that the public receives adequate advance notice and an opportunity to comment officially on any proposals to dispose of CCRs in mine sites.

Citizen Groups’ Concerns - Regulatory Authority

- Citizen Groups
  - Want enforceable federal EPA regulations
- NAS Report
  - Enforceable federal standards should be established for the disposal of CCRs in minefills.
    - Would require that state programs develop and implement needed management and performance standards specific to CCRs and minefilling.
    - Only through enforceable federal standards can acceptable minimum levels of environmental protection from CCR placement in coal mines be guaranteed nationally.
    - Guidance alone is not adequate to achieve the needed improvements in state programs for CCR minefills.
      - Not enforceable
      - Does not provide adequate opportunities for citizen participation

Citizen Groups' Concerns - Potential Impacts

- Citizen Groups
  - Filed petition, Feb. 9, 2004, to immediately halt placement of CCW into ground water.
  - Concerned about concentrations of heavy metals in leachate and deficiencies in the abilities of monitoring programs and placement safeguards in state minefill permitting programs.
- NAS Report
  - CCR placement in mines should be designed to minimize reactions with water and the flow of water through CCRs.
  - The presence of high contaminant levels in many CCR leachates may create human health and ecological concerns at or near some mine sites over the long term.
  - There are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessments difficult.

Plans for Future Action

- EPA is working with OSM as they amend the SMCRA regulations to better address minefilling in active coal mines as well as where there is federal funding of abandoned mines.
  - Consistent with the NAS recommendations and with EPA's Regulatory Determination
- EPA will develop a strategy to address minefilling at abandoned coal mines, in consultation with the states, OSM, and other stakeholders.
- Stakeholders will be provided opportunities to comment on proposed rules.

Contact Information

- EPA's Fossil Fuel Combustion web site:

  http://www.epa.gov/epaoswer/other/fossil/index.htm

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OFFICE OF SURFACE MINING (OSM) PERSPECTIVE ON RESPONSES TO THE NAS REPORT AND EPA RULEMAKING

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View Presentation

Abstract

Coal Combustion ByProducts (CCBs) are the noncombustible portion of coal and residues from various air pollution control technologies that are the by-product of electric power generation at coal fired power plants. CCBs are also known as “coal combustion residues” (CCRs), which is the term preferred by the National Research Council, and “coal combustion wastes” (CCWs). The amount of CCBs produced annually is currently more than 120 million tons. Some CCBs can be beneficially and commercially used in engineering applications or products such as cement or wallboard. The remainder must be placed in landfills, surface impoundments, or mines. CCB mine placement can assist in meeting reclamation goals at active coal mines and enhance the reclamation of abandoned mine lands. The placement in coal mines is currently regulated under either or both the Surface Mining Control and Reclamation Act of 1977 (SMCRA), administered by OSM and the Resource Conservation and Recovery Act of 1976 (RCRA). The solid waste rules under RCRA were written by the Environmental Protection Agency (EPA) but are administered by State Solid Waste Programs.

In early 2004, Congress directed EPA to fund a study by the National Academy of Sciences (NAS) to examine the health, safety, and environmental risks associated with using CCBs in reclamation of active, abandoned, surface, and underground coal mines. The study examined the health, safety, and environmental risks associated with using CCBs for reclamation in all major coal basins. The study also considered coal mines receiving large quantities of CCBs. The committee’s efforts focused on CCBs from utility power plants and independent power producers, rather than small business, industries, and institutions. The study was released in March 2006. Among the findings of the report are that OSM and the States that implement SMCRA should take the lead in addressing any of the recommendations and findings of the NAS report.

Following the release of the National Academies’ report, OSM has reviewed the committee’s recommendations and findings in order to plan its next actions. In addition, OSM has met with EPA and the IMCC as well as other State regulatory and AML programs to develop detailed plans including any necessary regulatory or oversight proposals. OSM is committed to drafting regulations addressing recommendations in the NAS report in concert with EPA.

Background

There is no provision in SMCRA directly relating to the placement of coal combustion by-products (CCBs) at coal mine sites. Additionally, SMCRA did not directly contemplate the disposal of solid wastes in a coal mine other than wastes generated by coal mining operations (e.g. coal processing waste, non-coal mine waste, and noncoal-related underground development waste). The permitting and performance regulatory standards apply to both CCBs and any other materials that may be placed in coal mines. Thus, all of the standard permitting requirements and environmental performance standards contained in the Act apply to operations which include CCB placement.

The U.S. Environmental Protection Agency (EPA) has been studying the environmental risks of CCBs for a number of years. The “Bevill Amendment,” which was passed as part of the Solid Waste Disposal Act Amendments of 1980, temporarily exempted from regulation under Subtitle C of RCRA certain large volume fossil fuel wastes and directed EPA to conduct a detailed and comprehensive study of fossil fuel wastes and prepared a Report to

Congress. EPA's report to Congress in 1988 concluded that ash resulting from the combustion of fossil fuels in electric utility power plants was not hazardous and regulation under RCRA Subtitle C was not needed.

In its May 22, 2000 Regulatory Determination, (65 FR 32214) the EPA reaffirmed that regulation of CCBs as hazardous waste under Subtitle C of RCRA was not warranted. However, the EPA further concluded that, to ensure consistent handling of CCBs used to fill surface or underground mines, national regulations under Subtitle D of RCRA, which governs disposal of solid wastes, may be warranted, as may modification of SMCRA rules. The EPA expressed concern that lack of specificity in SMCRA's monitoring requirements and the narrow provisions for the reassertion of jurisdiction after bond release would not conform to RCRA standards.

CCB placement on SMCRA mine sites is currently governed by State and Tribal solid waste disposal programs and the applicable requirements of SMCRA regulatory programs. In recent years, EPA has conducted three separate information collection programs related to CCB mine placement: (1) a risk assessment model based on an analysis of existing groundwater data associated with surface coal mining; (2) collection of State Regulatory Authority CCB damage case information; and (3) EPA/OSM joint investigations including: (a) field inspections of CCB placement at coal mine sites, (b) collection of state and federal SMCRA program requirements, and (c) their comparison to EPA requirements for municipal solid waste disposal. To date, EPA has not found any CCB damage cases on SMCRA mine sites.

The volume of CCB placement at SMCRA mines is generally controlled by economics. Current or foreseeable economics of CCB placement at mines is restricted to: (1) situations of low transportation costs (i.e. mine mouth power plants); (2) very small power plants that can not afford to develop their own RCRA solid waste landfill due to the low volume of material and then only if a coal mine is close enough so that transportation is affordable; (3) a unique beneficial application at the mine justifies additional transportation cost such as use of CCBs for road building or other construction material, encapsulation of acid forming materials, and subsidence control and mitigation of acid mine drainage. In the last two situations, the volume of CCBs placed at the mine represent less than 5% of the volume of coal removed. In the first or highest possible volume situation, the volume of CCBs placed at a mine mouth power plant may represent up to 25% of the coal removed at a specific mine. The American Coal Ash Association data show that for 2004, 122,465,119 tons of CCBs were produced. Mine placement used 1,692,313 tons. This data indicates that only 1.38% of the CCBs produced are placed back at mines. The U.S. Department of Energy data show that for 2004, 1,112,100,000 tons of coal was mined. This data indicates that CCBs placed at mines on a national basis represent no more than 0.15% of the tons of coal removed. The point is that although the potential exists for coal mines to handle a much larger volume of CCBs, economics dictates that actual volumes are quite low.

Beginning in 1994, OSM has taken an active role in encouraging and promoting technological advances, research, and technology transfer related to the placement of CCBs at mines. The primary activities and accomplishments of OSM in this area have been the establishment of a multi-interest group steering committee that has: (1) conducted six national interactive forums on CCB related topics; (2) edited, published, and distributed thousands of copies of the forum proceedings; (3) provided technical assistance to the American Society of Testing Methods on draft guidance for CCBs on mines; and (4) developed and managed an internet website dedicated to providing a user friendly guide to CCB literature, organizations, EPA rule-making, and educational events. OSM has signed a Memorandum of Understanding with the U.S. Department of Energy, National Energy Technology Laboratory (NETL) to collaborate on CCB research and issues. OSM staff serve on the: (1) national steering committee of the Combustion By-Products Recycling Consortium in order to assist in directing CCB research efforts by the U.S. Department of Energy; and (2) the technical program committee for the international biennial Symposiums conducted by the University of Kentucky (UK) Center for Applied Energy Research and the American Coal Ash Association. OSM staff have actively worked with the U.S. Environmental Protection Agency and the Interstate Mining Compact Commission since 1999 to investigate potential impacts to public health and the environment of CCB placement at mines and determine whether or not additional federal rulemaking is necessary.

In early 2004, Congress directed EPA to fund a study by the National Academy of Sciences (NAS) to examine the health, safety, and environmental risks associated with using CCBs in reclamation of active, abandoned, surface, and underground coal mines. The study examined the health, safety, and environmental risks associated with using CCBs for reclamation in all major coal basins. The study also considered coal mines receiving large quantities of CCBs. The committee's efforts focused on CCBs from utility power plants and independent power producers, rather than small business, industries, and institutions. The study was released in March 2006. Among the findings of the report are that OSM and the states that implement SMCRA should take the lead in addressing any of the recommendations and findings of the NAS report.

Current Activities

After discussions with EPA, states, and other interested parties, OSM has tentatively decided to propose to revise its regulations so that they will expressly provide for the disposal and beneficial use of CCBs as part of surface coal mining and reclamation operations permitted under Title V of SMCRA and in the reclamation of abandoned mine lands under an AML reclamation program approved under Title IV of the Act. OSM intends for these regulations to minimize the possibility that CCB disposal or use could cause adverse impacts on public health and the environment.

Our plan is to first publish an Advance Notice of Proposed Rulemaking (ANPR) which will give public notice of our intent and to request comments on what our regulations should address. Following the comment period, we intend to publish proposed rules, tentatively in the first half of 2007. It is our goal that, following the comments on the proposed rules, we would be able to publish final regulations in early 2008. This timeframe is ambitious, but we believe it is reasonable.

Our regulatory proposal will be based solely upon our statutory authorities under SMCRA. There is no intent to base any of our requirements on any other federal statute, and we have no authority to do so. As such, any regulations would be expected to rely heavily on existing regulatory constructs in our program. In addition, our proposals will only address coal mines regulated under Title V and those sites being reclaimed under an approved SMCRA AML program.

We are committed to allowing what works and what protects the environment to continue to function. We are also committed to considering the technical input we receive and to addressing the comments and concerns that arise during this rulemaking process. We will work with EPA and the states as we develop our rules and as we figure out how best to implement the requirements.

Conclusion

The use of properly managed CCBs on both active and abandoned mines can contribute to successful reclamation. For example, alkaline CCBs with cement-like properties can be used to encapsulate acid-forming or other toxic-forming materials to isolate those materials from contact with water and thus reduce or eliminate the formation of acidic or toxic mine drainage. Even when there is no site-specific beneficial aspect to CCB placement in mines, the use of mines as CCB disposal sites benefits the environment by preventing the surface disruption that would otherwise result from disposal of CCBs in landfills and surface impoundments, which normally are constructed on previously undisturbed sites or sites with productive land uses.

OSM is committed to making good decisions in the regulatory and AML programs based on good science and the provisions of SMCRA. At the heart of our approach is the desire to implement the purposes of SMCRA to protect the public and the environment from the detrimental impacts of past and present coal mining activities. Through the prudent use of CCBs in mine reclamation, and regulatory requirements that explicitly address concerns regarding placement of CCBs at coal mines, OSM can fulfill that purpose.

Acknowledgements

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John Craynon is currently the Chief of the Division of Regulatory Support in the Washington, D.C. headquarters of the Office of Surface Mining (OSM). The Division is responsible for setting the policy related to OSM's regulatory program and for serving as technical experts in mining and reclamation. In addition, the division provides regulatory, programmatic, and technical assistance for OSM's regional and field offices and the State regulatory agencies. The division also provides day-to-day support to the management of OSM and the Department of the Interior and serves as a liaison with other federal agencies and parties interested in OSM's programs, including the Office of Management and Budget and appropriate U.S. House of Representatives and U.S. Senate members and committees.

Mr. Craynon's government career over the past 23 years has included various positions with the U.S. Bureau of Mines, the Bureau of Land Management, and the Department of the Interior's Office of Environmental Policy and Compliance, prior to joining OSM in 1996. In these various jobs, his focus has been on mining and the environment and the technical, legal, and public policy issues related to mining. His work has related to diverse topics such as mountaintop mining, coal combustion byproducts, underground mine mapping, acid mine drainage, subsidence, hydrology, and invasive species issues.

Mr. Craynon has both Bachelor's and Master's degrees in Mining and Minerals Engineering from Virginia Tech. He is also a Professional Engineer in the Commonwealth of Virginia. Mr. Craynon has been an Adjunct Professor in the Department of Mining and Minerals Engineering at Virginia Tech and is a member of the Virginia Tech Department of Mining and Minerals Engineering Advisory Board. He is the past chair of the Coal Mining Sector of the Acid Drainage Technology Initiative. Mr. Craynon is a member of the Society for Mining, Metallurgy and Exploration, the National Society of Professional Engineers, the American Society of Mining and Reclamation, the International Mine Water Association, and the American Society of Civil Engineers.

OSM Perspective on Responses to the NAS Report and EPA rulemaking

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OSM, Washington, DC

Mine Placement Economic Realities

Limited to:

- Low transportation cost situations
  - Mine mouth power plants
- Small power plants without RCRA disposal facilities
- Beneficial applications

Volumes of CCBs placed at mines

- Around 1.4% of all generated CCBs placed in mines
- CCBs placed equal to 0.15% of coal mined
- Beneficial use cases: 5% of coal volume replacement
- Mine mouth power plants: maximum 25% of coal volume

History

- OSM has been working on mine placement issues for a number of years
  - 1994 Interagency Cooperation
  - 1996 Policy Statement
    - Mine Placement is an acceptable practice
  - IMCC, OSM, EPA meeting regularly since 1999 to formulate regulatory approaches

More OSM Background Activities

- Six interactive forums on CCBs
- Publication of Forum Proceedings
- Assistance to ASTM
- CCB Website

OSM CCB Participation

- USDOE Combustion Byproducts Recycling Consortium
- International Ash Utilization Symposium
- 2005 World of Coal Ash Symposium

Regulatory History

- 1988 EPA Report to Congress
  - No Subtitle C regulations needed
- 2000 EPA Regulatory Determination
  - No Subtitle C regulations needed
  - RCRA, SMCRA or a combination

EPA Information Gathering

- Risk assessment of groundwater data
- CCB damage case information
  - No SMCRA mine site damage cases
- Field investigations
- Comparison of RCRA and SMCRA requirements

NAS Study

- Directed by Congress
- Focused on coal mine placement
- Focused on identifying risks
- Released in March 2006

Craynon's Thoughts on the NAS Report

- NAS work (of any kind) is seen as definitive
  - Must work to build on the report
  - Must build on the attention
- Working "with" the report gets us where we need to go

SMCRA Regulatory Background

- No explicit regulatory provisions related to CCBs in SMCRA
- CCB placement subject to all permitting and performance requirements

Therefore…create rules

- Build on NAS statement that OSM and SMCRA states should take lead
- Better organize and clarify regulatory requirements

OSM Rulemaking Process

- Advanced Notice of Proposed Rulemaking (late 2006)
- Proposed Rulemaking (2007)
- Final Rulemaking (2008)

ANPR

- Seeking comments on intention to propose rule
  - Looking for input on what rule should address
  - Will not commit OSM to a single direction, but will announce our intention to regulate

Important things to note

- OSM rules will be based on existing SMCRA authorities (not RCRA)
- Rules will draw from existing regulations whenever possible
- Rules will collect authority into one place and make implicit requirements explicit

Rulemaking Content

- Title V
  - Permitting
  - Bonding
  - Monitoring
  - Performance Standards

Rules (cont.)

- Title IV (AML)
  - – Limited to sites using AML Fund monies
  - – Information requirements
  - – Analysis/Design requirements

OSM Goals

- Balance need for coal and opportunity to enhance mining and reclamation with CCB placement
- Ensure protection of the public and environment
- Enhance reclamation of mined lands

OSM Commitments

- OSM will work with States and EPA to develop rules proposals
- OSM will consider and address comments and technical input
- OSM will allow what currently works to continue

Hopes and Expectations

- ANPR will generate public input
- Rulemaking process will ensure the best regulatory program and AML reclamation
- State programs will be strengthened and enhanced
- CCBs will be used appropriately at mines

EPA Rulemaking

- EPA speaker addressed details
- OSM is committed to work with EPA and States
- Minefilling rules under SMCRA and EPA rules should complement each other

Conclusions

- OSM is committed to making good decisions based on good science
- CCB placement at mines can be means to better reclamation
- OSM’s commitment to protecting the public and the environment is at the heart of what we have planned

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STATE PERSPECTIVE ON THE NATIONAL ACADEMY OF SCIENCES REPORT "MANAGING COAL COMBUSTION RESIDUES IN MINES" AND RELATED OSM RULEMAKING

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Abstract

On March 1, 2006, the National Research Council released to the public its final report entitled "Managing Coal Combustion Residues in Mines." Pursuant to the findings and recommendations in the report, putting coal combustion residues (CCRs) back into mines is a viable option for disposal, as long as precautions are taken to protect the environment and public health. The report also acknowledged that CCRs could serve a useful purpose in mine reclamation, lessen the need for new landfills, and potentially neutralize acid mine drainage. The report recommends development of enforceable federal standards that give the states authority to permit the use of CCRs at mines but allows them to adopt requirements for local conditions. The author will report on the purpose of the NRC study and its recommendations and findings, particularly as they impact state regulatory authorities. The author will also report on the results of discussions between the states, OSM and EPA regarding future rulemaking activity growing out of the NRC's recommendations.

Introduction

On March 1, 2006, the National Research Council (NRC) within the National Academy of Sciences released to the public its final report entitled "Managing Coal Combustion Residues at Mines." The study was in response to a request from Congress and was initiated in June of 2004. The NRC conducted the study to examine the health, safety, and environmental risks associated with using coal combustion residues (also referred to as coal combustion wastes or coal ash) in reclamation at active and abandoned coal mines. The study was sponsored by the Environmental Protection Agency (EPA). The NRC looked at the placement of coal combustion residues (CCRs) in abandoned and active surface and underground coal mines in all major coal basins. The study also considered coal mines receiving large quantities of coal combustion residues. A profile of the utility industry was taken into consideration in designing the study to focus on the sources producing the greatest quantities of coal combustion residues. The study was to determine whether CCRs were placed and disposed of in coal mines with adequate safeguards and whether this activity is degrading water supplies in coal mines in contravention of the Surface Mining Control and Reclamation Act (SMCRA).

The NRC's efforts focused on coal combustion residues from utility power plants and independent power producers, rather than small business, industries, and institutions. The NRC examined regulatory structures and the interaction of programs under EPA's jurisdiction and those implemented by the Office of Surface Mining (OSM) in partnership with states under SMCRA. The NRC held six public meetings around the country between October 2004 and May 2005, and visited field sites related to their inquiry.

NRC Statement of Task

Specifically, the NRC's Committee on Mine Placement of Coal Combustion Wastes (Committee) addressed the following points:

1. The adequacy of data collection from surface water and ground water monitoring points established at coal combustion waste (CCW) sites in mines.

2. The impacts of aquatic life in streams draining CCW placement areas and the wetlands, lakes, and rivers receiving these drainages
3. The responses of mine operators and regulators to adverse or unintended impacts such as the contamination of ground water and pollution of surface waters
4. Whether CCWs and mines they are being put in are adequately characterized for such placement to ensure that monitoring programs are effective and groundwater and surface waters are not degraded. (This item is not explicitly in the NAS statement of task but is there implicitly.)
5. Whether there are clear performance standards set and regularly assessed for projects that use CCW for "beneficial purposes" in mines.
6. The status of isolation requirements and whether they are needed.
7. The adequacy of monitoring programs including:
   a. The status of long-term monitoring and the need for this monitoring after CCW is placed in abandoned mines and active mines when placement is completed and bonds released.
   b. Whether monitoring is occurring from enough locations;
   c. Whether monitoring occurs for relevant constituents in CCW as determined by characterization of the CCW; and
   d. Whether there are clear, enforceable corrective action standards regularly required in the monitoring.
8. The ability of mines receiving large amounts of CCW to achieve economically-productive post-mine land uses;
9. The need for upgraded bonding or other mechanisms to assure that adequate resources are available for adequate periods to perform monitoring and address impacts after CCW placement or disposal operations are completed in coalmines;
10. The provisions for public involvement in these questions at the permitting and policy-making levels and any results of that involvement;
11. Evaluate the risks associated with contamination of water supplies and the environment from the disposal or placement of coal combustion wastes in coal mines in the context of the requirements for protection of those resources by the Resource Conservation and Recovery Act (RCRA) and SMCRA.

NRC Findings and Recommendations (NRC 2006)

1. Conclusion
   a. The Committee believes that placement of CCRs in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material.
2. Value of existing CCR data and information
   a. The two most common CCR disposal options, surface impoundments and landfills, provide insights into the types of issues that can emerge when the soluble constituents of CCRs are not contained within the waste management system.
   b. Although disposal conditions may differ substantially from mine settings, landfills and surface impoundments are useful for understanding the specific conditions under which CCRs can potentially impact humans and ecosystems. The EPA has identified numerous cases of water contamination related to CCR landfills and surface impoundments that, in many cases, have caused considerable environmental damage. In some landfill settings, groundwater has been degraded to the point that drinking water standards were exceeded off-site. In other landfills and surface impoundments, contamination of surface waters has resulted in considerable environmental damage; in the most extreme cases, multiple species have experienced local extinctions. Such cases are instructive because these impacts can be clearly related to CCR disposal, and they help guide the selection of mining environments for CCR placement that are most protective of human and ecological health.
   c. The Committee's review of literature and damage cases recognized by EPA supports the EPA's concerns about proper management of CCRs.
   d. As of 2005, EPA had recognized 24 proven damage cases involving CCR landfills and surface impoundments. One CCR coal minefill is under investigation as a potential damage case by EPA.
   e. Comparatively little is known about the potential for mine-filling to degrade the quality of groundwater and/or surface waters particularly over longer time periods.

   f. There are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessment difficult.
   g. Currently, there are very few data available to directly indicate that placement of CCRs in abandoned or active coal mines is either safe or detrimental.

2. Potential Impacts
   a. Of the three methods currently available for disposal of CCRs (surface impoundments, landfilling, and minefilling), comparatively little is known about the potential for minefilling to degrade the quality of ground water and/or surface waters particularly over longer periods (decades to centuries). Additionally, there are insufficient data on the contamination of water supplies by placement of CCRs in coal mines, making human risk assessments difficult.
   b. The Committee concludes that the presence of high contaminant levels in many CCR leachates may create human health and ecological concerns at or near some mine sites over the long term.
3. CCR Disposal and Use Options
   a. The Committee recommends that secondary uses of CCRs that pose minimal risks to human health and the environment be strongly encouraged.
   b. With regard to CCR placement in minefills, the Committee concludes that while potential advantages (beneficial use*)* should not be ignored, the full characterization of possible risks should not be cut short in the name of beneficial use.
4. CCR Characterization
   a. In order to contribute to evaluation of the risk of placing CCRs at mine sites, the Committee recommends that CCRs be characterized prior to significant mine placement and with each new source of CCR. CCR characterization should continue periodically throughout the mine placement process to assess any changes in CCR composition and behavior.
   b. The Committee suggests some simple improvements to current leaching protocols. In particular, the CCR characterization methods used should provide contaminant leaching information for the range of geochemical conditions that will occur at the CCR placement site and in the surrounding area, both during and after placement. Samples that exceed pre-determined leaching criteria should be rejected for mine placement, although samples that meet the criteria may still need additional evaluation depending on the potential risks of CCR placement determined from the site characterization.
5. Site Characterization
   a. Current site characterization requirements of SMCRA focus on assessing the potential impacts of coal mining and reclamation but do not specifically address the impacts of CCR placement. The Committee recommends that comprehensive site characterization specific to CCR placement be conducted at all mine sites prior to substantial placement of CCRs.
6. CCR Use in Reclamation
   a. The disposal of CCRs in coal mines occurs under highly variable conditions, ranging from small quantities to massive minefills, from arid to wet regions, from remote to semiurban locations, from surface to underground mines, and from active to abandoned mines. Thus, the Committee endorses the concept of site-specific management plans, including site-specific performance standards.
   b. Given the known impacts that can occur when CCRs react with water in surface impoundments and landfills, special attention should be paid in reclamation operations to the interactions of water with CCRs. Specifically, the Committee recommends that CCR placement in mines be designed to minimize reactions with water and the flow of water through CCRs. Such methods include:
      (1) placement above the water table
      (2) compaction (in lifts)
      (3) cementation (cement addition)
      (4) use of impermeable liners, and
      (5) use of low-permeability covers.
7. Post Reclamation Water Quality Monitoring
   a. Based on its reviews of CCR post-placement monitoring at many sites visited during the course of the study, the Committee concludes that the number of monitoring wells, the spatial coverage of wells, and the duration of monitoring at CCR minefills are generally insufficient to accurately assess the migration of contaminants.
   b. The Committee found quality assurance and control and information management procedures for water quality data at CCR mine placement sites to be inadequate.

   c. The Committee believes that a more robust and consistent monitoring program is needed in situations involving CCR mine placement. The Committee recommends that the number and location of monitoring wells, the frequency and duration of sampling, and the water quality parameters selected for analysis be carefully determined for each site, in order to accurately assess the present and potential movement of CCR-associated contaminants.
   d. Although monitoring plans should be site-specific, downgradient wells should be sited with an understanding of the travel times for contaminants to reach these monitoring points.
   e. Depending on the individual site characteristics and the distances to downgradient wells, a longer duration of groundwater monitoring may be necessary at some sites to adequately assess the temporal release of contaminants, which can occur over several decades. To address these concerns, several monitoring points should be established along predicted flow paths that will yield early (prior to bond release) information that can be used to confirm predicted CCR leachate transport.
   f. At least one well or lysimeter, and preferably two, should be placed directly in the CCR to assess the field leaching behavior and confirm predicted contaminant flux.
   g. As part of the monitoring plan, quality assurance and control plans should be developed prior to CCR placement with clearly defined protocols for sampling and analysis, for data validation, and for managing systematic errors in analytical procedures.

8. <u>Performance Assessment</u>
   a. The Committee recommends that the disposal of CCRs in coal mines be subject to reasonable site-specific performance standards that are tailored to address potential environmental problems associated with CCR disposal.
   b. In areas where CCR leachate may interact with surface waters (directly or through groundwater interaction), more stringent requirements may be necessary to protect aquatic life.
   c. Where violations of permit requirements or exceedences of performance standards occur, authority for appropriate penalties or corrective actions must be available to mitigate the damage and prevent future violations.
9. <u>CCR Use in Abandoned Mine Lands and at Remining Sites</u>
   a. In order to assure adequate protection of ecological and human health, the Committee recommends that placement of CCRs in abandoned mines and at remining sites be subject to the same CCR characterization, site characterization, and management planning standards recommended for active coal mines.
10. <u>Research</u>
    a. The Committee recommends that research be conducted to provide more information on the potential ecological and human health effects of placing CCRs in coal mines, including:
       (1) Environmental behavior of CCRs placed at coal mines for protracted time scales over a range of climates, hydrogeologic settings, CCR types, and mining and reclamation techniques.
       (2) Fate and transport of contaminants from CCRs placed at coal mines and the potential for exposure by humans and biological communities for protracted time scales.
       (3) Improvement and field validation of leaching tests to better predict the mobilization of constituents from CCRs in the mine settings for comparison with post reclamation water monitoring results.
11. <u>Public Participation</u>
    a. Government agencies responsible for regulating CCRs should ensure that the public receives adequate advance notice of any proposals to dispose of CCRs in mine sites.
    b. The Committee recommends that any proposal to dispose of substantial quantities of CCRs in coal mines be treated as a "significant alteration of the reclamation plan" under SMCRA.
12. <u>Alternatives for Regulatory Authority</u>
    a. Neither SMCRA nor its implementing regulations currently address the use or placement of CCRs in an explicit manner. As a consequence, states vary in their approach and in the rigor with which they address CCR use in mines.
    b. The Committee concludes that although SMCRA does not specifically regulate CCR placement at mine sites, its scope is broad enough to encompass such regulation during reclamation activities.
    c. Some states have expressed concern that they do not have the authority to impose performance standards specific to CCRs. Therefore, the Committee recommends that enforceable federal standards be established for the disposal of CCRs in minefills.
    d. The Committee believes that OSM and its SMCRA state partners should take the lead in developing new national standards for CCR use in mines because the framework is in place to deal with mine related issues.

d. Regardless of the regulatory mechanism selected, coordination between OSM and EPA efforts is needed and would foster regulatory consistency with EPA's intended rulemaking proposals for CCR disposal in landfills and impoundments.
e. In all cases, guidance documents will also be necessary to help states implement their responsibility for managing CCR.

State Perspective on the Management and Regulation of Coal Combustion Residues

In May of 2000, the U.S. Environmental Protection Agency (EPA) published a Notice of Regulatory Determination on Wastes from the Combustion of Fossil Fuels. Among other things, and of particular concern to the states, EPA found that, although coal combustion by-products (CCBs) (or coal combustion residues (CCRs)) did not warrant regulation under subtitle C of the Resource Conservation and Recovery Act (RCRA) as "hazardous waste," the agency had determined that national regulations under subtitle D of RCRA are warranted when these wastes are disposed in landfills or surface impoundments, and that regulations under subtitle D and/or possible modifications to existing regulations established under the Surface Mining Control and Reclamation Act (SMCRA) are warranted when these materials are used as fill in surface or underground mines. IMCC was especially concerned about the "mine placement" aspects of the determination given the significant interplay between approved state regulatory programs under SMCRA and any potential adjustments to the national SMCRA regulations (which serve as a template for state regulatory programs).

Following publication of EPA's notice, IMCC suggested to both EPA and the Office of Surface Mining (OSM) that an intergovernmental forum would serve as a valuable mechanism to initiate discussions between state and federal governments concerning next steps pursuant to the regulatory determination. This suggestion followed on the heels of a resolution adopted by IMCC in May of 2000 affirming the appropriateness and effectiveness of state regulations and policies for the safe handling, recycling, beneficial use and placement of coal combustion by-products and supporting the management of CCBs without the application of federal RCRA subtitle C requirements.

The first of the state/federal dialogues occurred in May of 2001 and over the course of the next three years, the parties shared and discussed information and analyses of their respective regulatory programs under SMCRA and RCRA. The states also provided data and information from state approved permits where mine placement was predominant to demonstrate the types of environmental controls applicable in these situations and the environmental protection afforded by exiting regulatory standards. Copies of the various documents and notes generated at the four state/federal dialogues are available at www.epa.gov/epaoswer/other/fossil/index.htm.

Throughout the state/federal discussions, the states consistently articulated the following concerns to EPA and OSM, several of which were addressed in the NRC report:

1. SMCRA appears to serve as an adequate and effective baseline for any type of regulatory analysis concerning mine placement of CCRs. In this regard, the states see the SMCRA permit serving as the platform for CCR mine placement at coal mines. For non-coal mines, the states believe that the existing state permitting framework, which is often RCRA-based, is adequate.
2. It is essential to examine the effectiveness and comprehensiveness of existing state programs before adding additional regulatory requirements. Experience at the state level in implementing existing state and federal laws substantiates the adequacy of the existing regulatory structure.
3. There is a need to coordinate among all applicable statutes/regulations that impact the regulation of mine placement of CCRs, including SMCRA, RCRA, the Clean Water Act and the Safe Drinking Water Act. There is a belief that many of the necessary regulatory requirements are already in place in the context of these statutes and their respective regulatory programs.
4. There is an absolute need for flexibility to accommodate differences among the states related to geology, climate, ash characterization and agency operation. Comprehensive federal regulation will be difficult to implement on a nationwide basis due to these differences.
5. There needs to be consideration given to both coal and noncoal sites and the differences between them. In

> this regard, heavy-handed federal efforts to achieve some sort of uniformity will only undermine effective and efficient regulation at the state level.

As an overall objective in the area of regulating mine placement of CCRs, the states have strived to strike a balance between existing state regulatory program requirements and any gaps that may be defined and justified. Although there are differences among the states in the way they regulate mine placement of CCRs (for instance, in terms of sharing jurisdiction among several state agencies; relying primarily on the SMCRA program for mine placement at coal mines; and differentiating between beneficial use and classic disposal), there has been limited evidence of major gaps that require filling through new national regulations under either SMCRA or RCRA. And in those states that do not have well defined programs for mine placement of CCRs, it is usually because they have not had to deal with its beneficial use or disposal within their borders. Even in those states, a comparison of their programs with states who actively regulate mine placement of CCRs demonstrates that most, if not all, of the program elements are in place and would likely operate effectively when needed.

The few areas within state programs that have been shown to need some degree of shoring up, as suggested in the NRC report, can best be addressed through intergovernmental discussions, such as have occurred over the past several years. Also, through a benchmarking type of approach, states can identify areas in their programs that would benefit from fine-tuning and this can be accomplished by patterning these areas after other state programs. If and when specific regulatory gaps are confirmed to exist in a significant majority of state programs, then it would be appropriate to consider national guidance from OSM (the agency recommended by the NRC to take the lead in this area). However, all of the analyses of state programs undertaken to date by OSM and EPA do not justify the need for such guidance, and OSM has stated on numerous occasions that it believes state programs are adequate or structured in such a way as to address any gaps (at least as far as SMCRA programs for CCR mine placement at coal mines are concerned).

The states, via IMCC, had an opportunity to discuss their perspectives and concerns regarding the NRC report on July 26 with both OSM and EPA. The parties also had an opportunity to talk generally about anticipated next steps in light of the report. During the discussions, the states raised the following issues that relate to the specific findings and recommendations in the NRC report concerning the regulation of mine placement of CCRs:

1) CCR Characterization

- Test methods – the states believe that this is the key issue with regard to CCR characterization. There has been considerable controversy surrounding this matter, both in terms of the most reliable existing test method and the need for a newer, better test. The states are using what they believe are the best test methods available at this time. It would be helpful if OSM and EPA would consider developing a list of acceptable methods/tests from which the states can select, until such time as either OSM or EPA develop a better test. It is important for the states to have flexibility in choosing what they believe is the most appropriate method under the circumstances.
- Parameters – there needs to be agreement on what parameters we need to test for. The list on page 114 of the draft NRC report is very complete, but it includes some parameters, such as uranium, that may not be appropriate under the circumstances. Before the states request mine operators to test for these various parameters (which in most cases can be done in the labs), we need to be sure that there is a solid basis for doing so.
- Frequency – the frequency of testing must be left up to the states based on the conditions of the CCR and the site. Flexibility is key here.
- “Significant mine placement” – this is one of several terms used throughout the NRC report that needs to be defined. Is it necessary to characterize small amounts of ash that are being used at mines? Are there thresholds that can be established?

2) Site Characterization

- “Substantial placement of CCRs” – again what does this term mean? It should be defined with some specificity.
- Performance measures and permitting requirements – this is an area that lends itself well to referencing existing SMCRA performance measures and permitting requirements that would be applicable to mine placement (as they are to other aspects of the mining operation). The states recognize that it will be necessary to demonstrate more specifically how and to what extent existing requirements and standards do, in fact, apply to mine placement. A specific permit finding would likely be helpful here that documents the application of these requirements.

3) Management, Design and Monitoring

- Compliance point – with regard to monitoring, this is the key issue from the states’ perspective. We need to know where we are going to measure/monitor water quality with regard to mine placement of CCRs. This could be the permit boundary, a certain distance beyond the permit boundary or mine placement location, a receptor, etc. In any event, it must be defined in the new rules. And in setting this compliance point, OSM must keep in mind that some states have specific laws in place for well placement as part of their groundwater monitoring requirements.
- “Minimize reactions with water” – this is another term that needs to be defined. Consideration must be given to site conditions in doing so. There are places in the country where there is very little water (and hence no leachate), where placing CCRs below the water table is not problematic, and where the “water table” is defined on a regional basis, not on a site-specific basis. All of these situations must be taken into consideration.
- Site-specific management plan – these plans are critical to how the states structure permitting requirements and must be designed for the site conditions.
- Duration – in defining the duration of monitoring, it should be kept in mind that we are not dealing with landfills and therefore a RCRA approach will not work. Mine placement involves a higher degree of CCR characterization than is the case with landfills and hence the duration of monitoring will be different. Also, we need to be mindful of the impacts of monitoring duration on reclamation bonds. These bonds are tied to classic reclamation scenarios and do not lend themselves to long-term situations. If we move in the direction of extended periods of responsibility for monitoring of CCR placement, a different type of financial guarantee will be needed.

4) Performance Measures – similar to site characterization, the states believe that many of the existing SMCRA performance measures are applicable to mine placement, just as they would be for any part of the mining and reclamation operation. The only potential enhancements would be those noted above with respect to parameters for CCR characterization. In this regard, the Commonwealth of Pennsylvania has already developed several adjustments to its existing performance measures and permitting requirements, most of which reference existing standards that will now be applicable to mine placement.

5) Public Participation

- “Substantial quantities of CCRs” – this term needs to be defined, as suggested above. If we’re dealing with small quantities of coal ash, this should not be considered a “significant permit revision.” Furthermore, changes in the source of the ash should not be considered a significant revision. Only where an operator is going to be placing CCRs at a permitted site should a significant permit revision be required. Also, there should be a grandfathering provision once the rule is adopted for those situations where a permit already exists.

6) Reporting – what type of reporting does OSM anticipate? OSM should be cognizant of the impacts that quarterly reporting will have on both the states and mine operators, as well as the relative value of such frequent reporting. The states are also concerned about requirements for electronic reporting and the potential for one stop/one location reporting, both of which have merit but may require time to implement.

Other issues and perspectives raised during the meeting included the following:

- The western states emphasized the importance of site-specific flexibility that will allow states to account for unique differences based on climate, geology, etc.
- OSM and EPA should be aware that in some states (ND, TX, CO) there are separate regulatory authorities that deal with the RCRA aspects of mine placement of CCRs and that SMCRA rules and permitting requirements may need to be coordinated with these agencies.
- In response to a question about the type of performance standards that OSM anticipates, OSM indicated that those in sections 515 and 516 of SMCRA are sufficient and that the new rule will likely be a collection and re-application of existing standards as they apply to mine placement. There may be some new permitting requirements that explicitly show how an operator will specifically insure that the performance standards are met with respect to mine placement of CCRs. EPA agreed with this perspective.
- From a noncoal state's perspective, it was noted that flexibility will be important, especially with regard to mine placement at industrial mineral or metal/non-metal mines. It was suggested that the rules for disposal at landfills and surface impoundments be coordinated with those for minefilling to be sure that there are no serious conflicts. Test methods will also be critical to the on-going efforts to regulate in this area.

From the states' perspective, now that the NRC has completed its work and issued its report, we expect that OSM, in coordination with EPA, will move forward with its position on the need for and potential content of additional federal regulation of minefill practices for coal combustion residues. We believe that all of the information required by the agency to make this decision is now in hand and that it is well poised to render that decision. In the end, we anticipate that OSM, in coordination with EPA, can appropriately recommend that the states continue their on-going efforts to work cooperatively with both agencies to assess the effectiveness of their respective regulatory programs and make appropriate adjustments, given the flexibility and discretion afforded the states under SMCRA's state primacy design. To the extent that it is necessary to specifically demonstrate how and to what extent existing regulatory requirements are applicable to mine placement of CCRs, we believe OSM can accomplish this through the promulgation of narrowly drawn regulations or program guidance. Furthermore, we anticipate that the states will continue their benchmarking initiatives, which provide for the analysis and comparison of state program elements with the overall objective of enhancing their respective programs through the adoption of lessons learned during program implementation and the incorporation of innovative approaches. In the final analysis, we believe that our citizenry and the environment will be well served by state regulatory programs that fully comply with applicable federal laws and that reflect the results of the laboratories of invention inherent in state primacy. We also believe that an effective regulatory regime for the mine placement of coal combustion residues will insure that there are effective and safe alternatives to classic land disposal while enhancing the reclamation of both active and abandoned mined lands.

Greg Conrad is Executive Director of the Interstate Mining Compact Commission (IMCC), a multi-State governmental organization representing 23 mineral producing States. Greg has served in his position since 1988 and is responsible for overseeing several issues of importance to the States in the legislative and regulatory arenas including: surface mining and reclamation; mine waste; identification and restoration of abandoned mine lands; and various environmental issues associated with mineral production such as surface and ground water quality and quantity. Prior to joining IMCC, he served for nine years as senior counsel with the American Mining Congress, which is now part of the National Mining Association. While with AMC, he had primary staff responsibility for several coal related issues including transportation, leasing, research and development initiatives, and surface mining and reclamation. He has spoken and presented papers at a variety of conferences hosted by such organizations as the Eastern Mineral Law Foundation, the National Academy of Sciences, the American Association of State Geologists, the Conference of Government Mining Attorneys, the Colorado School of Mines, the Office of Surface Mining, the National Mining Association, the Environmental Law Institute and various State government groups. He has written extensively on mining issues for professional journals and magazines. He graduated from Michigan State University with a degree in Business Administration and later from the University of Detroit School of Law where he was an associate editor of the law review.

UTILITY SOLID WASTE ACTIVITIES GROUP (USWAG) PERSPECTIVE ON MINE PLACEMENT OF CCPS

Jim Roewer
Executive Director
Utility Solid Waste Activities Group
Washington, D.C.

View Presentation

Abstract

The utility industry is committed to ensure that coal ash (or, as we prefer to call them, coal combustion products or CCPs) is managed in an environmentally sound manner. We believe that the mine placement of CCPs is environmentally safe, and indeed, is environmentally beneficial. Four times, in the nearly 24 years of EPA's study of CCPs, EPA came to the conclusion that these materials do not warrant hazardous waste regulation – first in 1988; second in 1993; third in 1999; and finally in 2000. However, in the portion of its May 2000 regulatory determination regarding placement of CCPs in mines, EPA concluded that further study was needed to make a determination whether the existing regulatory system under the Surface Mining Control & Reclamation Act (SMCRA) was adequate or whether it needed to be supplemented either by additional regulations under SMCRA or under RCRA. EPA, working with the Interstate Mining Compact Commission, collected substantial data from mine placement sites around the country and to coordinate its work with other federal and state environmental and mining regulatory agencies, with the public, and with interested stakeholders. The result of this effort indicated that the states have robust regulatory programs addressing CCP mine placement, and, most significantly, that there were no demonstrated cases of environmental damage associated with the mine placement of CCPs. Nonetheless, in 2004, the National Academy of Sciences (NAS) established within the National Research Council a Committee on Mine Placement of Coal Combustion Wastes to further examine the issue of the implications and need for regulation of the mine placement of CCPs.

In spite of the fact that the Statement of Tasks of the Committee on Mine Placement seemed to presume that CCPs are the problem requiring a host of regulatory actions, we are pleased that the NAS recognized that the mine placement of CCPs can be an environmentally sound management practice. The NAS Report did recommend some regulatory improvements and the utility industry welcomes the opportunity to work cooperatively with other stakeholders – federal and state regulators, the mining industry and the public – to develop standards that will ensure that the mine placement of CCPs is conducted in a manner that continues to be protective of human health and the environment.

This presentation will focus on the utility industry's perspective of the NAS Report and the next steps in the development of CCP regulations.

Introduction

The utility industry is committed to ensure that coal ash (or, as we prefer to call them, coal combustion products or CCPs) is managed in an environmentally sound manner. We believe that the mine placement of CCPs is environmentally safe and environmentally beneficial. Indeed, the placement of CCPs in mines is a cost-effective and environmentally beneficial alternative to management in landfills and surface impoundments. CCPs have been used successfully to fill abandoned surface and underground mines for many years. Rather than manage large volumes of CCPs in surface impoundments and landfills, some utilities use the material to stabilize abandoned mines and mitigate the effects of acid mine drainage. While EPA regulations currently do not affect the placement of CCPs in mines, the Office of Surface Mining (OSM) of the Department of Interior has broad regulatory jurisdiction over mine reclamation under SMCRA and many states regulate the practice. From the electric utility perspective, it is clear that there is no need for a comprehensive federal regulatory program under RCRA to address CCP management, including disposal of CCPs in surface impoundments or landfills, or CCP mine placement. The utility industry, through improved management practices, and the states, through their existing authorities under

RCRA and SMCRA, is acting to ensure that CCP management is conducted in a manner that is protective of human health and the environment.

Regulatory History

On August 9, 1993, EPA determined that regulation of the four large volume fossil-fuel combustion wastes (fly ash, bottom ash, boiler slag, and flue gas desulfurization waste) as hazardous is "unwarranted" under RCRA Subtitle C. (See 58 Fed. Reg. 42466) In the second phase of the Bevill process, EPA addressed issues of co-management, ash derived from co-burning of coal from non-hazardous solid waste, ash derived from clean coal combustion, and combustion residues from burning oil and natural gas. EPA submitted its second Report to Congress on March 31, 1999 (See 64 Fed. Reg. 22820, April 28, 1999). On April 25, 2000, EPA issued its Phase II Regulatory Determination. (See 65 Fed. Reg. 32214, May 22, 2000). EPA concluded in the Phase II Bevill regulatory determination that hazardous waste regulation of fossil fuel combustion wastes "is not warranted," reaffirming the 1993 determination for coal combustion wastes and extending it to oil and gas combustion wastes as well as low volume wastes co-managed with high volume coal combustion wastes.

Thus four times, over nearly a quarter of a century of study of CCP management and regulation, EPA came to the conclusion that these materials do not warrant hazardous waste regulation – first in 1988; second in 1993; third in 1999; and finally, in 2000. However, in the portion of its May 2000 regulatory determination regarding placement of CCPs in mines, EPA concluded that further study was needed to make a determination whether the existing regulatory system under the Surface Mining Control & Reclamation Act (SMCRA) was adequate or whether it needed to be supplemented either by additional regulations under SMCRA or under the Resource Conservation and Recovery Act (RCRA). EPA, working with the Interstate Mining Compact Commission (IMCC), collected substantial data from mine placement sites around the country. To coordinate its work with other federal and state environmental and mining regulatory agencies, with the public, and with interested stakeholders: the IMCC coordinated a series of meetings among EPA, DOE, OSM, and state regulators on the issue in 2001 and 2002. In May 2003, EPA hosted a stakeholder meeting at which a number of citizens expressed their concerns about placement of CCPs in mines. In 2004, EPA held four "listening sessions" regarding CCP management (including mine placement) in Pennsylvania, Texas, and Indiana. The sessions produced a range of testimony from industry, state regulators, academics, environmental groups, and citizens. USWAG presented testimony at each of the listening sessions that delivered a positive message about the benefits of CCP placement in mines and rebutted concerns and issues raised to criticize the practice. The general impression in the wake of the listening sessions was that EPA did not hear any facts or allegations that differed substantially from those already in the agency's record prior to the public sessions.

Response to NAS Report

The overall result of this multi-year effort clearly indicated that the states have robust regulatory programs addressing CCP mine placement, and, most significantly, that there were no demonstrated cases of environmental damage associated with the mine placement of CCPs. Nonetheless, in 2004, as a result of a request from Congress, the National Academy of Sciences (NAS) established within the National Research Council a Committee on Mine Placement of Coal Combustion Wastes to further examine the issue of the implications and need for regulation of the mine placement of CCPs.

In spite of the fact that the Statement of Tasks of the Committee on Mine Placement seemed to presume that CCPs are the problem requiring a host of regulatory actions, the report's conclusions are not particularly offensive. The report endorses the use of CCPs in mine reclamation, and also makes very positive statements about the beneficial use of CCPs in other applications. Unfortunately, the NAS panel failed to fully appreciate the depth and breadth of existing OSM SMCRA and state regulatory controls – federal standards – that apply to CCP mine placement, and the report calls for OSM to develop enforceable federal regulations that specifically address the placement of CCPs in mines. It should be noted that while existing OSM standards do not explicitly address CCP mine placement, the standards are designed and implemented to ensure that mine reclamation activities, which do include CCP mine placement, are conducted in an environmentally sound manner. Thus the suggested changes need not entail a major overhaul of the SMCRA regulations. Other recommendations in the report are mostly technical, many of which are consistent with current industry practice.

Overall, we are pleased that the NAS recognized that the mine placement of CCPs can be an environmentally sound management practice. The utility industry welcomes the opportunity to work cooperatively with other stakeholders – federal and state regulators, the mining industry and the public – on implementation of some of the regulatory improvements suggested in the report. We are particularly pleased that OSM is moving to implement/develop standards that will maintain regulatory primacy with the states and that will ensure that the mine placement of CCPs is conducted in a manner that continues to be protective of human health and the environment.

Jim Roewer is the Executive Director of the Utility Solid Waste Activities Group (USWAG). USWAG consists of approximately 80 utilities, energy companies, and trade associations and is responsible for addressing solid and hazardous waste issues on behalf of the utility industry. USWAG's mission is to support its members production and delivery of energy in an environmentally sound and economic manner. Jim is responsible for overall program management, including the addressing of solid and hazardous waste and toxic substance issues on behalf of the utility industry, budget development & oversight, and membership marketing & recruitment. He serves as the Chairman of ASTM Subcommittee E50.03 on Pollution Prevention/Beneficial Use, and as a member of the Steering Committee of the Combustion Byproducts Research Consortium. He has served as Senior Environmental Manager in the Energy Policy Department of the National Rural Electric Cooperative Association (NRECA); Environmental Scientist in the Natural Resources Section of the Edison Electric Institute; Manager, State and Local Government Relations with the American Society of Mechanical Engineers; and Research Assistant with the Science Unit of the Illinois Legislative Research Service. Jim holds a MS in Environmental Science from the School of Public and Environmental Affairs at Indiana University and a BA in Biology from Wittenberg University.

Mineplacement and Regulation of CCPs

Jim Roewer

OSM Technical Interactive Forum

November 14 - 16, 2006

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CCP Regulatory Background

- 1980 Bevill Amendment
- 1988 Report to Congress
- 1993 Regulatory Determination on “High Volume” Wastes
- 1999 Report to Congress
- 2000 Regulatory Determination
- 2004 EPA CCP “Listening Sessions”

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CCP Regulatory Background

- 1988 Report to Congress (RTC I)
- 1993 Regulatory Determination (58 Fed. Reg. 42466)
  - High Volume Wastes do not warrant regulation under RCRA Subtitle C
  - **EPA "encourages the utilization of coal combustion wastes"**

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CCP Regulatory Background

- 1999 Report to Congress (RTC II)
- May 2000 Regulatory Determination
  - No Hazardous Regulation for CCPs
  - No regulation for any of the above when beneficially used
  - **EPA does “not wish to place any unnecessary barriers on beneficial use”**

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CCP Regulatory Background

- May 2000 Regulatory Determination
  - <u>No</u> Damage Cases from Mine Placement
  - SMCRA “is expressly designed to address environmental risks associated with coal mines.”
  - EPA to Develop National Regulations Under Subtitle D (or Modify SMCRA) for CCPs Used in Minefilling Operations

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NAS Study on Mineplacement

- Congressional Request Initiated Study 2004
- Initial Public Meeting in Washington, DC October 2004
- Field Meetings (Public Sessions & Facility Tours) in New Mexico, Texas, Indiana, Pennsylvania 2004 - 2005
- Final Report Released March 2006

Scope of Study
NAS Study on Mineplacement

- Adequacy of Surface, Groundwater Monitoring
- Impacts to Aquatic Life
- Regulator & Operator Response to Contamination
- Adequacy of Characterization of CCPs, Site

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Scope of Study
NAS Study on Mineplacement

- Adequacy of Performance Standards for CCP Beneficial Use
- Need for Isolation Requirements
- Adequacy of Monitoring Programs
  - Duration of Monitoring
  - Number & Location of Wells
  - Constituents Monitored
  - Corrective Action Standards

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Scope of Study
NAS Study on Mineplacement

- Adequacy of Restoration for Post-mine Use
- Financial Assurance for Monitoring & Corrective Action
- Public Involvement in Permitting & Policy Making
- Adequacy of Risk Assessment

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NAS Study on Mineplacement Conclusions

- Mineplacement Recognized as a “Viable Option”
- **No Damage from CCP Mineplacement**
- Regulatory Enhancements:
  - Improved Characterization of CCPs, Mine Sites
  - Robust Monitoring of Sites
  - Development of “Enforceable Federal Standards”

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CCP Mineplacement Regulations – Industry's Opinion

- Regulation as Non-Hazardous Waste
- Regulation Under SMCRA
- Regulation Implemented by the States
- Site-Specific Approach
- Performance-Based Standards

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CCP Mineplacement Regulations – NAS Recommendations

- That "… enforceable federal standards be developed that give the states the authority necessary to implement minimum national safeguards while allowing sufficient flexibility to adapt permitting requirements to locally specific conditions." (NAS Report, Chairman's Opening Statement, p. 3)

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CCP Mineplacement Regulations – NAS Recommendations

- Characterization of CCPs Prior to Placement
- Site Characterization Prior to Placement
- Site-Specific Management Plans & Performance Standards
- Groundwater Monitoring
- Disposal in Mines Subject to Site-Specific Performance Standards

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CCP Disposal Regulations – EPA Rulemaking

- Non-hazardous per 1993 and 2000 Regulatory Determinations
- NODA – Early 2007?
- Proposed Rule – May 2007
- Final Rule – 2008?

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CCP Disposal Regulations – Industry's Opinion

- Regulation as Non-Hazardous Waste
- Implemented by the States
- Performance-Based Approach
- Gap Filling Standards

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USWAG CCP Action Plan

- Developed in Response to Concerns Raised by EPA
  - Groundwater Monitoring
  - Placement in Sand & Gravel Pits
  - Dry Handling v Management in Surface Impoundments
- Final Version Released October 2006 after Discussion with EPA, States (ASTSWMO) & Environmental Groups (CATF)

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UTILITY INDUSTRY ACTION PLAN
FOR THE
MANAGEMENT OF COAL COMBUSTION PRODUCTS

Submitted to the

United States Environmental Protection Agency
Office of Solid Waste
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, D.C. 20460

by the

Utility Solid Waste Activities Group
701 Pennsylvania Avenue, NW
Washington, D.C. 20004-2696
202-508-5645

October 2006

USWAG

USWAG CCP Action Plan

- Voluntary Program Designed to:
  - Adopt Groundwater Performance Standards at Landfills, Surface Impoundment
  - Implement Comprehensive Monitoring Program to Measure Compliance with Performance Standards
  - Ensure no CCPs Placed in Sand & Gravel Pits without Appropriate Engineering Controls
  - Consider Dry Handling for New CCP Management Units

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USWAG CCP Action Plan – the Bottom Line

- Implementation of the Action Plan will Achieve Enhanced Environmental Protection on a More Rapid Timetable than Through EPA's Regulatory Process
- Will Fill any Perceived Gaps in State Regulations

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Regulation of CCP Mineplacement and Disposal -- Conclusions

- No Need for Comprehensive Federal Regulatory Program
  - Performance Based Standards for Disposal and Mineplacement
  - State Regulatory Oversight for Disposal and Mineplacement
  - EPA’s Role = Technical Assistance & Filling Gaps

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Questions?

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WHERE DO WE GO FROM HERE?

FORUM PARTICIPANT RECOMMENDATIONS

At the conclusion of the forum on November 16, 2006, the participants provided the following recommendations concerning issues or concerns deserving attention and efforts by the Coal Combustion By-Products Steering Committee.

1. OSM should have a two- to three-day training class or workshop (including a one-day field experience) that would provide training on the use of CCBs at mines.
2. Would like to see a full session of detailed case studies of CCB placement at mines in a future forum event.
3. Would like to see a workshop that would focus on groundwater modeling for CCB placement. What types of models are available, what types of data do you need, and what are the advantages or disadvantages of these models?
4. OSM currently has an AMD leaching protocol analysis underway under the Acid Drainage Technology Initiative. Since many of the concerns about CCBs leachate generation in groundwater are similar, perhaps OSM should consider a similar initiative related to potential leachate from CCB placement. The goal would be to develop the best available leaching protocols.
5. Need to provide more information on applications in underground mine settings. What is the feasibility of using these materials beneficially?
6. Recommend that OSM send out an e-mail notice to the forum participants when either EPA or OSM generates Federal Register notices related to this issue.
7. Develop a risk assessment analysis that would be acceptable to OSM and EPA.
8. Electric utilities are now required to provide watershed mitigation under the water intake rules at 316b. Some utilities are beginning to evaluate abandoned mine reclamation as one possible mitigation measure. This is a heads up that there may be additional funds available for abandoned mine reclamation.
9. We need to share our water monitoring strategies and specifications.

SURVEY RESULTS
FLUE GAS DESULFURIZATION BY-PRODUCTS AT COAL MINES AND RESPONSES TO THE NATIONAL ACADEMY OF SCIENCES FINAL REPORT "MANAGING COAL COMBUSTION RESIDUES IN MINES": A TECHNICAL INTERACTIVE FORUM
PARTICIPANT COMMENTS AND RECOMMENDATIONS

CATEGORY OF PARTICIPANTS	PARTICIPANTS #	PARTICIPANTS %
TOTAL PARTICIPANTS	124	
TOTAL COMPLETING THE SURVEY	37	100
LEVEL OF SATISFACTION WITH THE FORUM		
EXTREMELY SATISFIED	20	54
VERY SATISFIED	17	46
SATISFIED	0	0
DISSATISFIED	0	0
VERY DISSATISFIED	0	0

Compliments

1. OSM has done a great job of putting together a great coal ash forum….again!
2. This was an important meeting. Very timely. Thanks to OSM for keeping this initiative going.
3. An excellent program! Very timely. The whole impact of the forum was greater than the sum of the parts.
4. A very well planned and organized field tour. This was a highlight of the forum.
5. The field tour was very interesting and well organized. I liked how several of the presentations the next day discussed the sites that were visited.
6. Having the field trip first followed by the presentations was a very good format. I look forward to future events.
7. The field trip was well run and very informative.
8. This Ash Forum format is very good and should be copied by other OSM technology transfer forums.
9. This is a good format. Each session was not too long and the panel discussion allows a good opportunity for open interaction.
10. The speaker lineup was very good, well organized, and very professional.
11. The talks were well timed and spaced with adequate breaks.
12. The panel discussions were excellent in pulling together and clarifying the thoughts and ideas presented in the session.
13. Networking opportunities were excellent.

WHERE DID THE PARTICIPANTS COME FROM?
AND WHO DID THEY REPRESENT?

PARTICIPANT AFFILIATION	PARTICIPANT #	PARTICIPANT %
Electric Utility	26	21
State Mining Regulatory Agency	23	19
University	18	15
Mining	15	12
Consultant	15	12
OSM	10	8
DOE	5	4
U.S EPA	4	3
Conservation Group	3	2
Other	3	2
US Geologic Survey	2	2

REGIONAL REPRESENTATION	PARTICIPANT #	PARTICIPANT %
WEST	10	8
EAST	88	71
MID-CONTINENT	26	21

Participant Rating on Usefulness of Talks

4.0=EXCELLENT; **3.0**=GOOD; **2.0**=FAIR ; **1.0**=POOR

SESSION 1 FGD PLACEMENT AT MINES

PRESENTER	AVERAGE RATING	RATING RANGE
William Aljoe	**3.5**	**4-2**
Mary Stoertz	**3.0**	**4- 2**
Dennis Noll	**2.9**	**4- 2**
Warren Dick	**3.5**	**4- 3**
Paul Ziemkiewicz	**3.5**	**4- 3**
Barry Thacker	**3.2**	**4- 2**
OVERALL SESSION 1 AVERAGE	**3.3**	

SESSION 2 LEACHATE PROTOCOLS FOR HYDROLOGIC ASSESSMENT

PRESENTER	AVERAGE RATING	RATING RANGE
Debra Pflughoeft-Hassett	**2.8**	**4- 1**
Ishwar Murarka	**3.0**	**4- 1**
Ken Ladwig	**3.2**	**4- 2**

Craig Benson	**3.2**	**4-**	**2**
Candace Kairies	**2.8**		**4-1**
Andrew Garrabrants	**2.9**		**4-(-1)**
OVERALL SESSION 2 AVERAGE	**3.0**		

SESSION 3 PEER REVIEW OF NATIONAL ACADEMY OF SCIENCES CCB & MINING REPORT

PRESENTER AVER	AGE RATING		RATING RANGE
Richard Sweigard	**3.2**	**4-**	**1**
Ishwar Murarka	**3.4**	**4-**	**2**
Paul Chugh	**2.8**	**4-**	**2**
Harold Walker	**3.0**	**4-**	**1**
David Hassett	**3.2**	**4-**	**2**
Paul Ziemkiewicz	**3.6**	**4-**	**2**
Kimery Vories	**3.5**	**9.**	**5-2**
OVERALL SESSION 3 AVERAGE	**3.2**		

SESSION 4 REGULATORY STATUS

PRESENTER AVER	AGE RATING		RATING RANGE
Bonnie Robinson	**3.0**	**4-**	**2**
John Craynon	**3.7**	**4-**	**3**
Greg Conrad	**3.3**	**4-**	**2**
Jim Roewer	**3.5**	**4-**	**2**
OVERALL SESSION 4 AVERAGE	**3.4**		

Suggestions For Improvement

CCB Future Forums

- Beneficial Use and Risk Management in relation to CCB placement at surface mines.
- After OSM promulgates its new rules, have presentations by states on how their programs have changed.
- Use of FGD for agricultural applications.
- More mine site case studies where CCBs have been placed.
- Groundwater assessment for bond release.
- Options for treatment of low flow acid seeps with CCBs.
- More case studies of mining reclamation uses of CCBs with evidence of improvement.
- More information on the actual contaminants of concern (i.e. boron, arsenic, mercury, etc.). What are the pathways of exposure & impacts to ecosystems & human health.
- Have the next forum after the OSM rulemaking.
- How to communicate attributes of CCB placement to the public and the media.
- Need to have presentations by the coal industry as to the impacts of new regulations and the National Academy report.
- More on-site operational requirements and physical characteristics necessary for mine placement.
- Emphasize empirical case studies.
- Focused discussion of future research strategies.

OTHER

- Presentation of slides could have been improved. It was difficult to get good focus through the use of dual overhead projectors. Some presenters did not use colors and fonts in a way that slides could be easily read.
- Prefer not linear but semi circle seating for improved discussions.
- Hotel location was not ideal for participants without transportation.
- Power Point slides should use high contrast.
- Would prefer that all speakers use a visual presentation.
- Need to keep the speakers to 25 minutes so there is time for questions.
- Need to make sure that all talks contribute to a well focused session.
- Provide access to power point presentations on OSM Website.

APPENDIX 1: RECORDED DISCUSSIONS

Edited by
Kimery C. Vories
USDI Office of Surface Mining
Alton, Illinois

The following are the edited discussions that took place at the end of each speaker presentation and at the end of each topic session. The actual comments have been edited to translate the verbal discussion into a format that more effectively and efficiently communicates the information exchange into a written format. The organization of the discussion follows the same progression as that which took place at the forum. The topic of each question is arranged in alphabetical order for ease of access. A topical outline has been developed to aid in accessing the information brought out in the discussions.

The topic of each question is shown in alphabetical order in **bold.** The individual speaker questions are listed in outline format under the appropriate topic session and presentation title. Questions during the interactive discussions are listed at the end of the session in the following format.

SESSION # AND TOPIC AREA
1. Presentation Title
    - **Subject of Question or Comment**

SESSION #: INTERACTIVE DISCUSSION
Subject of Question or Comment

OUTLINE OF DISCUSSION TOPICS

SESSION 1: FGD PLACEMENT AT MINES

1. An Overview of FGD By-product Characteristics, Production, and Use: Prognosis for Mine Placement

2. FGD as an Impermeable Cap for Coal Waste
    - **Alkaline Recharge Trench**
    - **FGD Cap Thickness**

3. FGD as an Alkaline Amendment for Coal Waste
    - **Blend Ratios**
    - **Total Application Volume**
    - **Transportation Method**

4. FGD as a Soil Amendment for Mine Reclamation
    - **Application Limits due to Boron**
    - **Application Rate**
    - **Plant Tissue Trace Element Analysis**
5. Groundwater Effects of Coal Combustion Byproduct Placement in Coal Mines
    - **AMD Effect on FGD**
    - **Application Amount**
    - **Continuation of Water Monitoring**
    - **FGD Mixture**
    - **Form of Mercury**

6. FGD for Highwall Reclamation
   - **FGD Components**
   - **Transportation Distance**

SESSION 1: INTERACTIVE DISCUSSION
- **Dual RCRA & SMCRA Permit Requirements**
- **Economic Impact of CCB Placement**
- **Impact of Future Mercury Controls on Use of FGD**
- **Impact of OSM CCB Specific Rules**
- **Long Term Solubility of FGD**
- **OSM CCB Placement Training Course**

SESSION 2: LEACHATE PROTOCOLS FOR HYDROLOGIC ASSESSMENT

1. Development of a Standard Guide for Selecting a Leaching Protocol
   - **ASTM Conflicts with NAS Report**
   - **ASTM Search for a Best Available Test**
   - **Comprehensive Tests Versus Scenario Specific Test**
   - **Jurisdictional Concerns**
   - **Scenario Specific Tests**

2. Comparing Laboratory and Field Leaching of Coal combustion By-Product Constituents
   - **pH Values in Leachate**
   - **Value of pH as an Indicator in Leachate Tests**

3. Speciation and Attenuation of Trace Constituents in CCPs

4. Leaching of Trace Elements from Pavement Layers Stabilized with Coal Fly Ash
   - **Batch Tests as a Field Indicator for Selenium**
   - **Mineralogical Changes**

5. Solubility of FGD Gypsum Using a Continuously-Stirred Tank Reactor
   - **Sample Preparation**

6. An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials

SESSION 2: INTERACTIVE DISCUSSION
- **Comparison of Leachate Data with Drinking Water Standards**
- **Comprehensive Studies Needed to Determine Potential Impact of Mine Placement**
- **Kossen Test Applicability as a comparison to Existing Ground Water Quality**
- **Kossen Test Duration and Cost**
- **Need for Suite of Characterization Methods and Leachate Tests**
- **Public Confidence in Mine Placement**

SESSION 3: PEER REVIEW OF NATIONAL ACADEMY OF SCIENCES CCB & MINING REPORT

1. Managing Coal Combustion Residues in Mines: A Report of the National Academy of Sciences

2. Technical Comments on the National Research Council Report on Managing Coal Combustion Residues at Mines

3. National Academy of Sciences (NAS) Final Report "Managing Coal Combustion Residues in Mines": A Review

4. Comments on Managing Coal Combustion Residues in Coal Mines

5. A Review of the National Research Council Report on "Managing Coal Combustion Residues in Mines"

6. National Academy of Sciences Mine Fill Report: Critical Evaluation of Recommendations for Future Research

7. A Technical Review of the Final Report of the National Academy of Sciences "Managing Coal Combustion Residues in Mines"

SESSION 3: INTERACTIVE DISCUSSION

- **Appropriate Data for a New Mine or Power Plant**
- **Available Data Acceptability**
- **Committee Composition**
- **Congressional Response to NAS Report**
- **Consensus Process**
- **EPA Damage Cases**
- **Impact of NAS Report on Permitting**
- **Lack of Recognition of Ash Types**
- **Lack of Reference to Gorilla Pit Data**
- **Landfill Preference**
- **Preference for Peer Reviewed Data over Regulatory Data**
- **Recommendation on Long Term Research**
- **Relative Merit of Peer Review Process**
- **Report did not address Extensive Existing Engineering and Planning Information necessary to obtain a mine permit**
- **Risk Evaluation at Abandoned Mines**

SESSION 4: REGULATORY STATUS

1. Status of EPA's Regulation Development for Coal Combustion Wastes

2. OSM Perspective on Responses to the NAS Report and EPA rulemaking
   - **EPA Office of Water Concurrence on SMCRA Water Issues**

3. State Perspective on NRC Report re "Managing Coal Combustion Residues at Mines" and Related OSM Rulemaking
   - **Reconciliation of RCRA and SMCRA**
   - **State No More Stringent Than SMCRA Clause**

4. Utility Solid Waste Activities Group (USWAG) Perspective on Mine Placement of CCPs

SESSION 4: INTERACTIVE DISCUSSION

- **Federal Advisory Committee Panel**
- **Funding for Additional Research**
- **Timing of EPA & OSM Rulemaking**
- **Utility Dry versus Wet Disposal**
- **White versus Grey Literature**

DISCUSSION BY SESSION

SESSION 1: FGD PLACEMENT AT MINES

1. An Overview of FGD By-product Characteristics, Production, and Use: Prognosis for Mine Placement *William W. Aljoe[1], Charles E. Miller[1], Thomas J. Feeley, III[1], Andrea T. McNemar[2], Andrew P. Jones[2], and James T. Murphy[2], [1] U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, Pennsylvania and [2] Science Applications International Corporation*

2. FGD as an Impermeable Cap for Coal Waste *Mike Steinmaus, Monday Creek Restoration Project, New Straitsville, Ohio and Dr. Mary Stoertz, Ohio University, Athens, Ohio, and Mitch Farley, Ohio Dept. of Natural Resources, Div. of Mineral Resources Management*

Question: **(Alkaline Recharge Trench)** Did you consider adding an alkaline recharge trench between the pond and the coal waste pile?

Answer: That was not contemplated. We installed a SAP system above the coal waste pile and then open limestone channels for overland flow. I would like to go back to this site in about 7 years with a graduate student to assess its performance. After that assessment, it may be appropriate to add an alkaline recharge trench with something like steel slag.

Question: **(FGD Cap Thickness)** How thick was the cap over the coal waste pile?

Answer: The cap was 2 feet of pure FGD, 2 feet of an FGD/Gob mixture, with 8 inches of topsoil on top for support of vegetation.

3. FGD as an Alkaline Amendment for Coal Waste *Dennis Noll, Earthtech, Johnstown, Pennsylvania*

Question: **(Blend Ratios)** What were the blend ratios you used?

Answer: The blend ratios I used were 29% wet FGD sulfite, 70% fly ash, 1% quick lime.

Question: **(Total Application Volume)** What is the total amount of FGD materials that will be used in the reclamation project?

Answer: The site has been permitted to receive 16 million cubic yards of this mix of FGD materials. We have placed 1.7 million cubic yards to date. We are placing it a rate of about 250 cubic yards per year.

Question: **(Transportation Method)** How is the material delivered to the site?

Answer: It is being barged up the Mon River and then off loaded for transport overland by trucks the short distance to the site.

4. FGD as a Soil Amendment for Mine Reclamation *Dr. Warren Dick, The Ohio State University, Columbus, Ohio*

Question: **(Application Limits Due to Boron)** Are there any application rate limits based on potential toxicity of boron?

Answer: Based on my experience with studies on plant soil relations, you need to be careful with boron because it doesn't take very much for it to be toxic to plants. Boron is very leachable. If you can afford to wait, potentially toxic levels of boron will usually leach out of the soil. Boron is usually not toxic for animals.

Question: **(Application Rate)** Why did you choose the application rate of 125tons/acre?

Answer: This application rate was based on several factors: (1) the amount of alkalinity that it would add to the system; (2) the results of green house studies; (3) cost effectiveness related to transportation costs, and (4) some educated guesswork.

Question: **(Plant Tissue Trace Element Analysis)** Did you conduct any trace element analysis on the plants grown on FGD amended soils?

Answer: We have limited plant uptake data. We found that the Calcium and Sulfur levels were high. Compared to untreated sites, the manganese and aluminum levels were significantly reduced. The treatments definitely improved the quality of the plants.

5. Groundwater Effects of Coal Combustion Byproduct Placement in Coal Mines
Dr. Paul Ziemkiewicz, West Virginia University, Morgantown, West Virginia

Question: **(AMD Effect on FGD)** What do you expect to happen to this material over the long haul with AMD still being generated at the mine?

Answer: My observation is that by this time the mine is closed down with the ventilation turned off. During application there was still ventilation with some air moving through the mine. Without any fresh air supply this should minimize further pyrite oxidation.

Question: **(Application Amount)** How did you arrive at the 750,000 ton amount?

Answer: Metteki could still add more until they had closed out their refuse pile adjacent to the mine. They stopped injecting the FGD into the mine in 2004 and started using the FGD material to cap their refuse pile. So they would have the potential to add more in the future. The amount refers to the tonnage they generated during that time period.

Question: **(Continuation of Water Monitoring)** Is the water monitoring continuing and for how long?

Answer: It is still being monitored by the State of Maryland and I suspect it will continue as long as they continue pumping and maintain an NPDES permit for the AMD control.

Question: **(FGD Mixture)** Did you use straight FGD or was it mixed with something?

Answer: This was straight FGD with no lime added.

Question: **(Form of Mercury)** You mentioned that the mercury present was in an elemental form which could produce mercury in a gas form. Do you expect for this to happen and be discharged into the atmosphere?

Answer: This would happen if it were on the surface but in a sealed underground mine it would probably not go anywhere. How much will stay in the elemental form and how much will go into the sulfide form, I do not know.

6. FGD for Highwall Reclamation *Barry Thacker, Geo/Environmental Consultants, Inc., Knoxville, Tennessee and Ted Morrow, AEP Columbus, Ohio*

Question: **(FGD Components)** What was the form of scrubber sludge used and what was it mixed with?

Answer: This material came from the Conesville power plant which is 80% Calcium sulfite and 20% Calcium sulfate that is mixed with the total production of fly ash generated at the time and then fixed with lime. The mixture is about 0.7 parts fly ash to one part scrubber sludge with about 2-3% lime added. This material handles well and can be compacted with the strength you need for reclamation.

Question: **(Transportation Distance)** How far can you transport this material?

Answer: Right now the distance is not the determining factor. The problem is getting state agency approval when the land is not owned by the power company. One of the sites I showed you was 60 miles from the power plant to the coal mine. They hauled coal from the mine to the power plant and hauled scrubber sludge on the back haul back to the mine to do the reclamation. There is the potential for back haul for longer distances when you have coal being hauled from a mine to the power plant.

SESSION 1: INTERACTIVE DISCUSSION

Question: (**Dual RCRA & SMCRA Permit Requirements**) How many states require FGD placement activities at a mine to be incorporated into both a SMCRA permit and a solid waste permit?

Answer: In Ohio, there are two separate permits for active mining. For AML sites, you only need the approval of the mining program. In West Virginia, you only have to deal with the mining agency if it is declared a beneficial reuse of the material.

Question: **(Economic Impact of CCB Placement)** Have there been any studies that focus on the economic impact of mine placement of CCBs?

Answer: There was a study published this year by Andrew Stuart at the American Coal Council who conducted a study on the economic impact of CCB utilization that showed that at the current utilization rate of 40% of CCBs produced, the economic impact was estimated at $4.4 billion.

Answer: We need some type of federal standard so that states can regulate with a risk based standard for sites that are currently environmental liabilities. Similar to a brown field, these sites could be reclaimed with FGD materials so that they would have a reduced environmental liability but would not have to meet pristine standards.

Question: **(Impact of Future Mercury Controls on Use of FGD)** How will future mercury controls impact use of FGD materials?

Answer: If you have a wet FGD material you are already removing 70-90% of the mercury so further changes should not have a significant impact. If you have a dry FGD material, economics will dictate that you use a control technology that will not result in an increase in mercury to the FGD materials.

Answer: DOE did some studies on the release of mercury from FGD gypsum in wall board manufacturing plants. They found that there is a very strong temperature control over mercury release. In the final heat treatment process, you can volatilize a significant amount of mercury if the temperature goes above 325 degrees Fahrenheit. Below that temperature volatilization rates are extremely low. In this same study, they found that the gypsum derived from FGD tended to have a lower concentration of mercury with a higher rate of release than native gypsum. Although results may vary due to specific synthetic gypsum processes, their results showed no significant difference in actual total mercury release from synthetic gypsum or native gypsum.

Question: (**Impact of OSM CCB Specific Rules**) Do you think that having OSM develop minimum guidelines for CCB use will help?

Answer: It makes perfect sense for OSM to develop CCB placement minimum standards for SMCRA active coal mines. CCBs are being placed in a lot of mines that are not active coal mines regulated under SMCRA. I would think that development of standards for the wide variety of situations encountered with abandoned mines would be much more problematic.

Answer: Concerning the use of CCBs at active mine sites, anything that OSM and/or EPA can do to lessen regulatory uncertainty makes this an easier decision for the coal companies. The coal companies need to be convinced that they are not going to be looking at increased liabilities at some future date because the regulators decide to change the standards. You can't work out the economics if you don't know that the long term liabilities will be.

Question: **(Long-Term Solubility of FGD)** There are concerns about some of the chemical forms of FGDs that may go back into solution over the long term at some mine locations. What is known about the possibility of any of the forms of FGDs that might go back into solution after being placed at a mine?

Answer: The first place one would look for experience with FGD gypsum would be landfills that have placed this material long term. You need to design placement/disposal facilities to prevent infiltration/runoff. FGD gypsum may be soluble but probably only under geologic time. I think this is a "what if" question that we must answer, but it will not be a significant issue.

Answer: I don't think you will ever get enough long term data to satisfy all of the critics. I do think that there are a lot of sites that were initially sampled over the short term that could provide good long term data if funds were made available to allow additional monitoring of existing sites.

Comment: Gypsum is much more soluble than limestone and in Pennsylvania we have significant problems due to Karst development in limestone. I know of several houses that are falling apart due to construction over Karst areas. I think that it is important when people work with FGD materials that they report exactly they type of material they are working with. We need to know if it was primarily SO_3 or SO_4 (gypsum), was it mixed with fly ash and if so how much, and was it mixed with lime and if so how much.

Suggestion: (**OSM CCB Placement Training Course**) OSM should consider developing a specific training course on the technical aspects of CCB placement at mines.

Answer: OSM intends to develop a CCB training course under its National Technology Training Program just as soon as the regulatory issues are resolved and we know what to teach.

SESSION 2: LEACHATE PROTOCOLS FOR HYDROLOGIC ASSESSMENT

1. Development of a Standard Guide for Selecting a Leaching Protocol *Debra Pflughoeft-Hassett, University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota*

Comment: (**ASTM Conflicts with NAS Report**) I have a concern that the NAS report does not recognize mine placement as a use and lumps all placement at mines in the category of disposal. I am concerned that the way ASTM is phrasing this proposal that you could be excluding the most important uses. If placement at a mine is considered disposal, then your proposed protocols may come in conflict with the NAS report that does not recognize beneficial use at mines.

Comment: (**ASTM Search for a Best Available Test**) In one way it would be great to pick one leachate test that could tell you if a material is environmentally safe under any scenario. I don't know if this is possible, however. What ASTM is trying to do would be an interim step. It is my hope that we will be able to address existing technology in a way that gives us the most informed choices possible.

Comment: (**Comprehensive Tests Versus Scenario Specific Test**) Part of the reason we currently have 70 to 100 plus leaching tests is because we have pigeon holed many of the tests into scenario specific, use specific, or waste specific tests. I would prefer that ASTM just have an environmental aspect of materials committee where we could generalize a test for all types of wastes and scenarios. In Europe, all solid materials are handled in a very similar manner.

Comment: (**Jurisdictional Concerns**) One of the reasons ASTM is devising the standard this way is because of jurisdictional concerns.

Comment: (**Scenario Specific Tests**) I find it very useful to have a leachate test that not only addresses the solid material that is being placed in the environment but consideration of the environmental conditions under which the materials are to be placed.

2. Com paring Laboratory and Field Leaching of Coal combustion By-Product Constituents *Dr. Ishwar Murarka, ISH Inc., Sunneyvale, California*

Question: (**pH Values in Leachate**)How did the final pH values of your extracts compare relative to the 18 hour tests versus the 30 day tests?

Answer: The differences between the 18 hour tests and the 30 day tests were within 1 pH unit. The sequestration test after two or three tests went down about half a unit. There is a lot of organic matter in this ash, which is why I was not concerned about a pH change.

Question: (**Value of pH as an Indicator in Leachate Tests**) In your last couple of bar graphs, you are comparing tests which are designed for different purposes. The single batch extraction tests whether 18 hour or 30 hours are designed to create equilibrium between the liquid and solid phase. Your kinetic tests are not meant to create equilibrium otherwise you would not have a kinetic effect. So you would expect to see a different pattern. Your long term high liquid to solid ratio multiple extraction tests are designed to pull as much out of the solid phase as possible. When you use three different tests for different purposes it makes it very difficult to compare the tests. Each test has benefits when interpreted correctly. They would all integrate into a complete detailed characterization of a solid material. When you use a designed equilibrium test either 18 hour or 30 hour where the pH is the same it is not surprising that your concentrations for most elements would be the same. Sulfate would not be affected by pH but some of the other ones would be. In your kinetics tests, the pHs would be different because as you leach out alkalinity you would expect a different pH for every extract. You said that you didn't think that pH would be a strong indicator for inorganics but it is my opinion that pH is probably the strongest indicator for organics. I would have put pH at the top of your list as an indicator.

Answer: You may have misinterpreted my statement which concerned the pH of the extraction fluid; I did not say anything about the pH of the leachate. The message I was trying to illustrate was that for boron and sulfate, there is a big discrepancy no matter how you did the test with a coal combustion residue. The point I was trying to get across was that no batch test would give you an accurate indicator of field leachate values.

3. Speciation and Attenuation of Trace Constituents in CCPs *Ken Ladwig, Electric Power Research Institute, New Berlin, Wisconsin*

4. Leaching of Trace Elements from Pavement Layers Stabilized with Coal Fly Ash *Craig Benson and Tuncer B. Edil, Dept of Civil and Environmental Engineering, University of Wisconsin, Madison, Wisconsin*

Question: (**Batch Tests as a Field Indicator for Selenium**) You showed a large difference between the batch tests and the column flow through tests for selenium. Do you have an explanation for that? We have seen for the batch tests that they way under predict what we actually find in the field for selenium for some cases.

Answer: We had a 20:1 ratio in the batch test and column tests it was 1:1.

Question: (**Mineralogical Changes**) Are there mineralogical changes going on in these mixtures and did you do them at the same time?

Answer: There are cements that are forming within these mixtures. There is a host of solid phases that is forming. All of the tests were done a similar way and were done at a similar point in time.

5. Solubility of FGD Gypsum Using a Continuously Stirred Tank Reactor *Dr. Candace Kairies, Karl T. Schroeder and Robert Thompson, U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, Pennsylvania*

Question: (**Sample Preparation**) You said you did not prepare the sample in any way. You did not crush the gypsum. The higher solubility than you expected may have indicated a plaster phase (hemi hydrate) which is more soluble than gypsum.

Answer: Possibly. These materials were used a received.

6. An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials *Dr. David Kosson and Andy Garrabrants, Vanderbilt University, Nashville, Tennessee*

SESSION 2: INTERACTIVE DISCUSSION

Comment: (**Comparison of Leachate Data with Drinking Water Standards**) It is critical that leachate data from CCBs not be compared to drinking water standards. The placement should be designed to keep the effects of placement on site as these areas are not sources of public drinking water.

Drinking water standards were never meant to be applied to groun water. They were meant to apply to actual drinking water sources. They are only being used as ground water standards because most states have not gone to the trouble of implementing a groundwater classification system with site specific standards. Institutions that need site specific standards need to work with their regulatory agencies to get those groundwater classification systems in place.

Comment: (**Comprehensive Studies Needed to Determine Potential Impact of Mine Placement**) We have good information about leachate tests. We have observations about the destiny of the water once the CCBs are placed in the ground. What we have talked about is the transformation of the CCB material over time when it is saturated. We know there is cementation and that there are changes to hydrologic properties. Many of these changes can not be addressed with leachate tests alone. I like column tests because you can address physical transformation of the media. If you want to predict the destiny of the water as it flows through the system, you need to understand how the physical system has changed and the chemical nature of the water being applied.

Question: (**Kossen Test Applicability as a Comparison to Existing Ground Water Quality**) Could you use the Kossen leachate test to project whether the addition of CCBs at a mine would exceed the background water quality level?

Answer: Yes, it could be used in that way.

Question: (**Kossen Test Duration and Cost**) How long does it take to characterize a specific CCB with the Kossen leachate test and what are the costs?

Answer: A full detailed characterization with 12 different pH units could be accomplished in a couple of weeks for about $10,000 for one replication.

Comment: (**Need for Suite of Characterization Methods and Leachate Tests**) The mining situation bears out some of the points that were made repeatedly today about the need to have a whole suite of characterization techniques and leaching procedures that are designed and selected to replicate the actual mining environment and CCB material to be placed. There is no one test that will give you that answer.

Comment: (**Public Confidence in Mine Placement**) The public will be more comfortable with mine placement as they become more aware of the large body of studies and testing that is available to insure that the environment is protected.

SESSION 3: PEER REVIEW OF NATIONAL ACADEMY OF SCIENCES CCB & MINING REPORT

1. Managing Coal Combustion Residues in Mines: A Report of the National Academy of Sciences
   Dr. Richard Sweigard, University of Kentucky, Lexington, Kentucky

2. Technical Comments on the National Research Council Report on Managing Coal Combustion Residues at Mines
   Dr. Ishwar P. Murarka, Ish Inc., Sunneyvale, California

3. National Academy of Sciences (NAS) Final Report "Managing Coal Combustion Residues in Mines": A Review
   Dr. Yoginder Paul Chugh, Southern Illinois University Carbondale, Carbondale, Illinois

4. Comments on Managing Coal Combustion Residues in Coal Mines
   Dr. Harold W. Walker, The Ohio State University, Civil Engineering Department, Columbus, Ohio

5. A Review of the National Research Council Report on "Managing Coal Combustion Residues in Mines,"
   David Hassett University of North Dakota, Energy and Environment Research Laboratory, Grand Forks, North Dakota

6. National Academy of Sciences Mine Fill Report: Critical Evaluation of Recommendations for Future Research
   Dr. Paul Ziemkiewicz, National Mined Land Reclamation Center, University of West Virginia, Morgantown, West Virginia

7. A Technical Review of the Final Report of the National Academy of Sciences "Managing Coal Combustion Residues in Mines"
   Kimery C. Vories, Office of Surface Mining, Alton, Illinois

SESSION 3 INTERACTIVE DISCUSSION

Question: (**Appropriate Data for a New Mine or Power Plant**) What I did not see addressed in the NAS report was what happens when you have a new mine that does not have any data. The reality is that in my area of the country there is very little opportunity for commercial use of these materials. When a new mine mouth power plant is constructed the ash will be hauled to the mine pit. The regulator will be asked to approve a permit for mine placement without any ash being available to analyze. What does the regulator do when there is no on site ash data available?

Answer: Although it is not unusual for a regulator to ask for a new mine or new power plant to submit on site data, the same principles of ash analysis apply across the board. We have lots of information on how many specific coals behave and what their trace element concentrations are. That information shows ranges of chemical concentrations that fall within very narrow bands. There is not that much variability.

Answer: In some cases, the coal from a new mine has been combusted in the lab and the ash analyzed and this has been accepted by the regulators.

Comment: (**Available Data Acceptability**) One issue was the use of the available data. The NAS was bombarded with reports from a wide variety of sources. One of the issues we struggled with was peer review. We were confronted with reports with conflicting information even from the same location. The only way we could find to accept one set of data over another was whether or not it was peer reviewed. The NAS decided to review everything but place more weight on peer reviewed data.

Comment: (**Committee Composition**) Another issue was the makeup of the committee, particularly concerning coal combustion residues. The NAS makes a distinction between bias and conflict. No one comes in with a blank slate. Instead the NAS tries to balance the committee between various points of view. They do try to eliminate people whose research program or business could be influenced by the outcome of the report. The down side is that in some cases the people with the greatest amount of experience may have a perception of conflict.

Question: (**Congressional Response to NAS Report**) How has congress responded to the report?

Answer: Congressman Rahall has been quoted in the press as "He was disappointed that the NAS report did not hold the agencies feet to the fire."

Comment: (**Consensus Process**) The NAS report is not the report that any individual committee member would have written. It was the report that all of the committee members could accept. I am sympathetic with many of the comments made by other speakers. Some of the comments may have been a misinterpretation or needed more background on the report.

Comment: (**EPA Damage Cases**) Another issue was the use of the EPA damage cases. There were no credible examples of damage cases at coal mines. In this case, there was really no data to look at. The NAS asked to look at the EPA damage cases for the purpose of looking at the conditions at those sites that contributed to the damage. Then how do those conditions relate to conditions you would find at a coal mine. The NAS did not rely on the EPA damage cases to suggest that the same thing would happen at a coal mine. Many of the EPA damage cases were in mono-fills in sand and gravel pits that have a very permeable environment at or near the water table, which is just asking for trouble. The NAS realized that you would not expect to find these conditions at a coal mine.

Question: (**Impact of NAS Report on Permitting**) As a result of the NAS report are we closer, the same, or further away from being able to place these materials in a coal mine?

Answer: I would think the NAS report has made the process of placement at coal mines more difficult.
Answer: Overall I think the report neither facilitates nor make it more difficult to do mine placement. It was an opportunity missed perhaps.

Answer: My assessment of the politics of mine placement of these materials is such that the NAS report will have little to no impact.

Question: (**Lack of Recognition of Ash Types**) There was a lot of data and testimony during the NAS investigation about the performance of certain types of coal ash. However, in the NAS report there seemed to be no recognition of environmental performance of different types of coal ash (i.e. type C, or F, or Fluidized Bed Ash)?

Answer: The committee looked more at the chemical constituents of ash rather than the different types of ash and I believe that all of these chemicals were addressed.

Question: (**Lack of Reference to Gorilla Pit Data**) The NAS recommended that contact with water be minimized yet there seemed to no reference to extensive data on the Big Gorilla pit in Pennsylvania where the ash had been placed below the water table?

Answer: Although situations where ash was placed below the water table and also where they may come in contact with acid mine drainage, may not have been addressed adequately. The NAS report tried to address the normal situation of ash placement in a mine environment. The NAS realized that is not possible to totally isolate coal ash from water in mine placement but tried to emphasize the importance of minimizing contact with water. Specifically concerning the Big Gorilla pit in Pennsylvania, the NAS committee was in agreement that filling the pit with fluidized bed ash was correcting a problem and it was a good thing. It was recognized that the site was seriously damaged and the pit filling was an improvement. This is why the committee recommended the same level of characterization of materials and the environment at an abandoned mine but would not apply the same performance standards.

Comment: (**Landfill Preference**) Another issue was the concern that the NAS considered RCRA landfills as the default setting. An assumption of the committee was that all liners eventually fail. The default setting that the committee actually preferred was that these materials would be incorporated into commercial products.

Comment: (**Preference for Peer Reviewed Data Over Regulatory Data**) I am concerned with the secondary status that regulatory data is being viewed by the committee versus peer reviewed data. It would be a rare case that a regulatory agency had available peer reviewed data with which to make regulatory decisions.

Comment: (**Recommendation on Long Term Research**) One of the speakers suggested that the recommendations for long term research represented a moratorium. There was some pressure on the committee to increase the bond liability period extensively. This would have made it unfeasible to permit a site for mine placement. The recommendation for long term research (greater than 10 years) was a compromise between no additional scrutiny and a long term liability period that would have eliminated the practice. Since the NAS report concluded that mine placement was a viable disposal option, NAS was not placing a moratorium on the activity.

Comment: (**Relative Merit of Peer Review Process**) Not everyone in the scientific community would regard as highly peer reviewed data as that indicated by the NAS report. Even in the peer review process where there is a lot of data, it is the writing that is peer reviewed not the data. In most cases, there is no difference in terms of level of scrutiny between data from a peer reviewed paper and data from a report that has not received peer review. Most peer reviewed papers are in single study academic research that has absolutely no relationship to what we are talking about.

Comment: (**Report Did Not Address Extensive Existing Engineering and Planning Information Necessary to Obtain a Mine Permit**) The report tends to perpetuate a misconception that ash is just placed without much planning at mine sites. Yet we have seen in this and many other conferences how extensive the planning and engineering that is involved in these very site specific applications. The ash placement is evaluated for both risks and benefits at the mine site. The hydrogeologic setting and the method of placement is evaluated in order to have a stable fill. We have a lot of experience with placing these materials in stable fills and this information can be used in guiding mine placement.

Response: The NAS experienced a great deal of variability at different mines and some of these mines did not have adequate planning and evaluation.

Question: (**Risk Evaluation at Abandoned Mines**) Does the NAS think it is OK to look at existing conditions (particularly at abandoned mines) and compare the risk of doing nothing with that of reclamation with ash? I did not see in the report that the NAS was recommending that these risks be balanced.

Answer: I think the answer to that is yes. The committee would support a risk assessment at abandoned mines that would weigh the risk of ash placement against the risk of ongoing health, safety, and environmental risk or damage.

SESSION 4: REGULATORY STATUS

1. Status of EPA's Regulation Development for Coal Combustion Wastes *Bonnie Robinson, Environmental Protection Agency, Washington, D.C.*

Question: (**EPA Office of Water Concurrence on SMCRA Water Issues**) What is the role of the EPA Office of Water concerning an action by OSM since the Office of Water must concur on any SMCRA regulations that affect water quality?

Answer: EPA has across the board work groups that cover the various agencies. This would be the same group of people involved with landfills, impoundments and mine filling. This group includes staff from the Office of Water. Any necessary concurrence would go through this group.

2. OSM Perspective on Responses to the NAS Report and EPA rulemaking *John Craynon, Office of Surface Mining, Washington, D.C.*

Question: (**NEPA Procedures Versus SMCRA Regulations for AML**) Concerning the AML program, do you think NEPA procedures could handle these issues with a directive rather than rulemaking?

Answer: It is theoretically possible that it could be handled with a directive. The problem is that directives and guidance are not enforceable. While we may not require anything more with a regulatory approach, regulations give a lot of people a greater comfort level that the environment will be protected.

Question: (**How Realistic is OSM Time Frame?**) Do you really think that OSM can put this together in the time frame suggested?

Answer: The time frame is optimistic but OSM is committed to try and make it happen. I believe a lot of the substance of the rule has already been prepared in previous efforts. OSM has staff that has been working on this for many years and knows what the requirements should be.

3. State Perspective on NRC Report re "Managing Coal Combustion Residues at Mines" and Related OSM Rulemaking *Greg Conrad, Interstate Mining Compact Commission, Arlington, Virginia*

Question: (**Reconciliation of RCRA and SMCRA**) Since SMCRA does not address disposal as under RCRA but rather will regulate placement of these materials under existing SMCRA authorities, how will the differences between RCRA and SMCRA be handled?

Answer: It is my understanding that it will be incumbent upon OSM to clarify that in its rulemaking. I think that it would appropriate for EPA to state in its rulemaking that CCB specific rules under SMCRA would satisfy their RCRA concerns.

Answer: Currently under SMCRA regulations you can dispose of coal waste in a mine pit so you should be able to regulate coal ash placement under SMCRA.

Comment: (**State No More Stringent Than SMCRA Clause**) Some states have provisions that require that the state regulations be no more stringent than SMCRA. This is one of the reasons it is necessary for OSM to write federal regulations so that a state can not say that they do not have the authority to write additional rules.

4. Utility Solid Waste Activities Group (USWAG) Perspective on Mine Placement of CCPs *James R. Roewer, Utilities Solid Waste Activity Group, Washington, D.C.*

SESSION 4 INTERACTIVE DISCUSSION

Question: (**Federal Advisory Committee Panel**) In the EPA talk it was suggested that EPA form Federal Advisory Committee Panels for both mine placement and disposal to afford greater opportunity for public input. Is this your response to concerns for greater public input into rulemaking?

Answer: EPA will provide stakeholders as much opportunity as possible to comment. There has been no decision to form a Federal Advisory Committee Panel.

Comment: I think it is very possible that citizen groups will go to congress and have congress direct EPA to create Federal Advisory Committee Panels on these issues.

Question: (**Funding for Additional Research**) We have heard a lot from NAS about the need for additional studies. Given the very flat budget of OSM and extremely modest applied science funding, where do we find funding to fill in some of the research gaps identified by NAS?

Answer: It has been very unfortunate that the DOE Combustion Byproducts Recycling Consortium funding has dried up because that was a wonderful opportunity to leverage resources to develop new markets for CCP products, develop new CCP products, encourage beneficial uses and investigate environmental issues related to CCP placement. We do need a new source of funding to answer some of these questions. Some people, however, are never going to be satisfied. In many cases, we have to continually prove that there are no negative impacts. There is probably an opportunity to develop a partnership to fund the research needs that would have a role for both the industry and the federal government.

Answer: There is valuable information that already exists that I don't think has been adequately appreciated. Pennsylvania has put together an excellent report on their mine filling program. This document has not received near the attention it deserves. This document has been peer reviewed. Pennsylvania has done by far the largest amount of mine filling in the country. This study has a lot of merit and value. This includes all of the data that refutes claims of new proposed damage cases. So before we go off generating a lot more data, we need to properly evaluate data we already have. This information has never been given its due by the scientific body that was supposed to have done that in the first place.

Answer: The Office of Fossil Energy within DOE has a budget that includes dollars and language. Until 2006, the language that accompanies the R & D funds said we could continue to work on CCB research and utilization issues. In the FY 2007 budget, the language is now silent or absent on CCBs. The problem is that DOE is no longer authorized to fund CCB research until such language is added back to our budget.

Answer: The funding for the NAS study came out of the existing EPA budget. EPA did not receive any additional funds from congress. Congress specifically required EPA to go to NAS so there was no possibility for going to the lowest bidder or possibility for competition.

Question: (**Timing of EPA & OSM Rulemaking**) From a mining industry point of view, I am concerned about the possibility of OSM putting out new regulations that may increase the cost mine placement much sooner than EPA will come out with regulations that will increase controls on utility impoundments and landfills. This has a potential to impact the mining industry. Has there been anything done to address timing of new mining regulations versus utility regulations?

Answer: EPA and OSM are coordinating our efforts in a consistent manner. The person at EPA that is the lead on utility impoundment and landfill rule making is Alex Livnat and he would be the person to contact concerning the timing of that rulemaking. EPA expects a Federal Register notice to go out sometime in 2007.

Answer: OSM and EPA management have already been meeting and have agreed that to the greatest extent possible we want to coordinate our actions and move in lock step with new rules.

Answer: Industry does like regulatory certainty in order to make decisions. If the utility rulemaking does get delayed, the practical effect of that would be tightening of controls that would be more stringent and increase costs for the utility. This should make continue to make management of costs for mine placement the best option.

Answer: One of the reasons for OSM acting quickly on this issue is due to what we experienced after we received and earlier NAS report on Coal Waste Impoundments. While we were deliberating with MSHA on how best to respond, Senator Bird decided that we were not moving fast enough so he required OSM to submit a report to congress. This resulted in a 9 month delay while we worked on the report to congress. So OSM's effort to quickly get out an advance notice of rulemaking is to let our friends on the hill know that we are paying attention to their concerns and doing something about it.

Question: (**Utility Dry Versus Wet Disposal**) Concerning the USWAG proposal for utility industry voluntary proposal to convert to dry disposal versus wet disposal, how can the industry volunteer to take on more expense?

Answer: It will cost a lot of money to convert a wet disposal system to a dry disposal system at landfills. Given the trend in state regulatory programs for NPDES discharge limits and you look at analytical capabilities to detect chemicals at lower and lower levels, these trends will force many utilities to opt for dry disposal. USWAG looked at this trend to determine if we could accelerate that trend. Any new source will have to have a zero discharge. The overall idea is to try to increase levels of environmental protection.

Comment: (**White Versus Grey Literature**) I would like to address the concerns raised that a lot of the literature that is available on CCBs has been ignored. I think that the issue really isn't about peer review but what information is available in the "white" versus "grey" literature. The lesson to be learned is that we need to get more of the existing information into the "white" literature (i.e. refereed journals). Problems with this approach include: (1) a relatively small audience that is interested in the issue; and (2) much of the data has already been published and refereed journals do not like to be the second publication source. But it does point out that a greater effort needs to be made to publish in refereed journals.

FLUE GAS DESULFURIZATION BY-PRODUCTS AT COAL MINES AND RESPONSES TO THE NATIONAL ACADEMY OF SCIENCES FINAL REPORT “MANAGING COAL COMBUSTION RESIDUES AT MINES”: A TECHNICAL INTERACTIVE FORUM

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WEDNESDAY, NOVEMBER 15, 2006

SESSION 1: FGD PLACEMENT AT MINES

Chairperson: Dr. Tarunjit Butalia, The Ohio State University, Columbus, Ohio

An Overview of FGD By-product Characteristics, Production, and Use: Prognosis for Mine Placement

William W. Aljoe[1.], Charles E. Miller[1.], Thomas J. Feeley, III[1.], Andrea T. McNemar[2.], Andrew P. Jones[2.], and James T. Murphy[2.], [1.] U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, Pennsylvania and [2.] Science Applications International Corporation

This paper provides an overview of the different types of flue gas desulfurization (FGD) processes currently in use at coal-fired power generating facilities, with an emphasis on the differences in the characteristics of the solid by-products that result from these processes. Wet FGD systems produce by-products whose characteristics depend on the degree of oxidation occurring within the system; for example, systems with little oxidation produce calcium sulfite sludges that do not dewater easily and must be stabilized, usually with a combination of fly ash and lime, before disposal or beneficial use takes place. Highly-oxidizing FGD systems produce calcium sulfates (FGD gypsum) that dewater more readily and are more suitable for direct disposal or re-use. Dry FGD systems and fluidized bed combustion systems produce relatively inseparable mixtures of fly ash and FGD by-products whose characteristics depend on both the coal being used and the other variables associated with the desulfurization processes. The inherent characteristics of the solid by-products determine the recycling markets for which they are best suited, and, in turn, affect the extent to which these by-products will become available for placement at mine sites. From a by-product producer's perspective, it is reasonable to assume that mine placement of FGD by-products will continue to represent a relatively low-value reuse market compared to "preferred" markets such as wallboard (for FGD gypsum), structural fills, and as a feedstock for various manufacturing processes. However, FGD by-product production at electric utilities is likely to increase substantially in the near future in response to recent air pollution control regulations. Moreover, in cases where the FGD system is used as a means of mercury removal from the power plant flue gas, some of the "preferred" reuse markets for the FGD by-products may be challenged by the negative perceptions associated with the presence of mercury. The ever-increasing cost of disposing of FGD by-products in dedicated landfills and surface impoundments makes it imperative that a wide variety of reuse alternatives, including mine placement, be evaluated and developed to the greatest extent possible. It is therefore important that the "recipients" of these by-products – the mine sites – become familiar with the types and characteristics of the materials they receive, and work with the material suppliers to achieve a placement scenario that benefits all parties.

FGD as an Impermeable Cap for Coal Waste

Mike Steinmaus, Monday Creek Restoration Project, New Straitsville, Ohio and Dr. Mary Stoertz, Ohio University, Athens, Ohio, and Mitch Farley, Ohio Dept. of Natural Resources, Div. of Mineral Resources Management

The Rock Run pile in Perry County, Ohio, is a coal-refuse pile deposited in the 1940's. The seven-acre pile contains coal-processing waste with hydraulic conductivities ranging from 2 x10-6 to 2 x10-4 m/sec, comparable to a silty sand. Prior to reclamation, water flowed across the pile from a deep mine discharge and from the larger watershed of the pile. Due to the high permeability of the material, the water infiltrated into the pile and emerged from the toe as acidic drainage into Rock Run. Water quality in Rock Run downstream of the pile prior to reclamation was pH 2.9 - 3.5; acidity 105 - 360 mg/l; and total iron 46 - 180 mg/l (40% ferrous). The pile was reclaimed in 1999 by draining impounded water, treating upstream deep-mine discharge with a SAPS (successive alkalinity-producing system), diverting surface runoff through reconstructed and lined stream channels, capping the regraded refuse with alkaline flue-gas desulfurization by-product (FGD), and then covering the FGD with topsoil and seed. Post-reclamation sampling was done for a year. After FGD capping and stream diversion, the water table in the pile was lower by as much as 10 m, attributable to decreased infiltration into the pile. Large vertical gradients indicated continued upward seepage at the pile's toe, into Rock Run. However, the pile seepage decreased by an estimated 53%, based on the vertical gradient. Groundwater was predicted to continue to seep into the pile because of its placement in a valley bottom. Water quality in Rock Run downstream of the pile after reclamation was pH 4.1 - 6.3; acidity 46 - 100 mg/l; and total iron 9 mg/l (no ferrous) to 80 mg/l (48% ferrous), with the higher iron concentrations measured soon after reclamation. Acidity loading downstream of the pile in Rock Run decreased from 290-2700 lbs/day to 16-122 lbs/day. Improvements are due to the combined effects of the capping and SAPS.

FGD as an Alkaline Amendment for Coal Waste

Dennis Noll, Earthtech, Johnstown, Pennsylvania

The coal combustion waste byproduct, identified as Flue Gas Desulfurization Material (FGD), is derived from a process typically used for reducing sulfur dioxide emissions from the exhaust gas systems of pulverized coal-fired boilers. This material varies from a wet sludge to a dry, powdered material. The wet sludge is produced by a limestone-based reagent wet scrubbing process and is predominantly calcium sulfite. This sulfite-rich FGD material has been used primarily as a low permeability embankment and road base material, but has also been experimented with as an alkaline amendment at active coal waste landfills. This study examines the scope of use as an alkaline amendment, the environmental assessment techniques used to justify this usage, and the results of monitoring to determine the fate of selected contaminants.

FGD as a Soil Amendment for Mine Reclamation

Dr. Warren Dick, The Ohio State University, Columbus, Ohio

Several flue gas desulfurization (FGD) processes create dry, solid products consisting of excess sorbent, calcium sulfite and calcium sulfate, and coal fly ash. These materials have a high capacity to neutralize acidity. Information is often lacking on the impacts, beneficial or otherwise, of using these products as amendments during mine reclamation. If good plant growth can be rapidly established, there is an overall improvement in environmental quality due to control of erosion and reduction in soil acidity. We studied the use of atmospheric fluidized bed combustion (AFBC) product as an amendment during reclamation of an abandoned surface coal mine site in eastern Ohio (Tuscarawas County). This site included approximately 25 acres of exposed, highly erodible underclay bordered on two sides by 45 acres of unreclaimed spoil and coal refuse. Acid mine drainage occurred due to oxidation of pyrite at the site and water pH ranged from 2.5 to 3.9 with high concentrations of acidity, aluminum, iron, sulfate and manganese. Six watersheds (one-acre each) were constructed by grading the underclay material to a 4% slope and recompacting the material to create an aquitard. Four feet of acidic mine spoil were then placed over the underclay. Three treatments were applied to the watersheds with each treatment being replicated twice. The treatments were (1) conventional reclamation using 50 tons/acre of agricultural lime followed by eight inches of borrow soil plus 20 tons/acres of additional lime mixed into the borrow soil; (2) 125 tons/acre of FGD product only that was incorporated eight inches into the mine spoil; and (3) a mixture of yard waste compost and FGD applied at a rate of 125 tons/acre of FGD product and 50 tons/acre of compost. Treatments were mixed into the borrow soil or spoil using a chisel plow and an offset disc. Areas outside of the small watersheds were reclaimed either by conventional methods (Treatment 1) or by using FGD plus compost (Treatment 3). These areas were used to study treatment effects on interstitial water and groundwater quality. Surface or tile drainage water from the watersheds was diverted through measuring flumes and analyzed. Vegetative harvest was also measured. Results showed that biomass production during the first year was greatest with conventional reclamation but sufficient plant cover developed for all treatments to control erosion. After the first year, biomass production became more uniform among treatments. All treatments increased surface runoff water pH to >7 and decreased soluble Al concentrations. Groundwater quality was not affected by FGD treatment but interstitial water had higher pH and specific conductance in samples from FGD treated areas versus borrow soil areas. Also increased in FGD treated areas were concentrations of sulfate, magnesium, and boron. Reclamation of the abandoned mine site occurred in 1994 and personal observations in 2006 indicate a vigorous stand of grasses and some small bushes for all treatments alike and a seemingly healthy ecological system.

Groundwater Effects of Coal Combustion Byproduct Placement in Coal Mines

Dr. Paul Ziemkiewicz, West Virginia University, Morgantown, West Virginia

The effects of adding coal combustion byproducts (CCB) to acidic mine waters are presented through a series of case studies. They include surface and underground mines. CCB applications include: disposal, barriers and grouts. Class F fly ash, fluidized bed combustion ash, flue gas desulfurization solids were included in the study. In each case, CCBs were applied with the object of mitigating acid mine drainage. The case studies include both successful and unsuccessful acid mine drainage control. The mines are located in the eastern and mid western USA in pyritic, bituminous coal measures. Also evaluated is the effect of CCB application on drainage quality. The case studies include pre and post-application water quality monitoring data. Acid mine drainage typically contains a substantial suite of toxic elements. In most of the case studies, their concentrations are substantially reduced. However, concentrations of some constituents such as calcium, magnesium and sulfate typically increase. Special attention is given toxic elements such as arsenic, selenium and mercury.

FGD for Highwall Reclamation

Barry Thacker, Geo/Environmental Consultants, Inc., Knoxville, Tennessee and
Ted Morrow, AEP Columbus, Ohio

Ohio has over 100,000 acres of abandoned mine land (AML) in need of major reclamation efforts. Dangerous highwalls, acid mine drainage, and silt-laden runoff are just some of the problems associated with such sites. The AML trust fund, maintained from fees paid by active mining companies, has enabled some land in Ohio to be reclaimed, but conventional reclamation can rarely be justified due to the high cost.

An abandoned highwall in Coshocton County, that is 1,800 feet long and up to 140 feet high, is being backfilled and reclaimed using alkaline flue gas desulfurization (FGD) material produced at the Conesville Generating Station. Water emerging from the augered coal seam at the base of the abandoned highwall is acidic. Backfilling will reduce air and water infiltration and thereby reduce the quantity, and improve the quality, of acidic runoff from the site.

Prior to the start of construction, a toxicity characteristic leaching procedure (TCLP) test was performed on the FGD material using acidic seepage from the site to generate leachate for analysis. The results justified the use of the FGD fill for reclamation purposes. As scrubbers continue to be built to reduce air emissions at power plants, the use of FGD material offers a cost effective way to reclaim abandoned highwalls. Performance monitoring data developed from the reclaimed highwall in Coshocton County can be used to document the benefits of such reclamation practices.

SESSION 2: LEACHATE PROTOCOLS FOR HYDROLOGIC ASSESSMENT

Chairperson: Debra Pflughoeft-Hassett, University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota

Development of a Standard Guide for Selecting a Leaching Protocol

Debra Pflughoeft-Hassett, University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota

Many industrial resources have existing and developing markets in a wide variety of applications, including raw feed materials to other processes, components of building materials, and geotechnical materials. The use, reuse, and recycling of these industrial resources is generally considered a preferred management option to disposal. Many industrial resources are required to be evaluated for their potential to release contaminants into the environment. In the U.S. Environmental Protection Agency (EPA) Public Meeting on Development of New Waste Leaching Procedures under the Resource Conservation and Recovery Act (RCRA) Program in July 1999, it was indicated that leaching tests are likely still the best means of evaluating large volume wastes given the great uncertainties associated with both the fate and transport models and the health impact values. EPA summarized the issues associated with the toxicity characteristic leaching procedure (TCLP), which is based on a codisposal mismanagement scenario where it is assumed the industrial resource in question will be disposed of in a sanitary landfill. While the TCLP may be appropriate for evaluating materials that are to be disposed of in sanitary landfills, the intent for the use of the TCLP is not consistent with use scenarios for industrial resources under most conditions. However, many states recommend or require that the TCLP be used in evaluating industrial resources that are intended for use, especially if the material is to be land-applied. While other leaching methods, developed and used for a variety of purposes, are available as options for characterizing industrial resources, identifying the most appropriate leaching method for a given industrial resource in a use application is frequently not based on relevant scientific criteria. An effort has been initiated by the American Society for Testing and Materials (ASTM) International E50 Committee on Environmental Assessment to develop a standard guide that delineates the steps for identifying and selecting a laboratory leaching procedure(s) for evaluating the potential environmental performance of industrial resources materials that are used, reused, and/or recycled. The guide will provide a logical sequence of criteria to aid chemists, laboratory analysts, and others in selecting one or more leaching procedures that will allow the development of scientifically valid and legally defensible data on environmental performance of industrial resources. Industrial resources are defined as products, by-products, coproducts, or other materials that result from industrial activities including power production, metal casting, metal refining, and paper or wood product manufacture.

A Comparison of Laboratory Leaching Results and Field Data

Dr. Ishwar Murarka, ISH Inc., Sunneyvale, California

Speciation and Attenuation of Trace Constituents in CCPs

Ken Ladwig, Electric Power Research Institute, New Berlin, Wisconsin

The overall objective of this project was to evaluate the impact of key constituents captured from power plant air streams (principally arsenic, selenium and mercury) on the disposal and utilization of coal combustion products (CCPs). Specific objectives of the project were: 1) to develop a comprehensive database of field leachate concentrations from a wide range of CCP management sites, including speciation of arsenic, selenium, and mercury; 2) to perform detailed evaluations of the release and attenuation of arsenic species at three CCP sites; and 3) to perform detailed evaluations of the release and attenuation of selenium species at three CCP sites.

Field leachate samples were collected from 29 fly ash and FGD solids management sites from several geographic locations in the United States to provide a broad characterization of major and trace constituents in the leachate. In addition, speciation of arsenic, selenium, chromium, and mercury in the leachates was determined. Results were used to compare leachate characteristics for different management scenarios (ponds and landfills) and different CCP types (e.g., ash and FGD solids). Arsenic and chromium in ash leachate are usually dominated by the oxidized forms, As(V) and Cr(VI). Selenium was mostly in the form of Se(IV), although there were a significant number of samples dominated by Se(VI). Se(IV) dominated in impoundment settings when the source coal was bituminous or a mixture of bituminous and subbituminous, while Se(VI) was predominant in landfill settings and when the source coal was subbituminous/lignite. Mercury concentrations were very low in all samples, with a median of 3.8 ng/L in ash leachate and 8.3 ng/L in FGD leachate. The organic species of mercury always had low concentration, usually less than 5 percent of the total mercury concentration.

Adsorption of arsenic species in soils was generally non-linear with respect to concentration. For all three sites, adsorption of As(V) was significantly greater than As(III). Linear distribution coefficients calculated from adsorption isotherms at a concentration of 1 mg/L ranged from about 30 to 350 L/kg for As(V), and from about 5 to 50 L/kg for As(III). The impact of sulfate concentrations on adsorption were soil dependent and most pronounced for As(III). In general sulfate tends to decrease adsorption of arsenic species onto the soils. Adsorption of As(V) was generally enhanced by calcium in solution but As(III) adsorption was not much influenced by calcium.

Adsorption of selenium species in soils was also generally non-linear with respect to concentration. For all three sites, adsorption of Se(IV) was significantly greater than Se(VI). Linearized concentration-specific distribution coefficients calculated from adsorption isotherms at an initial solution concentration of 1 mg/L ranged from 5 to about 500 L/kg for Se(IV), and from 2 to 18 L/kg for Se(VI) for the soils tested. The presence of sulfate decreases adsorption of selenium with effects being soil dependent but always greatest for Se(VI). The presence of calcium had a small effect on Se(IV) adsorption, but a negligible effect on Se(VI) adsorption.

Leaching of Trace Elements from Pavement Layers Stabilized with Coal Fly Ash

Craig Benson and Tuncer B. Edil, Dept of Civil and Environmental Engineering, University of Wisconsin, Madison, Wisconsin

Cementitious coal fly ashes are being used with increasing frequency in the Midwestern United States to stabilize subgrades and recycled pavement materials (RPM) during construction of highways. Blending soil or RPM with cementitious fly ash can result in considerable gains in bearing resistance and stiffness, thereby expediting construction and potentially increasing the service life of pavements. However, leaching of trace elements from stabilized materials, and the potential impacts to underlying groundwater, remain a significant concern. Consequently, a research program was undertaken to characterize leaching of trace elements from fly-ash stabilized materials. This research program consisted of batch and column leaching tests conducted in the laboratory, lysimeter studies conducted at field sites with full-scale stabilized pavement layers, and development of a model that can be used to evaluate potential impacts to groundwater. Each of these elements is described in this presentation.

The laboratory studies have shown that trace elements leach from soil-fly ash mixtures prepared with inorganic soils in a first-flush leaching pattern that can be described by the advection-dispersion-reaction equation with instantaneous linear sorption. In contrast, mixtures prepared with organic soils and RPMs typically exhibit a delayed-response pattern that is not readily described using classical transport theory. In either case, estimates of peak concentration can generally be made using concentrations from a water leach test and a conservative scaling factor. Data collected from the lysimeters at the field sites generally confirm these leaching patterns.

The model (WiscLEACH) can be used to simulate leaching of trace elements from pavements layers stabilized with fly ash. Vertical flow and transport is assumed in the vadose zone beneath and adjacent to the pavement, whereas vertical and horizontal transport is assumed in groundwater. First-flush or delayed-response leaching patterns can be simulated. Output from the model consists of the temporal concentration record at user defined locations in the subsurface, contours of concentration in the subsurface at various times specified by the user, or peak concentrations at a point of compliance specified by the user (e.g., monitoring well at the limits of the right of way). The model is operated using a convenient graphical user interface in the Windows® operating system and is available in the public domain.

Solubility of FGD Gypsum Using a Continuously-Stirred Tank Reactor

Dr. Candace Kairies, Karl T. Schroeder and Robert Thompson, U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, Pennsylvania

A continuous, stirred-tank extractor (CSTX) is a highly effective technique for evaluating the leachability of contaminants from flue gas desulfurization (FGD) products and other materials with low permeability or cementitious properties. The continuous stirring provides constant mixing as occurs in more traditional batch-leaching tests while the continuous flow provides data over a wide range of pH values and liquid/solid ratios such as those seen in column leaching studies. Release of a number of elements was examined in detail over a range of pH values extending from the material's natural, slightly alkaline pH to the acidic pH conditions commonly associated with mine sites. The results indicate that the leaching behavior of individual elements depends on several factors including, but not limited to, the solubility of the mineral phases present and the pH. The bulk gypsum is moderately soluble; dissolution is controlled by its solubility product and hydration reactions but does not depend on the pH. Elution and pH profiles indicate the presence of alkaline material(s) that buffer the system during the initial leaching of the FGD gypsum. Many elements are not leached until the buffering capacity is exhausted and the pH drops. Certain metals, including arsenic, cobalt, lead and mercury, are not released during the leaching of most samples and become concentrated in a minor, highly insoluble residue remaining at the end of each experiment. Differences in behavior among the samples investigated in this study indicate the need to evaluate FGD gypsum prior to use at a particular mine site.

An Integrated Framework for Evaluating Leaching in Waste Management and Utilization of Secondary Materials

Dr. David Kosson and Andy Garrabrants, Vanderbilt University, Nashville, Tennessee

SESSION 3: PEER REVIEW OF NATIONAL ACADEMY OF SCIENCES CCB & MINING REPORT

Chairperson: Peter Michael, Office of Surface Mining, Pittsburgh, Pennsylvania

National Academy of Sciences Report

Dr. Richard Sweigard, University of Kentucky, Lexington, Kentucky

The Committee on Mine Placement of Coal Combustion Wastes was appointed by the National Research Council and given the charge of investigating the practice of placing coal combustion residue (CCR) in coal mines. The eleven-point Statement of Task required the committee to examine the health, safety, and environmental risks associated with using CCR for reclamation in active and abandoned coal mines. The study considered all major coal basins. The committee focused on CCR from utility power plants and independent power producers, rather than small business, industries, and institutions.

The committee consisted of 14 members representing a broad spectrum of expertise and experience. The process involved six public testimony sessions from October 2004 to August 2005 held in Washington, D.C.; Farmington, NM; the Navajo Nation, NM; Austin, TX; Evansville, IN; and Harrisburg, PA. During the information gathering meetings, the committee, subgroups of the committee, and individual committee members also visited several mine sites that were currently using or had previously used CCR for minefilling.

The report consists of eight chapters. In addition to an introductory chapter, subsequent chapters address: CCR production, characteristics, reuse, and placement technologies; the behavior of CCR in the environment; potential environmental impacts, considerations for human health, and reasons for concerns regarding placement of CCR in mines; an overview of the regulatory framework governing the placement of CCR in mines; the risk management framework for CCR disposal including material and site characterization and prediction methodologies; site management strategies including reclamation and monitoring practices; and a summary of the committee's overall management approach. The committee concluded that "placement of CCR in mines as part of coal mine reclamation may be an appropriate option for the disposal of this material. In such situations, however, an integrated process of CCR characterization, site characterization, management, and engineering design of placement activities, and design and implementation of monitoring is required to reduce the risk of contamination moving from the mine site to the ambient environment. Enforceable federal standards are needed for the disposal of CCR in minefills to ensure that states have specific authority and that states implement adequate safeguards."

Dr. Ishwar P. Murarka

Ish Inc., Sunneyvale, California

In my technical comments I will make observations regarding the following NRC Committee recommendations:

The Committee recommends that secondary uses of CCR that pose minimal risks to human health and the environment be strongly encouraged. The Committee in the report then states that there are three major disposal practices for CCR – namely Landfills, Surface impoundment and Mine Filling. My observations -- Secondary uses and mine disposal are they the same? In my thinking I want to use CCR in a responsible manner and I do want to discourage disposal to the maximum extent possible.

With regards to CCR placement in mine fills, the NRC Committee concludes that while potential advantages should not be ignored, the full characterization of possible risks should not be cut short in the name of beneficial use. Then the Committee specifically recommends that CCR placement in mines be designed to minimize reactions with water and the flow of water through the CCR. Beneficial use of CCR for neutralization of acid mine drainage does require that maximum amount of chemical reactions occur so that the abatement of acid mine water is accomplished. If reactions are minimized then the benefits will not be derived and there is no need to fully characterize risks from a water free environment in which the CCR are entombed.

To contribute to the evaluation of risks of placement of CCR at mine sites the Committee recommends that CCR be characterized prior to significant placement and with each new source of CCR. I will illustrate through specific example of actual characterization data of CCR for many chemicals for each quarter for many years while mine placement of ash occurred and what does the analysis/evaluation of the dataset tell us in terms of risks as well as benefits of the CCR placement.

Let me leave a question for everyone in the audience to respond to as I complete my technical comments. Has the NRC report provided scientific and societal directions for balancing and resolving the beneficial reuse/secondary use/disposal in mines of CCR now?

Dr. Yoginder Paul Chugh
Southern Illinois University Carbondale, Carbondale, Illinois

This author will provide a review of the report with emphasis on several areas: 1) evaluation of damage cases and resulting observations related to impacts of CCRs placements in mine fills, 2) physical and geochemical properties of CCRs and development of informed risk, 3) geologic and geotechnical site characterization needs, and 4) engineering and planning related to placement of CCRs in mine settings including underground placement. Research needs in each area will also be identified and briefly discussed.

David Hassett
University of North Dakota, Energy and Environment Research Laboratory, Grand Forks, North Dakota

This review of the National Research Council's prepublication report on the management of coal combustion by-products in coal mines focuses on the areas of expertise of the author. These include ash hydration reactions, ash characterization through chemical means to include leaching and modeling of leaching results to determine the potential for environmental impacts. The author supports the responsible placement of coal combustion by-products (CCBs) in appropriate mine settings. In the context of this review, the author will present information to facilitate the environmentally responsible management of CCBs in mines, focusing on scientifically valid methodologies to assess the performance of CCBs in the environment. A discussion of the research recommendations will also be provided.

Dr. Paul Ziemkiewicz

National Mined Land Reclamation Center, University of West Virginia, Morgantown, West Virginia

All scientific effort should be judged against expectations and resources consumed in their production. The NRC report was well endowed with both. The NRC report dated March 2006 took roughly a year and over one million dollars to prepare. From this one would expect an exceptionally thorough report both with respect to acquisition of data and quality of analysis. However, the committee quickly came upon several serious problems that stem from the lack of a strong research base:

1. Un-systematic characterization of CCBs,
2. Spotty monitoring of CCB application sites,
3. Inconsistent, if any, analysis of monitoring results,
4. Little understanding of the interactions among CCB, mine spoil and groundwater,
5. Effects of CCB on improvement or further degradation to existing, polluted mine water.

Thus the committee was limited by historic data shortfalls. There has been very little funding available to undertake research into the environmenal effects of CCB minefills. Much of the research was initiated in response to EPA's 2000 Report to Congress and much of that research is still in the early stages. It is likely that the committee has spent several times over in one year what has been invested in CCB minefill research over the past ten years. It is not surprising, therefore, that we have a very expensive report that identifies a lack of fundamental understanding of the interactions among groundwater, CCB and mine spoil and then repeats a well-known list of research needs.

Lacking direct evidence, the committee then refers to non-analogous CCB disposal sites in flood plain gravels, impoundments and other non-mine settings. As a result, the report consists of a superficial appreciation of the issue, generalities, and obvious conclusions. Nevertheless, the conclusions, while obvious, would find agreement among most knowledgeable practicionners.

Key findings of the report:

- Many damage cases involving non-mining CCR landfills or impoundments were identified.
- Not a single damage case related to CCR minefills was found.
- Regulation of CCR minefills should remain with OSM, not EPA through EPA/RCRA as subtitle C or D wastes.
- OSM should develop national standards that mainly focus on pre-CCR placement site characterization, better leaching tests, post placement monitoring and environmental performance standards.
- Main contaminants of concern (based on CCR landfills and impoundments) are Boron,

Selenium and Arsenic.

- Environmental risks would be mitigated by disposal above the groundwater table, decreasing the permeability of the CCB mass and better characterization of its leaching potential.

The paper will evaluate the key conclusions as they relate to the techical appreciation of the CCB minefill issue, risk reduction and research needs.

A Technical Review of the Final Report of the National Academy of Sciences "Managing Coal Combustion Residues in Mines"

Kimery C. Vories,Office of Surface Mining, Alton, Illinois

On March 1, 2006, the National Research Council released to the public its final report by the National Academy of Sciences "Managing Coal Combustion Residues (CCRs) in Mines." Based on the news release of the National Academy of Sciences (NAS), putting coal ash back into mines for reclamation is a viable option for disposal, as long as precautions are taken to protect the environment and public health. The report also acknowledged that CCRs could serve a useful purpose in mine reclamation, lessen the need for new landfills, and potentially neutralize acid mine drainage. The report recommends development of enforceable Federal standards that give the States authority to permit the use of CCRs at mines but allows them to adopt requirements for local conditions.

The report lists 40 findings or recommendations under 12 categories. This paper addresses these findings on a case by case basis to evaluate their merits against the extensive record of data and scientific studies on the subject. The NAS has chosen to use the term "Coal Combustion Residues" where OSM has historically used the term "Coal Combustion By-Products." The terms are interchangeable. The author is in agreement with the NAS findings that support: (1) the use of these materials in mine reclamation; (2) the need for specific Federal regulations under the Surface Mining Control and Reclamation Act of 1977 (SMCRA) that spells out the minimum permitting, bonding, and environmental performance standard requirements when they are placed on active coal mines; (3) the research priorities to specifically address the hydrogeologic fate of CCBs and any leachate generated by those CCBs in relation to public health and environmental quality; and (4) to develop mining appropriate leachate tests. A limitation of the report is in its inability to: (1) acknowledge the profound differences between regulatory environments that control placement of CCBs at mines; (2) evaluate available ground water monitoring data and scientific research within the context of the applicable regulatory environments; and (3) acknowledge the volumes of scientific studies and State regulatory data that shows no degradation of water quality due to placement of CCBs at SMCRA mines for the last 29 years.

SESSION 4: REGULATORY STATUS

Chairperson: Alfred Dalberto, Pennsylvania Department of Environmental Protection, Bureau of Mining & Reclamation, Harrisburg, Pennsylvania

Status of EPA's Regulation Development for Coal Combustion Wastes

Bonnie Robinson, Environmental Protection Agency, Washington, D.C.

As required by the Federal Resource Conservation and Recovery Act (RCRA), EPA completed a special study and issued a Report to Congress on the effects on human health and the environment of the disposal and utilization of coal combustion waste (CCW). In May 2000, EPA issued a regulatory determination explaining its findings that CCW does not warrant regulation as RCRA Subtitle C hazardous waste, but that national RCRA Subtitle D non-hazardous waste management regulations are warranted for certain CCW management practices. The practices are management in landfills, surface impoundments, and in surface or underground mines ("minefill"). EPA has been working with the Office of Surface Mining to consider whether RCRA Subtitle D, the Surface Mining Control and Reclamation Act, or some combination of both statutes are most appropriate to ensure protection of human health and the environment. In March 2006, the National Academy of Sciences (NAS) released a report on "Managing Coal Combustion Residues in Mines." The speaker will provide an update on EPA's regulatory activity and describe plans for responding to the NAS report.

OSM Perspective on Responses to the NAS Report and EPA rulemaking

John Craynon, Office of Surface Mining, Washington, D.C.

Coal Combustion Residues (CCRs) are the noncombustible portion of coal and residues from various air pollution control technologies that are the by-product of electric power generation at coal fired power plants. The amount of CCRs produced annually is currently more than 120 million tons.

Some CCRs can be beneficially and commercially used in engineering applications or products such as cement or wallboard. The remainder must be placed in landfills, surface impoundments, or mines. CCR mine placement can assist in meeting reclamation goals at active coal mines and enhance the reclamation of abandoned mine lands. The placement in coal mines is currently regulated under either or both the Surface Mining Control and Reclamation Act of 1977 (SMCRA), administered by OSM and the Resource Conservation and Recovery Act of 1976 (RCRA). The solid waste rules under RCRA were written by the Environmental Protection Agency (EPA) but are administered by State Solid Waste Programs.

In early 2004, Congress directed EPA to fund a study by the National Academy of Sciences (NAS) to examine the health, safety, and environmental risks associated with using CCRs in reclamation of active, abandoned, surface, and underground coal mines. The study examined the health, safety, and environmental risks associated with using CCRs for reclamation in all major coal basins. The study also considered coal mines receiving large quantities of CCRs. The committee's efforts focused on CCRs from utility power plants and independent power producers, rather than small business, industries, and institutions. The study was released in March 2006. Among the findings of the report are that OSM and the States that implement SMCRA should take the lead in addressing any of the recommendations and findings of the NAS report.

Following the release of the National Academies' report, OSM has been reviewing the committee's recommendations and findings in order to plan its next actions. In addition, OSM has begun discussions with EPA and IMCC on a plan for coordinated actions. OSM has also met with EPA and the IMCC as well as other State regulatory and AML programs to develop detailed plans including any necessary regulatory or oversight proposals. OSM is committed to drafting regulations addressing recommendations in the NAS report in concert with EPA.

State Perspective on NRC Report re "Managing Coal Combustion Residues at Mines" and Related OSM Rulemaking

Greg Conrad, Interstate Mining Compact Commission, Arlington, Virginia

On March 1, 2006, the National Research Council (NRC) released to the public its final report entitled "Managing Coal Combustion Residues at Mines." Pursuant to the findings and recommendations in the report, putting coal ash back into mines is a viable option for disposal, as long as precautions are taken to protect the environment and public health. The report also acknowledged that CCRs could serve a useful purpose in mine reclamation, lessen the need for new landfills, and potentially neutralize acid mine drainage. The report recommends development of enforceable Federal standards that give the States authority to permit the use of CCRs at mines but allows them to adopt requirements for local conditions. The author will report on the purpose of the NRC study and its recommendations and findings, particularly as they impact state regulatory authorities. The author will also report on the results of discussions between the states, OSM and EPA regarding future rulemaking activity growing out of the NRC's recommendations.

Utility Solid Waste Activities Group (USWAG) Perspective on Mine Placement of CCPs

James R. Roewer, Utilities Solid Waste Activity Group, Washington, D.C.

The utility industry is committed to ensure that coal ash (or, as we prefer to call them, coal combustion products or CCPs) is managed in an environmentally sound manner. We believe that the mine placement of CCPs is environmentally safe, and indeed, is environmentally beneficial. Four times, in the nearly 24 years of EPA's study of CCPs, EPA came to the conclusion that these materials do not warrant hazardous waste regulation – first in 1988; second in 1993; third in 1999; and finally in 2000. However, in the portion of its May 2000 regulatory determination regarding placement of CCPs in mines, EPA concluded that further study was needed to make a determination whether the existing regulatory system under the Surface Mining Control & Reclamation Act ("SMCRA") was adequate or whether it needed to be supplemented either by additional regulations under SMCRA or under RCRA. EPA, working with the Interstate Mining Compact Commission, collected substantial data from mine placement sites around the country and to coordinate its work with other federal and state environmental and mining regulatory agencies, with the public, and with interested stakeholders. The result of this effort indicated that the states have robust regulatory programs addressing CCP mine placement, and, most significantly, that there were no demonstrated cases of environmental damage associated with the mine placement of CCPs. Nonetheless, in 2004, the National Academy of Sciences (NAS) established within the National Research Council a Committee on Mine placement of Coal Combustion Wastes to further examine the issue of the implications and need for regulation of the mine placement of CCPs.

In spite of the fact that the Statement of Tasks of the Committee on Mineplacement seemed to presume that CCPs are the problem requiring a host of regulatory actions, we are pleased that the NAS recognized that the mine placement of CCPs can be an environmentally sound management practice. The NAS Report did recommend some regulatory improvements and the utility industry welcomes the opportunity to work cooperatively with other stakeholders – Federal and state regulators, the mining industry and the public – to develop standards that will ensure that the mine placement of CCPs is conducted in a manner that continues to be protective of human health and the environment.

This presentation will focus on the utility industry’s perspective of the NAS Report and the next steps in the development of CCP regulations.

FLUE GAS DESULFURIZATION (FGD) BY-PRODUCTS AT COAL MINES AND RESPONSES TO THE NATIONAL ACADEMY OF SCIENCES FINAL REPORT “MANAGING COAL COMBUSTION RESIDUES IN MINES”

SPEAKER BIOGRAPHIES

William W. Aljoe P.E. is the Project Manager, Environmental Projects Division, Strategic Center for Coal, U. S. Department of Energy, National Energy Technology Laboratory (NETL). Duties include providing technical and project management expertise on environmental issues related to coal-based power systems, evaluating technological and regulatory trends, formulating criteria for technological advancement, identifying the most promising approaches for advancing program objectives, and assessing the effectiveness of new concepts and ideas for achieving programmatic missions and regulatory goals. He has served as the coordinator and primary point-of-contact for NETL R&D programs related to coal utilization by-products and air quality. He has also managed of research projects on coal byproduct utilization, power plant emission control technology, air quality measurement, air pollutant transport and deposition, and health impacts of air pollution. Previously he worked for the U.S. Bureau of Mines (1983-1996) - Mine hydrogeology and geochemistry of mine drainage; noise control and human engineering of mining equipment. He holds a B. S. in Mining Engineering, Penn State University, 1978; M.S. Civil Engineering, University of Pittsburgh, 1992. U.S. Department of Energy (1997- 2004)

Dr. Craig H. Benson PhD, PE is Professor of Civil & Environmental Engineering and Geological Engineering at the University of Wisconsin-Madison, where he has been a member of the faculty since January 1990. For the last 20 years Dr. Benson has been conducting experimental and analytical research in geoenvironmental engineering, including various aspects related to the reuse of industrial byproducts in civil and geotechnical engineering. This research has included laboratory studies, large-scale field experiments, and computer modeling. Dr. Benson has received several awards for his work, including the Presidential Young Investigator Award from the National Science Foundation and the Distinguished Young Faculty Award from the US Dept. of Energy. Dr. Benson has also received the Huber Research Prize as well as the Croes, Middlebrooks, Collingwood, and Casagrande Awards from the American Society of Civil Engineers. Dr. Benson is a member of the Geo-Institute, is Editor-in-Chief of the ASCE/GI *Journal of Geotechnical and Geoenvironmental Engineering*, and is chair of ASTM committee D18.04 on Hydrologic Properties and Hydraulic Barriers. Dr. Benson has a BS from Lehigh University and MSE and PhD degrees from the University of Texas at Austin. All degrees are in Civil Engineering, with the MSE and PhD degrees specializing in geo-engineering. Dr. Benson is a licensed professional engineer.

Michael Carey joined the Ohio Coal Association as President in 1999. As the State's chief advocate for Ohio's coal industry, he is responsible for representing its interests before Ohio's General Assembly. He directs the association's legislative agenda and develops media contacts in order to strengthen the voice of Ohio's coal industry. He also oversees the association's financial matters, including its Education Committee and fundraising events. He currently serves as President of the American Coal Coalition and is a spokesman for Americans for Balanced Energy Choices (ABEC). Mr. Carey is also Chairman of the Ohio Coal Development Office Technical Advisory Committee, a member of the National Mining Association, the Society for Mining, Metallurgy and Exploration and the Ohio Chamber of Commerce. Prior to joining the Ohio Coal Association, Mr. Carey worked for United States Congressman Bob Ney. He began his tenure with the Congressman in 1991 and was promoted from within until 1998. Most recently, Mr. Carey served as the Congressman's District Director where he acted as a liaison between the office and other government agencies and was responsible for the district staff, daily briefings, and congressional seminars for the public and media. Mr. Carey also served as the Congressman's Executive Assistant and Congressional and State Senate Campaign Manager. His education includes a Bachelor of Arts in History from The Ohio State University and Associate of Science in Economics form the Marion Military Institute.

Dr. Yoginder Paul Chugh is a professor in the College of Engineering at Southern Illinois University Carbondale. He has over 15 years of experience in research and management of CCBs, with emphasis on management in mines. He developed and administered the Coal Combustion Residues Management Program (CCRM) for the State of Illinois during early 1990s. He was awarded the USDOE 4-year award on Demonstration of Underground Management of CCBs for Subsidence Control. In this project he developed and demonstrated paste backfill technology using sulfate-rich scrubber sludge, F-ash, and small amounts of lime to backfill abandoned areas of coal mines for subsidence control. During this project he also developed and demonstrated pneumatic backfilling technology for FBC fly ash for acid mine drainage control and subsidence control. Subsequently, he demonstrated paste backfill technology at another underground mine in Illinois using crushed coarse coal waste, and non-compliant FBC fly ash and F-fly ash. In addition to the above experience related to management in mines, he has also developed and field demonstrated CCBs-based crib and post materials for use in mines. He has developed and demonstrated structural materials using sulfite rich sludge, FBC fly ash, and F-ash that are environmentally benign. Most recently, he has successfully developed automotive brake pads that meet and exceed SAE specifications for brake materials and contain 55-60% fly ash. He currently has two patents related to CCBs management. He has disclosed the third intellectual property idea to the university administration. He has served as Director, Combustion Byproducts Recycling Consortium-Midwest Region since its inception. Dr. Chugh holds BS, MS, and PhD degrees in Mining engineering, the latter two from Penn State University.

Greg Conrad is Executive Director of the Interstate Mining Compact Commission (IMCC), a multi-State governmental organization representing 20 mineral producing States. Greg has served in his position since 1988 and is responsible for overseeing several issues of importance to the States in the legislative and regulatory arenas including: surface mining and reclamation; mine waste; identification and restoration of abandoned mine lands; and various environmental issues associated with mineral production such as surface and ground water quality and quantity. Prior to joining IMCC, he served for nine years as senior counsel with the American Mining Congress, which is now part of the National Mining Association. While with AMC, he had primary staff responsibility for several coal related issues including transportation, leasing, research and development initiatives, and surface mining and reclamation. He has spoken and presented papers at a variety of conferences hosted by such organizations as the Eastern Mineral Law Foundation, the Conference of Government Mining Attorneys, the Colorado School of Mines, the Office of Surface Mining, the National Mining Association, the Environmental Law Institute and various State government groups. He has written extensively on mining issues for professional journals and magazines. He graduated from Michigan State University with a degree in business administration and later from the University of Detroit School of Law where he was an associate editor of the law review.

John Craynon is currently the Chief of the Division of Regulatory Support in the Washington, D.C. headquarters of the Office of Surface Mining (OSM). The Division is responsible for setting the policy related to OSM's regulatory program and for serving as technical experts in mining and reclamation. In addition, the division provides regulatory, programmatic, and technical assistance for OSM's regional and field offices and the State regulatory agencies. The division also provides day-to-day support to the management of OSM and the Department of the Interior and serves as a liaison with other Federal agencies and parties interested in OSM's programs, including the Office of Management and Budget and appropriate U.S. House of Representatives and U.S. Senate members and committees.

Mr. Craynon's government career over the past 23 years has included various positions with the U.S. Bureau of Mines, the Bureau of Land Management, and the Department of the Interior's Office of Environmental Policy and Compliance, prior to joining OSM in 1996. In these various jobs, his focus has been on mining and the environment and the technical, legal, and public policy issues related to mining. His work has related to diverse topics such as mountaintop mining, coal combustion byproducts, underground mine mapping, acid mine drainage, subsidence, hydrology, and invasive species issues.

Mr. Craynon has both Bachelor's and Master's degrees in Mining and Minerals Engineering from Virginia Tech. He is also a Professional Engineer in the Commonwealth of Virginia. Mr. Craynon has been an Adjunct Professor in the Department of Mining and Minerals Engineering at Virginia Tech and is a member of the Virginia Tech Department of Mining and Minerals Engineering Advisory Board. He is the past chair of the Coal Mining Sector of the Acid Drainage Technology Initiative. Mr. Craynon is a member of the Society for Mining, Metallurgy and Exploration, the National Society of Professional Engineers, the American Society of Mining and Reclamation, the International Mine Water Association, and the American Society of Civil Engineers.

Warren A. Dick is a Professor of Soil Science in the School of Environment and Natural Resources at The Ohio State University, Wooster, OH. He grew up on a farm in North Dakota and has both a practical knowledge of soils and agriculture as well as solid scientific training and experience. Since 1990 he has worked extensively on characterizing flue gas desulfurization (FGD) products and developing land application uses of these products. The goal of his research efforts is to develop uses that make sense both economically and environmentally. The use of

FGD as a soil amendment for mine reclamation was one of Warren's first research projects and this led to numerous other FGD-related projects. Warren was recently involved (September, 2006) in hosting a workshop in St. Louis, MO on "Research and Demonstration of Agricultural Uses of Gypsum and Other FGD Materials" and in writing a major review on this topic for the Electric Power Research Institute (EPRI). Warren has been very active professionally and teaches a graduate level course on soil and environmental biochemistry at The Ohio State University. He has served as Editor of the Journal of Environmental Quality and Editor-in-Chief of the Soil Science Society of America.

Dr. Andy Garrabrants is an Assistant Research Professor in the department of Civil and Environmental Engineering at Vanderbilt University in Nashville, TN. He has 10 years of experience in development of leaching protocols, interpretation methodologies and assessment models, primarily for inorganic constituents in hazardous, radioactive and mixed waste systems. Other research interests include (i) release assessment approaches for low-volatility organics, (ii) leaching chemistry and long-term durability of cement-based solidification/stabilization (S/S) treatments and containments, and (iii) physiochemical models for estimating source terms for risk assessment and risk evaluation. He is actively involved with ASTM International D-34 Committee on Waste Management and leads a task group on Waste Leaching Techniques. He is also a member of the American Institute of Chemical Engineers, American Society of Civil Engineers, and the Society for Risk Analysis. He holds a B.S. (1994), M.S. (1998), and Ph.D. (2001) degree in Chemical and Biochemical Engineering from Rutgers, the State University of New Jersey.

David J. Hassett is a Senior Research Advisor at the Energy & Environmental Research Center (EERC) of the University of North Dakota. He also serves as the Fuels Analyst for the State of North Dakota. Mr. Hassett's principal areas of interest and expertise include the application of analytical chemistry to address environmental issues associated with trace element occurrence, transport, and fate; coal combustion by-product (CCB) management; groundwater quality; and air quality. Additional areas of expertise include interaction between groundwater and CCBs as related to the leachability of trace elements and hydration reactions of CCBs. He has extensive laboratory experience, is a member of several professional organizations, has authored or coauthored over 300 publications, and holds a patent entitled "Enhanced Ettringite Formation for the Treatment of Hazardous Liquid Wastes." He received his B.S. in Chemistry and Mathematics from Winona State University in Winona, Minnesota, in 1966 and continued with graduate studies in Chemistry from 1970 to 1975.

Dr. Candace L. Kairies is currently a visiting assistant professor at Denison University and a Faculty ORISE researcher with the Coal Utilization Byproducts group at DOE's National Energy Technology Laboratory (NETL) in Pittsburgh, Pennsylvania. Her research with NETL focuses on the stability of and the mechanisms behind the capture and retention of mercury and other metals in FGD materials. She holds a B.S. in Environmental Science (Westminster College), a M.S. in Environmental Science and Management (Duquesne University), and a Ph.D. in Geology (University of Pittsburgh).

Dr. Ann G. Kim has been a researcher with the U.S. Bureau of Mines and the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy. She has extensive experience with mining related environmental issues, such as acid mine drainage, surface and underground mine fires, spontaneous heating in coal mines, methane desorption from coal, and the use of coal utilization by-products (CUB) in the reclamation of inactive or abandoned mines. Most recently, she directed a long term column leaching study of CUB. She is the primary author of more than 75 technical publications. Dr. Kim earned a BA in Chemistry/Physics from Carlow College, an MS in Earth and Planetary Science from the University of Pittsburgh, an MS in Engineering Management from the National Technological University, and a PhD in geochemistry at the University of Pittsburgh. She retired from NETL in 2005, but continues to work with that organization as a research associate.

Ken Ladwig is a Senior Project Manager at EPRI, responsible for research on the management and use of coal combustion products (CCPs). Since joining EPRI in 1999, he has worked on various aspects of CCP and groundwater research, including the potential for environmental release, disposal site management, groundwater assessments and remediation at CCP sites, attenuation of inorganic chemicals, and CCP use options. Previously, Mr. Ladwig worked for more than 15 years in CCP management and contaminant transport research at Science & Technology Management Inc., Wisconsin Electric Power Company, and the United States Bureau of Mines.

Dennis Noll is a Registered Professional Geologist in Pennsylvania and has practiced for a total of 35 years in the field of environmental geology. In 1980 he co-founded Earthtech, a firm largely dedicated to dealing with the environmental requirements of mining companies and energy producers. He has managed numerous projects for Earthtech that involve the environmental aspects of coal combustion byproducts and coal waste. Many of these projects have dealt with the beneficial use of those byproducts generated by conventional and circulating fluidized bed boilers. Earthtech, under Noll's guidance, currently provides environmental oversight at numerous coal combustion byproduct and coal waste placement sites.

Ms. Pflughoeft-Hassett is a Senior Research Advisor and the Program Manager for the Coal Ash Research Center at the EERC. Prior to her current position at the EERC, Ms. Pflughoeft-Hassett has performed CCB research related to characterization, regulation, and marketing. She has also worked on projects assessing environmental impacts of CCB management. She manages the research effort of the Coal Ash Resources Research Consortium® (CARRC®) and other CCB research at the EERC and has been instrumental in developing ASTM International standards for CCB use applications. Ms. Pflughoeft-Hassett is a member of several professional organizations, including the ASTM Committee on Environmental Assessment, Risk Management, and Corrective Action. In addition, she has coauthored over 100 publications. She received her B.S. in Chemistry from the University of North Dakota in 1982.

Bonnie Robinson is a geologist with the U.S. Environmental Protection Agency, Office of Solid Waste, in Washington, D.C. She has 30 years of industry and government experience specializing in the management of wastes generated by the exploration and production of oil and gas, and the mining and mineral processing of ores and minerals. She has been with EPA for 16 years. Before coming to EPA, she was a petroleum geologist managing exploration and development projects throughout the western and mid-western U.S. She is a member of the Geological Society of America and the American Association of Petroleum Geologists (AAPG), and is a Past Vice President of AAPG's Division of Environmental Geosciences.

Jim Roewer is the Executive Director of the Utility Solid Waste Activities Group (USWAG), where he is responsible for overall program management, including the addressing of solid and hazardous waste, and toxic substance issues on behalf of the utility industry, budget development & oversight, and membership marketing & recruitment. He serves as the Chairman of ASTM Subcommittee E50.03 on Pollution Prevention/Beneficial Use, and as a member of the Steering Committee of the Combustion Byproducts Research Consortium. He has served as Senior Environmental Manager in the Energy Policy Department of the National Rural Electric Cooperative Association (NRECA); Environmental Scientist in the Natural Resources Section of the Edison Electric Institute; Manager, State and Local Government Relations with the American Society of Mechanical Engineers; and Research Assistant with the Science Unit of the Illinois Legislative Research Service. Jim holds a Masters of Science in Environmental Science from the School of Public and Environmental Affairs at Indiana University, and a B.A. in Biology from Wittenberg University.

Dr. Richard J. Sweigard, is chairman and professor in the Department of Mining Engineering at the University of Kentucky. Prior to his academic positions, he was an engineer for Betz-Converse-Murdoch and a consulting engineering geologist. Dr. Sweigard's research falls under the category of environmental impacts of mining including alleviation of excessive compaction of reconstructed soil, post-mining land use, slope stabilization on abandoned mine lands, and disposal of coal combustion by-products. He is a registered engineer in Pennsylvania and his professional activities include the Society for Mining, Metallurgy, and Exploration; the American Society for Surface Mining and Reclamation; and the American Society of Civil Engineers. Dr. Sweigard served as a member of the National Academies Committee for the Study on Preventing Coal Waste Impoundment Failures and Breakthroughs. He received his Ph.D. in mining engineering from the Pennsylvania State University.

Dr. Mary Stoertz is an Associate Professor of Hydrogeology in the Department of Geological Sciences at Ohio University, where she has worked since 1994. She is also the Director of the interdisciplinary Appalachian Watershed Research Group at OU's Voinovich Center of Leadership and Public Affairs. Her efforts have focused on restoration of rivers damaged by acid mine drainage from coal mines and coal refuse. She is the AEP Professor of Watershed Science, and in 2006 won the Eighth Annual Interstate Mining Compact Commission (IMCC) Minerals Education Award in "Mining Awareness Educator" Category. In 2005, she won the Minerals Education Award from the Ohio Department of Natural Resources, for "Initiating classes at the university that provide for site characterizations of mine lands prior to restoration efforts." Mary has an M.S. (1985) and Ph.D. (1990) from the University of Wisconsin, and a B.S. from the University of Washington (1980).

Barry Thacker, P.E. is president of Geo/Environmental Associates, Inc., a consulting engineering firm in Knoxville, Tennessee. He is also founder of the Coal Creek Watershed Foundation, Inc., a non-profit watershed restoration group. Mr. Thacker holds bachelor of science and master of engineering degrees in civil engineering from the University of Louisville and has published over 50 articles on engineering, watershed restoration, and regulatory compliance topics. He is a registered professional engineer in 12 states and received the 2003 Hoover Medal from an international consortium of engineering societies for his civic and humanitarian achievements.

Kimery Vories is a Natural Resource Specialist/Technology Transfer employed by the Office of Surface Mining since 1987. He is chairperson of several multi-agency, multi-interest group steering committees that hold forums, publish proceedings, and manage Internet Websites on mining and reclamation issues related to the technical aspects of Coal Combustion By-Products, Prime Farmland Reclamation, Bat Conservation and Mining, and Reforestation. He has been professionally employed in coal mining and reclamation since 1979 with over 60 related professional publications. He serves on: (1) the National Steering Committee and is the Midwestern Review Team Chair for the USDOE Combustion By-Products Recycling Consortium; (2) the Coal Combustion By-Products Working Group Chairman for the Acid Drainage Technology Initiative Coal Mining Section; and (3) is the team leader for the Office of Surface Mining National Technology Transfer Team. He holds a BA & MA in Biology/Geology from Western State College of Colorado with an additional 3 years Post MA Graduate work in Ecology and Reclamation at the University of Massachusetts and Colorado State University.

Dr. Paul Ziemkiewicz is the Director, National Mine Land Reclamation Center, West Virginia University and the West Virginia Water Research Institute since 1988 and 1991 respectively. Previously he directed the reclamation research program in coal and oil sand mining for the Alberta Government's Department of Energy. He also served on Alberta's regulatory review committee and served as the research manager of the Province's coal technology research program. Dr. Ziemkiewicz has over 80 publications on the topic of mine land reclamation, acid mine drainage and coal ash application in mines. He received a B.S. and M.S. from Utah State University in biology and range ecology respectively. He then received a Ph.D from the University of British Columbia in Forest Ecology in 1979.

2006 CCB Forum Field Trip

Production, Management, And Use Of Flue Gas Desulfurization By-Products In The Ohio Coal Mining Region

November 14, 2006

Field Trip Coordinator

Dr. Tarunjit Butalia

Coal Combustion Products Extension
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Columbus, Ohio

Guidebook Editor

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Field Trip Leaders:

Jody Belviso	American Electric Power
Tarunjit Butalia	The Ohio State University
Dana Limes	American Electric Power
Ted Morrow	American Electric Power
Cheryl Socotch	Ohio Department of Natural Resources
Ben Stuart	Ohio University

Bus Tour Leaders

Mike Dillman	Ohio Department of Natural Resources
Ralph J. Haefner	USGS – Ohio Water Science Center
Wanda Stratton	Ohio Mineland Partnership
Harold Walker	The Ohio State University
William Wolfe	The Ohio State University

CONTENTS

Information By Site

Additional Information

Trip Schedule

Tuesday, November 14, 2006 (Times listed are tentative and subject to change.)

8:30 AM..........................**Leave University Plaza Hotel & Conference Center**

View the OSM video "A Page in Time".

View video of Conesville power plant before reaching Conesville.

10:15 AM........................**Arrive at Conesville Plant Main Gate**

10:15 – 10:25 AM ....**Site #1**.............. **AEP Conesville Power Plant**
Dana Limes (AEP)

Plant drive through viewing Units 1-6, lime receiving, lime storage, the scrubber for Units 5-6 and FGD dewatering/stabilization

10:25 – 10:45 AM ....**Site #2**.............. **FGD Storage Pad at AEP Plant**
Dana Limes (AEP)

Stop at the fresh FGD storage pad. We will view and hear descriptions of the plant air pollution control equipment, scrubber design, and the FGD waste stabilization process.

10:55 – 11:15 AM ....**Site #3**.............. **AEP Conesville FGD Landfill**
Dana Limes (AEP)

Stop at the landfill overlook for Phase A (current cell being filled) with descriptions of the design, construction, operations, and planned closure.

11:15 – 11:35 AM ....**Site #4**.............. **FGD Landfill Leachate/Wastewater Treatment**
Dana Limes (AEP)

Stop at the landfill leachate/wastewater treatment facility for description on leachate collection, treatment, waste characterization, and groundwater monitoring

11:45 AM **Arrive at Coal Prep Plant Main Gate**

View video of coal prep plant, coal refuse reclamation, and AML highwall reclamation site.

11:45 – 11:50 AM .... Site #5.............. AEP Coal Prep Plant & Coal Refuse Disposal
Jody Belviso (AEP) & Ted Morrow (AEP)

Drive past the coal prep plant and coal refuse reclamation site.

11:50 – 12:20 PM........... Site #6.............. FGD Highwall Reclamation
Cheryl Socotch & Jody Belviso (ODNR)

Stop at and drive through the Highwall AML Reclamation Project.

12:45 – 1:45 PM............. Lunch

1:50 PM .... Site #7.............. SR 541 Embankment Repairs Using PFBC Ash
Tarunjit Butalia (OSU)

Drive through SR 541 PFBC ash embankment location.

2:00 PM .... Site #8.............. Woodbury Wildlife FGD Parking Lot Base
Tarunjit Butalia (OSU) & Dana Limes (AEP)

Stop at the Woodbury Wildlife FGD parking lot base.

View OARDC surface mine reclamation video.

2:45 PM .... Site #9.............. Broken Aro Reclamation Project
Ben Stuart (OU) & Cheryl Socotch (ODNR)

Stop at the Broken Aro reclamation site.

View Ohio Mineland Partnership video.

3:30 PM .... Depart for Columbus

5:00 PM .... Arrive at hotel in Columbus

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Introduction

The state of Ohio generates approximately 10 million tons of coal combustion by-products (CCBs) annually as the result of approximately 90% of Ohio's electricity being generated from the burning of coal. These CCBs include fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) materials. In the past, most of these CCBs (particularly FGD material) were put in landfills or surface impoundments, resulting in the largely non-productive disposal of these materials. The utilization of CCBs as raw materials for civil engineering, mine land reclamation, agricultural applications, and manufacturing uses makes possible (1) a decrease in the need for landfill space, (2) the conservation of natural resources for the state, (3) better and more durable products, (4) the continued use of Ohio's high-sulfur coal reserves, (5) significant economic savings for end users, and (6) reduction in the overall cost of generating electricity.

The field trip tour will include:

1) A power plant equipped with FGD systems and an associated landfill,
2) A coal preparation plant where FGD material has been used as;
    a. Alkaline amendment and final cover for coal refuse disposal area
    b. Mine seal and structural fill material to reclaim an AML highwall
3) A state wildlife area with an FGD parking lot and FGD mine seal project involving re-mining of coal.

During the tour, we will visit several CCB project sites and discuss others that did not fit into our limited one day schedule. We hope you enjoy our presentations, discussions and the beautiful scenery of Ohio as we travel quite some distance today.

Dr. Tarunjit S. Butalia, P.E.
Coordinator, Coal Combustion Products Extension Program
The Ohio State University

Acknowledgments

A field trip of any size requires the help of numerous organizations and people. We wish to thank the following companies and their very knowledgeable and helpful people in making this trip possible:

American Electric Power Company
  The Conesville Power Station
  The Conesville Coal Preparation Plant

The Ohio State University
  The Coal Combustion products Extension Program

Ohio Department of Natural Resources
  Division of Mineral Resources Management

Office of Surface Mining
  Mid-Continent Regional Office

Ohio University

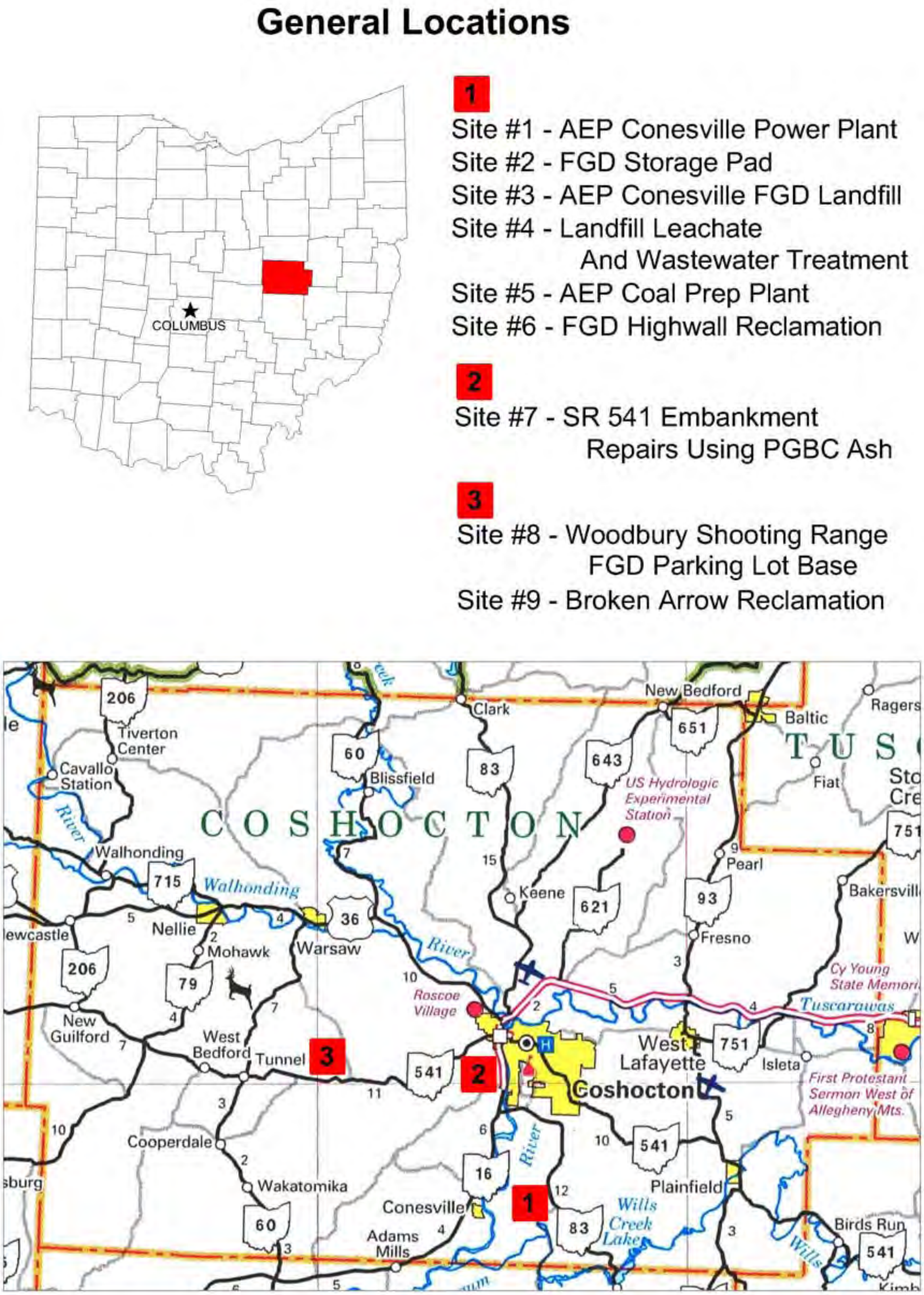
United States Geological Survey
Ohio Water Science Center

Ohio Mineland Partnership

Ohio Coal Association

Ohio Air Quality Development Authority
  Ohio Coal Development Office

Figure 1 – Map of General Locations



Notes

Site #1

AEP Conesville Power Plant

A drive through of the power plant site.

Major features of the Conesville Power Plant will be noted and discussed as the buses drive through the plant. Figure 2 shows a view of the power plant from the east, you will enter the main gate and travel from left to right on the east side of the plant you see. The six generating units are also numbered from left to right.

Figure 2 – Conesville Power Plant.

The Conesville Power Plant is operated by American Electric Power (AEP). This AEP electric power generating station operates four coal-fired combustion units. Units 1 and 2 are retired. Units 3 through 6 are pulverized coal (PC) boilers. The units are equipped with electrostatic precipitators (ESPs) that capture fly ash. The plant generates ash at a rate of approximately 7 to 10 percent (i.e., 7 to 10 tons of ash per 100 tons of coal). For the cyclone units, this quantity is about 80 percent bottom ash or slag. For the PC units, the ash is roughly 80 percent fly ash.

Figure 3 – Water vapor rising from the Conesville Power Station on a cold day.

Following the ESPs, Units 5 and 6 are equipped with wet scrubbers to remove sulfur from the flue gas. For this reason, coal burned by these two units does not require washing prior to combustion. The wet scrubbers generate flue gas desulfurization (FGD) waste at a rate of approximately 30 to 40 percent (i.e., 30 to 40 tons of FGD waste per 100 tons of coal burned).

Bottom ash and slag is slurried and pumped to on-site surface impoundments. Fly ash from Units 4 through 6 can be slurried and pumped to the surface impoundments or managed dry, which is the preferred method. Fly ash from Units 1 through 3 is always managed wet. The FGD product from Units 5 and 6 is approximately 3 percent solids as generated. It is pumped to thickeners that raise it to about 30 percent solids, then to vacuum filters that raise it to 45 percent solids. The FGD product then is mixed with dry fly ash and some lime and placed in a storage pile for 2 to 4 days before it is transported to the facility's landfill, approximately 3 miles from the plant.

The on-site surface impoundments cover approximately 80 acres and have separate sections that receive fly ash and bottom ash, respectively. Individual ponds are allowed to dewater so the ash can be excavated for transport and placement in the facility's landfill. The excavation operation is nearly continuous, moving from one pond to the next pond as it becomes ready.

Figure 4 - Closer view of the Conesville Power Plant from the main gate.

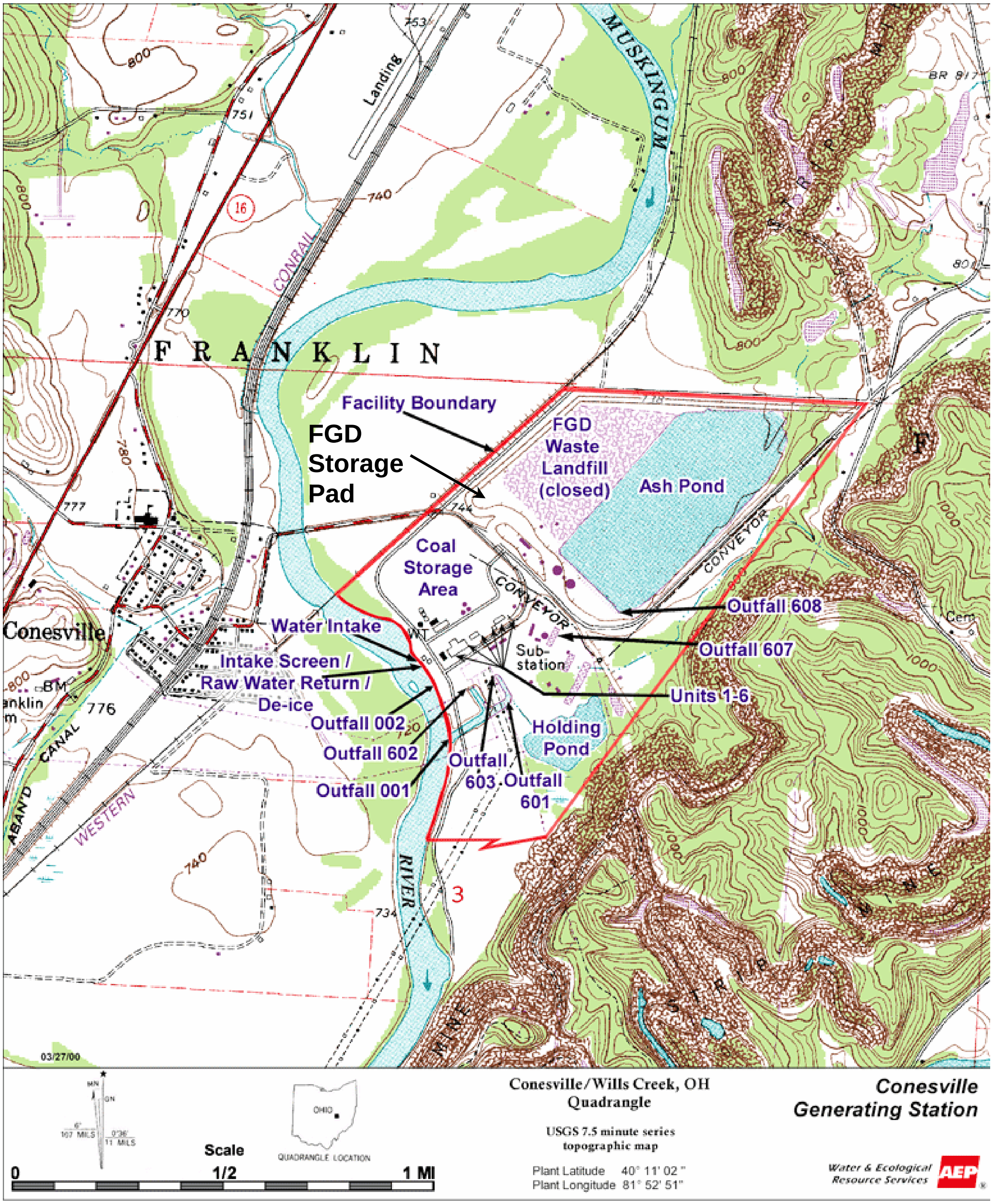


Figure 5 – Map of Conesville Generating Station with some facilities named.

Table 1 - AEP Plant Facts

Unit	Capacity (MW)	In-service Date	Current Status	Fuel	Cooling System	Emission Controls		
						PM	NOx	SO2
1	125	1959	Retired					
2	125	1957	Retired					
3	165	1962	Active	Coal	Once – through	ESP	LMB	
4	780	1973	Active	Coal	Closed cycle	ESP	OFA	(1)
5	400	1976	Active	Coal	Closed cycle	ESP	OFA	FGD
6	400	1978	Active	Coal	Closed cycle	ESP	OFA	FGD

(1) Scheduled to be equipped with a scrubber and SCR in early 2009.

Table 2 - AEP Plant Facts (Units 3-6)

Capacity:	1745 MW
Annual coal use:	4 million tons
Annual lime use:	100,000 tons
Water use:	
• Withdrawal	160 MGD
• Return	140 MGD
• Consumption	20 MGD

Stack height:	
• Unit 3	450 feet
• Unit 4	800 feet
• Unit 5/6	800 feet
Annual CCBs	
• FGD	600,000 tons
• Fly ash	320,000 tons
• Bottom ash	80,000 tons

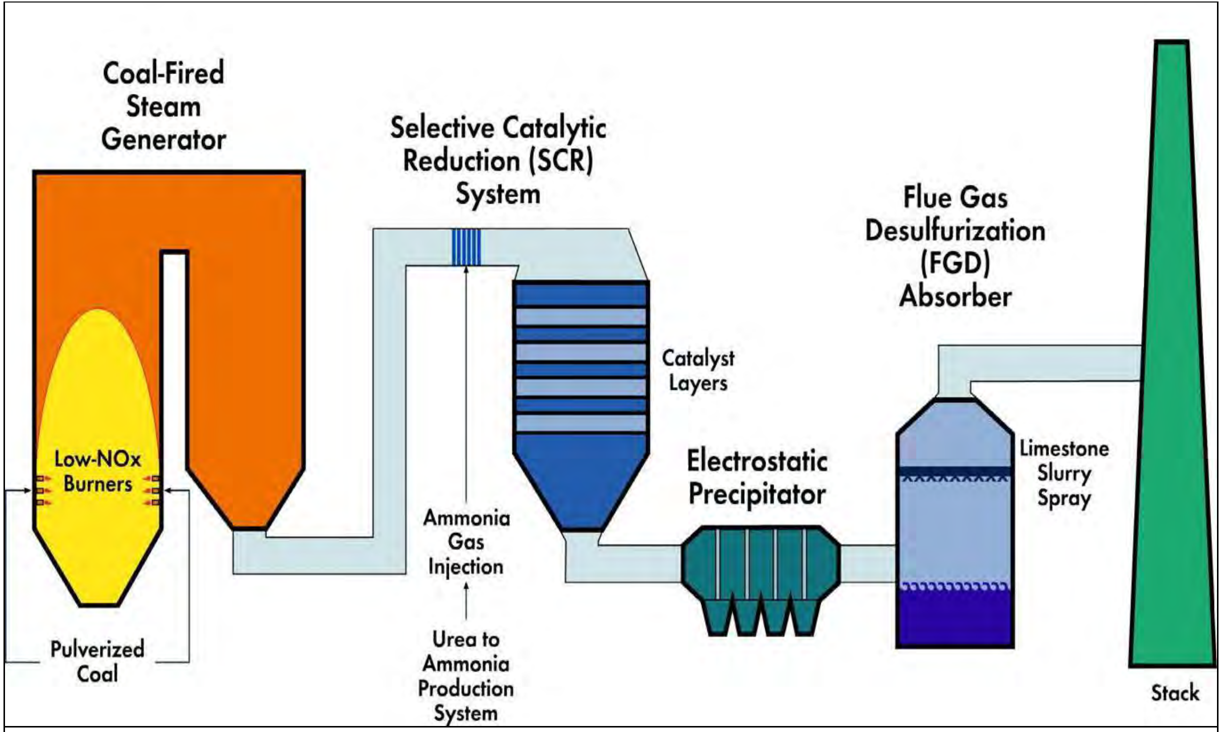


Figure 6 – The Flue Gas Stream

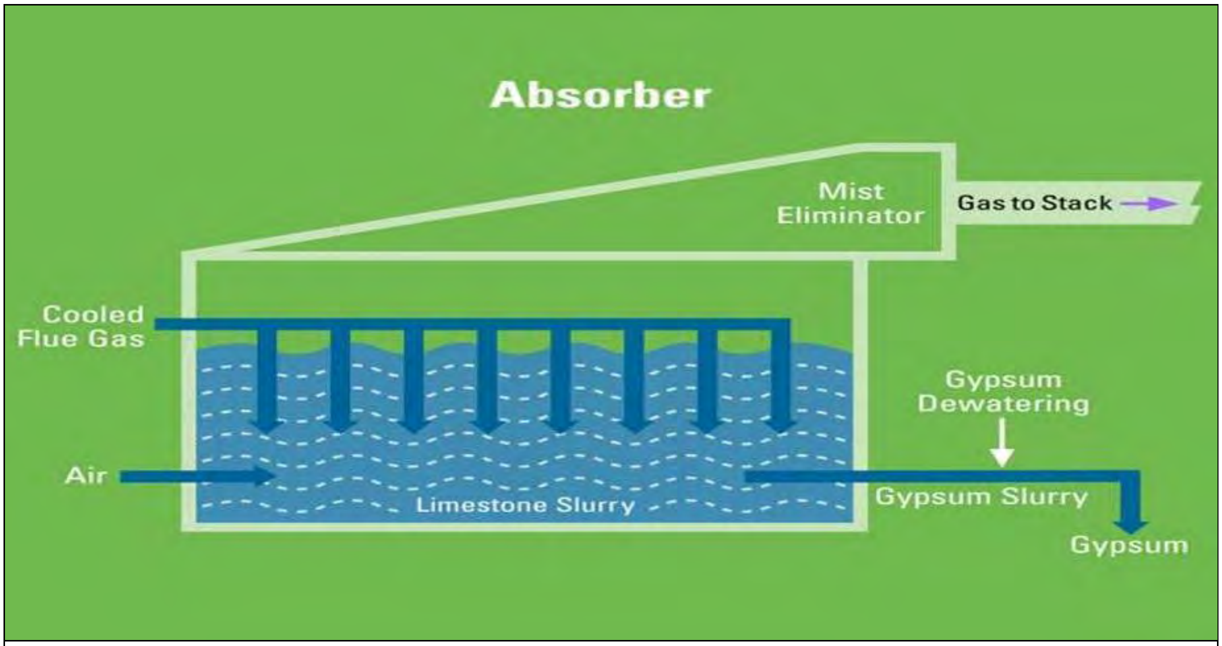


Figure 7 – Jet Bubbling Reactor

Notes

Site #2

FGD Storage Pad

Ash Handling Facility And A Stop At The FGD Storage Pad.

After the drive through the Conesville generating plant and seeing some of the major features, the tour will stop at the FGD Storage Pad. Here the FGD material is loaded in trucks for transport to the landfill or beneficial uses.

Figure 8 – FGD Storage Pad.

Ash Handling systems

The Conesville Plant consists of six coal-fired generating units. Units 1 and 2 were retired from service in 2005. The plant and associated facilities are shown in Figure 5. All generating units are equipped with electrostatic precipitators (ESPs) that capture fly ash particles entrained in the combustion gases prior to leaving the stacks. The fly ash particles collect in hoppers at the base of the ESP and are either conveyed with water via piping to the plant's ash pond, or pneumatically conveyed by piping to dry storage silos. Fly ash collected from Unit 3 is sluiced to the ash pond. The fly ash collected from Units 4 – 6 can be sluiced to the ash pond or conveyed to silos.

Units 1 and 2 were wet bottom units that produced a bottom ash type material known as boiler slag. This material was conveyed with water through pipelines to the bottom ash pond. Units 3 – 6 are dry bottom units that produce a conventional bottom ash product. This material is also wet sluiced to the same pond.

The plant's ash pond system is divided into three distinct areas (fly ash pond, bottom ash pond, and clear water pond) by splitter dikes. The largest area is referred to as the fly ash pond, which is further subdivided by a series of internal dikes. These internal dikes facilitate the re-routing of fly ash sluice water during times when maintenance dredging is required. During most years, fly ash is excavated from the pond and placed in the landfill.

The second largest area is the bottom ash pond. This pond is routinely excavated. Excess material that can not be sold is periodically placed in the landfill. Bottom ash is also commonly used for constructing temporary access roads on the surface of the active landfill phase.

The small clear water pond receives the treated effluent from the other two ash ponds prior to conveying the combined water discharge to the plant's reclaim pond. The clear water pond receives a very low solids loading relative to the other two ash ponds and rarely requires maintenance dredging.

FGD Process

Units 5 & 6 are equipped with flue gas desulfurization (FGD) systems. Lime and water are mixed and sprayed into the combustion gases downstream of the ESPs. The lime reacts with sulfur compounds in the combustion gases producing calcium sulfite/calcium sulfate sludge. The sludge is conveyed by piping to thickener tanks for initial dewatering. The thickener underflow is sent to a surge tank that feeds three vacuum filters where further de-watering occurs. The filter cake from the vacuum filters is conveyed to pug mills where fly ash and lime are added to produce a stabilized FGD material. The FGD material is stockpiled at a storage pad for a few days to allow the material to cure. Upon curing, the FGD material is excavated from the pile and loaded into trucks for delivery to the landfill. A schematic of the sludge treatment process is shown in Figure 9.

The fly ash silo (T-4) is equipped with an ash conditioning and truck load-out system. The conditioning system adds water to the ash to facilitate loading, transport, unloading, and placement of the ash. The fly ash stored in the T-4 silo can either be incorporated into the FGD mix or hauled directly to the landfill.

Use of Byproducts

The FGD product generated at the Conesville plant is not placed in any active mines. There is an abandoned mine land (AML) highwall reclamation project that will be discussed later.

While some FGD product is used to build cattle feed lots, in general, transportation costs are much greater than disposal costs. Therefore, the use of Conesville FGD product has been limited to small volume uses. AEP, company-wide, sends about 20 percent of its Coal Combustion Product (CCP) to beneficial uses, mostly cement and concrete applications.

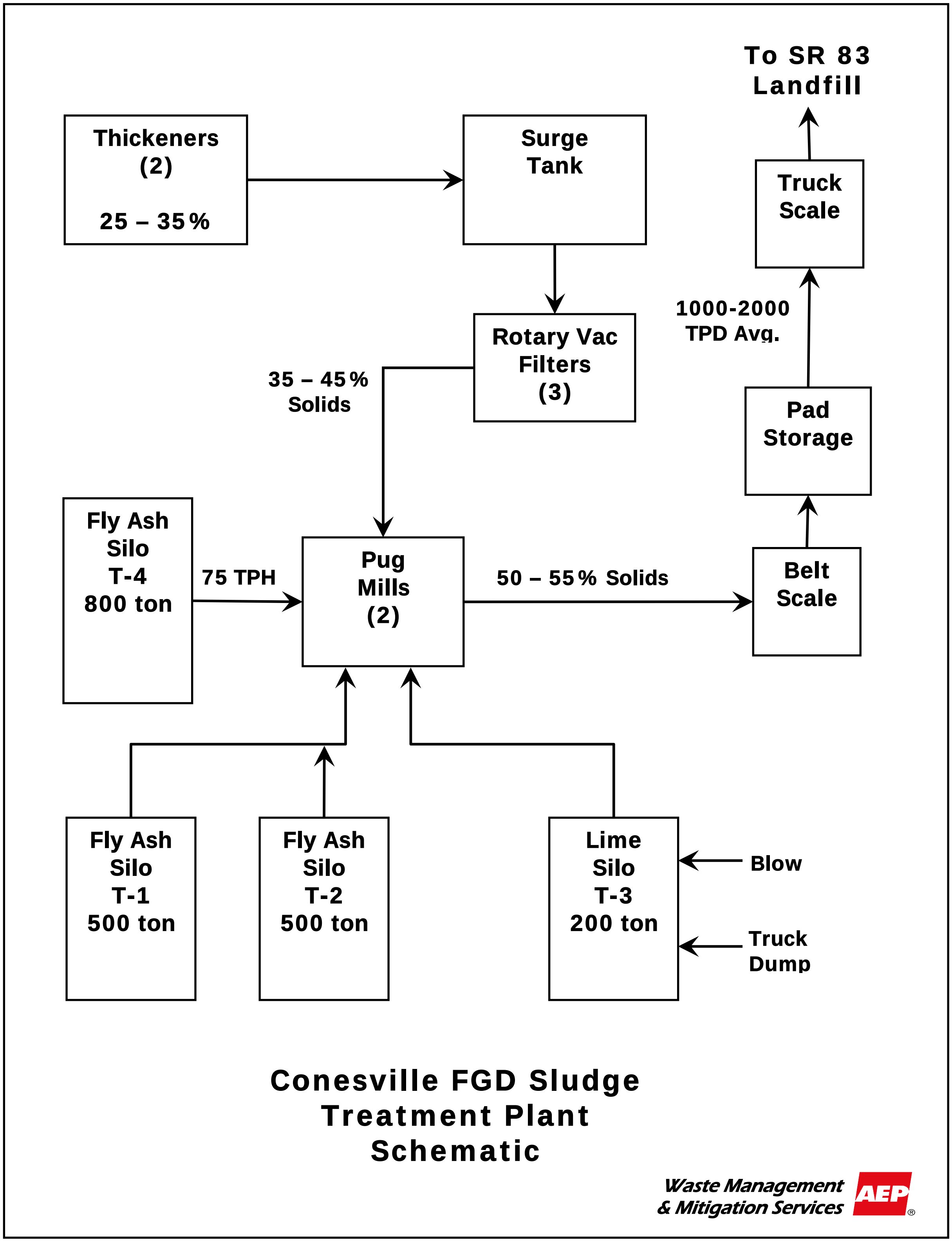


Figure 9 – Schematic Of FGD Ash Treatment And Handling.

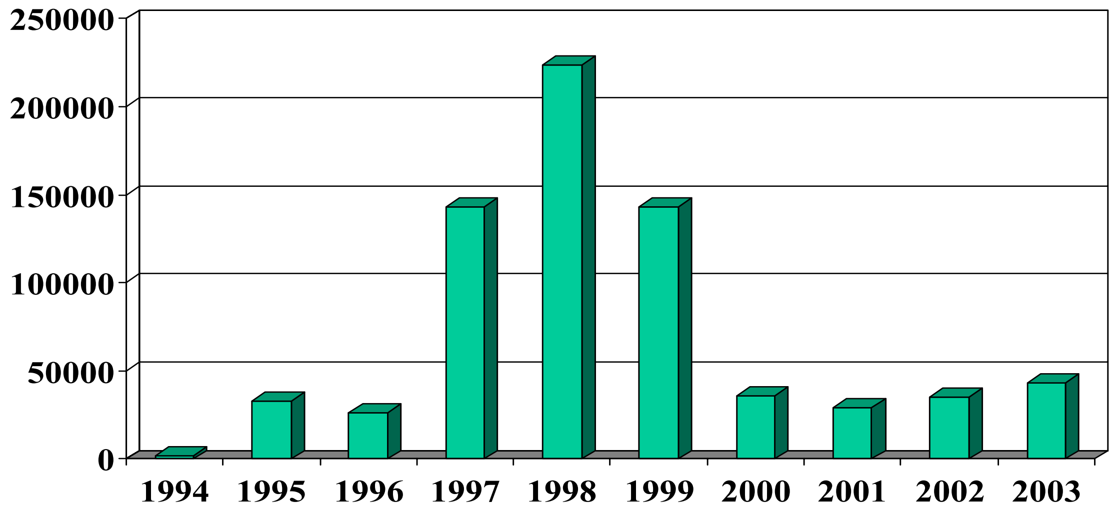


Figure 10 – Conesville Plant 1994 – 2003 FGD Use.

	Tons	Number of Projects
Mine Reclamation	636,175	12
Feedlots/ Hay Storage	79,016	268
Sub-bases	7,340	4
Pond Liners	10,671	3

Table 3 – Conesville Plant 1994 – 2003 FGD Use.

	Alkaline Amendment	**Low Permeability Cap**	**Mine Seal**	**Pond Liner**
Freeport	×			
Caldwell	×			
Rehoboth	×	×		×
Coal Prep Plant-Refuse	×	×		
Broken Aro		×	×	
Roberts – Dawson	×		×	
Rock Run		×		

Table 4 – Mine reclamation projects where FGD ash was used.

Wet Flue Gas Desulfurization (WFGD) System

How a wet scrubber works

Scrubbers or flue gas desulfurization (FGD) systems use chemical and mechanical processes to remove sulfur dioxide (SO_2) from gas produced by burning coal.

The process and illustration below describe a wet limestone flue gas desulfurization system with a jet bubbling reactor absorber unit.

- Air and cooled and saturated flue gases are injected into a tank of limestone slurry.
- The injected gases bubble through the slurry creating a frothy layer where SO_2 from the flue gas stream is absorbed.
- The injected air oxidizes the gas while the limestone slurry neutralizes it.
- The resulting product — gypsum slurry — is kept in suspension and is removed as a portion of the tank contents is pumped out for gypsum dewatering.
- The oxidized gas with more than 90% of the SO_2 removed bubbles up and makes its way out the stack.

What is SO_2?

Sulfur dioxide (SO_2) is a gas that forms when the sulfur in coal is burned. SO_2 dissolves easily in water and, when limestone and air (oxygen) are present, calcium sulfate or gypsum forms. SO_2 is a precursor of acidic deposition (acid rain) associated with the acidification of soils, lakes and streams.

Why is AEP installing scrubbers?

FGD systems will help AEP improve the environmental performance of its power plants. AEP's FGD system investments will enable the company to comply with phase one of the new Clean Air Interstate Rule. AEP continuously evaluates alternatives for meeting such requirements. After extensive study, AEP has determined that installing FGD systems at carefully selected power plants is the best option for all stakeholders, cost-effectively providing maximum environmental benefits.

How efficient are FGD systems?

Current wet scrubber technology can consistently achieve more than 90% removal of SO_2 from flue gas.

Do scrubbers remove other coal combustion gases?

Yes. An FGD system also can remove oxidized mercury from the gas stream. This will help AEP meet its target reductions for mercury as well as for SO_2.

Other information

- Power plants have cut SO_2 emissions by more than one third from 1980 levels (the year cited in the 1990 Clean Air Act amendments), according to EPRI. Between 1990 and 2001, AEP cut its SO_2 emissions by some 44% while coal-fired generation increased by 10%.
- A WFGD system neither uses nor produces harmful chemicals. Its product – gypsum – may be marketed for use in drywall, cement and other products or can be safely landfilled.
- WFGD technology increases the amount of water vapor emitted through the stack. This alters the physical characteristics of the plume, which is billowy white water vapor.

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Figure 10 – WFGD System

Notes

Site #3

AEP Conesville FGD Landfill

A Stop With A View On Top Of The Landfill.

The buses will drive to the top of the landfill and park. We will have a view overlooking the Phase A area currently in use.

Figure 12 – Phase A area of AEP Landfill.

The facility's landfill is located approximately 3 miles from the plant and was constructed in a valley between old mine highwalls. Under the Ohio EPA's disposal regulations, landfills are classified into one of four classes based on the characteristics of the waste they can receive. Class I landfills have the most stringent requirements and Class IV the least stringent. The Conesville landfill is regulated as a Class III landfill, as are AEP's other CCW landfills in Ohio. According to the AEP representatives, no one has yet been able to permit a Class IV landfill because of the ground-water non-degradation requirements associated with this class of landfill.

Figure 13 – Placing and spreading FGD ash, AEP Landfill.

The current landfill was opened in 1987 and expanded in 1993. The landfill was permitted in phases. Phase E was recently filled and will soon be capped. Phase A (the last permitted section to begin operating) is now receiving material and has about 3 years of capacity.

Before opening Phase A, AEP was required to grout some old mine auger holes to prevent differentially settlement. This grouting was accomplished using a fly ash grout mix. Permitting is being worked on to raise the central area of the landfill an additional 100 feet in elevation. This would add more capacity and about three to four years of life.

There are approximately 51 monitoring wells for the landfill, monitoring three underlying aquifers. The facility uses chloride as an indicator parameter for monitoring. Chloride is observed in the leachate at about 1,000 mg/L, compared to single digit concentrations in the aquifers. In the history of the landfill, only one well has had a statistically significant excursion from background concentrations. After assessment monitoring, this excursion was not clearly attributable to a release from the landfill, and the facility was returned to detection monitoring.

Figure 14 – Hay field on top of the landfill, AEP Landfill.

Table 5 – FGD Landfill Information, AEP Conesville Power Plant

Landfill Type – Class III Residual Solid Waste Landfill

Pre-landfill site conditions – Unreclaimed strip mine valley.

Permit (Year)	Footprint (Acres)	Capacity (MM CY)	Max. Height (Ft.)
1985 52		3.6	170
1993 47		8.4	170
2006 (Vertical	Expansion)	3.5	270
Completion 99		15.5	270

Annual Waste Disposal		Landfill Design Components
• FGD waste:	550,000 tons	• Subgrade isolation layer: 5 ft. recompacted soil.
• Fly ash:	230,000 tons	• Liner: 1.5 ft. clay/30 mil PVC geomembrane.
• Bottom ash:	50,000 tons	• Leachate system: 1 ft. sand and piping.
• Total:	830,000 tons	• Final cover: 2 ft. clay/ 1 ft. topsoil.

Site Monitoring Program

- Wastewater treatment facility discharges (2) – Daily
- Groundwater interceptor drain outfalls (4) – Biweekly
- Leachate collection system outfalls (3) – Quarterly
- Groundwater monitoring wells (51) – Semiannually
- Waste characterization – Annually

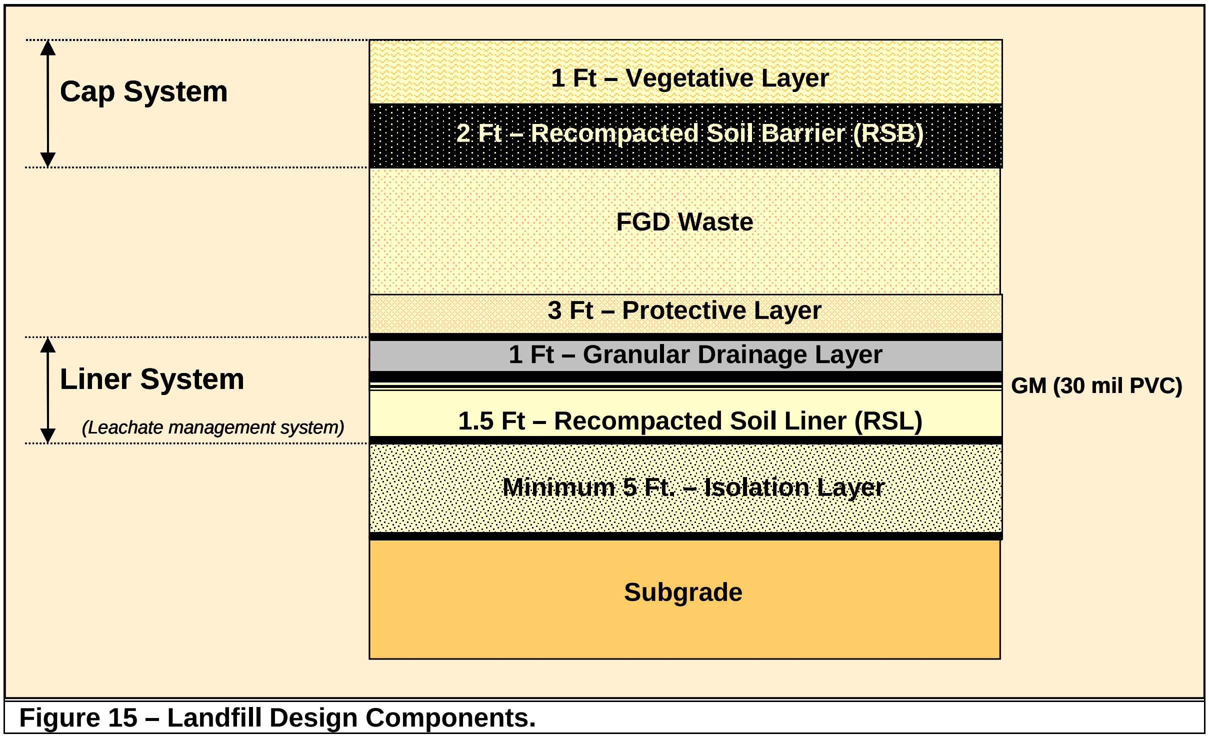


Figure 15 – Landfill Design Components.

Figure 16 – Recompacted Soil Liner, Phase A Area.

Figure 17 – Geomembrane Liner Installation, Phase A Area.

Figure 18 – Leachate Collection Piping, Phase A Area.

Figure 19 – Leachate Collection System Drainage Layer (Sand), Phase A Area.

Notes

Site #4

FGD Landfill Leachate/Wastewater Treatment

Stop For A Description On The Leachate Collection And Monitoring.

Figure 20 – Treatment ponds and facility, AEP Landfill.

Table 6

CONESVILLE RESIDUAL WASTE LANDFILL
LEACHATE COLLECTION SYSTEM
ANNUAL FLOW DATA – 2005

In Million Gallons

MONTH	601 (EAST)	602 (WEST)	603 (EAST)	TOTAL
January	1.7980	1.0540	0.4960	3.3480
February	0.8036	0.7756 0.	4284 2.	0076
March	0.7440	1.0540 0.	4805 2.	2785
April	0.8850	0.7650 0.	4800 2.	1300
May	0.4743	0.9610 0	.4805 1	.9158
June	0.3810	0.9900 0	.4560 1	.8270
July	0.5580	1.4725 0.	5425 2.	5730
August	0.3875	1.0540 0	.5580 1	.9995
September	0.3600	0.9300 0.	4650 1.	7550
October	0.3565	0.7750 0.	4960 1.	6275
November	0.7650	0.7500 0.	4650 1.	9800
December 0.4650		0.5518 0.4929	1.5097	
TOTAL 7.	**9779**	**11.1329**	**5.8408**	**24.9516** **or** **68,361 GPD** **or** **47.5 GPM**

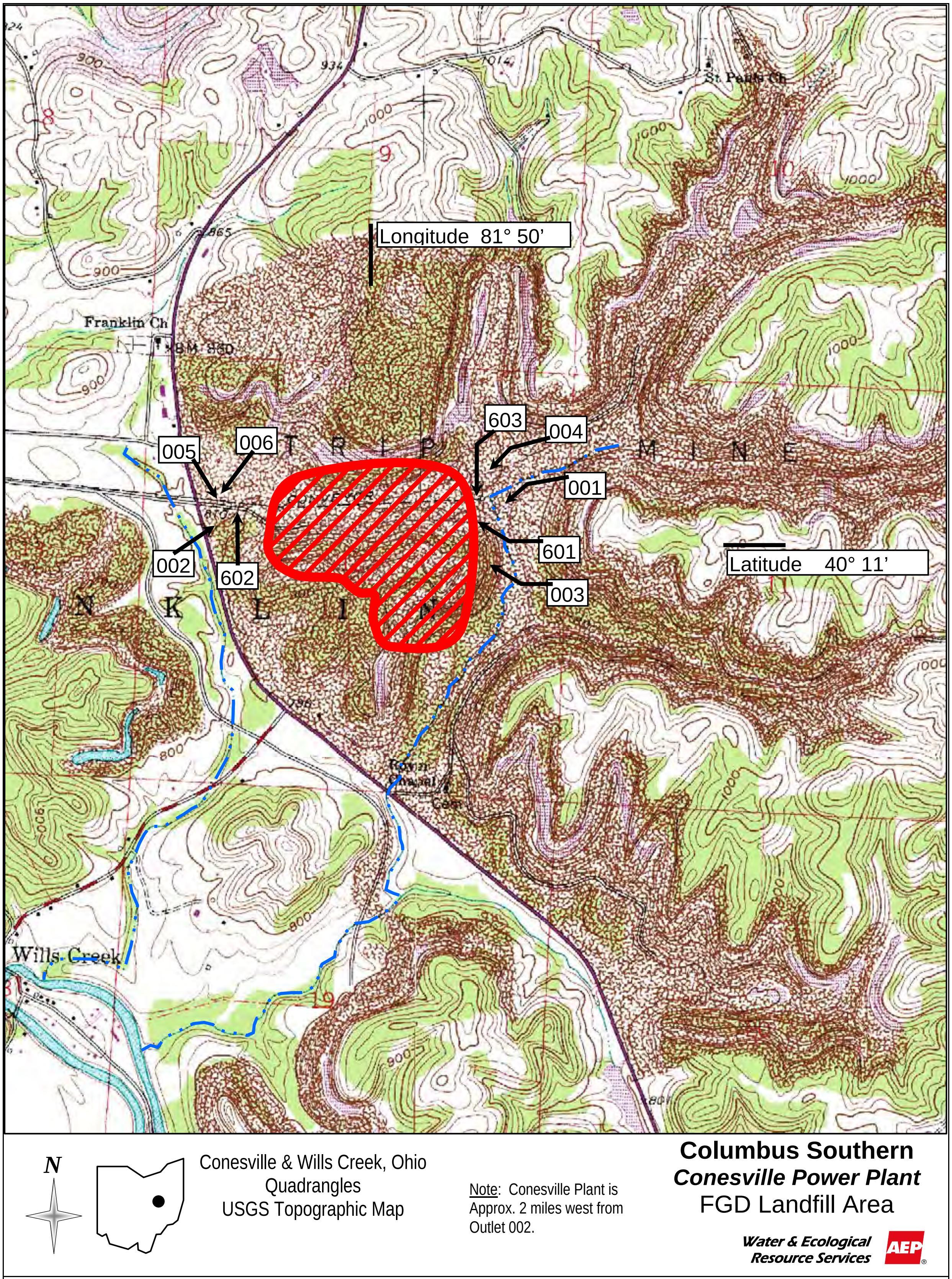


Figure 21 – Groundwater Interceptor, Leachate, and Pond Discharge Monitoring Locations.

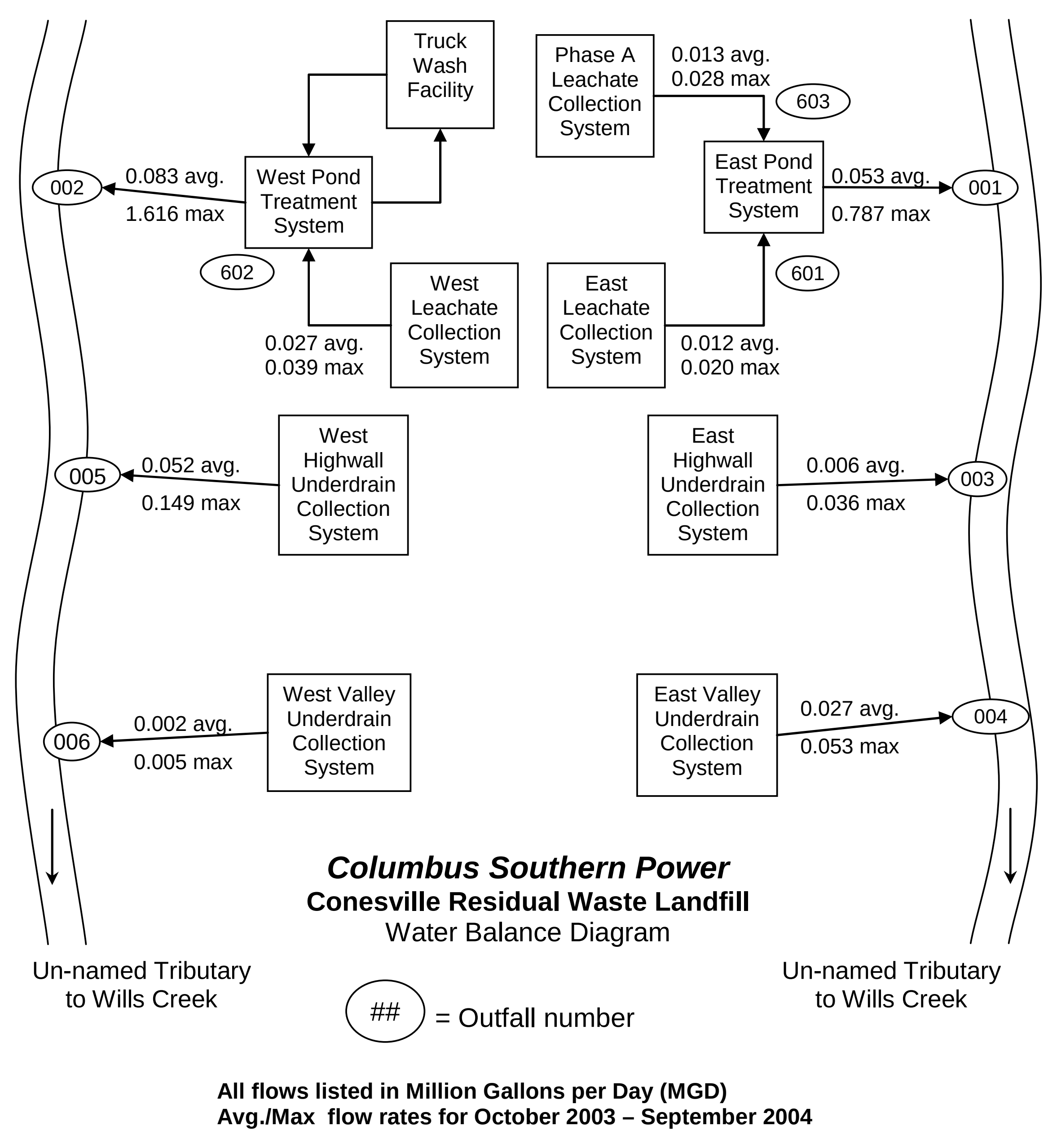


Figure 22 – Water Balance Diagram, AEP Landfill.

Table 7 –AEP Landfill, leachate data for 2005.

CONESVILLE RESIDUAL WASTE LANDFILL
LEACHATE COLLECTION SYSTEM
MONITORING DATA – 2005

Parameter	Units	March			June			August			September			December		
		601	602	603	601	602	603	601	602	603	601	602	603	601	602	603
Arsenic	MG/L	.015	.026	.004	.019	.026	.013	.019	.032	.016				.027	.037	.009
Barium	MG/L										.042	.055	.054			
Cadmium	MG/L	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005				<.0005	<.0005	<.0005
Chromium	MG/L										<.002	<.002	<.002			
Fluoride	MG/L										0.1	0.1	0.2			
Lead	MG/L										<.002	<.002	<.002			
Mercury	MG/L										<.0002	<.0002	<.0002			
Selenium	MG/L	<.005	<.005	<.005	<.005	<.005	<.005	.002	.003	.004				.015	<.005	<.005
Silver	MG/L										.0007	.0006	.0009			
Chloride	MG/L				1050	1388	1350							938	1363	1325
Iron	MG/L	.020	.030	<.010	<.010	<.010	<.010	<.010	.020	<.010				<.010	<.010	<.010
Manganese	MG/L	<.010	.030	.080	<.010	.020	.040	.020	.030	.210				.060	.030	.110
Sodium	MG/L				244	278	316				247	276	300	200	258	268
Sulfate	MG/L	1150	1735	1725	1665	-	1805	1725	1625	1745				1470	1660	1800
TDS	MG/L				-	-	4680							3616	4471	4769
pH	S.U.	9.6	9.8	9.3	9.9	10.1	7.5	9.6	9.8	9.6	9.9	9.9	9.6	9.5	10.0	9.4
T. Alkalinity	MG/L				106	194	152							54	178	130
Conductivity	UMHOS				6493	6160	6440							4988	6331	6630
Temperature	°C				17	17.8	17.9							13.9	14.4	13.8
Calcium	MG/L	470	808	809	692	808	744							694	932	997
Boron	MG/L				1.50	3.82	3.74							1.54	3.81	4.37
Molybdenum	MG/L				.166	.262	.314							.143	.335	.325
Magnesium	MG/L	19.3	3.3	6.1												
Potassium	MG/L				422	521	794							366	462	523
G. Alpha	pCi/L				37	52	23									
G. Beta	pCi/L				479	645	818									

601 – East (Phase A) Leachate Collection System

602 – West Leachate Collection System

603 – East (Phase C) Leachate Collection System

Site #5

AEP Coal Prep Plant & Coal Refuse Disposal

Videos of the coal prep plant and use of FGD material at the coal refuse reclamation site will be shown.

Each of the AEP-affiliated mining divisions has a coal-preparation plant, except for Southern Ohio Coal Company's Meigs Division, which has two such facilities. Coal washing provides a higher, more consistent quality of coal for the AEP System's generation plants.

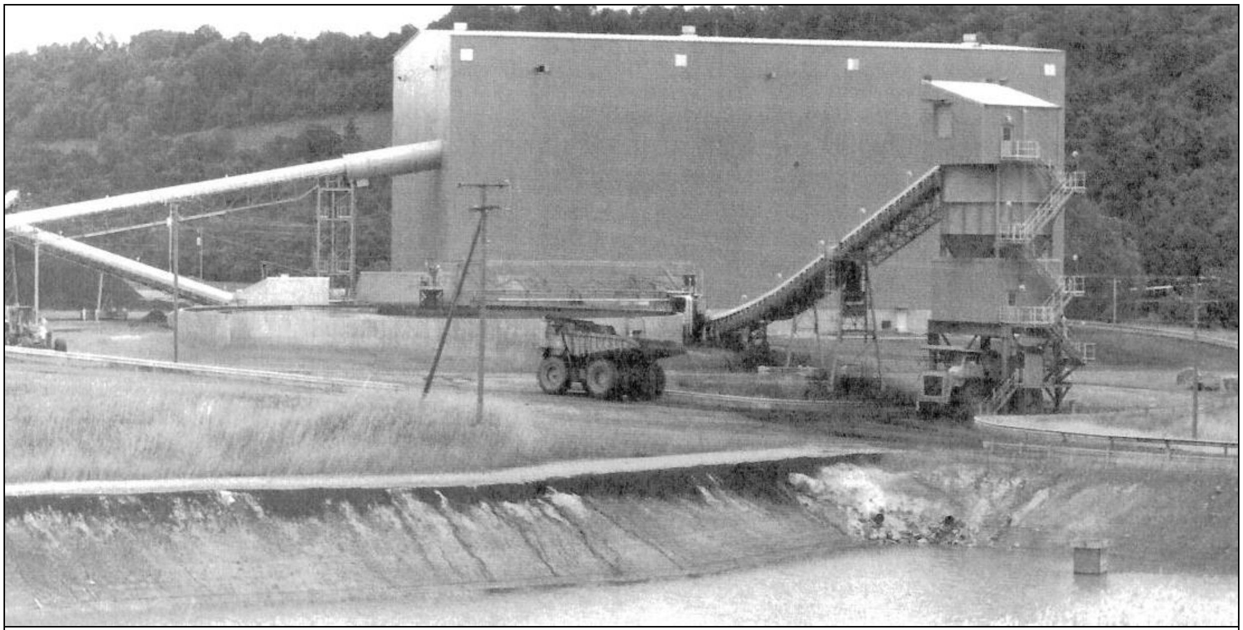


Figure 23 – The Conesville preparation plant computerized control center puts all the plant circuits at the fingertips of a control room operator. In addition to monitoring for efficiency, the control center can shut down any circuit in case of an emergency.

Coal washing

The Conesville prep plant can handle 1,000 tons of coal per hour utilizing modern technology and intricate machinery. The Conesville coal preparation plant transforms raw coal into a quality fuel for use at the Columbus and Southern Ohio Electric Company's Conesville generating station.

Built at a cost of $35 million, the coal-processing facility was placed into commercial operation in early 1985. Incorporated as the Conesville Coal Preparation Company, the plant, which is located just two miles south of the Conesville generating station in southwestern Coshocton County, Ohio, operates as a subsidiary of C&SOE.

Why coal is washed

Raw coal contains a certain amount of impurities, such as ash and sulfur. When coal with high ash content is burned by the generating facility, the ash can cling to the boiler tubes. If the ash fuses together to form slag, it can drop to the bottom of the furnace, seal over the ash removal equipment and shut down the generating unit.

Coal washing improves boiler availability at the generating plant. It reduces the plant's maintenance requirements and helps in producing the lowest possible cost per generated kilowatt-hour.

The completion of the Conesville coal preparation plant is also the latest in a series of steps that C&SOE has taken to assure that the Conesville generating plant is in compliance with U.S. Environmental Protection Agency regulations pertaining to sulfur-dioxide emissions.

A three-circuit system

Within the walls of the plant, which has the capability of processing 1,000 raw tons of coal per hour, a crew of approximately 35 employees operates the three coal-cleaning circuits. The circuits are designed to handle different sizes of coal from the nearby Simco-Peabody surface mining operation and other suppliers.

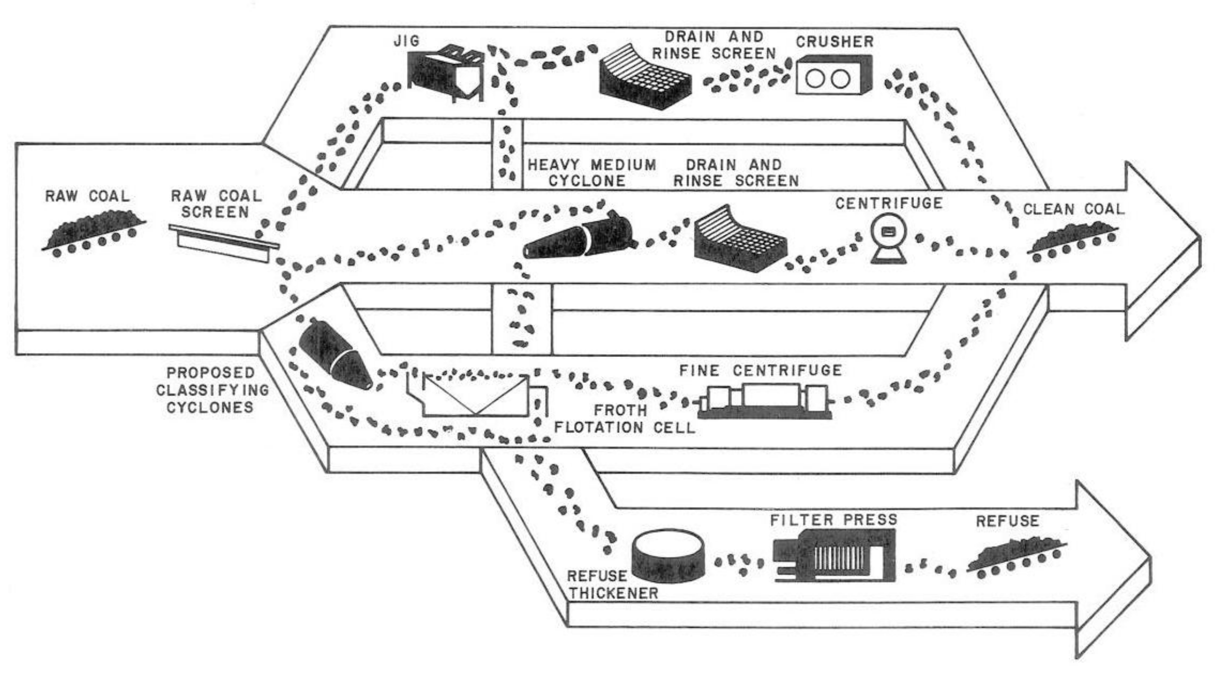


Figure 24 – The Conesville preparation plant computerized control center puts all the plant circuits at the fingertips of a control room operator. In addition to monitoring for efficiency, the control center can shut down any circuit in case of an emergency.

As raw coal enters the plant by conveyor, it passes over a screen which separates it by size. Coarse coal with a diameter of 3/8-inch to six inches will be cleaned by a jig. Intermediate-sized coal, ranging from 3/8-inch to 28-mesh, is handled by heavy media cyclones which separate coal from impurities using centrifugal force.

Coal which is smaller than 28-mesh is very fine and can pass through a screen that has 784 openings per square inch. It is cleaned by a process known as froth flotation. All the cycles operate on a closed-circuit system, which means water utilized in the plant will be cleansed of sediment and other impurities and used again.

Coarse coal entering the plant reports to the jigging circuit for processing. The main ingredients in the screening circuit are air, which is introduced under high pressure, and water.

To begin the process, raw coal is fed into the jig's tank. Pressurized air lifts and agitates the coal and water mixture. Rock and other refuse matter is removed from the coal and sinks to the bottom of the tank. Once at the bottom, the unwanted materials exit through refuse gates. The coal, being lighter, washes over small dam- like structures called "weirs," and continues through the circuit. Excess water is then drained off before the clean coal is conveyed out of the plant.

In the intermediate circuit, a slurry comprised of raw coal, water and magnetite (a heavy, iron-based mineral that elevates the specific gravity of water) is fed under pressure into a cyclone. Centrifugal force directs the rock and other impurities to the outside wall and out the bottom of the cyclone. The coal, which is lighter, stays near the center of the cyclone and is forced out through the top. Clean coal and refuse from the heavy media cyclones are sent to separate drain and rinse screens where the magnetite is recovered for reuse.

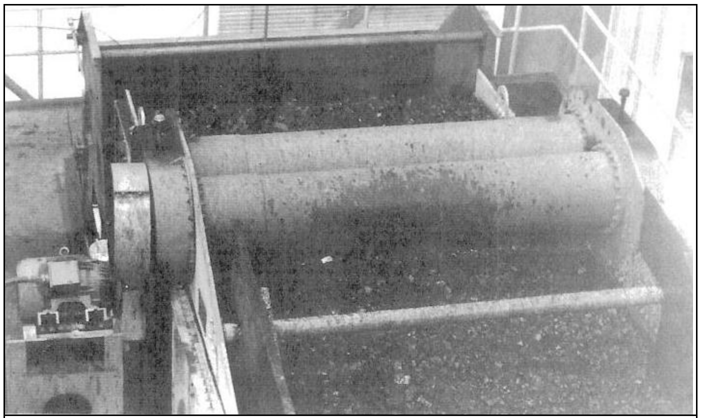
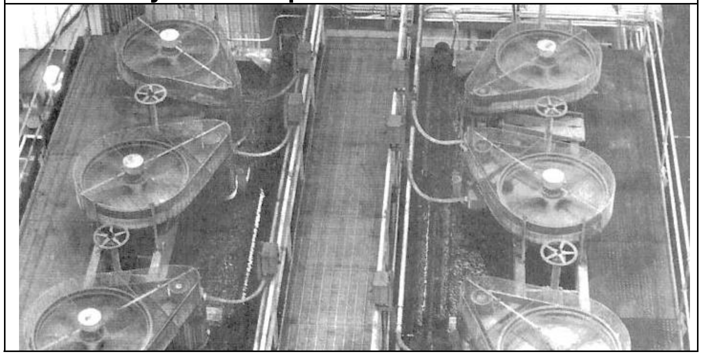


Figure 25 – Since coal comes in various sizes, the Conesville prep plant utilizes three different circuits in its operation. At top, a jig separates impurities and pyritic sulfur from the coal with pulsating air and water. At bottom, a bank of froth flotation cells cleans very fine coal particles.



The fine coal passing through the Conesville preparation plant is cleaned by froth flotation, one of the most technically advanced coal cleaning processes in the world. The principle of gravity, which works so well in other coal cleaning methods, cannot effectively clean fine coal.

Prior to entering the froth flotation cell, the fine coal is mixed with water. This slurry is then treated with a conditioning agent which allows attachment of the fine coal particles to air bubbles. As the slurry enters the cell, it is directed toward an agitator. Not only does the agitator create air bubbles, it helps the coal cling to the bubbles. Consequently, the coal and bubbles float to the surface where the froth concentrate is removed by paddles. The fine refuse stays at the bottom of the cell before exiting through a discharge pipe.

Overseeing the entire operation at Conesville is a control-room operator. Like several other prep plants on the AEP System, the Conesville facility is equipped with a computer-assisted monitoring system. Linked to all circuits in the plant, the computer checks machinery performance, spots any problem areas, and assists management in diagnosing the cause of the problem.

Quality control

Since coal quality and plant efficiency are such important factors, the Conesville preparation plant also houses a state-of-the-art laboratory.

Staffed by highly trained technicians, the preparation plant lab features sophisticated equipment which tests the coal's sulfur content, ash content, BTU, or heat rate, and moisture level. The lab technicians are also responsible for monitoring the performance of the machinery throughout the plant. Tests run on raw coal, clean coal, coal slurry and the refuse matter leaving the plant help ensure that each circuit is operating at maximum efficiency.

The efficiency of the Conesville prep plant is vital considering the stringent environmental standards that have been placed on the Conesville generating station. Raw coal entering the prep plant usually contains sulfur content ranging from 5.0 to 6.0 percent. When it exits, that figure has been reduced to only 2.5 or 3.0 percent. Also, while the ash content of the coal is significantly reduced, the BTU rate is enhanced. When it enters the plant, the coal contains ash near the 15 percent level. Upon leaving, the clean coal has about five percent ash. Meanwhile, the heat rate is boosted from about 10,500 to approximately 12,300 BTU.

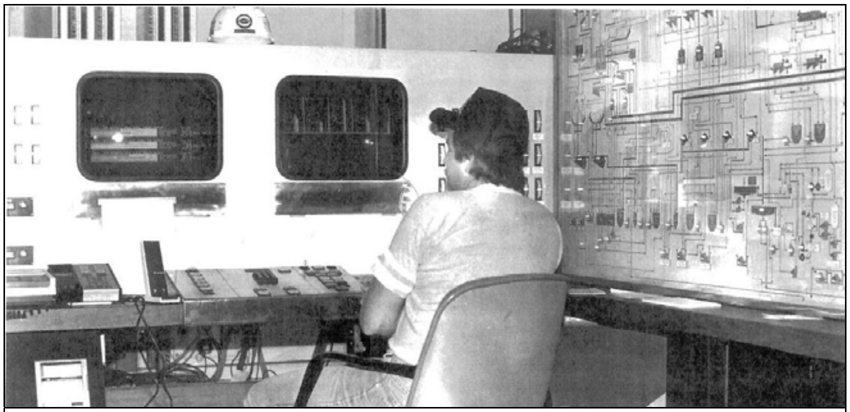


Figure 26 – The Conesville preparation plant computerized control center puts all the plant circuits at the fingertips of a control room operator. In addition to monitoring for efficiency, the control center can shut down any circuit in case of an emergency.

Another environmental checkpoint built within the Conesville complex is the nearby acid mine drainage (AMD) treatment facility. Built just west of the prep plant, the AMD facility treats surface water runoff that has come into contact with coal on the prep plant site. The pH of that water is neutralized before it is returned to nearby Wills Creek and other streams.

When cleaned coal finally leaves the preparation plant, it is stockpiled in an area near the raw coal stockpile. The clean coal stockpile can accommodate 30,000 tons, and the washed coal is directed onto a conveyor that leads to the Conesville generating station through a 15-foot diameter coal reclaim tunnel.

Solid refuse from the preparation plant is taken to another area adjacent the plant where it is compacted and stabilized in accordance with all environmental regulations. The compacted material is ultimately covered with topsoil and grass.

By delivering quality fuel to the generating station while maintaining the delicate environmental balance of the region, the Conesville coal preparation plant operates as a vital link in the creation of cost-efficient electricity.

Coal Refuse Disposal Reclamation Using FGD Material

The original refuse area can be seen on the right side of the road as the bus leaves the prep plant. This refuse area was used from 1984 until 2005 and contains approximately 7 million tons of refuse. The coarse and fine refuse that are separated from the raw coal in the cleaning process are disposed of on-site in the refuse area in two foot compacted lifts. Flue gas desulfurization material, commonly called FGD, is placed intermittently in one foot compacted lifts on top of the two feet of compacted refuse. The FGD material serves as an intermediate cover material. Three feet of compacted FGD material with one foot of soil on top is used as final cover material on completed areas. The area is then seeded with a mixture of grasses and legumes and mulched.

The Bureau of Mines demonstrated that certain bacteria play an important role in the pyrite oxidation process. The oxidation of ferrous iron to ferric iron is greatly enhanced by the presence of sulfur and iron oxidizing bacteria. The role of bacteria as a catalyst in the pyrite oxidation process increases as the pH drops. Important factors in controlling the generation of acid from the pyrite oxidation process are;

- Minimizing exposure to air
- Minimizing contact with water
- Limiting dissolved oxygen and the formation of ferric iron
- Controlling iron and sulfur oxidizing bacteria and
- Maximizing available alkalinity to maintain a near neutral pH.

FGD material has a low permeability. Covering the combined refuse with a one foot compacted layer of FGD material will create a physical barrier to air, oxygen, and water contact with refuse prior to the refuse turning acidic. This is a characteristic of FGD that is not available with normal alkaline addition. The FGD material will also function as a chemical barrier to the pyritic oxidation process. This characteristic of FGD is also not available with normal alkaline addition.

The use of FGD material as an intermediate and final cover material for the active refuse area will minimize the generation of acid and associated soluble metals by inhibiting pyrite oxidation processes. The FGD cover will create a physical, chemical, and biological barrier to elements which are necessary for acid generating reactions to occur.

The area on your left is the current active refuse disposal area. A one foot compacted layer of FGD material is used as an intermediate cover on this area as well, and three feet of compacted FGD material with one foot of soil is used as final cover material.

The drainage from the coal refuse disposal areas and the preparation plant site is collected in two holding ponds and routed to the wastewater treatment plant for treatment prior to discharging to the receiving stream.

The company's ultimate objective is to eliminate or reduce the need for perpetual water treatment following reclamation of the site. Reducing or eliminating perpetual treatment is enhanced by the elimination of ongoing acid generation.

Notes

Site #6

FGD Highwall Reclamation Project

We will stop here to see and discuss this use of FGD material.

The Conesville Coal Preparation Company, Conesville Generating Station and the Ohio Department of Natural Resources (ODNR) are working together to reclaim a 1950s-vintage surface mine that was abandoned, leaving behind acid mine drainage and a dangerous 100-foot highwall.

Figure 27 – Portion of highwall before reclamation work began. emergency.

The abandoned mine is located on Conesville Coal Preparation Company's property. Runoff from approximately 30 acres mixes with seepage emerging from the coal seam, resulting in water with a pH of about 3.0. Currently, the prep plant must treat this acidic water to neutralize its caustic effects before it leaves the property. The pit generates approximately 100 gallons per minute of acid mine drainage water.

"This is a long-term problem for us," said Royal Wilson, technical services and administrative manager for Conesville Coal Preparation Company, which washes the coal Conesville Power Plant burns in its units 1, 2, 3 and 4.

"It's a liability here now and a liability for AEP for years to come. While there are extra costs associated with doing this reclamation now, in the long run, we will save millions of dollars in

Figure 28 – FGD material placed in one end of the old pit and highwall.

costs for perpetual treatment of this runoff. Ultimately, this also will improve the water quality of (nearby) Wills Creek."

Ted Morrow and Jody Belviso of AEP´s Environmental Services Department worked with the ODNR Abandoned Mine Land (AML) program manager and staff to successfully negotiate a "no-cost" contract with the state for the beneficial use of flue gas desulfurization (FGD) material for the reclamation of this site. AEP will bear the costs associated with the reclamation project.

Conesville FGD product is being used to eliminate a dangerous 100-foot highwall and acid mine water runoff from the coal pit at the base of the highwall. FGD will be used to backfill the highwall to the approximate original contour and to seal the pit floor and any auger holes, thereby allowing the mine to fill with groundwater that eliminates oxygen from reacting with the water to form acid mine drainage. The reclamation also includes construction of diversion ditches and installation of two groundwater monitoring wells.


Figure 29 – FGD material being deposited on site.

Chet Vance supervises Conesville Power Plant's land filling of the coal combustion by-products – fly and bottom ash – generated by the power plant's six units and FGD product from the power plant's units 5 and 6 scrubbers. While ash and FGD material are marketable products, the power plant generates more than can be sold for beneficial purposes. Unsold products go to the plant's active landfill – a 99-acre, four-phase site southeast of the plant.

This pit and several others like it are the visible reminder that the lands were once surface mined for coal. Prior to the 1977 surface mine reclamation law, mine operators left highwalls exposed, and reclamation simply meant planting trees. The 1977 law requires mining companies to remove all structures and return the land to its original or better condition. Reclamation of abandoned surface mines creates some challenges usually not encountered at active mine sites. In normal surface mine reclamation, the work is done right behind the mining operation, which begins with the removal of vegetation, topsoil and remaining materials. The topsoil is set aside for later use in the reclamation process. In this case, topsoil has to be found.

Eliminating the acid mine drainage involves using approximately 1.6 million tons of FGD material produced by the Conesville scrubbers to backfill the highwall. When the backfilling is done, the area will be graded to its original contour, topsoil replaced and reseeded.

Figure 30 – Starting at one end of the cut, FGD material is placed to fill the old pit and cover the highwall.

Morrow estimates it will take approximately four years to complete the final reclamation of the site. "We're just now getting a good start," he said.

ODNR is enthusiastic about the overall potential, Morrow said. This is the largest project utilizing FGD for reclamation of abandoned mine lands in the state thus far.

Randy Miller, Conesville Prep Plant superintendent, views this beneficial use of a waste product as an excellent example of partnering with the power plant and the state of Ohio. This project results in environmental improvement and a significant cost savings to the company.

Reference: AEP website, http://www.aep.com/about/coalCombustion/currentProjects/FGD.htm

Figure 31 – Unloading FGD material to be spread out.

Notes

Site #7

SR541 Embankment Repairs Using PFBC Ash

Discussion of the project as the buses drive over the location.

Ohio State Route 541 suffered major surface settlement incidents immediately west of Coshocton in Coshocton County during 1985, in 1989, and again in 1993. Attempted repairs included a pile-supported retaining wall that failed to prevent movement and was itself moved down slope about 2 meters (Kim, 1995). The damage was caused by repeated rotational sliding movement mainly on a water saturated grayish clayey-shale layer that coincided with the original natural ground surface 11 meters below the road level.

Figure 32 – Existing damage to SR 541 after attempted repairs.

The Ohio Department of Transportation (ODOT) was aware of flue gas desulfurization (FGD) by-product use in highway fills due to discussions with the Civil Engineering Department at The Ohio State University. ODOT decided to utilized FGD by-product in the SR 541 embankment repairs as a demonstration project.

Compacted Pressurized Fluidized Bed Combustion (PFBC) ash has excellent strength properties and low permeability. The PFBC material used to reconstruct the highway embankment came from AEP's Tidd plant. The work was done over the winter of 1993 and the road reopened to traffic in March 1994.

The portion of the road affected by the slide was constructed in 1966 over a large fill. The first phase of the project involved the excavation of approximately 310,000 cubic feet of soil from above the slip plane. Half of the excavated soil was stockpiled for later use at the site while the rest was transported off site. At least two low volume springs were encountered during excavation and much of the soil moved off site was saturated. Several under drains were required and constructed to direct water away from the load bearing portions of the embankment.

The second phase involved the placement and compaction of FGD material. Self-loading scrapers delivered the material stocked onsite, as bulldozers spread it evenly over an area 40 feet wide and 100 feet long. The first two foot lift was placed and compacted in one day. Within 12 hours of placement the FGD had gained enough strength for the scrapers to drive over it without leaving tire tracks. The FGD buttress was constructed up to a height of 13 to 16 feet. The thickness of layers and the amount of water added to the FGD were not strictly monitored. It was observed that the material had a wide workable range and did not have to be mixed with laboratory precision to yield excellent strengths. The original embankment material was then placed on top of the FGD buttress in controlled lifts and the final road surface was constructed.

Figure 33 – SR 541 after PFBC placement and before paving.

During the first and second phase of the embankment repairs, regular monitoring of the water quality upstream and downstream of the project was done. The variations in pH and total dissolved solids were within the acceptable range of fluctuations associated with the stream. However, water samples taken from underdrains showed a significant rise in sulfates and total alkaline measured as $CaCO_3$. The volume of stream flow was so much greater than the volume of water being expelled through the underdrains that the total system appeared unaffected by the increase in measured sulfates and $CaCO_3$ in the leachate. Since the construction of the project, ODOT installed a system of inclinometers, piezometers and deformation measuring gauges at the site. The monitoring data indicates little or virtually no movement of the FGD embankment slope.

Butalia, T.S., and Wolfe, W.E., and Dick, W.A., 1999, **Developments In Utilization Of CCPs In Ohio**, Proceedings of 13th International Symposium on Use and Management of Coal Combustion Products (CCPs) , Orlando, Florida, January 11-15, 1999.

Kim, S.H., Nodjomian, S., and Wolfe, W.E., 1995, **Field Demonstration Project Using Clean Coal Technology By-Products**, Proceedings of 11th International Symposium on Use and Management of Coal Combustion By-Products (CCBs), Orlando, Florida, Jan 15-19, American Coal Ash Association and Electric Power Research Institute, EPRI TR-104657, V. 1, p. 16(1-15).

Site #8

Woodbury Wildlife FGD Parking Lot Base

We will stop here to see and discuss this use of FGD material.

ODNR Division of Wildlife provides shooting ranges at several areas throughout the state. Located approximately seven miles west of Coshocton, Ohio just off State Route 541, the Woodbury Shooting Range opened in December 2000. It provides a safe and controlled environment for the whole family to enjoy shooting sports.

The Woodbury range is unique in size and offerings. Located northwest of the intersection of SR541 and County Road 17, it is built on reclaimed strip-mined lands. The range will accommodate up to 55 shooters at one time on the 550 feet of firing line. There are 25, 50, 100 and 200-yard ranges and a shotgun area for trap shooting. There is also an archery range adjacent to the 25-yard shooting range.

Figure 34 – ODNR Woodbury Wildlife Shooting Range.

Funding for the project was provided primarily from ODNR Division of Wildlife monies derived from the sale of licenses and permits. Other assistance was provided in the form of labor and materials. R & F Coal Company completed the earth moving for the range as part of their reclamation efforts. American Electric Power's Conesville Plant provided base material consisting of stabilized FGD material valued at $27,000 for the parking lot, with all costs absorbed by AEP. Lubugh, Inc., an independent contractor, hauled and compacted the base material, and constructed the shooting range parking lot, which greatly exceeded their original scope of work to be performed. This resulted in an $11,000 savings for the Division of Wildlife. Residents of the Chillicothe Correctional Institute built shooting benches, while numerous local contractors provided materials, labor, and technical assistance.

According to project coordinator, Tim Shearer, AEP's Conesville Plant not only provided the base materials, but they obtained the necessary permit approval from the Ohio Environmental Protection Agency. "Without the assistance of AEP's Conesville and Lubugh, Inc., the range would not have met our opening date nor our budget constraints. On behalf of the sportsmen and women, as well as the ODNR Division of Wildlife, I extend our gratitude to these companies for their assistance" stated Shearer.

Range construction was guided by the National Rifle Association and the National Shooting Sports Foundation, as well as professionals within ODNR Division of Wildlife. A lead recycling system was installed in the backstops to insure that no lead will leave the shooting range except through approved recycling methods.

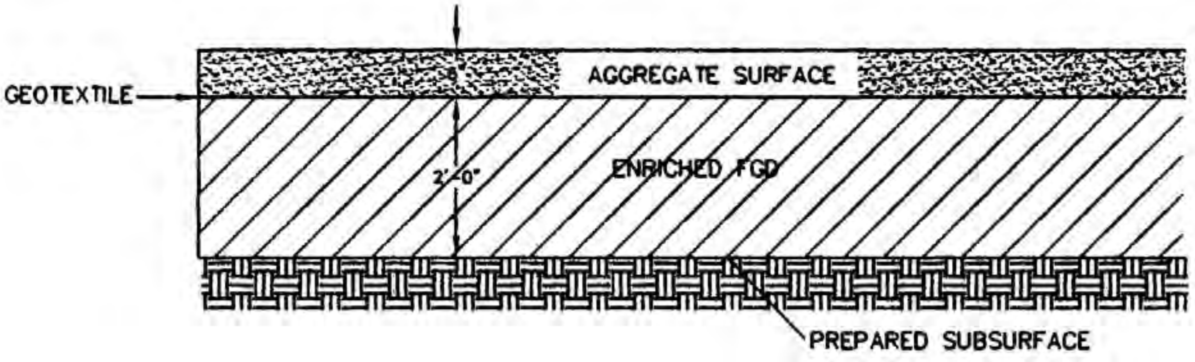


Figure 35 – Woodbury Shooting Range FGD Placement design.

Nearly 5,400 tons of stabilized FGD material from the AEP Conesville power station was applied as a base material. The FGD material was compacted in two lifts of about 12 inches each for a total average base thickness of 24 inches.

Table 8 – Area of base layers for parking lots:	
Parking lot 1:	60' x 450' x 2'
Parking lot 2:	60' x 335' x 2'
Vehicular lane between lot 1 and 2:	60' x 265' x 2'

News Release, New Shooting Range Opens In Coshocton County, December 18, 2000. Ohio Department of Natural Resources. http://www.dnr.state.oh.us/htdocs/news/dec00/1218shooting.htm

Figure 36 – ODNR Woodbury Wildlife Shooting Range during winter visit.

Site #9

Broken Aro Reclamation Project

We will stop and take a short walk to see this site.

Figure 37 – Broken Aro Reclamation site in 2005.

The Broken Aro Mine site is located about seven miles west of Coshocton, Ohio on State Route 541 at the Woodbury Wildlife Preserve. An abandoned underground mine complex last mined in 1910, this site forms the headwaters of the Simmons Run Watershed. A No. 6 and a deeper No. 5 coal seam on the 40-acre site have been mined by means of underground mining in the 1910's. The mining operations produced acid mine drainage (AMD) which polluted receiving streams with acidity and heavy metals, killing aquatic and plant life. In the mid 1990's, R & F Coal Company was surface mining the Middle Kittanning (#6) coal seam on Permit Number D-1071.

The coal operator had intentions to continue to remove coal in this area through economical methods, however it was soon discovered that the old mine works were much more extensive than originally anticipated. Problems encountered included reduction of coal recovery (to avoid interception of the old mine works), and the potential for AMD liability. As a result, R & F Coal Company made a decision to exclude this area (the remining portion) of the Broken Aro reserve permit. Sometime after R & F Coal Company made the decision to not effect and mine the area located in the Simmons Run drainage area, company personnel discussed the possibility of eliminating this portion of the area from the active D-permit and correct the problems through a Division AML (Abandoned Mined Land) project. Generally, coal removal is not permitted as part of an AML reclamation project, however discussions were advanced that would allow the coal operator to mine through a portion of the old workings to expose the mine openings in the highwall.

Once exposed, the openings would be sealed utilizing fixated Flue Gas Desulfurization (FGD) material from the nearby Conesville Power Plant operated by American Electric Power (AEP). The purpose behind using the FGD product to seal the exposed mine voids and exposed highwall would allow the voids within the abandoned underground mine to fill with groundwater, minimizing the oxidation of exposed pyrite materials within the mine void. The FGD seal has a low hydraulic conductivity, which limits water from seeping out of the underground mine, and a high alkalinity which may neutralize any acidic water in contact with the seal, or AMD water that might seep from the mine.

The final seal was approximately 2600 feet long, 15 feet wide and was installed in two 4-6 foot compacted lifts for a total height of 8-12 feet. The seal was constructed concurrent with mining activities to maintain a continuous hydraulic barrier. The seal has retained water inside the mine complex and has decreased the contaminant loads to Simmons Run, as detailed in the journal article referenced below. In summary, the FGD seal has shown that it has improved water quality inside the mine, reduced the quantity of water seeping from the mine, and reduced contaminant loads to Simmons Run by up to 97%. The seasonal cycling of the mine water elevations has had a small, but noticeable, effect on contaminant profiles. It is important to either lower the concentration of the contaminants or the flowrate so that ultimately the total loading decreases. In this project, both the concentrations and flowrates have consistently decreased due to the mine seal, which is optimal for contaminant load reduction.

M. T. Rudisell, B. J. Stuart, G. Novak, H. Payne and C. S. Togni, 2001, **Use of flue gas desulfurization by-product for mine sealing and abatement of acid mine drainage,** FUEL, Vol. 80, pp. 837-843.

Figure 38 – Broken Aro Project, grubbing and preparation of site.

Figure 39 – Broken Aro Project, dumping FGD in trench against highwall.

Figure 40 – Broken Aro Project, moving and blending FGD with dozer.

Figure 41 – Broken Aro Project, compacting FGD material with dozer.

Figure 42 – Broken Aro Project, using a backhoe to fill mine openings.

Figure 43 – Broken Aro Project, the first lift is nearly complete.

Figure 44 – Broken Aro Project, the final grade is sloped to shed water.

Figure 45 – Broken Aro Project, the FGD ready for backfilling and reclaiming.

Figure 46 – Broken Aro Project, the Broken Aro site after one year.

Figure 47 – Broken Aro Project, the Broken Aro site after three years.

Appendix A

List of Acronyms

AEP	American Electric Power Company
AMD	Acid Mine Drainage
AML	Abandoned Mine Land
CCB	Coal Combustion Byproduct
CCP	Coal Combustion Product
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization (scrubber) ash
EORDC	Eastern Ohio Resource Development Center
EPA	Environmental Protection Agency
GPD	Gallons Per Day
GPM	Gallons Per Minute
LNB	Low NOx Burner
MW	Megawatt
MGD	Million Gallons per Day
NOx	Nitrogen Oxides
NRCS	Natural Resources Conservation Service
ODOT	Ohio Department of Transportation
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OFA	Overfire Air
OSM	Office of Surface Mining
PC	Pulverized Coal boilers
PFBC	Pressurized Fluidized Bed Combustion ash
PM	Particulate Matter
PTI	Permit-To-Install
SCR	Selective Catalytic Reduction
SR	State Route
SWCD	Soil and Water Conservation District
USGS	United States Geological Survey
WFGD	Wet Flue Gas Desulfurization system

Appendix B

http://ohioline.osu.edu/aex-fact/0332.html

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THE OHIO STATE UNIVERSITY

FactSheet

Extension

Ohio State University Fact Sheet

Food, Agricultural and Biological Engineering

590 Woody Hayes Dr., Columbus, Ohio 43210

Construction of Livestock Feeding and Hay Bale Storage Pads Using FGD Material

AEX-332-99

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Excessively muddy conditions at livestock feeding and watering areas can have detrimental effects on farm operations. The animals have to expend a considerable amount of energy just to move through mud. This can result in higher feed costs as well as reduced weight gain by livestock. Hay bales stored on wet ground can take on moisture, leading to early deterioration and as much as 50% spoilage. Avoidance of muddy conditions can result in increased animal performance and significant monetary savings for producers, as well as a cleaner farm environment.

To avoid muddy conditions, it is often desirable to construct a stable, impermeable, and sloped surface so that water drains off rather than accumulates on the area. Flue Gas Desulfurization (FGD) material is currently being used as an inexpensive and reliable product in the construction of feeding pads. It is also being used for constructing pads for hay bale storage so that the bales can be protected from mud and moisture. Pads constructed of FGD are not as strong, hard, or durable as concrete, but for these applications, FGD pads improve conditions of the area substantially for usually far less expense than concrete.

The objective of this publication is to provide livestock producers, landowners, and supervising agency personnel with an overview of the use of FGD product in pad construction. This fact sheet includes information on pad installation, regulatory constraints, pad location and sizing, maintenance and repair, and economic issues.

What is FGD?

The removal of sulfur dioxide from flue gases at coal-fired facilities results in the generation of large amounts of Flue Gas Desulfurization (FGD) material. The FGD material may be dry or wet depending on the desulfurization process. The wet scrubbing process, which is commonly used by large electric utilities in Ohio, involves the injection of a reagent (typically hydrated quicklime) into the flue gases. The wet product generated (commonly referred to as FGD filter cake) is a dewatered mixture of sulfites and sulfates of the reagent, unreacted reagent, and some water. Calcium sulfite content is typically greater than 70% while the calcium sulfate content is approximately 13%. Fly ash and additional quicklime are added to stabilize the FGD filter cake. This stabilized (fixated) FGD material is gray in color and looks like silty clay. Research conducted at The Ohio State University and reviewed by the Ohio Environmental Protection Agency (OEPA) has shown that leachate from the fixated FGD material generally meets the national primary drinking water standards. The fixated FGD material meets the "nontoxic" criteria of OEPA's Division of Surface Water.

Fly ash and quicklime-enriched FGD filter cake, when mixed at the power plant in proper proportions, will form a chemical cementious reaction that, upon adequate compaction in a fairly fresh state (moisture content of 40-55%), gains strength and durability. Quicklime-enriched FGD material is considered to be a manufactured product when produced at a generating facility. The beneficial use of quicklime-enriched FGD product for livestock feeding or hay bale storage pads is not subject to additional OEPA review when used in accordance with the statewide permit-to-install (PTI) issued by Ohio EPA (Application No. 07-0037, dated June 25, 1997).

Livestock Feeding Pads

Concrete or stone aggregate typically has been used for constructing livestock feeding pads. However, research conducted at The Ohio State University has shown that construction of pads using compacted FGD product is an inexpensive and reliable alternative. The first cattle feeding pad using FGD material was constructed in 1992 at the Eastern Ohio Resource Development Center (EORDC) near Belle Valley in Noble County. Cyclone ash from American Electric Power's (AEP) Tidd plant was used. Additional feeding (Figure 1) and hay bale storage pads (Figure 2) were constructed at the EORDC farm in 1993 using wet FGD material from AEP's Conesville plant. The success of these demonstration projects led to statewide approval of FGD pads for these two applications using AEP's lime-enriched FGD product. In the summer of 1997, twenty-four livestock feeding and hay bale storage pads, ranging in size from 1,500 square feet to 15,000 square feet, were constructed in eastern and southeastern Ohio. In 1998, more than 150 FGD pads were constructed in 12 counties in Ohio.

Figure 1. Livestock feeding pad

Figure 2. Hay bale storage pad

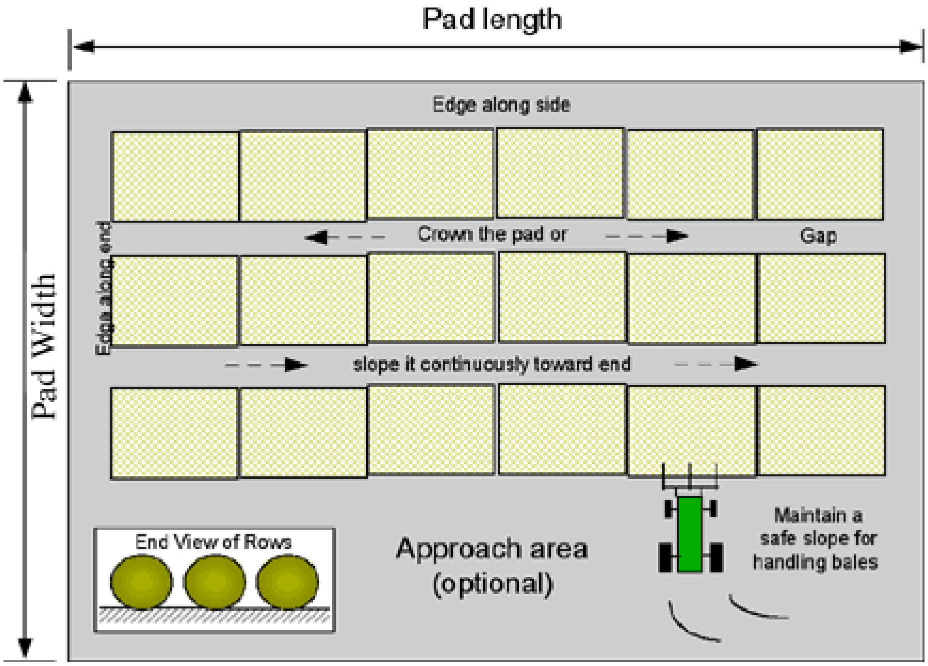

Figure 3. Hay bale storage on constructed FGD pad.

Hay Bale Storage Pads

FGD pads may be constructed for storing hay bales (primarily large, round bales as shown in Figure 3). Appropriate pad design allows bales to be placed so that precipitation drains away from them relatively quickly. Rain and snow will collect in troughs formed by bales whose sides touch, so leave a gap between adjacent rows of bales. Drain water from the pad by either crowning the pad across its length or constructing the pad with some continuous fall toward one end; provide 1% or greater grade in either case. Side-slope should be small compared to the lengthwise grade--or water will collect along the uphill side of rows/bales. If the side-slope and lengthwise grade are similar for a site that is suitable otherwise, plan to systematically place gaps every couple of bales along each row to reduce ponding around the bales (and adjust pad length accordingly).

Approach areas may be included along the perimeter of the hay bale storage--along ends of the pad if bales will be typically handled by their ends or along sides of the pad if handled by their sides (latter case shown in Figure 3)--to improve access to the bales. If used, approach areas should be wide enough to allow bale-handling equipment to access the nearest bales, including a turn, without dropping a wheel off the pad. Use concrete rather than FGD in any areas where handling equipment is likely to make frequent turns and in areas which will accommodate more than just bale-handling equipment. Material will rapidly slough off the pad surface under intensive use by equipment.

Reasonable grades must be maintained on a pad for safe operation of bale-handling equipment, especially along the length of a pad when bales are to be handled from the side. Also consider operator safety at locations associated with bale transport, such as turns in drives and places where bales are likely to be elevated. Consult manufacturer recommendations provided for your equipment before investing resources into a questionable site.

Regulatory Issues

OEPA approved the statewide construction of FGD pads on June 25, 1997. A PTI (Application No. 07-0037) was issued to AEP for providing quicklime-enriched FGD product from its Conesville and Gavin power plants for the construction of livestock feeding and hay bale storage pads. As long as the conditions outlined in the PTI are followed, landowners and livestock farmers generally do not have to obtain additional authorization from OEPA. This fact sheet has been prepared to be in conformity with the PTI issued by OEPA.

Sources of FGD

The material to be used in the construction of the pads is the fixated FGD product generated at coal-fired power plants which has been enriched with an adequate amount of fly ash and extra quicklime so that the total lime content is 4-6%. Lime-enriched FGD product that has been approved for constructing pads is currently available from AEP's Conesville power plant (Coshocton County) and Gavin power plant (Gallia County). The Gavin FGD material typically has a lower moisture content than Conesville FGD material. The material is currently available free of cost at the plants. The Conesville plant may be willing to transport the material free of cost within Coshocton County.

Pad Location

Runoff will occur from FGD pads, just as if they were made of concrete. This runoff needs to be controlled to avoid polluting nearby waterways. Livestock feeding and hay bale storage pads constructed of lime-enriched FGD material need to be located on a farm such that a healthy farm environment can be maintained. As per OEPA restrictions, FGD pads may not be located:

- within 100 feet of a stream, pond, or wetland unless runoff control structures are in place;
- within a 100-year floodplain unless the area is protected with a control structure;
- within 300 feet of a well for drinking water (human or livestock) unless the potentially affected property owner provides a written statement to OEPA describing the use of the well water and signifies approval of the pad;
- within 5 feet of a seasonal high water table;
- within 1,500 feet of a public water supply well;
- within the delineated boundaries of an OEPA-endorsed wellhead protection plan area; and
- at a location which would create a nuisance condition or cause an adverse impact to public health or the environment.

Additionally, pads must not be located in areas which are identified by a soil survey as subject to flooding, or likely to convey manure runoff directly to a waterway (via a cow-path, ditch, drive, etc.) regardless of the separation distance.

Installing control structures such as catch basins, small earth dikes, etc., can accommodate many of these siting restrictions. Local Natural Resources Conservation Service (NRCS) and Soil and Water Conservation District (SWCD) personnel can assist in the planning of control structures and may be able to identify sources of monetary assistance.

If animals will be confined on a pad rather than allowed to access the pad at their leisure from a pasture to eat or drink, the area may be considered to be a feedlot and, by definition, an "Animal Feeding Operation." In order to limit the liability of producers and retain the protections of the OEPA PTI, strategies for controlling runoff from such pads need to be designed by a professional and implemented on the farm prior to construction.

Sizing

The size of the FGD pad selected can significantly affect the cost and efficiency of the livestock operation. The pad should be large enough to accommodate the present animal population as well as allow for future additions to the herd as projected by the owner or operator of the facility. However, an excessively large pad can result in unnecessarily high construction costs. A livestock feeding pad should be large enough to accommodate the animals that are eating or drinking, plus about 6 feet along the perimeter to allow the animals to conveniently move to and from the feeder or water. A **worksheet** is included to size hale bale storage pads. Feeding pads should be sized in conjunction with development of a runoff-control strategy. For illustrative purposes, an FGD pad that is 100' x 100' and approximately 12"-15" thick will require 500-600 tons of FGD product.

An open pad does not usually constitute a controlled manure storage facility in Ohio and FGD product is not currently approved as a construction material for manure storage. Therefore, any scraped manure/material should be transported to a designed storage facility or to a field for application as soon as feasible.

Livestock access areas can also be constructed of FGD material if animals will regularly use the areas. An access area is defined as land which immediately surrounds a pad and will reasonably only support traffic that is directly associated with the pad. Use of FGD to construct drives, lanes, and other traffic ways is not allowed under current Ohio EPA permit authority.

Installation Procedure

FGD pads need to be constructed between May 1 and August 30 to minimize potential freeze/thaw effects. This will allow the FGD material to cure for a sufficient amount of time before being exposed to freezing weather. If the FGD material is too dry or too wet, it cannot be compacted properly. The moisture content of the material during compaction should range from 40-55%. For successful installation of FGD pads, the following procedure is suggested as per the PTI issued by OEPA:

- Comply with the location restrictions specified in the Pad Location section.
- Excavate the site to expose the subgrade. Clear the area of any vegetation, sod, manure, organic soil, and debris.
- Establish a reasonable grade for positive drainage. A maximum slope of 3-5% is suggested. Slopes in excess of 8% can cause excessive erosion of the pad.
- Compact the exposed subgrade with compaction equipment (roller) or hauling equipment (loaded truck, tractor) prior to placement of FGD. If excessively weak or wet soils are encountered, remove the soil, backfill with FGD and compact.

Figure 4. Delivery of FGD

Figure 5. Spreading of FGD

- Place FGD material within 3 days of delivery to the site (Figure 4). If the FGD material delivered to the site is too wet to be compacted, let the FGD material remain in a pile for a day and then apply it to the pad site. Spreading of FGD does not facilitate drying of the material.
- Spread FGD to the appropriate depth by using a bulldozer, tractor blade, or grader (Figure 5). Break large lumps using dozer tracks, tractor tires, Rototillers, etc.
- Add additional lime, quicklime fines, or cement to the FGD product if so desired by the owner of the facility. No additional lime needs to be added to the FGD product.
- Pads should be made in layers, whenever possible, to improve pad durability. FGD material that has less than 50% moisture content (Gavin FGD material) should be compacted in three layers (up to 5 inches each) or at least two layers (up to 7.5 inches each). Due to less desirable workability, wetter FGD material (Conesville FGD) may be formed into a pad as a single layer provided extra attention is dedicated to thoroughly consolidating the material.
- Compact each layer (extremely important) as shown in Figure 6 to consolidate the FGD material and obtain a uniform, solid surface. Use a smooth-drum or sheepsfoot roller or equipment with equivalent compactive effort (earthmoving equipment or heavy farm tractor). Remove any boulders of FGD that cannot be easily broken and worked into the layer.


Figure 6. Compaction of FGD


Figure 7. Completed FGD pad

- Rough up the top 1/2 to 1 inch of each layer/lift prior to the placement of the next layer to provide adequate bonding between the two layers.
- Keep the total thickness of the compacted FGD pad less than 15 inches.
- Smooth-roll the top layer to provide a uniform, solid surface. A 1/2-inch to 1-inch layer of gravel may be rolled into the finished surface to improve traction. If farm equipment will be operated on the pad area often, strengthen the top layer with 5% quick lime, Portland bag cement, or 15-20% lime kiln dust (added at the site).
- Feather-roll (down to zero depth) the edges of the pad. Otherwise use earthen or steel edging forms.
- Keep the pad surface moist for a minimum of 7 days to allow for proper curing. Cover the pad with straw or sheets of plastic.
- Keep livestock off the pad for at least 30 days following the initial 7-day curing period.
- Install fence posts, if needed, within 30 days of constructing the pad. Otherwise the FGD material may become too difficult to penetrate.

The two most important criteria for successful installation of an FGD pad (see Figure 7) are the moisture content of the FGD product and the compactive effort used to consolidate the material.

Maintenance

Periodically, manure or waste feed will need to be removed from a pad. This is usually carried out using a skid loader or box scraper. Pad life is expected to depend on the amount of use by livestock and equipment. While scraping the pad, caution should be taken not to remove excess amounts of FGD. To extend a pad's life, leave a thin cover layer over the pad surface rather than gouging into the FGD when scraping the pad. Incidental amounts of FGD that are removed during scraping may be spread with the manure. The pad is expected to lose about 1/4 to 1/2 inch of FGD material every year due to these incidental losses. After a few years of service, if the top surface of the pad shows small patches or holes, repair by filling in with inexpensive ready-made cementious materials. If local failures on the top surface are extensive, then clean the surface thoroughly and put an additional layer of compacted FGD on top of the existing pad. If for any reason the pad needs to be removed from the farm, then the FGD product will become subject to waste disposal requirements and must be taken to a licensed landfill.

Economics

The cost of using the FGD product for constructing livestock feeding and hay bale storage pads compares favorably with conventional materials such as concrete or rock aggregate. Twenty-four FGD pads were constructed in the summer of 1997 in Gallia and Coshocton counties. A cost analysis was carried out for six of the FGD pads installed in Gallia County. The cost summary comparison is listed in Table 1. Estimates were prepared using cost guidelines developed by NRCS and local prices for equipment operators, materials, and

Table 1. Cost Summary for FGD Pads Constructed in Gallia County

Project ID	Area (ft2)	Actual FGD cost	Estimated aggregate cost	Estimated concrete cost
1 11,350		$4,542	$7,143	$15,507
2 3,008		$1,272	$1,959	$4,001
3 7,980		$4,300	$5,174	$10,489
4 5,400		$2,499	$3,147	$7,150
5 2,100		$951	$1,374	$2,903
6 5,424		$2,888	$3,563	$7,073
Average cost		$2,742	$3,727	$7,854
Ratio to FGD cost	1		1.36	2.86
FGD savings as %			**26.4%**	**65.1%**

transportation in the Gallia County area. On average, an FGD pad constructed in Gallia County cost approximately $2,750 with approximately half of the cost for trucking of FGD and the rest for site work and material placement. The total cost of the FGD pads was about 26% less than the estimated cost for construction using aggregate and about 65% less than the estimated cost for concrete pads. For Coshocton County, where the FGD material may be delivered free to the site by the Conesville plant, the projected savings compared with aggregate and concrete would be 63% and 83% respectively. This represents a significant amount of monetary savings for farmers installing pads using the FGD product.

Contact Information

More information on the use of FGD product for constructing livestock feeding and hay bale pads can be obtained from the following:

- For technical information, contact American Electric Power's Geotechnical Engineering Section at (614) 223-2940.
- For regulatory guidance, contact Ohio EPA's Division of Surface Water at (614) 644-2025.

Construction of FGD livestock pads needs to be a part of an overall farm plan. NRCS personnel can assist interested farmers in developing a farm conservation plan. Owners and operators of livestock facilities should contact their county Extension agent, Soil and Water Conservation District, NRCS personnel and the following:

- To use FGD product of AEP Conesville Plant (Coshocton County)
  Bill Jewett, AEP: (740) 829-4121 or 4083
  Rob Senita, AEP: (740) 829-4034
- To use FGD product of AEP Gavin Plant (Gallia County)
  Doug Workman, AEP: (740) 367-7331

Farmers must provide the following information at the time of placing the order for the FGD product:

- contact and phone number
- owner and operator of farm
- address of farm
- dimensions of the feeding/storage pad
- estimated quantity of FGD product needed
- estimated pick-up date

The manufacturer of the FGD product shall provide to the user the following documents:

- a copy of Ohio EPA approved specification sheet
- a copy of the product Material Safety Data Sheet
- documentation that the FGD product meets Ohio EPA's "nontoxic" criteria

Summary

Construction of livestock feeding and hay bale storage pads using quicklime-enriched fixated FGD product is a reliable and economical solution to excessively muddy conditions in high rainfall areas such as Ohio. This fact sheet covered the characteristics of FGD material and the regulatory issues involved. It included recommendations for siting, sizing, installing, and maintaining pads as well as performance data of FGD pads. An economic analysis of pads constructed in Gallia County was presented. The inexpensive and reliable use of this material can result in significant cost savings for farm operators and owners while improving the quality of farm operations in Ohio.

More Information

More information on the uses of FGD and other coal combustion products can be obtained from the following Internet web site: http://ccpohio.eng.ohio-state.edu

or by contacting the pilot Extension program project coordinator:

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