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COMBUSTION BYPRODUCTS RECYCLING CONSORTIUM

Ashlines

a program of the National Mine Land Reclamation Center at West Virginia University in cooperation with the U.S. Department of Energy - National Energy Technology Laboratory www.netl.doe.gov

To promote and support the commercially viable and environmentally sound recycling of coal combustion byproducts for productive uses through scientific research, development, and field testing.

CCB Use in Mine Filling Applications:

A Review of the Literature and Case Studies

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Surface and underground mining combine to produce over 800 million tons of coal annually, and the vast majority of this coal is burned in utility boilers to generate electricity. Combustion of coal in utility boilers produces coal combustion residues or byproducts (CCBs) in the form of fly ash, bottom ash, boiler slag, and flue gas desulphuri-zation (FGD) sludge.

In 2003, U.S. electric utilities produced approximately 122 million tons of CCBs. Coal fly ash constituted about 70 million tons, the bottom ash/boiler slag accounted for about another 20 million tons, and the remaining 30.8 million tons were FGD materials.

Mine reclamation has been identified as a long-term, large-volume beneficial use market for CCBs. Nonetheless, use of CCBs in mine reclamation currently is performed on a limited basis relative to the overall quantity of CCBs generated each year. Only 0.68 million tons of fly ash, 1.2

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million tons of bottom ash, and about 0.39 million tons of FGD materials were used in mining applications in year 2003 (American Coal Association, 2004).

Although CCBs possess several beneficial physical and chemical properties, there are concerns from regulators and environmental groups regarding the potential for release of toxic chemicals in the leachates from CCBs. Therefore, scientifically sound information is needed so that environmental concerns can be adequately and reliably identified and addressed.

The Combustion Byproducts Research Consortium (CBRC) selected Ish, Inc., and GeoTrans, Inc., to conduct a literature review and review of information from several case studies involving CCB use for mine application. Cofunding for the review was provided by Public Service Company of Colorado, McDonald Farms, American Coal Ash Association, Utility Solid Waste Activities Group, GeoTrans, Inc., and Ish, Inc.

The purpose of the project is to inform regulators, environmental interest groups, and the generators of CCBs about the benefits and impacts of CCB use for mine filling. The complete project report contains information gleaned from the literature about the chemical and physical characteristics of CCBs produced in the U.S., along with some information on mine spoil material. Background information on coal mines and a brief discussion of the geochemistry in coal mines is included, particularly to describe the formation of acid mine drainage (AMD).

The final project report also presents a summary of available data on water quality characteristics of mined areas and a description of the geochemical interactions between the AMD water and CCBs. A summary list of mine sites where CCBs are being utilized for filling the mined land and/or for abating AMD conditions is also included.

The final report (project 99-EC-W5) will be available later this fall on CBRC's Web site at **http://wvwri.nrcce.wvu.edu**. Following is some information from the report.

Use of CCBs in Mines

Mine reclamation represents a potential beneficial use of CCBs that has received increased attention in recent years. Coal mining operations have produced both open pits and deep underground cavities that can be filled by CCBs.

CCBs possess physical and chemical characteristics that are both environmentally and economically beneficial. Placement of CCBs into deep mines can provide structural support to abate subsidence, and placement of CCBs in surface mines or other open pits can aid in restoring mined land to beneficial use. Use of CCBs as mine backfill may provide the additional potential benefit of limiting impacts of AMD.

Many CCBs are alkaline materials that can neutralize acidic groundwater and/or inhibit production of acid. Placement of CCBs in mines also may reduce the permeability of mine strata and divert water away from acid-generating materials.

Literature Search Results

Beneficial use of CCBs for coal mine reclamation occurs in varying degrees across the U.S. Injection of CCBs into

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deep mines has been performed to provide structural support for subsidence abatement, and placement of CCBs in surface mines has been utilized to reclaim mined land to original grade and to mitigate AMD. Such practices have been employed at both active and abandoned coal mines.

Several surface and deep mines in the U.S. that have utilized CCBs for reclamation are identified in this study. Thirteen were selected for review based on availability of site-specific data required to perform a reasonable evaluation of the benefits and impacts of CCB placement on groundwater quality. Tables and graphs are included in the final report, when available, to illustrate important aspects of each case study.

These case studies represent a large range of CCB uses, from the filling of mine pits to using CCB grout mix to minimize/eliminate acid mine drainage. Following is a brief summary of case studies from the report:

Wyodak Mine, WY

Placement of fly ash, bottom ash, and scrubber ash in mined areas at Wyodak began in 1978. Approximately 5,000,000 cubic yards of ash has been placed in 13 separate pits. Results indicate that the average groundwater quality throughout the Wyodak site compares favorably with the Wyoming Department of Environmental Quality class III (livestock use) standard. Mean concentrations for all of the measured constituents in wells are at or below class III standards.

Keensburg Mine, CO

Reclamation at the Keenesburg Mine site is being performed using fly ash and bottom ash derived primarily from combustion of Keenesburg coal. Ash was placed at least 5 feet above the pre-mining groundwater table, and reclamation includes placement of a vegetative final cover consisting of at least 5 feet of compacted overburden and 3 feet of topsoil material.

Comparison of the water quality in up-gradient versus down-gradient wells, and sampling events prior to ash placement (1978-1986) relative to sampling events following ash placement (1988-2000), show little evidence that elevated levels of regulated constituents in site groundwater are a direct result of leaching from the ash.

Trapper Mine, CO

Trapper mine is a surface coal mine located approximately 6 miles south of Craig, Colorado. The mine began operation in 1977 and produces up to 2.8 million tons of coal annually. Deposition of CCBs in the mined out areas of Pit A began in 1984.

Trapper Mine has managed approximately 390,000 tons of CCBs per year since 1984, with total disposal quantities approaching 7 million tons to date. Current ash placement practices involve deposition of sufficient overburden material into the pit bottom, such that the ash is placed above the expected post-mining groundwater table. Overburden materials are placed above the ash and revegetated as part of the final reclamation plan.

Comparison of the historic groundwater concentration data with Colorado standards indicate little or no evidence of groundwater impacts associated with most of the analyzed constituents.

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Savage Mine, MO

Savage Mine has been in operation since 1958 as a surface lignite mine and currently produces 250,000 tons of lignite annually. The mine began utilizing fly ash and bottom ash as backfill in 1987.

Annual volume of ash received by the Savage Mine is variable and dependent upon the amount of coal burned by Holly Sugar in relation to the quantity of sugar beets processed. The estimated cumulative volume of ash placed between 1987 and 2000 is approximately 130,000 cubic yards.

Mount Storm Mine, WV

The Mount Storm case study concerns placement of coal ash in an active coal strip mine. The down-gradient groundwater monitoring data reveals no evidence of contamination over the 10-year period of operation.

Coal ash (both bottom and fly) is being placed at a rate of about 800,000 tons annually in an active strip mine near an electric power plant in West Virginia. The strip mine provides coal for the power plant and is located on the plant property. Ash placement began in 1987. No ash has been placed below the water table, because the groundwater table is deeper than the mine floor.

Universal Mine, IN

In 1988, PSI Energy, Inc., (now Cinergy Corporation) acquired a portion of the Universal Mine site containing the final cut pit for the express purpose of coal ash deposition and surface mine reclamation. Indiana DNR issued a permit to PSI Energy to dispose of fly ash/bottom ash from its nearby Wabash River Station to fill and reclaim the mine pit.

Between April 1989 and the end of October 2001, Cinergy placed approximately 1.6 million tons of coal ash from a nearby power plant to completely fill the open-pit. The monitoring data to date indicate that the alkaline coal ash leachate has been effective in improving the AMD water quality that was present at the site. The coal ash leachate neutralized the acidic pH, increased alkalinity, essentially eliminated acidity, and significantly decreased manganese, iron, and sulfate concentrations. There were no indications of any other trace metals migration via the mine-seep. However, the coal ash leachate did increase significantly boron concentrations in the mine seep water.

Midwestern Abandoned Mine, IN

Midwestern abandoned coal mine is a case study where a state agency elected to place CCBs with a Poz-O-Tec cap (a mixture of FGD sludge, fly ash, and quicklime), which resulted in reduced infiltration and improvement in water quality by neutralization.

The mine consists of approximately 550 acres of previously mined land, which, in some instances, intersects with abandoned deep mining of the same coal seam.

Based on the monitoring results, Branam et al. (1999) concluded that using CCBs to reclaim the Midwestern Abandoned Mine has resulted in the reduction of AMD leaving the site. The authors ascribe this response to the reduction in vertical recharge of oxygenated water by the fixated scrubber sludge cap

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and the neutralization provided by the alkaline CCBs.

Arnold Willis City Mine, IN

The Arnold Willis City underground coal mine in Indiana is an example in which fixated scrubber sludge (FSS) has been successfully injected into an abandoned underground coal mine for stabilization by filling mine voids. Groundwater monitoring data indicated that trace metals and sulfide remained unaffected by the placement of FSS.

An FSS grout consisting of a mixture of FGD scrubber sludge, fly ash, lime, and water was developed for injection in the abandoned deep mine to abate surface subsidence and reduce acid mine drainage. A total of 12,502 cubic meters of FSS was injected over an eight-week period, resulting in filling of about five acres of the mine.

Harwick Mine Complex, PA

The Harwick Mine Complex includes the Monarch, Old Harwick and Cornell Mines covering approximately 7,000 acres. The complex is a deep mine and was operated from about 1932 through June 1970.

The mine disposal operation consists of a wet ash handling system to pump 10 percent solids slurry for a distance of approximately 8,000 feet to two operating injection boreholes at the Harwick Mine Complex. Approximately 3 to 4 million gallons per day of the slurry are conveyed. Approximately 150,000 tons of coal ash is injected annually in the mine along with millions of gallons of water. The water quality data from samples of the mine water indicates no adverse effect on the water in the Harwick Mine Complex.

Clinton County, PA

The Clinton County, Pennsylvania, mine provides an example of how placement of FBC ash in a closed-surface coal mine can result in beneficial effects on water quality, because of the favorable geochemistry that occurs. The alkaline FBC ash neutralizes the acidic AMD waters resulting in precipitous decreases in arsenic, cadmium, and aluminum concentrations due to lower solubility and precipitation of solids.

Results indicate that the injection of grout caused a temporary increase in pH from about 2.3 to about 9, as the alkaline FBC ash neutralized the acidic AMD waters. The pH increase resulted in precipitous decreases in arsenic, cadmium, and aluminum concentrations reflecting lower solubility and precipitation to solid phase compounds.

However, within a short time, the pH again became acidic, with sulfate and aluminum returning to the pre-grouting concentrations, although arsenic and cadmium remained at much lower levels.

Big Gorilla Pit, PA

In eastern Pennsylvania, there are several pre-act stripping pits in the middle of an anthracite coal basin where active strip and deep mining for coal was practiced since the 1800s. The strip mined pit known as Big Gorilla was one such location.

The Pennsylvania Department of Environmental Protection's Regional Mining office in conjunction with the

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Wilkes-Barre Regional office issued a demonstration permit for the placement of cogeneration-derived dry fly and bottom ash into standing water in the Big Gorilla Pit. Ash deposition has taken place since August 1997. Over three million tons of ash was used to completely fill the pit which contained acid mine water pool.

The Big Gorilla water has maintained a consistently high pH value in response to the placement of ash. Iron, manganese, magnesium, aluminum, and zinc all have decreased significantly. One long-term effect of ash placement in the former Big Gorilla mine pool will be the prevention of acidic water production through the surface mine pool.

Red Oak Mine, OK

The Red Oak coal mine was operated from 1907 to 1925 utilizing the room-and-pillar extraction method. The mine, which covers approximately 46.5 acres, contains water pools or reservoirs of AMD.

The University of Oklahoma and the Oklahoma Conservation Commission injected 418 tons of FBC ash in 15 hours into this acidic (pH 4.3) flooded mine to chemically alter the mine water.

Winding Ridge Project

The Maryland Department of Natural Resources Power Plant Research Program and the Maryland Department of Environment Bureau of Mines launched a joint effort with private industry to demonstrate large-volume beneficial uses of CCBs to create flowable grouts for placement of abandoned, underground coal mines to reduce acid formation. In April 1995, this multi-year project initiative started with the Winding Ridge Demonstration project, which involved injection of a 100 percent CCB grout into the Frazee Mine, located near Friendsville, Garrett County, Maryland.

The Winding Ridge demonstration project at the Frazee Mine has shown that CCB grout mixture can be beneficially used for abandoned, underground coal mine to reduce acid formation as well to fill mine voids with a high-strength, low-permeability material that would control mine subsidence. The placement of the CCP grout appears to have not caused an unacceptable water quality impact either.

Conclusions

This literature review report on the use of CCBs in mine filling activities provides a readily available resource for regulators, general public, environmental interest groups and potential CCB users synthesizing technical information on a range of case studies. Each case study is different in several details and provides the readers insights into the use of CCBs and their benefits and limitations. The technical information can be used to determine and decide on environmentally compatible uses of CCBs in surface and underground coal mines.

More Information

The CBRC Web site at **http://wvwri.nrcce.wvu.edu/programs/cbrc** features program news, factsheets, project reports, contact information, a calendar of events, and publications, including *Ashlines*, which is available in electronic pdf format only. To be placed on the CBRC electronic mailing list, send an e-mail to **cbrc@nrcce.wvu.edu**. Or contact the CBRC Consortium Manager, Tamara Vandivort, at Tamara.Vandivort@mail.wvu.edu or at 304.293.2867.

Calendar

Sept. 25–28, 2006

23rd Annual International Pittsburgh Coal Conference
Pittsburgh, PA
www.engr.pitt.edu/pcc

The Twenty-Third Annual International Pittsburgh Coal Conference will focus on environmental emissions issues and technologies surrounding the continued use of coal and the development of future coal-based energy plants to achieve near-zero emissions of pollutants, reduced costs, and high thermal efficiency while producing a suite of products to meet future energy market requirements. Technical, business, and policy-related papers will be presented at the conference.

October 24–25, 2006

20th Western Fuels Symposium International Conference on Lignite, Brown, and Subbituminous Coals
Denver, Colorado
http://www.undeerc.org/wfs/

The goal of the Twentieth Symposium on Western Fuels is to provide a forum in which industry, government, and research organizations can share up-to-date information on the role of lignite, brown, and subbituminous coals in meeting future energy demands.
Low-rank fuels have unique properties that present challenges and opportunities related to meeting future environmental regulations and in the development and application of advanced technologies.

June 11–13, 2007

Sustainable Construction Materials and Technologies
Coventry University, Coventry, UK
www.uwm.edu/dept/cbu/coventry.html

This conference will highlight case studies and applied research that show new and innovative ways of achieving sustainability of construction materials and technologies. Papers have been invited on all the different materials used in construction, including cementitious materials (fly ash, wood ash, silica fume, slag, natural pozzolans, and others); aggregates; admixtures, concrete; timber; masonry; metals; plastics; glass; bitumen; lime; and gypsum, and on paints, adhesives, preservatives, and preservation processes.
Sponsored by Coventry University and University of Wisconsin-Madison Center for By-Products Utilization

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