

INDUSTRY/UNIVERSITY/GOVERNMENT
COOPERATIVE RESEARCH PROGRAM
FOR
DISPOSAL AND UTILIZATION OF COAL COMBUSTION
RESIDUES FROM ILLINOIS BASIN
COAL USERS

1
(DUCCR)
BY

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Abstract. About 140 m. tons of coal is produced annually from the Illinois Coal Basin, which is located in Illinois, southwestern Indiana, and western Kentucky. A vast majority of recoverable reserves and production from the Illinois Coal Basin is, however, high-sulfur coal. Illinois, Indiana, Kentucky, and Missouri are among the top ten sulfur dioxide producer in the U.S. and will give to significantly reduce emissions over the next decade to meet the requirements of the CAAA. This could be achieved through the use of FGD and FBC processes rather than switching over to low-sulfur western coal. The use of these clean coal technologies will significantly increase generation of coal combustion residues which must be disposed of or utilized. Over the next ten years, it is expected that Illinois coal users alone may produce about 15 m. tons of coal combustion residues annually. Therefore, there is an urgent need to determine cost efficient, environmentally safe methods of handling and disposal and utilization of these residues. The development of these methods will not only aid the coal industry in the midwest but throughout the U.S. This paper describes the research program "Disposal and Utilization of Coal Combustion Residues from Illinois Basin Coal Users" (DUCCR) which was recently approved by the State of Illinois to deal with the issues related to disposal and utilization of coal combustion.

Introduction

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- 1 Paper presented at the 1992 9th Annual National ASSMR Meeting, June 14-18, 1992.
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"Disposal and Utilization of Coal Combustion Residues from Illinois Basin Coal Users" (DUCCR) is a new (January, 1992) research program of the State of Illinois funded by the Illinois Department of Energy and Natural Resources through the Illinois Coal Development Board. The DUCCR is the cooperative research effort with participation from industry (coal companies, utilities, etc.), academic

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institutions, and state and federal agencies. This paper briefly describes the background from the research program and the type of research it proposes to undertake to assist the Illinois Basin Coal industry.

Background of the Problem

In the U.S, energy resources may be termed as "Strategic or Critical Minerals", which must be protected and conserved for national security reasons. Last year's events in the Middle East have brought these issues to the forefront again in establishing a U.S. energy policy. Coal is an abundant national resource which has helped and can continue to help ensure America's energy security and independence. The U.S. is ranked number one in coal production in the world, with over 975 m.tons produced in 1989. During the same year, the U.S. consumed about 900 m.tons of coal; about 80 pct of this was utilized for power generation. At the current rate of production of about one billion tons per year, the U.S. has ample proven reserves of coal to last at least 300 years.

Conventional combustion of coal in coal-fired boilers results in a considerable amount (10-12% of coal combusted) of residues (fly ash, bottom ash, boiler slag, etc.) which must be disposed of or utilized in an environmentally sound manner. The more recent commercial clean coal technologies such as flue gas desulfurization (FGD) using wet scrubbers and fluidized bed combustion (FBC)

produce even more (10-15% of coal combusted) residues than the conventional coal-fired boilers. According to statistics compiled by the American Coal Ash Association (ACAA), in 1989 the U.S. produced about 88m.ton of coal combustion residues from about 766m.ton, boiler slag - 4m.tons, and FGD slug - 16m.tons. Overall, about 25% of these residues were utilized, and the remaining were disposed primarily in landfills. The utilization of the residues by type of residue (percent of the amount produced) was distributed as follows: fly ash - 19%, bottom ash - 34%, boiler slag - 59%, and FGD sludge - 0.7%.

The Electric Power Research Institute has estimated the current national average disposal cost for residues to be about \$10/ton and expects it to increase three-fold over the next decade due to increasing environmental regulation and associated costs. Recently passed federal Clean Air Act Amendments (CAAA) requirements to cap utility emissions of sulfur dioxide at 8.9m.tons in the U.S. and to reduce nitrous oxides emissions by about 2.0m.tons after the year 2000 are expected to severely impact the utilization of high-sulfur coal. Utilities and other large coal users will either substitute low-sulfur coal or adopt clean coal combustion technologies, which will greatly reduce emissions of sulfur oxide into the atmosphere. The more common processes currently available to reduce sulfur oxides are flue gas desulfurization (FGD) and fluidized bed combustion (FBC). It is expected that

about 55,000 MW of additional generations will be scrubbed by the year 2000. Other technologies currently under development such as gasification, liquefaction, advanced coal beneficiation, direct combustion in gas turbines and diesels, dry and wet FGD processes may also produce large amounts of residues, with significantly different physical and chemical characteristics than the residues produced today. The requirement to remove air-toxins from flue gases is also expected to change the characteristics of residues. Thus, the use of clean coal technologies in the future is expected to significantly increase the volume and change the characteristics of residues produced. Some of the impacts of these actions by utilities may be summarized as follows.

1. Overall increase in residue generation from about 88m.tons annually in 1989 to about 250m.tons annually by the year 2000.
2. Significant increase in quantities of FGD sludge from about 15m.tons in 1989 to about 45m.tons in 2000. Unless effective environmentally sound technologies can be developed for utilization of FGD sludge, most of it will have to be disposed of sulfite and sulfate rich sludge in different host environments.
3. Low temperature combustion technologies require to control

nitrogen oxides will increase carbon content in the residues which may significantly impact utilization of fly ash.

The impacts described above will be particularly severe for states producing/using high sulfur coals such as Illinois, Indiana, Ohio, Missouri, Kentucky, and West Virginia. Disposal and utilization of these residues in an economical and environmentally sound manner is a very important consideration for utilities nationwide deciding whether to use high-sulfur coal or to switch to low-sulfur coal to meet the requirements of the CAAA.

Statement of the Problem

Illinois is known to have the largest resource of bituminous coal in the United States (1990 Illinois Coal Facts, p.8). About 140m.tons of coal is produced annually from the Illinois Coal Basin, which is located in Illinois, southwestern Indiana, and western Kentucky. A vast majority of recoverable reserves and production from the Illinois Coal Basin is, however, high-sulfur coal. Illinois, Indiana, Kentucky, and Missouri are among the top ten sulfur dioxide producers in the U.S. and will have to significantly reduce emissions over the next decade to meet the requirements of the CAAA. This could be achieved through the use of FGD and FBC processes rather than switching over to low-sulfur western coal. The use of these clean coal technologies will significantly increase

generation of coal combustion residues which must be disposed of or utilized. Over the next ten years, it is expected that Illinois coal users alone may produce about 15m.tons of coal combustion residues annually. Therefore, there is an urgent need to determine cost efficient, environmentally safe methods of handling and disposal and utilization of these residues. The development of these methods will not only aid the coal industry in the midwest but throughout the U.S.

Although considerable research has been done on utilization of coal combustion residues, most of it has been directed on fly ash, bottom ash, and boiler slag and very little of it has been on residues generated from combustion of Illinois Basin coals (McCarthy et al. 1985, 1986, 1987, 1988; Hemmings et al., 1989; Day et al., 1990). A very limited amount of research has been done on characterization, disposal and utilization of FGD and FBC residues from Illinois Basin coals but considerably more remains to be done. Furthermore, co-disposal and co-utilization of coal wastes from the Basin (typically acidic) with coal combustion residues (typically alkaline) present possibilities to minimize surface and ground water pollution problems. A favorable resolution of combustion residues disposal and utilization problems is critical to maintaining a healthy midwest Coal industry.

Research Program Goals and Objectives

The goals of the proposed six-year research program are:

- 1) Conduct highly focused applied research and demonstration studies to permit industry to utilize and to dispose of coal combustion residues from Illinois Basin coal users in an economic and environmentally sound manner, and
- 2) Develop data for federal and state regulatory agencies so that efficient, effective, and sound rules and regulations can be developed for permitting and monitoring of environmental impacts of the disposal and utilization of residues from Illinois Basin coals.

Specific Objectives of the DUCCR Program include:

- 1) Develop cost effective, environmentally sound technologies for the disposal and utilization of coal combustion residues. Some alternatives to be considered will include:
 - o Utilization of residues in agronomic, construction, manufacturing, and ground control or mine subsidence control;
 - o Underground disposal alone or in combination

with coal processing residues in abandoned and/or active mines;

- o Surface disposal alone or in combination with coal processing residues on surface areas of surface and underground coal mines.
- 2) Prepare comprehensive technical documentation of engineering, economic, and environmental information developed during research activities.
- 3) Develop decision-making tools to assist the coal and utility industries, and regulatory agencies with selection of appropriate disposal technologies.
- 4) Identify appropriate regulatory requirements and environmental monitoring programs to ensure environmental safety and foster public acceptance.
- 5) Prepare publications and conduct seminars designed to disseminate results of research, and demonstration work to users (industry, researchers, federal and state agencies, legislative bodies, etc) and other pertinent information to the public at-large.

Research Program

Previous and Ongoing Studies: An Overview

The utilization of coal combustion residues is not a new idea and has been practiced since the turn of the century. Residues have been disposed of

primarily in landfills, abandoned underground mines, or surface mines. The residues have also been used as virgin or in combination with manufactured engineering materials such as portland cement, lime, sand, stone etc. Since the enactment of the Resource Conservation and Recovery Act (RCRA) in 1976, the concern for potential air, surface water, and groundwater pollution, as well as land use impacts due to disposal and utilization of residues has significantly increased. In 1980, and again in 1988, coal combustion residues were classified as non-hazardous solid waste (subtitle D), whether they were disposed of or utilized. Conventional coal-fired boiler residues, flue gas desulfurization residues (FGD), most advanced clean coal technology residues, and some coal processing residues are presently exempted from being classified as hazardous. However, these exemptions could change in the future and significantly impact disposal and utilization alternatives.

Considerable research has been done and continues to be done by the U.S. Department of Energy (USDOE), the Electric Power Research Institute (EPRI), the University of North Dakota Energy and Environmental Research Center (UNDEERC), the U.S. Bureau of Mines (USBM), the U.S. Environmental Protection Agency (USEPA), Pennsylvania State University, Purdue University, Radian Corporation, Baker, Inc. on the disposal and utilization of coal combustion residues. Most of the results of these studies have been included in Materials

Research Society Symposia Proceedings (I-VI), (McCarthy et al., 1985, 1986, 1987, 1988; Hemmings et al., 1989; Day et al., 1990) and EPRI reports and manuals (Battelle, 1987; ETHURA Grants Pass, 1986; Little, 1985; Battelle, 1987; Radian Corporation, 1990; Radian Corporation, 1990; Battelle, 1989; Battelle, 1988; Battelle, 1988; Battelle, 1987; University of Alberta, 1986; Radian Corporation, 1984; Stanford University, 1983). Except for an ongoing USDOE - Radian - UNDEERC study, most of these studies have been conducted on coals other than Illinois Basin Coals. Over the past about 10 years, Southern Illinois University at Carbondale and ISGS have also been engaged in studies related to the disposal and utilization of coal combustion residues (Huck and Chugh, 1985; Huck and Chugh, 1982; Chugh and Heidenger, 1980; Chugh et al., 1990; Chugh and Chandwani, 1988; Devaniter and Ray, 1990; Dreher, Roy, and Steele, 1991; Chou, Demir, Cahill, Chaven, Phillips, and Sotomayer, 1987; Dreher and Pevear, 1985; Gluskoter, Ruch, Miller, Cahill, Dreher, and Kuhn, 1977; Rostam-Abadi and Moran, 1990; Dreher and Finkelman, 1986; Rostam-Abadi and Chen, 1989; Roy, Mravaik, Krapac, Dickerson, and Griffin, 1988; Peters, Dreher, Hamilton, Mitro, and Cannon, 1982; Roy and Griffin, 1982; Cobb, Master, and Treworgy, 1979; Steele and Cline, 1989; Krapac, Smyth, and Griffiffin, 1984; Bradford, Berggren, and DuMontelle, 1983; Krausse, Damberger, Nelson, Hunt, Ledvina, Treworgy, and White, 1979; Bauer and Hunt, 1982; DuMontelle, McKay, and Gibson,

1982; Killey, Hines, DuMontelle, 1985; Stohr and Su, 1991, Herzog, Griffin, Stohr, Follmer, Morse, and Su, 1989; Davis, 1987; Davis, 1987; Davis, 1987; Sami, Smith, and Davis, 1987; Davis, 1989). In addition, a large study has been initiated by the Ohio Coal Development Office, USDOE, Ohio Edison, American Electric power, EPRI, and Dravo on land applications, uses of dry FGD by-products from FBC residues, spray driers, and duct sorbent injections (Dick, Beeghly, and Satomayer, 1991). Limited information is also available on the utilization of residues on agricultural lands.

Over the past few years, coal companies in the Illinois Basin have actively looked at available options to dispose of fly ash, FGD, and FBC residues. Currently, one mine operator is successfully disposing of fly ash underground; one plans to dispose of it in a surface mine. Two mine operators plan to dispose of FBC residues and coal processing waste in combination. One mine operator is considering disposing of FGD residues in an active underground mine. Significant interest among mine operators in the Illinois Coal Basin provides DUCCR with a unique opportunity to conduct laboratory and field research and demonstration studies.

Research Program Components

It is proposed that the research program will have at least five major components:

- 1) Characterization of residues and by-products,

- 2) Disposal technology in surface facilities, surface mines alone or in combination with coal processing and coal mining residues,
- 3) Determination of environmental impacts of surface and underground disposal and utilization,
- 4) Residue utilization and by-products recovery from combustion residues, and
- 5) Socioeconomic, policy, and legal issues.

A brief discussion of the five research program components listed above is given in the following paragraphs. This is based on a limited literature review, discussions with a few experts from federal and state agencies, and input from Illinois Coal Basin coal companies and utilities. Specific research projects within the component areas will be developed based on identified research needs from: 1) an in-depth literature review and synthesis during Year 1; and 2) input from the USDOE, EPRI, USBM, USEPA, UND, the Illinois Environmental Protection Agency (IEPA), limestone companies, coal users, the coal industry, coal users, sorbent manufacturers, selected experts from research institutions and consulting companies.

Characterization of Residues and By-Products.

Characterization studies are a prerequisite to the development of environmentally sound and economic methods of disposal and utilization of residues.

Characterization studies may be subdivided into four categories: physical, chemical, engineering, and regulatory. Physical characteristics include particle size and shape, porosity, permeability, water content, etc. The chemical characterization includes determination of different minerals, chemical constituents and their forms, trace elements, their leaching characteristics, and feasibility of their extraction for use in industry. Engineering properties include short and long-term handling and flow properties, strength-deformation properties, dewatering properties, weathering properties, and how the residues may react with their natural environment and with disposal, utilization, and handling systems.

Characterization for regulatory purposes is extremely important for: 1) residue classification from Federal and State laws; 2) impact on coal mining and coal utilization industries from current and proposed regulations; 3) compliance characteristics; and 4) development of simpler and more meaningful characterization techniques based on field performance of residues in disposal areas and utilization products. The physical and chemical characteristics of residues are variable even for a single combustion source because of variable coal composition and combustion temperature. For this reason, engineering as well as regulatory characteristics also vary considerably.

Considerable research has

been done (McCarthy and Lauf, 1985; McCarthy and Glesser, 1986; McCarthy et al., 1987; McCarthy et al., 1988; Hemmings et al., 1989; Day et al., 1990; Battelle, 1987; Battelle, 1987; Battelle, 1987; Radian Corporation, 1984; Stanford University, 1983) on the characterization of residues from conventional coal combustion technologies. Limited data are also available for technologies such as FGD and FBC (Chugh et al., 1990; Davis, 1987; Davis, 1987; Electric Power Research Institute, 1988; Yaverbaum, 1987; Jones, Blande, and Rose, 1987; Harness and Chung, 1987), but data gaps exist. Residues from emerging coal technologies will require considerably more characterization in the laboratory as well as in the field. A large number of characterization techniques are available and their suitability for different types of residues in different natural environments needs to be defined.

At present, little or no characterization data exist in the open literature for co-disposal or co-utilization of coal combustion residues with coal processing wastes from the Illinois Coal Basin. It is proposed to collect such characterization data under the DUCCR program. The following research areas have been identified as important:

- 1) Synthesis of available data on bed ash, fly ash, and FGD sludge from wet and dry scrubber systems for currently utilized and developing coal technologies.

- 2) Develop comparisons between combustion residues and other commonly utilized commercial products to identify differences and similarities.
- 3) Identify important chemical and physical characteristics of residues and by-products and their determination procedures for industry and regulatory agencies.
- 4) Identify co-disposal and co-utilization possibilities and associated environmental impacts for combustion, FGD, and coal processing residues based on developed properties.
- 5) Identify by-products recovery potential from combustion as well as processing residues.

Disposal Technology.

Technology for the disposal of residues in landfills from conventional coal combustion is relatively well developed. Advanced clean coal technology residues generally contain high levels of calcium compounds such as calcium oxide. This can lead to thermal pollution and curing and hardening of combustion residues during the transportation and disposal of residues. Since space in landfills is rapidly decreasing and land in the Illinois Coal Basin is prime agricultural land, surface and underground mines (active and abandoned) have been identified as possible sites for disposal of coal wastes and coal combustion residues. Considerable work has been done by the USBM in disposal technology (Rubin et

al., 1981). Most of this work was for use in disposal of coal processing wastes and fly ash. These technologies will require some modification for disposal and management of residues from advanced combustion technologies, alone or in combination with coal processing wastes. Similarly, utilization of residues, alone or in combination with coal processing residues, will require development of technology for the transport, handling, and storage of residues. The following areas of research have been identified as important to the DUCCR program:

- 1) Synthesis of available data on dry and wet disposal technologies to identify those suitable for surface and underground disposal of combustion residues, alone or in combination with coal processing residues.
- 2) Identify conditions suitable for viable technologies and develop their relative economics.
- 3) Develop system components for each viable technology identified above. For example, for a wet underground disposal system, development work on a range of solids concentrations, co-disposal mixtures, and borehole spacing is needed.
- 4) Recommend the design of wells suitable for underground disposal in mines as well as for monitoring of environmental impacts to comply with the Groundwater Protection Act and regulations.

- 5) Recommend procedures as well as technologies for dealing with fugitive dust, while practicing dry disposal techniques.
- 6) Identify liner (soil, clay, synthetic) requirement studies for surface as well as underground mine disposal.
- 7) Develop bulkhead design for wet and dry underground disposal.
- 8) Identify techniques for mapping abandoned underground mine workings from the surface to plan underground disposal.

Environmental Impacts of Disposal and Utilization.

Management of combustion residues requires consideration of possible adverse impacts on air, surface and groundwater, and land use. Improved disposal or utilization techniques may also suggest a modification of environmental regulations to ensure environmental safety. Impacts on groundwater due to leaching and transport of major, minor, and trace elements is considered to be the most serious environmental problem. A large amount of field experimental data on groundwater impacts has been collected by USDOE, EPRI, Radian Corporation, and UNDEERC but most of it is for monofills of combustion residues. Similar types of data will need to be collected in the DUCCR program for co-disposal fills of combustion residues and coal processing wastes in a variety of geological and hydrological conditions. Fugitive dust generated during the handling

of dry combustion residues can be a serious health and safety problem which must be suitably abated. Research areas identified for additional study are given below:

- 1) Geological and hydrogeologic site investigation studies and techniques for planning disposal projects.
- 2) Collection of groundwater quality data by monitoring monofill as well as co-disposal fill areas under a variety of soil, topographic, and geologic conditions. These data need to be collected for both surface and underground disposal areas,
- 3) Prediction of groundwater impacts using residue characterization data, geologic and hydrogeologic data, and soil data,
- 4) Review of current standards for groundwater impacts and establish revised standards, if appropriate,
- 5) Reclamation techniques required to minimize the effects of disposal on agricultural productivity and quality,
- 6) Long-term impacts of disposal and utilization,
- 7) Simulation and prediction of field environmental impacts from laboratory studies, and comparison to field study data.
- 8) Surface contamination from fallout of combustion

residues,

- 9) Wind erosion of materials, and
- 10) Surface subsidence due to wet underground disposal techniques.

Residue Utilization and By-Products Recovery.

Currently, about 25% of the conventional coal combustion residues and 0.7% of the FGD sludge is being utilized in markets such as cement and concrete products, structural fills, road base and sub-base, mineral filler in asphalt, snow and ice control, blasting grit and roofing granules, coal mine grouting applications, wallboard etc. Data on use of FBC residues is not available. In the future, two factors will tend to decrease the amount of residues being utilized on a percentage basis: 1) the production of residues from advanced clean coal technologies such as the FGD and FBC is expected to increase dramatically, particularly in the Midwest, and suitable uses for these have not been developed to the extent that they have been developed for conventional coal combustion residues, and 2) proposed RCRA classification of residues as "solid waste" will impede the utilization potential of residues. Therefore, additional research is required to evaluate the large volume utilization potential of residues as engineering materials in an environmentally sound manner, as well as to consider recovering valuable by-products from residues. The following research areas were identified as important for the DUCCR program:

- 1) The possibility of using fully oxidized FGD sludge for quality gypsum wallboard,
- 2) Making lightweight blocks for construction of underground stoppings for ventilation control,
- 3) Disposal of residues between two sets of stoppings to develop explosion proof stoppings,
- 4) Development of facing cements for stoppings to minimize leakage and to provide flexural strength,
- 5) Development of lightweight prismatic bars to replace wooden posts and crib members underground,
- 6) Microbial treatment and beneficiation of residues,
- 7) Feasibility of co-utilization of coal processing/coal combustion residues,
- 8) Making structurally acceptable products,
- 9) Feasibility of recovering some trace elements as useful by-products,
- 10) Feasibility of using residues for catalysts in coal-conversion processes,
- 11) Possibility of developing cements for grouted roof bolts, and
- 12) Utilization of residues in agriculture, highway construction, and mine reclamation.

Socioeconomic, Policy, and Legal Issues. The development of disposal and utilization alternatives under the DUCCR program will require the formulation and/or resolution of several policy and legal issues. The socio-economic impacts of these alternatives must also be considered. The program research will identify the relative economics of different alternatives developed during the course of this study. The research in this program will also be directed toward: 1) the classification of coal combustion residues and coal processing wastes alone or in combination, and 2) development of simple, but scientifically valid, tests for use by industry and state and federal agencies for permitting and compliance purposes. For example, a simpler, less costly leachate test will be explored for use on Illinois Basin coal residues. The industry representatives have identified the following research areas to be important:

- 1) Underground disposal of residues would be performed environmentally most sound. Issues pertaining to underground disposal include:
 - (i) legal rights for mined-out space,
 - (ii) subsidence rights due to wet disposal,
 - (iii) surface rights for drilling boreholes,
 - (iv) utilization potential of health and safety hazards associated with venting of noxious

gases into the atmosphere,

- (v) water pollution potential of excess water being pumped to the surface, and for aquifers below and between the injection zone and surface.
 - (vi) availability of impact on water resources,
 - (vii) pollution of groundwater,
- 2) Possibility of developing small-scale industries using residues as raw material,
 - 3) Relative economics of viable disposal and utilization technologies developed during the course of the program, and their market impacts,
 - 4) Assessment of legislation and regulations in light of research findings and recommend revisions, if warranted.

Information Transfer Program

An effective broad-based information transfer program at both the regional and national levels will be an integral part of the DUCCR program. The most important objective of the information transfer program will be to ensure that the information developed is effectively communicated to all user groups. Therefore, program activities will be developed and conducted at different levels of complexity with regard to the basic

scientific and practical application aspects of residue disposal and utilization.

Concluding Remarks

The development and commercial use of clean coal technologies for combustion of high sulfur coal will require significant research in efficient and effective disposal and utilization of coal combustion residues. Recognizing this need, the State of Illinois has initiated the DUCCR research program. Active participation of the industry in the program will keep the research applied and focused and ensure that the results are transferred to the users in a timely manner. The broad research program presented here will become focused within a year. The author would welcome suggestions and comments on the research program.

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