CURRENT PRACTICES AND ISSUES FOR PLACEMENT OF COAL COMBUSTION BY-PRODUCTS IN MINE SETTINGS[1]

by

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Abstract. The placement of coal combustion by-products (CCBs) in mine settings is viewed quite differently by various stakeholders. A summary of key research on placement of CCBs in mine settings is presented. A limited survey of current practices for placement of CCBs in surface mine settings was performed by the Energy & Environmental Research Center (EERC), and the results are summarized. The survey provides a brief comparison of eastern and western practices as reported by appropriate state agencies. This document also discusses the importance and impact of valid scientific information and citizen groups on the perception of regulating entities that have responsibility for approving practices related to placement of CCBs in mine settings.

Introduction

The United States has produced about a billion tons of coal per year. Most of this coal is consumed within the United States for the generation of electric power, with nearly a third of the coal consumed in just four states—Texas, Indiana, Ohio, and Pennsylvania. Since the early 1970s, power industry coal consumption has doubled.

Fly ash, bottom ash, and boiler slag are among the residues resulting from the combustion of coal in different types of power plants. Systems used in coal-fired power plants that capture sulfur and other emissions also produce solids, usually called flue gas desulfurization (FGD) material. These large-volume materials, fly ash, bottom ash, boiler slag, and FGD are frequently referred to as coal combustion by-products (CCBs) or coal combustion products (CCPs) by industry. They are also commonly referred to as coal combustion wastes (CCWs) by some regulatory agencies, and the Environmental Protection Agency (EPA) refers to them as fossil fuel combustion (FFC) wastes. Throughout the paper, we will be using the neutral designation, CCBs, to refer to these coal combustion residues.

Each year 70% of CCBs are disposed of in landfills, impoundments, and coal mines. About 30% of the material goes to uses in construction, engineering, and manufacturing. When placed in mine settings, these materials have proved to be useful in the treatment of acid mine drainage, mitigating subsidence from underground mining, mine restoration, and soil reconditioning.

Are CCBs a waste or a resource? Should they be buried forever or stored in monofills for later utilization? Are they dangerous to human health and the environment or can they be appropriately managed, treated, stored safely, and used? These fundamental questions play a key role in public debate and the management and regulation of coal combustion residues at the federal, state, and local level across our country. The placement of CCBs in mine settings is a current focus of this debate and warrants discussion.

This paper considers these fundamental issues through the practice of returning coal combustion residues to coal surface mines, a practice termed haulback placement. The following sections address the current status of mine haulback placement and summarize the state of research on this topic. The paper ends with a concise discussion of the authors' views of the current state of the debate and research needs.

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Status of Haulback Placement

Recently, a summary of information on the practice of haulback placement of CCBs was prepared based on 1) a review of key literature sources (e.g., EIA1997, Coal Age 1999, Daly and others, 1982) and 2) a telephone survey of state-level regulators in 10 of the 23 coal-producing states in the continental United States. Much of this effort was performed under a contract for the Utility Solid Waste Activities Group. An attempt was made to 1) summarize western and eastern surface mine populations, production, and the occurrence of CCB mine placement and 2) briefly compare and contrast practices between the East and West.

The 10 coal-producing states surveyed represent 44% of the surface mines, 82% of coal production, and 30% of the coal-fired power plants found in the conterminous United States.

In 1996, coal was produced from 1018 surface mines in 23 states—10 states east of the Mississippi and 13 states west of the Mississippi. Based on a survey of state regulators, there are approximately 60 mine sites where CCBs have been placed, are currently being placed, or are permitted for CCB mine placement. These sites represent about 5% of the total number of U.S. surface mines. Differences exist between the eastern and western United States with respect to 1) surface mine populations, production levels, and operations; 2) the association of electrical generation facilities with mines; and 3) the use of CCBs in mine placement.

The relatively small mine population of the West is dominated by relatively young, aereally extensive surface mines, most of which produce in excess of a million tons per year. Coal is produced from 13 of the 21 states in the conterminous United States west of the Mississippi. In 1996, the west produced 500 million tons of coal (mainly low-rank coal) from 115 active mines (90 surface mines and 25 underground mines), and western surface mines accounted for over 454 million tons in annual production (mainly subbituminous and lignite coal; 43% of the total annual U.S. coal production and over 91% of production west of the Mississippi). Fifty-six of these surface mines produced over a million tons per year, and these major mines collectively accounted for 98% of western surface mine production. The 26 surface mines of Wyoming, all producing in excess of 1 million tons, accounted for nearly a third of western surface mines, nearly half of western million-ton-plus mines, and nearly two-thirds of western production from surface mines. Most western mines have been active for less than 30 years.

Six of the 13 coal-producing states in the western region were surveyed for CCB placement in mines. These states—Montana, North Dakota, Wyoming, Colorado, New Mexico, and Texas—account for two-thirds of the active surface mines, 95% of surface mine coal production, and 35% of the coal-fired power plants west of the Mississippi. Haulback placement of so called large-volume CCBs has been documented for 16 active western surface mine sites (i.e., 20% of the 90 active western surface mines), one inactive surface mine, and two abandoned underground mine settings. Most of the sites at active mines have associated minemouth electrical generating facilities (adjacent client generation facilities).

The relatively large mine population of the East is divided nearly equally between underground and surface mines, with the great majority of mines producing under 1 million tons. In 1996, 564 million tons of coal (mainly bituminous) was produced from 1787 mines in 10 of the 27 states east of the Mississippi. Surface (927) and underground (860) mines occur in nearly equal numbers, but nearly two-thirds of the production was from underground mines.

The eastern United States contains more than 10 times the number of surface mines found in the West. However, only 4% of eastern surface mines produce over 1 million tons per year in contrast to the West, where 62% of surface mines produce in excess of 1 million tons. As shown in Table 1, Kentucky, West Virginia, and Indiana account for almost three-quarters of production and 34 of the 40 eastern mines with over a million tons of production. Pennsylvania and Ohio have moderate production from a relatively large number of smaller mines. The remaining states—Alabama, Maryland, Illinois, Tennessee, and Virginia—have a relatively small number of mines and low production. Pennsylvania (318), Kentucky (227), West Virginia (107), and Ohio (74) account for 82% of the 887 eastern surface mines of less than a million tons capacity.

The four of the ten eastern coal-producing states that were contacted with respect to mine placement—Illinois, Indiana, Ohio, and Kentucky—account for half of the major eastern surface mines, one-third of eastern surface mines, half of production, and 29% of eastern coal-fired power plants. Mine placement is occurring, considered, completed, or has been permitted for 30 sites in the survey area, that is, at approximately 9% of the surface mines in the states surveyed. Because the states surveyed contain no minemouth facilities, the CCBs must be hauled back to the mine, usually over a considerable distance, either from in-state utilities or from client utilities in other states.

This general survey indicates that placement is limited to some combination of CCPs or large-volume wastes. There were no reports of mine placement for 1) small-volume wastes such as coal-cleaning wastes and boiler-cleaning wastes or 2) mixtures of small- and large-volume wastes. Regulators reported that small-volume wastes were handled at the site of generation, that is, in most cases, at the utility. This holds for the West where there are a number of minemouth facilities as well as for the East where mine placement would, in most cases, require transport over considerable distances from the point of generation.

In many cases, small-volume wastes are not specifically forbidden for mine placement by statute, but as with any material under consideration for mine placement, small-volume wastes would have to meet certain regulatory criteria as well as gain the approval of various state entities involved in the permitting process. On the other hand, under the proposed Mine-Generated Solid Waste Disposal regulations (Chapter 21 in the State Code), Wyoming would recognize two utility waste-related categories: 1) Coal Combustion Wastes, which refers to the so-called large-volume CCB streams (fly ash [FA], bottom ash [BA], and FGD) and 2) Mine-Generated Solid Waste, which includes small-volume wastes and discarded materials generated by minemouth power plants. Disposal of liquid wastes would not be allowed within the mine setting. The majority of small-volume wastes are liquids.

Most state regulations and practices favor placement of materials above the water table. However, most regulations allow for the consideration of placement in saturated settings, given appropriate hydrogeology and favorable results from leaching and characterization tests. Examples of this flexible regulatory approach are as follows: North Dakota has developed standards for the use of fly ash-based flowable fill for abandoned underground mines in saturated settings. The Wyoming Department of Environmental Quality will allow the placement of bottom ash in a saturated setting in the Black Thunder mine after obtaining favorable results from leaching tests. Mine placement at or below the water table is allowed in Illinois and Indiana given favorable initial results from leaching tests, appropriate site monitoring, and acceptable results from ongoing materials characterization and testing and site monitoring.

<u>Summary of Research on Mine Placement of CCBs</u>

Research studies have presented several scenarios in which CCBs may be utilized beneficially in a mined setting:

- Use of CCBs for abatement of acid mine drainage or for treatment of acid mine spoils (Schueck and others, 1993; Ackman and others, 1993; Stehouwer and others, 1993; Rafalko and Petzrick, 1999; Golden, 1999).

- Use of CCBs in reclamation activities or highwall mining (Paul and others, 1993; Robl and Sartaine, 1993).

- Placement of ash as a low-strength structural material in an underground mine for reclamation and prevention of subsidence (Chugh, 1993; Butler and others, 1995; Rafalko and Petzrick, 1999; Golden, 1999).

These three options represent most, but not all, scenarios under which CCBs would be returned to the environment in a mined setting. Mine applications have previously been considered disposal, but in light of the relatively benign nature of CCBs, and the documented benefits of mine placement, disposal does not fully reflect the situation.

Several projects have been performed to evaluate the environmental performance of CCBs (Moretti and Manz, 1996; Pflughoeft-Hassett and others, 1993a, b; Beaver and others, 1987; Stevenson and others, 1989; Pflughoeft-Hassett and others, 1996; EPRI, 1987; Carlson and Adrcano, 1993; Hassett, 1991; Hassett, 1993). Other characterization information, including bulk chemical composition, mineralogical composition, and physical and engineering characteristics are also published in many of the reports noted as well as in the EERC's Coal Ash Properties Database (Pflughoeft-Hassett and others, 1991).

Solid residues from the combustion of low-rank coals, which generate leachates at high pH, tend to form the mineral ettringite. Ettringite has the capacity to chemically fix elements such as arsenic, boron, chromium, molybdenum, selenium, and vanadium that exist as oxyanions in aqueous solution. Thus ash that would leach to release low concentrations of several problematic trace elements at lower pH tends to form stable minerals, incorporating some of the more problematic trace elements found in coal ash, at high pH. Although ash is generally benign with respect to leaching significant concentrations of potentially problematic elements, proper and environmentally sound testing should be conducted. This testing should be done using long-term as well as short-term leaching procedures to determine the total mass of trace elements that may potentially be mobilized and the trends of analyte chemistry evolution. Although the leachate chemistry of most trace elements is characterized by a slow increase in concentration toward an equilibrium plateau, some of the oxyanionic trace elements can actually increase to a plateau quickly and then exhibit a trend of decreasing solution concentration. This is important to understand, since it is the long term that is usually important in assessment of potential for environmental impact.

Investigations of the environmental performance of CCBs in field settings are less available. A field demonstration at Center, North Dakota, where fly ash and scrubber sludge were placed into a mined area was performed by the EERC. The only observed impact was caused by the disturbance of the environment at the time of mining. An increase in total dissolved solids, mostly from sodium sulfate, was observed, but this rapidly returned to background levels (Beaver and others, 1987). A similar mine fill study was done in a wet environment near Wilton, North Dakota (Moretti and Manz, 1996; Butler and others, 1995), where the ash was placed below the water table. Again, there was an increase in dissolved solids that rapidly returned to background levels. Current investigations (Rafalko and Petzrick, 1999; Golden, 1999) tend to evaluate the use of by-products from advanced coal combustion systems like fluidized-bed combustion (FBC) in underground mine filling and associated remediation of acid mine drainage. The alkaline nature of some CCBs (including duct injection residues/FBC residues and low-rank coal fly ash) can be capitalized on for abatement of acid mine drainage and spoils (Schueck and others, 1993; Ackman and others, 1993; Stehouwer and others, 1993; EPRI, 1996; Rafalk and Petzrick, 1999; Golden, 1999).

The primary conclusion that can be drawn is that return of ash to the mined settings is a sound high-volume use of this versatile engineering material for land reclamation, and in the case of underground mines, for stabilization to prevent future subsidence. Treatment of acid mine drainage and spoils has high potential, especially for high-volume, alkaline residues from advanced coal processes. Impacts from trace elements, the primary concern, have been minimal or unmeasurable in almost all instances where monitoring has been carried out. There have been examples where groundwater quality has been shown to actually improve from the placement of coal by-products in the environment (Ackman and others, 1993; Paul and others, 1993).

Discussion

Often discussions of state regulations or regulations concerning CCBs in general begin with a comparison of what one or more of the states with stringent regulations are doing. With the large number of regulations and standards the various states have enacted for testing ash for potential for environmental impact and the variety of standards to which ash is held (rarely Resource Conservation and Recovery Act [RCRA] limits), it is apparent to the authors that all cannot be right. It can also be said that because one state has more stringent regulations than another, it does not follow that the state with the most stringent regulation is practicing the best environmental stewardship. The fact that someone else is doing it does not automatically confer validity to the practice. The authors feel that scientific merit must be preserved as the cornerstone of the regulatory process.

In a report of the U.S. House of Representatives Task Force on the Health of Research, it was stated that "Policy makers today are not faced with a shortage of information. What they often lack, however, is reliable new information that they can use" (Brown, 1992). Not only is reliable information lacking, but a consensus on testing methods that yields this information has yet to be achieved. Ash is often tested using the toxicity characteristic leaching procedure (TCLP), but a rational examination of this method, taking into account that it was designed for evaluating wastes codisposed of in sanitary landfills, indicates that its use is clearly invalid for CCBs placed in monofills. Tests such as the American Society for Testing and Materials (ASTM) shake leach and more generic tests such as the synthetic groundwater leaching process (SGLP) and long-term leaching (LTL), developed at the EERC, are used in one form or another in several states.

Interpretation of the data raises another set of issues. Ash, which one would think should be held to RCRA criteria, is often set into a category of materials whose leachates must meet drinking water standards, a standard that many construction materials could never meet. Even the idea of using drinking water standards, standards meant to evaluate water intended for consumption, seems unreasonable considering that not all uncontaminated groundwater meets drinking water standards. Although it is not the intent of this document to suggest appropriate standards, the authors want to emphasize that consensus is needed and that a reasonable approach formulated by scientists who understand CCBs must be a major part of the process.

There are numerous citizen and environmental groups active in issues related to ash utilization and disposal. It is our belief that these groups perform a valuable function in that they allow researchers and regulators as well as producers and marketers of ash to determine public opinion and concerns. Under these conditions, the scientific validity of the concern is not an issue. The public is concerned, and the public deserves to be provided with scientifically valid information. The public's concern may reflect a valid problem, stem from a general lack of information, or reflect outdated, incorrect, or incomplete information. Regardless, it seems that one of the jobs of scientists should be to address perceived as well as real problems. This should be done using scientifically valid methods and published in a manner clear to anyone reading results of current research. The authors also feel that citizen groups, as well as environmental groups, should provide input into the overall process but allow scientists and engineers to work out scientific methods. As in other disciplines, although the procedures may seem simple enough and may be based on a fairly common-sense approach, underlying complexities and principles warrant that the actual practice of the craft be limited to those skilled in state-of-the-art understanding and methodology. So it is in nearly all scientific disciplines.

It is the contention of many researchers in ash disposal and reuse that the most logical placement is return to the initial source, the mine. The authors feel that scientific arguments can be made that the placement of CCBs in the mine is not only logical, it may also be beneficial.

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TABLE 1

Summary of CCB Mine Placement in Surveyed States

Region	State	Active Surface Mines	Coal-Fired Power Plants	Minemouth Plants	Confirmed Surface Mines with CCB Placement[1]
West	ND	5	9	5	5
	MT	7	3	1	1
	WY	26	7	2	2
	CO	4	14	1	2
	NM	6	4	2	2
	TX	13	18	6	3
Subtotal [2]	-	61	55	17	15
East	IL	11	23	0	26
	IN	34	25	0	11
	OH	90	34	0	4
	KY	237	21	0	1
Subtotal [3]	--	382	103	0	42
Total [4]		443	158	17	57

1 Includes permitted, closed, inactive, and active sites.

2 Survey accounts for approximately 66% of the 91 active surface coal mines west of the Mississippi, 95% of western surface mine production, and 35% of coal-fired power plants in the West.

3 Survey accounts for approximately 41% of the 927 active surface mines east of the Mississippi, 53% of eastern surface mine production, and 29% of the coal-fired power plants in the East.

4 Survey accounts for about 44% of conterminous U.S. surface mines, 82% of conterminous U.S. surface mine production, and 30% of coal-fired power plants in the conterminous United States.