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Project Summary

EPA Coal Cleaning Program: FY 1979 Progress Report

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The report describes work performed by a dozen organizations to explore opportunities for wider use of coal as an environmentally acceptable energy source. Many aspects of coal were studied during 1979, including the use of low sulfur coal, removal of coal sulfur by coal cleaning, and measurement of emissions from the cleaning processes themselves. Seventeen projects were active in three major research categories: environmental assessment, technology assessment and development, and pollution control technology.

Several projects were directed toward achieving a better knowledge of the characteristics of estimated coal resources. One approach was to develop an understanding of the effects of geologic formation processes on the properties of the resulting coal—especially sulfur and ash content. Another approach was to develop empirical data bases from multiple source sampling programs, past and present, to help identify constituents of coal deposits and relate them to environmental and economic concerns.

Other studies evaluated certain coal cleaning techniques, equipment, and systems to assess possibilities for their improvement. Alternative strategies for compliance with sulfur dioxide (SO_2) emission rules for coal combustion were explored, as were assessment and control of pollution from coal cleaning processes.

This report was submitted in fulfillment of Contract 68-02-3136 by Versar Inc. under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period from October 1, 1978 through September 30, 1979, and work was completed as of June 30, 1980.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

United States mineable coal resources are estimated at 1.5×10^{12} Mg, enough to supply the U.S. with electric power for 800 years at 1976 comsumption rates. In addition, coal is a versatile fuel which can be tailored to many specific uses by appropriate preparation and treatment. The benefits of coal preparation have not been fully explored, and to that end the U.S. Environmental Protection Agency (EPA) is coordinating a coal cleaning program in conjunction with the U.S. Departments of Energy and Interior. This program aims to evaluate the multiple possibilities of coal preparation and to assist in the development of technologies for coal beneficiation and concurrent pollution control. During 1979, EPA sponsored work on 17 projects related to coal preparation, which were carried out by a dozen organizations.

1979 Coal Cleaning Program Highlights

Specific projects in the EPA coal cleaning program exhibit a variety of

approaches to the achievement of environmentally acceptable and economically feasible coal use.

Coal Quality

A program being performed by the U.S. Geological Survey (USGS) under Interagency Agreement EPA-IAG-DX-E685 addresses characterization of coal quality. The overall objective of this program is to typify the chemical, mineralogical, and physical properties of U.S. coal resources. This knowledge is essential to an assessment of the extent of a particular deposit and its potential for use under stringent environmental regulations or sophisticated industrial process requirements. Data and statistical summaries of 617 eastern coal samples collected in FY 78 were reported by Zubovic and others in USGS Open-File Report 79-665. During FY 79, 660 samples of eastern U.S. coals and approximately 500 samples of western coals were analyzed. Statistical data summaries on 19 chemical elements considered to be deleterious to the environment are presented. Comparison of the FY 79 eastern coal averages with averages for 4,810 samples of U.S. coals shows that eastern coals have higher average contents of most of these elements. Only Cd and Mn are significantly higher in the average U.S. coal than in eastern coals. Detailed analytical data on individual samples will be available from Zubovic and others in 1980.

Geology of Contaminants in Coal

A second USGS effort in 1979, performed under the same agreement, correlated coal geology with coal contaminants. During FY 79, USGS focused on the geologic controls on mineral matter variation of the Homer City, PA, dedicated reserves of the Upper Freeport coal bed. Parametric statistics were applied to the analytical data and resulted in the following conclusions:

- Variation in mineral matter content of the Upper Freeport reserves was primarily controlled by inherent plant ash and the surrounding hydrologic environment.
- Low ash and low sulfur coal is the product of peat that formed under highly acid conditions (pH <4.5), whereas coal with higher ash and sulfur was formed under pH conditions of 4.5 to 7.5.

Mineral Matter and Trace Elements in Coal

The Illinois State Geological Survey is also participating in EPA's coal cleaning program under Grant No. R806654. This project will establish an elemental and mineralogical interpretation of the Illinois No. 5 and No. 6 coals, which can be used to locate coal with environmentally hazardous or economically recoverable elements. The interpretations can be used for selecting and developing coal cleaning techniques.

Non-clay mineral analyses were completed in 1979 for 15 face channel and drill core samples and for 27 float/sink separations. Major minerals present included pyrite, calcite, quartz, kaolinite, illite, and expandable clay minerals.

Clay mineral analyses were completed for 10 of the composite face channel and drill core samples with the following results:

Coal	% Kaolinite	% Illite	% Expandables
No. 5	29	37	34
No. 6	31	40	29

As more data become available, individual clay mineral percentages for both coals will be mapped and interpreted for trends.

Coal Environmental Profile System

Research Triangle Institute (RTI) is performing an environmental assessment study within the EPA coal cleaning program under Contract 68-02-3170. The Coal Environmental Profile System (CEPS) is a project activity under development to provide a characterization of the environmental effects of coal transport/handling/storage systems, coal cleaning processes, and coal combustion processes. To implement this study, RTI designed a generator to produce a coal dust aerosol from raw coal, and repeated runs in the dust generator with western Kentucky No. 9 and North Dakota Zap lignite that showed that coal dust presents a significant inhalation hazard.

When exposed to air, coal combines with oxygen and releases heat. This low temperature burning is incomplete and generates a spectrum of organic compounds of the same general type as those arising from pyrolysis or devolatilization of coal. The lower rank western coals, which represent the largest U.S. reserves, are particularly prone to this type of self-heating. Differential scanning calorimetry (DSC) was used to identify coals that require special attention. The rate of heat absorption or generation was measured as the temperature of a coal sample increased linearly. A plot of heat release vs. temperature for three different fuels is shown in Figure 1. Further refinements of these tests are planned.

Environmental Assessment Study

A major project begun by Battelle Columbus Laboratories, under EPA Contract 68-02-2163, was continued by Versar, Inc. and Teknekron Research, Inc. under EPA Contract 68-02-3136. As documented in EPA Report EPA-600/7-79-073b (NTIS PB 300671), Battelle Columbus Laboratories provided several automated data bases and two computer models that are being used in the ongoing effort by Versar and Teknekron.

A major goal of the project is establishment of a strong emissions data base for physical coal cleaning (PCC) processes by a sampling and analysis program that includes physical, chemical, and biological testing of pollutant emission streams. Discharges already identified as having potentially adverse environmental effects are leachate and runoff from waste ponds and piles; fugitive dust from coal crushing and sizing areas, storage piles, and refuse piles; and thermal dryer emissions.

The Resource Process Assessment Model (RPAM) developed by Battelle Columbus Laboratories is being used by Teknekron to project coal usage and availability by SO_2 emission parameter. During FY 79, model capabilities were extended, coal reserve data bases were correlated to determine geographical compatibility, and a production data base for the year 1976 was formed using annual reports submitted by coal companies to state agencies. The revised model is identified as the Coal Assessment Processor (CAP) model.

Sulfur content and heating value data for 53 different coal-source/cleaning-plant combinations were statistically analyzed to document the effectiveness of commercially operating coal cleaning plants in reducing sulfur and enhancing heating value and to define the effect of physical coal cleaning on sulfur variability. Analysis showed that both the absolute standard deviation and the relative standard deviation for all three

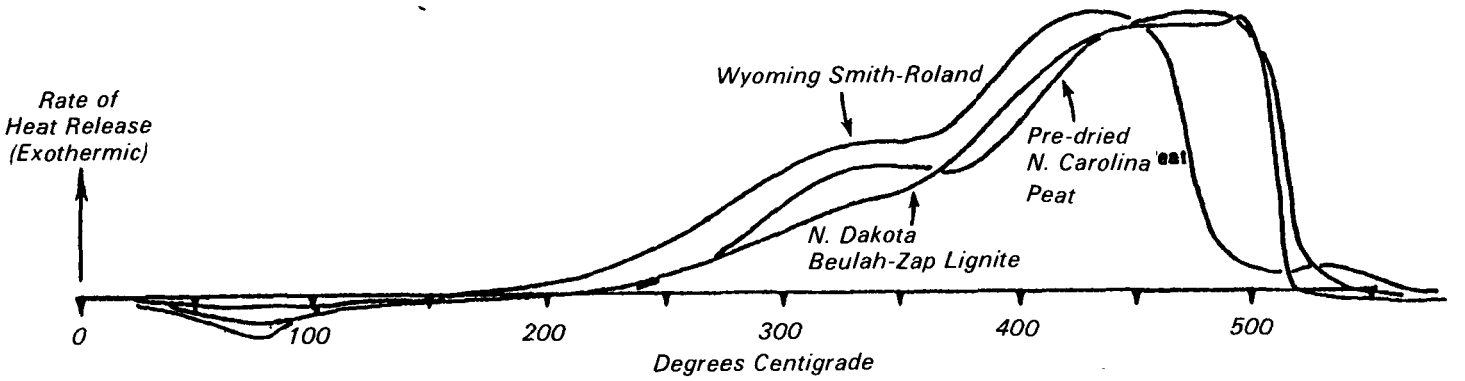

Figure 1. DSC results for carbonaceous fuels in air, 5°C/min.

coal characteristics were reduced by the coal preparation process.

Battelle Hydrothermal Process

Battelle Columbus Laboratories, under EPA Contract 68-02-2187, continued to work for improvement of their chemical coal cleaning (CCC) process. The Battelle Hydrothermal Process treats a 70 percent minus 200 mesh coal with aqueous sodium and calcium hydroxides at elevated temperatures and pressures. This treatment has been found to remove nearly all pyritic sulfur and 25-50 percent of organic sulfur from Appalachian and eastern interior coals. Zinc oxide, ferrous and ferric hydroxides, reduced activated ferric oxide, and ferrous carbonate were found to be effective in removing the major portion of the sulfide sulfur from the spent leachant. Operating costs for a self-contained hydrothermal treatment plant were estimated at $30.34/Mg ($27.52/ton) for a typical eastern coal, and $6.89/Mg ($6.25/ton) for a western subbituminous coal. Certain coals with low organic sulfur and high pyritic sulfur can be cleaned more efficiently by a combination of hydrothermal and physical coal claining. Costs for this scenario were estimated at $18.85/Mg ($17.10/ton).

Homer City Coal Cleaning Plant

A project is being performed by the Pennsylvania Electric Co. (Penelec) (EPA Contract 68-02-3124) at the advanced coal cleaning pilot plant under construction near the Homer City Generating Station Power Complex in Homer City, PA.

During 1979, the effectiveness of the electrostatic precipitator (ESP) equipment was measured while firing run-of-mine coal in the two types of precipitators that are used at the Homer City Power Station. The oldest precipitator performed marginally well, while the newest and conservatively designed unit No. 3 performed outstandingly when run-of-mine coal was burned. An additional series of tests with ESP plate rapping suspended for various periods of time revealed that performance can be improved markedly by controlled plate rapping in sequence.

Another accomplishment was the development of a system to compile operating cost data from the plant. Also, a coal laboratory was set up with specialized equipment for performing coal washability, ash, and particle size distribution analyses of large quantity samples.

Dense-Medium Cyclone Project

Under Interagency Agreement EPA-IAG-D6-685, the Department of Energy, in cooperation with EPA, EPRI, and the Homer City preparation plant owners, is conducting a comprehensive pilot plant study on dense-medium cycloning of fine coal at lower-than-normal specific gravities of separation (~1.30).

During 1979, approximately half of a series of 60 tests was done with magnetite and water to define the effects of various combinations of pressure and flow rate. A comparison was begun of techniques for analysis of size distribution of magnetite below 325 mesh, and a newly designed device to test slurry viscosity was being calibrated and modified.

Coal Cleaning Technology Assessment

During 1979, Versar Inc. performed a study under EPA Contract 68-02-2199 to assess the applicability of using three pollution control technologies—low sulfur coals, PCC, and CCC—for compliance with SO_2 emission regulations for industrial boilers (report EPA-600/7-79-178c; NTIS PB 80-174055). Results showed that representative low sulfur western coals could meet all emission levels down to 520 ng SO_2/J (1.2 lb $SO_2/10^6$ Btu). The representative low-sulfur raw eastern coal could achieve emission levels above 860 ng SO_2/J (2.0 lb $SO_2/10^6$ Btu), and, when physically cleaned, the coal could be used to meet an emission level of 520 ng SO_2/J (1.2 lb $SO_2/10^6$ Btu). The representative high sulfur eastern coal could be cleaned to meet the emission level of 645 ng SO_2/J (1.5 lb $SO_2/10^6$ Btu), but chemical coal cleaning was required to comply with more stringent limits.

Another part of the study was sampling and analysis to evaluate the performance of three types of coal cleaning equipment—heavy-media cyclones, hydrocyclones, and froth flotation units—in reducing pyritic sulfur content of fine coal. Versar's subcontractor, Denver Equipment Division of Joy Manufacturing Co., submitted field reports containing the results from these tests in 1979, and Versar began preliminary data analyses.

Evaluation of Physical and Chemical Coal Cleaning

Under EPA Interagency Agreement IAG-D9-E721-BI, the Tennessee Valley Authority in Muscle Shoals, AL, completed a study (report EPA-600/7-79-250; NTIS PB 80-147622) of seven coal cleaning processes (three physical, three chemical, and one combination) to evaluate sulfur removal and economic viability of the processes when used alone and in combination with flue gas desulfurization (FGD). From the analyses, the following conclusions were reached:

- Physical coal cleaning is a commercial cost-effective method of meeting an emission limit of 520 ng SO_2/J (1.2 lb SO_2/10^6 Btu) for coals with sulfur levels below about 1.2 percent.
- Physical coal cleaning plus partial scrubbing with limestone FGD is generally cost effective in meeting the above limit for feed coals with sulfur contents below about 3 percent.
- Coal cleaning plus partial scrubbing with limestone FGD is generally less cost effective than limestone FGD alone in providing 85 percent SO_2 reduction.
- A potentially advantageous SO_2 emission control approach is pelletization of finely ground cleaned coal with limestone.

Physical Coal Cleaning Computer Economics

A second project being performed by TVA (EPA-IAG-D9-E721-GP) is the development of a computer program that determines the most economical approach for sulfur removal using physical coal cleaning plus partial limestone scrubbing. The program will accept site-specific input variables such as coal composition, boiler size, transportation costs, cleaning process details, sulfur removal efficiencies, emission standard goals, and economic premises. No results are yet available, since the project was approved during the last week of FY 79 and scheduled for completion in early 1981.

Coal Cleaning Costs and Benefits

In FY 79, under EPA Contract 68-02-2603, PEDCo identified and quantified the benefits of using physically cleaned coal versus run-of-mine coal for utility steam electric generation. It was found that the combined total of all of the benefits addressed by PEDCo usually exceeded the cost of cleaning the coal. PEDCo recommends additional projects aimed at quantifying coal cleaning benefits and presents an annotated bibliography of related studies.

Coal Desulfurization Using Microwave Energy

General Electric Company, under EPA Contract 68-02-2172, is continuing research into a process developed by that company prior to 1979. The coal cleaning process uses microwave energy to remove 50 percent of the pyritic sulfur. In combination with sodium hydroxide, it removes more than 95 percent of the pyritic sulfur and about 60 percent of the organic sulfur. During 1979 further experiments have shown that microwave heating (in the absence of NaOH) converts pyrite (FeS_2) to strongly magnetic pyrrhotite ($Fe_{1-x}S$) which can then be magnetically removed. Another significant result is that the atmosphere of the microwave treatment has an important effect on the nature of the conversion product. When treatment was performed in the presence of air, iron oxide was produced; in the presence of argon, pyrrhotite resulted. The experimental correlation between the microwave treatment atmosphere and the new phases produced ambiguous results, and more analyses and data interpretation remain to be done. However, the potential for coal desulfurization by the microwave process appears to be promising.

Environmental Studies of Coal Cleaning Processes

The Tennessee Valley Authority is also conducting a project (EPA-IAG-D8-E721-GA) which aims to characterize the waste streams and leachate from refuse piles generated by coarse coal beneficiation. An additional goal is to assess coal cleaning's effect on the ash composition and wastewater characteristics in a coal-fired power plant. Data from a level C coal cleaning plant were evaluated in 1979. For this plant, the cleaned coal product contained less ash, more energy per unit weight, and approximately the same amount of total sulfur as the raw coal.

Based on the single plant sampled, the total quantity of trace metals remaining for disposal after the combustion of cleaned coal would be less than that from combustion of raw coal, but a higher concentration of some trace metals would be found in the ash from combustion of the cleaned coal. Mercury appeared to be substantially concentrated in the cleaned coal, but this observation was based on only one sample of feed coal. The dissolved concentrations of Mn, Cu, Zn, Ba, and As in the fine refuse slurry were below the water quality criteria for domestic water supply intakes proposed by EPA.

Preservation of Reactor Test Unit and Desulfurization of Gob Pile Samples

The development by TRW of the Meyers Process for leaching of pyritic sulfur from coal has been sponsored by EPA (Contract 68-02-1880) through construction and operation of a 7 Mg/d (8 ton/d) test plant termed the Reactor Test Unit (RTU). An inspection program in 1979 showed that the reactor vessel, the reactor internals, and the slurry recirculation loop equipment were severely corroded. It was recommended that the original stainless steel reactor be replaced with a new reactor made of titanium.

A modification of the Meyers Process, the Gravichem Technique, was investigated at bench scale in FY 79. TRW concluded that application of the Gravichem Process to eastern and midwestern steam-coal resources would reduce SO_2 emissions in the United States by 45-58 percent. It was also found that the Gravifloat portion of the Gravichem Process can recover depyrited, very low ash and low sulfur fuel from waste coal fines found in slurry ponds. In addition, the Gravifloat coal in oil or water slurry is a potentially excellent fuel for use in coal conversion units. Future work with the RTU will be done under the direction of the U.S. Department of Energy, to whom the test unit was transferred in September 1979.

Trace Element Characterization and Removal/Recovery from Raw Coal and Coal Preparation Wastes

The overall objectives of a Los Alamos Scientific Laboratory (LASL) research program (EPA-IAG-79-D-X-0521) are to assess the problem of trace element contamination in coal waste drainage and to identify suitable control technologies. In the past year, studies of the mineralogy and elemental composition

of low sulfur coal refuse samples collected from the Appalachian area were performed and the aqueous leaching behavior of the materials was investigated.

Leaching tests were conducted on the refuse material and these data were analyzed using Multimedia Environmental Goals established by EPA. Based on this criterion, LASL identified Al, Cu, Fe, Mn, Ni, and Zn as those elements of environmental concern in the leachates from the sample of Appalachian region refuse that was studied. Calcining (high temperature treating of the refuse) and co-disposal with lime or other attenuating agents or sorbents were found to be the most promising control strategies applied directly to the refuse. Preleaching of the refuse and sealing of the pile were found to be less effective.

LASL also initiated studies on the effectiveness of using a variety of sorbents such as clays, soils, and solid coal combustion byproducts on high-sulfur coal refuse leachates. Alkaline neutralization was shown to be the most effective and least costly of the refuse drainage treatment options studied. Ion exchange and reverse osmosis both proved to be technically feasible methods for reducing the contaminants in refuse drainage to acceptable levels; however, the need to neutralize the solutions sharply reduces the applicability of these methods.

Relative cost effectiveness, treatment duration, possible hazardous classification, and permanency of the most promising control method were also studied and reported in DOE document LA-8039-MS.

Oil Agglomeration for Effluent Control

Battelle Columbus Laboratories is investigating techniques to enhance the efficiency of oil agglomeration for recovery of coal from preparation plant wastes (EPA Contract 68-02-3108). A previous laboratory study completed by Battelle under EPA contract 68-02-2112 demonstrated that coal recoveries of 90 percent or greater can be realized by using oil agglomeration on coal cleaning wastes (report EPA-600/7-79-025b; NTIS PB 293210). The present Battelle effort is directed at evaluating pretreatment techniques to enhance separation of pyrite from coal in the oil agglomeration process. The study also aims to assess the performance of oil agglomeration as an alternative or adjunct to existing effluent control of coal cleaning plants.

The 1979 slurry samples from one Kentucky and one Illinois coal cleaning plant were characterized for their solids content, settling characteristics, sieve size distribution, and concentrations of ash, sulfur, and coal. Surface pretreatment methods for pyrite were screened by using pyrites and cleaned coal collected at the same place and time as the slurry samples. The most effective pretreatment method determined by the screening test was then used to treat the blackwater sediments. When completed in 1980, these studies should suggest agents and conditions which give optimum pyrite rejection and maximum coal recovery from coal cleaning blackwater.

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The complete report, entitled "EPA Coal Cleaning Program: FY 1979 Progress Report," (Order No. PB 81-219 560; Cost: $9.50, subject to change) will be available only from:

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