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# Environmental Assessment of Coal Cleaning Processes: First Annual Report; Volume I. Executive Summary

## Interagency Energy/Environment R&D Program Report

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by

A. W. Lemmon, Jr., S. E. Rogers, G. L. Robinson,
V. Q. Hale, and G. E. Raines

Battelle-Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

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EPA Project Officer: James D. Kilgroe

Industrial Environmental Research Laboratory
Office of Energy, Minerals, and Industry
Research Triangle Park, NC 27711

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Office of Research and Development
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# FOREWORD

Many elements and chemical compounds are known to be toxic to man and other biological species. But, our knowledge concerning the levels and conditions under which these substances are toxic is extremely limited. Little is known concerning the emission of these pollutants from industrial processes and the mechanisms by which they are transported, transformed, dispersed, or accumulated in our environment.

Portions of the Federal Clean Air Act, the Resource Conservation Recovery Act, and the Federal Water Pollution Control Act require the U.S. Environmental Protection Agency (EPA) to identify and regulate hazardous or toxic substances which result from man's industrial activities. Industrial pollutants are often identified only after harmful health or ecological effects are noted. Remedial actions are costly, the damage to human and other biological populations is often irreversible, and the persistence of some environmental contaminants may endanger future populations.

EPA's Office of Research and Development (ORD) is responsible for health and ecological research, studies concerning the transportation and fate of pollutants, and the development of technologies for controlling industrial pollutants. The Industrial Environmental Research Laboratory, an ORD organization, is responsible for development of pollution control technology and conducts a large environmental assessment program. The primary objectives of this program are:

- The development of information on the quantities of toxic pollutants emitted from various industrial processes--information needed to prioritize health and ecological research efforts.

- The identification of industrial pollutant emissions which pose a clearly evident health or ecological risk and which should be regulated.

- The evaluation and development of technologies for controlling pollution from these toxic substances.

The coal cleaning environmental assessment program has as its specific objectives the evaluation of pollution and pollution control problems which are unique to coal preparation, storage, and transportation. The coal preparation industry is a mature yet changing industry and in recent years significant achievements have been made in pollution abatement.

In focusing on the effectiveness and efficiency of coal cleaning processes as methods of reducing the total environmental impact in the use of energy derived from coal, this report describes the progress made on all facets of this program during the first year of its existence. The information derived from the studies performed will be used to evaluate the overall desirability of expanding the use of coal cleaning as a means of mitigating environmental impacts caused by the burning of coal.

## ABSTRACT

Battelle's Columbus Laboratories is performing an environmental assessment of coal cleaning processes under Contract No. 68-02-2163 with the Industrial Environmental Research Laboratory [Research Triangle Park (IERL/RTP), North Carolina] of the U.S. Environmental Protection Agency (EPA). This report describes progress on this program during the first year of work. A strong base of engineering, ecological, pollution control, and cost data is being established through data gathering and systems analysis efforts.

In addition to program management, three task areas have been defined. These technically-oriented functions are: system studies, data acquisition, and general program support.

Systems studies have specifically focused on three subtasks. The development of information on coal cleaning process technology has been emphasized in the first of these subtasks, while the second has been concerned primarily with defining the technological and cost status of the control of pollutants from coal cleaning and refuse disposal operations. The third subtask relates to the establishment of criteria for meeting environmental goals. Substantial progress was made on these three subtasks and early availability of draft reports of accomplishments is anticipated. But effort on a fourth subtask designed to acquire process data was terminated to avoid duplication of the effort of another EPA contractor.

Data acquisition subtasks have been directed at the planning needed as the forerunner of the anticipated environmental field testing programs. Progress has been made in: developing and describing the overall environmental test program, developing the rationale for selection and selecting the evaluation sites, specifying the experimental testing techniques to be used, and developing the master site test plan. Based on a statistical rationale, ten unique site categories have been specified for testing; experimental techniques are based on accepted U.S. EPA and open literature methods.

General program support has consisted of: obtaining background environmental data in the vicinity of and refining a computer simulation model for use in studying the performance of the demonstration coal cleaning facility near Homer City, Pennsylvania; operating the coal cleaning information center; providing support for a sulfur emissions study for the Organization for Economic Cooperation and Development; participating in the USSR-US technical information exchange program; and studying and evaluating physical coal cleaning as an $SO_2$ emission control strategy. A draft report on the latter physical coal cleaning evaluation has been submitted to the Office of Air Quality Programs and Standards.

This first annual report consists of two volumes: Volume 1 - Executive Summary and Volume 2 - Detailed Report. It covers the period from July 2, 1976, through September 30, 1977.

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# INTRODUCTION

Battelle's Columbus Laboratories has contracted (Contract No. 68-02-2163) with the Industrial Environmental Research Laboratory, (Research Triangle Park [IERL/RTP], North Carolina) of the U.S. Environmental Protection Agency (EPA) to perform an environmental assessment of coal cleaning processes. The broad objective of Battelle's program with EPA is to perform a comprehensive assessment of the environmental pollution which results from transportation, storage, cleaning (physical and chemical), and refuse disposal of coal. In addition, combined techniques to achieve environmental goals, such as coal cleaning combined with stack-gas scrubbing to reduce the pollution potential of coal-fired power plants, will also be assessed. Increased use of both physical and chemical coal cleaning techniques for the removal of sulfur and ash-forming constituents is extremely important in an era of growing dependence on coal as a major domestic source of energy. The advantage of coal cleaning processes is the removing of portions of sulfur, ash, and a variety of other unwanted materials from the raw coal prior to any oxidation or reduction reactions.

In order to optimize the overall control of emissions from plants that use coal, it is necessary to assess the pollution potential of coal cleaning processes, allied operations, and in certain cases the end uses of coal. This optimization process will also include an economic evaluation of the benefits derived from coal cleaning, e.g., reduced cost of ash transportation, simplified boiler design, less boiler downtime, increased boiler capacity, smaller dust collectors and ash-disposal systems, and reduced costs for $SO_2$ control.

The broad goals of this program are to establish a strong base of engineering, ecological, pollution control, and cost data which can be used to determine which coal cleaning processes are most acceptable from both an environmental and economic viewpoint. This information could be used also to identify needs for the development of pollution control technology.

The program is organized into three major task categories: (1) system studies, (2) data acquisition, and (3) general program support. The program is further divided into subtasks which correspond to technical directives received from the EPA Project Officer.

The following substasks were active during the year and were designated by the three-digit numbers as indicated.

Systems Studies

- Technology Overview (211)
- Detailed Process Descriptions (222)
- Process Data Acquisition (232)
- Develop Assessment Criteria (241)

Data Acquisition

- Develop Environmental Test Program (411)
- Select Evaluation Sites (421)
- Develop Experimental Techniques (431)
- Test Plan Development (451)

General Program Support

- Coal Cleaning Demo Planning (813)
- Coal Cleaning Information Center (821)
- OECD Support (831)
- US-USSR Information Exchange (841)
- Evaluation of Physical Coal Cleaning as an $SO_2$ Emission Control Strategy (851)

The activities for these various subtasks are described in sections of the two volumes, "Executive Summary" and "Detailed Report", as indicated by Table 1.

In addition to completion of the ongoing tasks listed above, future activities in the remaining 21 months of the contract are planned for the following subtasks. These efforts are briefly described in the Future Efforts chapter of this report.

Systems Studies

- Pollution Control Trade-Off Studies (251)
- New Control Technologies (271)
- Revised Process Descriptions and Impact Assessments (281)
- Revised Technology Overviews (291)

TABLE 1. RELATIONSHIP OF ORGANIZATION OF BATTELLE'S PROGRAM FOR ENVIRONMENTAL ASSESSMENT OF COAL CLEANING TO EACD* ANNUAL REPORT CATEGORIES

| Category in Management Summary and Detailed Report | Subtask Number** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Systems Studies | | | Data Acquisition | | | | General Program Support | | | | |
| | 211 | 222 | 241 | 411 | 421 | 431 | 451 | 813 | 821 | 831 | 841 | 851 |
| **Current Process Technology Background** | | | | | | | | | | | | |
| Process Information | x | | | | | | | | | | | |
| Status | x | x | | | | | | | | | | |
| Schedules | x | | | | | | | | | | | |
| Priorities for Further Studies | x | | | | | | | | | | | |
| **Current Environmental Background** | | | | | | | | | | | | |
| Potential Pollutants and Impacts in All Media | x | x | x | | | | | | | | | |
| Federal and State Standards and Criteria | | | x | | | | | | | | | |
| Other Regulatory Requirements | | | x | | | | | | | | | |
| Occupational Health/ Epidemiological Data | | | x | | | | | | | | | |
| Dose/Response Data | | | x | | | | | | | | | |
| Transport Models | | | x | | | | | | | | | |
| **Environmental Objectives Development** | | | | | | | | | | | | |
| Establishment of Permissible Media Concentrations | | | x | | | | | | | | | |
| Define Emission Goals | | | x | | | | | | | | | |
| Non-Pollutant Impact Goals | | | x | | | | | | | | | |
| Bioassay Criteria | | | x | | | | | | | | | |
| Decision Criteria for Prioritizing Pollutants | | | x | | | | | | | | | |
| Methodologies Being Developed | | | x | | | | | | | | | |
| Source Analysis Models | | | x | | | | | | | | | |
| **Environmental Data Acquisition** | | | | | | | | | | | | |
| Existing Data for Each Process | x | | | | | | | | | | | |
| Sampling and Analytical Techniques | | | | | | x | | | | | | |
| Test Program Development | | | | x | x | | x | | | | | |
| Preoperational Environmental Monitoring | | | | | | | | x | | | | |
| MEG Pollutant List and Recommended Additions for Consideration | | | x | | | | | | | | | |
| **Control Technology Assessment** | | | | | | | | | | | | |
| Control Systems and Disposal Option Information | | x | | | | | | | | | | |
| Control Process Pollution and Impacts | | x | | | | | | | | | | |
| **Control Technology Development Status** | | | | | | | | | | | | |
| (no activity) | | | | | | | | | | | | |
| **Environmental Alternatives Analysis** | | | | | | | | | | | | |
| Pollutant Ranking | | | x | | | | | | | | | |
| Modification of Computer Models for Evaluating Process Technology | | x | | | | | | x | | | | |
| **Technology Transfer** | | | | | | | | | | | | |
| Newsletter Status Reports | | | | | | | | | x | | | |
| Information Centers | | | | | | | | | x | | | |
| Other Reports Issued | | | | | | | | | | x | x | x |

* EPA Energy Assessment and Control Division, Research Triangle Park, North Carolina.

** Task 232 is utilized for input to Task 222 and, thus, is not reported separately.

Data Acquisition

- Test Support Development (441)
- Testing (461)
- Data Reporting (471)

General Program Support

(as authorized by EPA).

## CURRENT PROCESS TECHNOLOGY BACKGROUND

A technology overview study has been performed to review the objectives and U.S. methods for coal cleaning process technologies and related environmental control. A technology overview report*, based on this study, provides a background against which the requirements can be established for development of coal cleaning technology and the control of the associated pollutants evolved from these processes and related activities. Also, the physical and chemical properties of coal important to coal preparation have been described, and the pertinent literature on washability of many U.S. coals compiled.

### Process Information

Coal preparation processes can be considered as encompassing all activities between the mining of coal and the end use of cleaned coal. These activities include coal sizing, cleaning, transportation, storage, and refuse disposal.

The principal coal cleaning processes used today are oriented toward product standardization and ash reduction, with increased attention being given to sulfur reduction. Coal preparation in commercial practice is currently limited to physical processes. In a modern coal cleaning plant, the coal is typically subjected to (1) size reduction and screening, (2) separation of coal from its impurities, and (3) dewatering and drying.

In a modern coal cleaning plant, the crushed coal is often divided into coarse, intermediate, and fine sizes; and separation of ash and pyrite from the coal is then accomplished with a variety of devices for the

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* Min, S., Tolle, D. A., Holoman, V. L., Grotta, H., and Minshall, C. W., "Technology Overview of Coal Cleaning Processes and Environmental Controls", Review Draft Report (unpublished) to the U.S. Environmental Protection Agency, Contract No. 68-02-2163, Battelle Memorial Institute, January, 1977.

three individual size groupings. In coarse coal circuits, the coal is cleaned with one or a combination of gravity separation equipment such as jigs, launders, or heavy-medium vessels. The intermediate-size coals are usually cleaned with concentration tables or heavy-medium cyclones. In cleaning of fine-size coal, froth flotation or hydrocyclones are often employed. Following the wet cleaning process, the product requires dewatering or complete drying depending on the ultimate use and transportation systems being utilized.

As a result of stream pollution regulations and the coal industry's desire to improve fine coal recovery, recirculation and treatment of wash water are integral parts of the operation of a modern coal cleaning plant. In particular, closed water circuits have grown in popularity because they eliminate discharge to streams, reduce make-up water, and allow for recovery of coal. Since closing the circuit results in the build-up of slimes, it is necessary to remove a certain portion of these fine solids. Standard equipment generally applied in a closed water circuit consists of thickeners, cyclones, filters, and/or solid bowl centrifuges.

The disposal of coal cleaning plant waste is a worldwide problem of increasing magnitude. Coal refuse consists of waste coal, slate, carbonaceous and pyritic shales, and clay associated with a coal seam. It is estimated that about 25 percent of the raw coal mined is disposed as waste. Coal refuse disposal involves two quite separate and distinct materials--a coarse refuse (+28 mesh) and a fine refuse (-28 mesh). The coarse refuse is normally disposed in an embankment by dumping either from an aerial tramway or from trucks. The fine refuse is normally removed from the preparation plant water circuit as a thickener underflow and impounded into nearby settling ponds.

Transportation of coal from the mines or preparation plants to the point of consumption is one of the most important factors affecting coal utilization because transportation costs frequently account for between one-third and one-half of the delivered price of coal.

In conjunction with transportation and storage of coal, a wide variety of materials handling operations is needed. These include loading and unloading, stacking and reclaiming, and transferring coal in a plant. As the amounts of coal to be handled have grown, the material handling systems have become more mechanized and equipped with more automatic and integrated control devices.

## Schedules

More than 450 commercial, physical coal cleaning plants are in operation in the United States, primarily for reducing the ash content of coals. An advanced concept, multi-stream coal cleaning (MSCC) plant is being constructed at Homer City, Pennsylvania. It is the first commercial plant using physical coal cleaning as a means of complying with $SO_2$ power plant emission standards. In the interim configuration since mid-summer of 1977, this plant is operating at a capacity of 900 T/hr of ROM coal; the clean coal product is being used in existing utility boilers to meet an $SO_2$ emission requirement of 4.0 lb $SO_2$/million Btu. In the final configuration, this plant will operate at a capacity of 1200 T/hr of ROM coal. The deep-cleaned coal product will be used in a new boiler to meet an $SO_2$ emission regulation of 1.2 lb $SO_2$/million Btu; the middling coal product will then be used for the existing units.

Chemical coal cleaning is an emerging technology. The most advanced process is exemplified by a pilot plant of the Meyers process built by TRW and funded by EPA. The facility processes up to 8 metric tons per day. Initial operation began in July, 1977.

## Status

### Conventional Physical Coal Cleaning

Physical coal cleaning is a proven technology for upgrading raw coal by physical removal of associated impurities. There are over 450 physical coal cleaning plants located in the U.S. which handle over 400 million tons of raw coal per year. The commercial practice of coal cleaning is currently limited to the gravity methods together with minor application of the froth flotation methods. Jigging still handles the largest portion of coal cleaning, but dense-medium processes and concentrating tables are becoming more popular; froth flotation is starting to play an important role.

Sulfur reduction by physical cleaning varies widely. Physical cleaning is capable of removing, on the average, about 50 percent of the pyritic sulfur and 30 percent of total sulfur. The result depends on the washability of coal, unit processes employed, and separating density.

In order to provide a systematic assessment of environmental impacts, coal preparation has been classified into four levels according to the coal sized being washed. The coal preparation plants are then categorized into nine generic types based on coal cleaning processes employed. These levels of preparation and types of plants are summarized in Table 1.

## New Physical Coal Cleaning Processes

Physical cleaning of coal in current practice can remove only a portion of the pyritic sulfur content. The percentage that is removed by any given technique depends, not only on the technique, but also on the size and distribution of pyrite grains within the coal. In some cases, where the pyrite exists in large relatively discrete crystals, a high degree of separation is easily obtained. On the other hand, if the pyrite consists of small grains mixed intimately through the coal matrix, separation by physical means can be extremely difficult.

A number of new techniques for physical coal cleaning have been investigated to improve the separation of pyritic sulfur from fine coals. Among them are magnetic separation, two-stage froth flotation, oil agglomeration, heavy liquid separation, and chemical comminution. These processes are only in the experimental stage and need considerably more work to determine their full potential.

## Priorities for Further Studies

Increasing demand for coal as a primary energy source combined with the stringent regulations for sulfur dioxide emissions from coal combustion results in increased pressure to expand coal preparation operations. There are still, however, many technical and/or economic uncertainties which must be overcome before more extensive commercialization of coal cleaning as a method of $SO_2$ emission control can be realized. Major areas which require additional research, development, and demonstration activities are as follows:

(1) Development of improved techniques for accurately predicting the cleanability of raw coals

TABLE 2. GENERIC TYPES OF COAL PREPARATION PLANTS

| Level | Plant Type | Coal Size and Unit Operation: Coarse (3 x 3/8 in.) | Medium (3/8 in x 28 M) | Fine (28 M x 0) |
|---|---|---|---|---|
| 1 | A | CS | | |
| 2 | B | CS + J/DMV + MD | | |
| 3 | C | CS + J/DMV + MD | ← AT → | |
| 3 | D | CS + J/DMV + MD | ← WT + MD → | |
| 3 | E | CS + J/DMV + MD | ← DMC + MD → | |
| 4 | F | CS + J/DMV + MD | WT + MD | HC + MD + TD |
| 4 | G | CS + J/DMV + MD | WT + MD | F + MD + TD |
| 4 | H | CS + J/DMV + MD | DMC + MD | HC + MD + TD |
| 4 | I | CS + J/DMV + MD | DMC + MD | F + MD + TD |

Legend:

Level 1 - Crushing and Sizing
Level 2 - Coarse Size Coal Beneficiation
Level 3 - Medium Size Coal Beneficiation
Level 4 - Fine Size Coal Beneficiation
CS - Crushing and Sizing Devices
J - Jigs
DMV - Dense-Medium Vessels
DMC - Dense-Medium Cyclones
AT - Air Tables
WT - Wet Concentrating Tables
HC - Hydrocyclones
F - Froth Flotation Units
MD - Mechanical Dewatering Devices
TD - Thermal Dryers

(2) Development of improved techniques for quality control of coal cleaning processes to produce cleaned coal of consistent sulfur content

(3) Development of improved and economical techniques for liberating and removing fine-size pyrite

(4) Development of improved and economical techniques for dewatering and drying fine coal

(5) Development of commercially viable techniques for removal of organic sulfur

(6) Development of improved methods and expanded capacity for coal transportation

(7) More complete determination of the environmental impacts and economic costs of coal cleaning.

## CURRENT REGULATORY/ENVIRONMENTAL BACKGROUND

### Standards and Criteria

Federal laws constituting the principal regulatory authority for emissions from coal cleaning, transportation, storage, and handling, are:

- Clean Air Act Amendments of 1970 and 1977
- Federal Water Pollution Control Act Amendments of 1972.

The major Federal regulations which are applicable to coal activities as related to environmental pollution are concerned with air and water pollution control. In addition, health standards for the workplace environment have been promulgated to regulate exposure to various airborne contaminants. Solid wastes generated from coal preparation are generally subject to land disposal. Federal guidelines for land disposal of solid wastes, accepted or excluded, are nonspecific in terms of definite quantities which can or cannot be disposed. Pursuant to Section 211 of the amended Solid Waste Disposal Act, the guidelines are mandatory for Federal agencies and are recommended to state, interstate, regional, and local governmental agencies for use in their solid waste disposal activities. Other regulations pertaining to solid waste disposal are the Federal Water Pollution Control Act, the Comprehensive Resource Conservation and Recovery Act (RCRA) of 1976 (P.L. 94-580), and regulations for the disposal of waste from coal preparation and handling operations on the surface of land associated with underground mining established by the Geological Survey of the U.S. Department of the Interior.

### Air Pollution Regulations

The Clean Air Act Amendments of 1977, enacted August 7, 1977, have significantly modified the Clean Air Act Amendments of 1970, as amended June, 1974; some of these modifications will interact with coal cleaning.

One of the most important is the amendment of Section 111, covering new source standards of performance. From the previous basis of an absolute limitation on criteria pollutants (e.g., 1.2 lb $SO_2/10^6$ Btu) for fossil-fuel-fired stationary sources, the amendment regulates a combination of a maximum emission limitation and a percentage reduction in emissions from the level which would have resulted from the use of fuels not subject to treatment prior to combustion. Any cleaning of the fuel after extraction and prior to combustion may be credited toward compliance with the above standards of performance.

The actual values to be achieved have not yet been specified and are currently under consideration to evaluate technical and economic constraints. There are indications that the percentage reduction of sulfur may fall in the range of a 90 percent reduction, paired with a 0.2 lb $SO_2/10^6$ Btu minimum and a 1.2 lb $SO_2/10^6$ Btu maximum emission limitation. Although reductions in allowable emissions of $NO_x$ and particulates are also probable, these should have only a minor impact on the cleaning of coal. The revised standards of performance are to be promulgated in the fall of 1978.

The atmospheric emission of several potentially hazardous air pollutants found in coal (beryllium and mercury) is already regulated. The establishment of regulations governing arsenic emissions is now under consideration, with a decision anticipated early in 1978. Other hazardous pollutants under consideration include polycyclic organic matter (POM) and lead, with uncertain decision dates.

Depending somewhat upon the $SO_2$ regulations finally promulgated, these amendments are likely to influence significantly the role of coal cleaning in the utilization of coal. They may preclude the sole use of cleaning as a method of compliance with federal $SO_2$ emission regulations. In other instances, such as non-attainment areas, combinations of cleaning and stack gas scrubbing both may be required to meet severe emission limitations.

*Water Pollution Regulations*

There have been no major new Federal acts affecting water pollution since the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). New regulations have, however, been proposed under this Act which will affect coal cleaning plants. Recently proposed new source performance

standards would permit discharge of process wastewater from coal cleaning plants which recycle waste water.

The establishment of effluent limitations for approximately 129 toxic pollutants is under investigation; most of these are organic compounds which would not be present at significant concentrations in effluents from coal cleaning plants. Similarly, nearly 100 toxic substances are being evaluated relative to the establishment of Federal water quality criteria. If any of these are adopted they would affect primarily state regulations. This program is not yet sufficiently advanced to predict the nature and extent of impacts upon coal cleaning.

## Solid Waste Disposal Regulations

A number of the components of the Resource Conservation and Recovery Act of 1976 (RCRA) will affect coal cleaning operations, in ways not yet determinable, since several years will be required to fully implement the provisions of the Act. Like its predecessor, the Solid Waste Disposal Act, RCRA will leave the promulgation of governing regulations and their enforcement to the individual states; there will not be specific Federal limitations. The Federal role is to consist of financial and technical assistance and leadership in the development, demonstration, and application of new and improved methods of waste management.

Section 8002 of the Act calls for a detailed and comprehensive study on solid wastes from active and abandoned surface and underground mines, the scope of which will presumably include coal preparation. The report of the study (no publication date is specified) shall include recommendations for Federal and non-Federal actions concerning environmental effects. The findings of this study may influence disposal procedures for coal refuse.

## Potential Pollutants and Impacts to the Environment

### Potential Pollutants

Many different pollutants have been identified as being associated with raw coal or with some segment of the coal industry. Over 800 compounds have been identified from the coking of coal (an oxygen-deficient regime). A number of lists from various sources, containing hundreds of elements and compounds, have been compiled. However, the original investigations were performed by different investigators, so that there are major differences in the manner and format in which the results were presented. In some cases, the approach was mineralogical; individual minerals and classes were identified. In others, where wet chemical analyses were performed, results were variously reported as oxides or in some other analytical convention, or, often, on an elemental basis. Trace element analysis results, by either emission spectrography or by spark source mass spectrography (SSMS), are reported as the element, giving no indication of the chemical form(s) present.

Examination of this basic problem led to the conclusion that the list of pollutant boundaries for this study had to be narrowed to eliminate pollutants which result from coking-type reactions. Most of the selected compounds will be present in minute quantities, in gases from oxidizing combustion, such as is encountered in thermal coal dryers or in coal-fired power plants.

The pollutants associated with the cleaning of coal are primarily inorganic compounds associated with the ash fraction. Water will be the principal receptor of these pollutants. Largest air emissions will include fugitive dust from coal handling and transfers, and particulates and combustion products from coal dryers.

For the first phase, a list of 75 substances was chosen from among those which already have been identified as pollutants of concern and whose presence in finite concentrations in coal cleaning processes is known or suspected. The Priority I pollutants for this study were drawn from a number of sources, including:

- EPA criteria pollutants for air
- Pollutants identified by effluent guidelines for

coal mining and coal preparation

- Substances included in EPA "Quality Criteria for Water"
- Toxic and hazardous pollutants listed by EPA which may be associated with coal cleaning.

In addition to these specific pollutants, a number of more general non-chemical pollutants and aggregated pollutant parameters were included in the list. The proposed list, shown in Table 3, includes 49 elements and 23 chemical substances or aggregated pollutant parameters. Substances on the list were chosen as a function of priority on a number of factors, including their recognition by EPA as pollutants to be regulated, their elemental group, their abundance in coal, and the availability of information on toxicity, abundance, fractionation factors, etc. Existing and proposed standards and criteria, judged to have application to coal cleaning processes are indicated on Table 3.

Although the Priority I list satisfies the requirement of a manageable list containing the important pollutants expected from coal cleaning processes, there appeared to be a need for an even more abbreviated list suitable for preliminary testing of some of the concepts and approaches to environmental assessment. To meet this need, an abbreviated "short list" has been proposed, which includes the following chemical pollutants:

| | |
|---|---|
| Arsenic | Manganese |
| Beryllium | Selenium |
| Cadmium | Sulfate sulfur |
| Iron | Sulfur dioxide |
| Mercury | Nitrate nitrogen |
| Lead | Nitrogen oxides |

This list, which includes both air and water pollutants, will be used to evaluate chemical and physical transport models, as well as estimated emissions and permissible concentrations.

Future work will include the selection of a list of Priority II pollutants. Analysis of these Priority II pollutants probably will result in the upgrading of a few to the Priority I group, with the rest assigned to a category of less important pollutants.

TABLE 3. PROPOSED PRIORITY I POLLUTANTS FOR COAL CLEANING PROCESSES

| Elements | Specific Pollutant Limitations** A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| Aluminum | | | | | | | |
| Antimony | | X | | | | | |
| Arsenic | | X | | | X | | X |
| Barium | | X | | | X | | X |
| Beryllium | | | X | | | | X |
| Boron | | X | | | | | X |
| Bromine | | X | | | | | |
| Cadmium | | | | | X | X | X |
| Calcium | | X | | | | | |
| Carbon | | | | | | | |
| Cerium | | | | | | | |
| Cesium | | | | | | | |
| Chlorine | | X | | | | | X |
| Chromium | | X* | | | X | | X |
| Cobalt | | X* | | | | | |
| Copper | | X* | | | | | X |
| Fluorine | | X | | | | | |
| Gallium | | | | | | | |
| Germanium | | | | | | | |
| Indium | | | | | | | |
| Iodine | | X | | | | | |
| Iron | | | | | X | | X |
| Lanthanum | | | | | | | |
| Lead | | | | | X | | X |
| Lithium | | | | | | | |
| Magnesium | | | | | | | |
| Manganese | | X | | | X | | X |
| Mercury | | | X | | X | X | X |
| Molybdenum | | X | | | | | |
| Nickel | | X | | | | | X |
| Niobium | | | | | | | |
| Nitrogen | | | | | | | |
| Oxygen | | | | | | | |
| Phosphorus | | | | | | | X |
| Potassium | | | | | | | |
| Rubidium | | | | | | | |
| Selenium | | | | | X | | X |
| Silicon | | | | | | | |
| Sodium | | | | | | | |
| Strontium | | | | | | | |
| Sulfur | | | | | | | |
| Tellurium | | X | | | | | |
| Thorium | | | | | | | |
| Tin | | | | | | | |
| Titanium | | X | | | | | |
| Uranium | | X | | | | | |
| Vanadium | | X | | | | | |
| Zinc | | X | | | X | | X |
| Zirconium | | X | | | | | |

| Groupings | Specific Pollutant Limitations** A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| Alkalinity | | | | | | | X |
| Ammonia | | X | | | | | X |
| Cyanide | | X | | | X | X | X |
| Chlorides | | | | | X | | |
| Nitrates | | | | | X | | X |
| Sulfides | | | | | | | |
| Sulfates | | | | | X | | |
| $SO_x$ | X | X | | | | | |
| $NO_x$ | X | X | | | | | |
| Total Suspended Solids (TSS) | | | | | | | |
| Total Dissolved Solids (TDS) | | | | | X | | |
| Chemical Oxygen Demand | | | | | | | |
| Total Suspended Particulates (TSP) | X | | | X | | | |
| Carbon Dioxide | | X | | | | | |
| Carbon Monoxide | X | X | | | | | |
| Hydrocarbons | X | | | | | | |
| Photochemical Oxidants | X | | | | | | |
| Oil and Grease | | | | | | | X |
| Phenols | | X | | | X | | X |
| Organic Sulfur Compounds | | | | | | | |
| Organic Nitrogen Compounds | | | | | | | |
| Polycyclic Organic Materials (POM's) | | | | | | | |
| Carbon Chloroform Extract (CCE) | | | | | X | | |

* Column headings are defined as follows:
- A. National Primary and Secondary Ambient Air Quality Standards
- B. OSHA Standards for Workroom Air Contaminants
- C. National Emission Standards for Hazardous Air Pollutants
- D. New Stationary Source Performance Standards (Coal Preparation Plants)
- E. Drinking Water Regulations (EPA and PHS)
- F. EPA Toxic Pollutant Effluent Standards (Proposed)
- G. EPA Water Quality Criteria (Proposed-not regulations)

** Metal fume standard.

## Estimation of Emission Concentrations

Determination of the amounts of the Priority I substances in the coal and their distribution through the coal cleaning and utilization processes is a key component of the environmental assessment. In order to evaluate the effect of coal cleaning on removal of potentially harmful major and trace elements in coal, it is necessary to determine the distribution of these elements in raw coal, cleaned coal, refuse, and waste discharges. These fractionation factors are estimated from experimental data and from theoretical approaches. Using estimated material balances and a simple computer model, several exploratory simulations have been performed. This work is to be continued and expanded as more and better data become available. These values of emission concentrations are required as input to dispersion models to permit the calculation of ground level concentrations (GLC) for air pollutants and surface water concentrations for water pollutants.

## Impacts to the Environment

Pollutants from coal cleaning processes are released as airborne gases and particulates, waterborne ions and compounds (including dissolved and suspended substances), and elements and compounds associated with solid refuse piles. The ecological impacts of these pollutants are broken down in the following review according to their effects on human health, aquatic biota, terrestrial biota, and entire ecosystems.

Human Health. Many pollutants associated with coal cleaning and burning are known to be toxic to humans. Air pollutants, probably the greatest health hazard, are known in addition to their primary direct toxic effects, to cause secondary effects by aggravating existing disease conditions. However, the quantity of certain pollutants, such as metals, and metal compounds, may also be of great concern in the water effluents, due to the potential for leaching these toxic trace elements from coal refuse and storage piles.

In assessing the potential health impacts of toxic pollutants, occupational health and epidemiological data were summarized in the form of threshold limit values (TLV's) relevant to the major and minor elements

found in coal and coal ash. The TLV's were used in the calculation of estimated permissible air concentrations, since they are one of the best sources of toxicologic data for humans in regard to industrial pollutants in the air. The TLV's have been developed by the American Conference of Governmental Industrial Hygienists and are based on animal toxicology data and on measured effects produced on humans working in a specific atmosphere. No attempt has been made to summarize any other industry-related health or epidemiological literature.

TLV's were found for only 37 of the 80 elements known to occur in coal and coal ash. These values permitted the calculation of estimated permissible concentrations (EPC's) in air for those 37 elements.

Aquatic Biota. Of the wide variety of toxic chemicals that are known to be associated with coal and coal preparation activities, the metals are of great environmental significance. Metals are often introduced into aquatic ecosystems as byproducts of acid mine drainage residues. Metals are highly toxic to aquatic organisms, especially fish, and some are highly bioaccumulative. The drainage of acid waters from coal storage and refuse piles poses a serious threat to the aquatic environment because of the ensuing change in pH. Overall, the effects of acid drainage on aquatic communities include a reduction in diversity and density of organisms and a dominance by pollution-tolerant organisms. Suspended solids can affect aquatic biota by several mechanisms, e.g., blanketing and abrasive action. These environmental effects can severely affect aquatic biota by endangering the integrity of community structure through alterations of the food chain.

Terrestrial Biota. Air pollutants which stress vegetation can cause reduced growth or death. Pathways of the coal cleaning associated pollutants to terrestrial animals include:

(1) Inhalation of gases, aerosols, and particulates
(2) Ingestion of contaminated water
(3) Ingestion of vegetation covered with particulates and/or vegetation which has absorbed pollutants from the soil
(4) Ingestion of contaminated animals
(5) Absorption of pollutants through the eyes or skin

Effects of these toxic trace elements include organ system injury, carcinogenicity, genetic and neonatal toxicity, and immunological injury. However, caution must be used in assessing the effects of pollutants on terrestrial animals, since much of the available information on effects involves the investigation of single pollutant effects on laboratory animals. Much more research is needed on the synergistic (or antagonistic) effects of the combination of pollutants released from coal cleaning and burning on terrestrial animals.

Ecosystems. Ecosystems are the basic fundamental units of "nature" in which the organisms and nonliving environment are interrelated. These dynamic units may be conceived and studied in a variety of sizes, such as a small pond, a large lake, or a tract of forest. Generally, the larger and more diverse ecosystems are more stable and more independent of adjacent systems.

Pollutants emitted from coal cleaning processes can both accumulate and disperse, in both a physical and a biological sense, depending upon the characteristics of the pollutant and the environmental compartment. Activity was initiated recently to develop simplified models for both the physical and biological transport of key pollutants. Models for physical transport will apply to air, water, and porous media (soils and geologic formations).

Literature is currently being searched for specific data on the physical and biological transport of the key pollutants. Simplified model runs using estimated emission concentrations for the key pollutants from hypothetical Type B and Type I coal cleaning plants will be performed. This output will assist in the interpretation of environmental impact of such facilities and serve as trial runs for later, more extensive analysis.

## Dose/Response

Dose/response data for use in calculating estimated permissible water concentrations (EPC for water) were obtained from the National Institute for Occupational Safety and Health (NIOSH) registry. In order to calculate the EPC for water using the formula developed by Handy and Schindler*, it was necessary to know either the $LD_{50}$** and $LD_{LO}$*** value for oral ingestion of a given pollutant by rats. However, these oral values were available for only 3 of the 80 elements (antimony, cobalt, and indium) known to occur in coal or coal ash which were reviewed to calculate permissible air concentrations. If an EPC is desired for all of the potential pollutants from coal cleaning processes, formulae for calculation of an EPC must be modified to use other types of dose/response data. However, for several pollutants known to occur in coal there are no dose/response data in the NIOSH registry. In these cases, the dose/response value for such an element can only be approximated by extrapolation from known values for elements with similar chemical behavior.

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* Handy, R. and Schindler, A., "Estimation of Permissible Concentrations of Pollutants for Continuous Exposure", EPA-600/2-76-155, U.S. EPA, IERL, Research Triangle Park, North Carolina (June 1976), 136 pp.

** $LD_{50}$ - Lethal Dose Fifty. The calculated dose of a pollutant which can be expected to cause the death of 50 percent of an experimental animal species population by any route other than inhalation.

*** $LD_{LO}$ - Lethal Dose Low. The lowest dose of a pollutant, other than $LD_{50}$, reported to have caused the death of humans or animals by any route other than inhalation over any time period and by any number of individual portions.

## ENVIRONMENTAL OBJECTIVES DEVELOPMENT

Establishment of permissible media concentrations of pollutants is needed for pollution control development guidance, e.g., for setting pollutant emission goals. Pollutant emission goals can, of course, be set on the basis of best practicable technology, but from a health/ecological viewpoint, such standards have the potential of being either too lax or unnecessarily restrictive.

In view of the state-of-the-art, the permissible media concentrations are designated as "estimated permissible concentrations" (EPC's), and they are regarded only as estimates, subject to later revision as more data become available. The establishment of EPC's is recognized as a critical area central to the entire environmental assessment. Unfortunately, there is no accepted method for setting EPC's. A number of approaches have been suggested, based on various manipulations of TLV, $LD_{50}$, $LD_{LO}$ values, etc. Many of the original experimental data are in a form not directly usable, and methods for interconversion and extrapolation are lacking.

Since a multimedia approach is being taken to the environmental assessment of coal cleaning, estimated permissible concentrations are needed for all three media--air, water, and land--and these will be integral parts of the multimedia environmental goals (MEG's), which are to be established. EPC's are especially germane for the air and water media, which man and biota utilize directly. Because of the heterogenous nature of soils, and the fact that, normally, there must be at least one transfer before a soil pollutant impacts man, determination of EPC's for soil proves to be a difficult task.

## Bioassay Criteria

Quantitative toxicological data (e.g. $LD_{50}$, TLV, and others) form the basis for estimating permissible concentrations in air and water media for individual substances. However, these data do not provide a basis for accounting for synergistic and antagonistic interactions between pollutants in complex mixtures, such as are encountered in effluents from coal cleaning and other energy processes. To better evaluate the characteristics of such complex mixtures, a new bioassay protocol is being developed by Battelle through the EPA/IERL Fluidized Bed Combustion Program (Contract No. 68-02-2138). This protocol may be used to assess the relative toxicity of an effluent by some combination of nine biological tests. Three of the nine biological tests (microbial mutagenicity, cytotoxicity, and rodent acute toxicity) are designed to address potential human health effects. The other six biological tests for ecological toxicity assessment are as follows:

- freshwater algal assay
- acute static water bioassay
- unicellular marine algae bioassay
- marine animals static bioassay
- stress ethylene plant response assay
- soil-litter microcosm tests.

These tests provide a direct measure of toxicity and mutagenicity for which there are few available data. The procedures, when developed, will be utilized for the coal cleaning program to assess samples from test sites, and will also be considered in the development of estimated permissible environmental concentrations and emission goals.

## Methodologies Being Developed

There is a critical need for a sound and rigorous method for converting toxicological and epidemiological data to permissible environmental concentrations, which does not depend upon a number of arbitrary or unsupportable assumptions for such estimation. Battelle's Columbus Laboratories is attempting to advance the state-of-the-art by developing an improved

methodology. Achievement of the ultimate goal may be beyond the reach of the current program, but it is anticipated that significant progress will be made.

Two specific areas of achievement are (a) review of formulae for estimating permissible concentrations, and (b) development of rationale for extrapolation from animals to man and other organisms. Battelle has concluded that a formula qualifies as "best" when it is (a) simple, (b) appropriate for mixtures, (c) utilizes $LD_{50}$, TLV, or other quantitative toxicological measurements, (d) incorporates knowledge of target species, target organs and biological half-life, (e) considers chemical state of pollutant mixtures, and (f) has a supporting rationale for the use of safety or adjustment factors.

Attempting to extrapolate toxicity data from animals to man requires the development of a systematic approach backed up by research and testing. The available data encompass a wide variety of test animals and toxicant administration procedures, and methods are needed to interconvert these data and to extrapolate them to man. Review of the literature shows there are two basic methods for extrapolating toxicity responses from animals to man. In Method I, responses of various species untested by the same toxicant is projected with the relationship.

$$Y = aW^b,$$

Where

Y = a response

a = a constant (derived from regression of W, Y data)

W = organism's weight

b = a constant (derived from regression of W, Y data).

In Method II, one equation deals with responses of many different toxicants on one animal species; extrapolation proceeds from one animal species to another.

Battelle plans to use these approaches along with the "best" formulae to further develop estimated permissible concentrations of selected substances to humans, other organisms, and ecological systems around coal cleaning facilities.

## Source Analysis Models

The source analysis model (SAM) basically involves the utilization of normalized hazard factors determined by computing the ratio of concentration of a substance in a polluted stream to the goal concentration from the MEG analysis. This approach is being investigated by another contractor, and no work on it is being conducted at Battelle.

## ENVIRONMENTAL DATA ACQUISITION

### Existing Data for Each Process

Published environmental data from coal cleaning processes are essentially nonexistent. The following discussion briefly characterizes the kinds of data that are anticipated and the variations expected from physical and chemical cleaning.

#### Physical Coal Cleaning

Physical coal preparation has been classified into four levels according to the coal sizes at washing and categorized into nine generic types of plants based on coal cleaning processes employed as indicated in Table 2. Chemical coal cleaning processes constitute another type, but the technologies are still in the development and testing stages.

The nine physical cleaning plant types represent the majority of coal preparation facilities throughout the United States, and each type is expected to produce different environmental consequences of coal preparation although there are many similarities.

Thus, a spectrum of potential pollutants will yield a wide variety of kinds of environmental data. The most simple preparation plant consisting of only crushing and sizing will have solid waste consisting of coarse rock and tramp iron, air pollution of coal dust and dust from refuse piles, and water pollution from surface run-off around the facility. As washing or cleaning circuits are added, a quantity of contaminated process water is generated, containing acidity or alkalinity, suspended solids, dissolved solids, iron, ammonia, and sulfates. Sludge and coarse refuse represent additional solid waste. Processes employing dense media cyclones or other dense media treatments will result in a small amount of an additive, usually magnetite, being present in both the waste water and solid waste. Washing of fine coal results in a fine refuse addition to the solid waste.

Use of froth flotation introduces additional chemical reagents to both solid waste and waste waters; first, residual organic and inorganic reagents added deliberately to the flotation circuit, and second, the metal ions and complexes contributed to the aqueous phase due to dissolution by some of the flotation reagents. Cleaned fine coal, resulting from a wet process, must be dried. Thermal dryers normally take coal that has been partially dewatered by mechanical means and remove as much of the remaining water as may be required by a specific market. Emissions from thermal dryers include carbon monoxide, carbon dioxide, hydrocarbons, sulfur dioxide, and oxides of nitrogen, particulates, and fly ash.

## Chemical Coal Cleaning

The wastes from chemical coal cleaning have not been completely identified, but all processes produce coarse refuse from crushing and sizing as in the physical cleaning processes. Subsequent discussion relates specifically to the Meyers process, which is furthest along in development of the chemical cleaning processes.

The only positively identified air emission stream from a vent gas scrubber will be 90 percent oxygen and 10 percent sulfur dioxide plus volatile organic compounds. Solid wastes from the Meyers process include gypsum, elemental sulfur, and iron sulfates (mixed ferrous and ferric). Liquid wastes may include sulfuric acid, wetting agents, and agents to control foaming, depending upon the coal characteristics. It is probable that all of the sulfuric acid which is not recycled will be neutralized and disposed with solid waste. In the Meyers process, it may be necessary to add heat to emissions similar to those produced by thermal dryers, i.e., furnace combustion products.

## Sampling and Analytical Techniques

### Objectives

Applicable methods of sampling and analyses for the purpose of assessing the environmental effects of coal cleaning plants were developed in the following:

- Selection of sampling methods which are appropriate to anticipated pollutants from the various media
- Recommendation of accepted or new methods of preservation, storage, transfer, and preparation of samples for analyses
- Identification of analytical methods which possess the desired detection and sensitivity limits for the expected pollutants at the required levels of characterization
- Evaluation of the assessment strategy of the phased versus the direct approach in regard to convenience, cost, and utility
- Documentation of the overall desired or recommended procedures of sampling and analysis.

### Development of Experimental Techniques

The phased approach for determining the extent of pollution potential of a process is divided into three consecutive levels of effort. Level I is used as a survey tool to identify existing broad problems and to evaluate the possible adverse environmental effects of effluents. As such, representative sampling is not required and analytical results within a factor of ±2 or 3 are acceptable. Level II is an extensive qualitative, semiquantitative program that is intended to identify specific substances that exist in effluent streams thought to have significant environmental effects following Level I analysis. Level III is a quantitative study of the effects of process variables on the emission of specific substances which were identified by Level II analysis as causes of environmental effects.

An alternate to the phased strategy is the direct approach. This approach requires quantitative analyses of one set of representative samples. This is essentially a Level II procedure and assumes that prior knowledge

is available as to the nature of emissions of the technology being investigated. For environmental studies of coal cleaning facilities, Battelle recommends the direct approach with the assumption that it will be less costly to avoid repeated sampling trips to any one plant where process effluent streams are known in advance. The result is that samples may be taken at Level II intensity, screened at Level I, and followed up with Level II analysis as needed. Appropriate methods are planned for chemical analyses, including spark source mass spectrometry for inorganic elements in solids and liquids, gas chromatography for inorganic gases, and low molecular weight organic compounds, and gas chromatography, infrared spectroscopy, and gas mass spectrometry for higher molecular weight organic compounds after resolution for functional groups and typing by solvent separation.

## Test Development Program

A test program was developed to provide overall guidance for the field program, identify sources of coal cleaning pollutants, and select the ecological compartments to be evaluated for the environmental effects of those pollutants.

### Site Selection Procedure

The procedure for selecting test sites has been developed to permit the study of as many variables as possible with a limited number of field trips. The recommended selection scheme was obtained by applying a statistical rationale for sequential sampling.

Four variables were selected for study. These variables which are expected to have the greatest influence on the kinds of pollution controls needed for coal cleaning operations are neutralization potential (N), pyritic sulfur (S), annual precipitation (R), and process technology (T) (Table 4). Based on the low (0) and high (1) potential pollution levels for each of these variables, 16 types of site categories are possible.

The recommended sequential sampling design for the existing coal cleaning plant categories are shown in Table 5. One site from each site category is to be sampled in the sequence from 0 to 10, as shown in Column 2, with

TABLE 4. CLASSIFICATION VARIABLES AND ASSOCIATED LEVELS USED TO DEFINE SITE CATEGORIES

| Variable | Low Level (0) | High Level (1) |
|---|---|---|
| N (Neutralization potential) | pH $\geq$ 7.5* | pH $\leq$ 6.0* |
| S (Pyritic sulfur) | $\leq$ 1.0% | $\geq$ 3.0% |
| R (Average annual rainfall) | $\leq$ 15 in/yr | $\geq$ 25 in/yr |
| T (Coal cleaning process technology | Plant Types A and B≠ | Plant Types F through I≠ |

* pH of soil in the receiving environment. As defined, low level of N actually refers to a low pollution potential which is, in fact, a high ability to neutralize acid streams.

≠ See Table 2 in "Current Process Technology Background" for definitions of plant types.

TABLE 5. RECOMMENDED SEQUENTIAL SAMPLING DESIGN FOR COAL CLEANING PLANTS

| Group Number | Site Category (1) | Site Characteristics (N, S, R, T) (2)(3) | Geographic Regions (4) |
|---|---|---|---|
| 1 | 1 | (1111) | NA |
| | 2 | (1110) | NA |
| | 3 | (1011) | NA |
| | 4 | (0111) | MW |
| 2 | 5 | (1010) | NA |
| | 6 | (0110) | NA |
| | 7 | (0011) | MW, SA |
| | 8 | (0010) | MW, SA |
| 3 | 9 | (0001) | W |
| | 10 | (0000) | W |

(1) One site from each site category is to be sampled in the sequence from 1 through 10, with site category 1, defined as (1111), sampled first and site category 10, defined as (0000), sampled last. The sampling may be terminated after sampling 4 site categories (Option C), 8 site categories (Option B), or 10 site categories (Option A).

(2) See Table 4 for definitions of low (0) and high (1) levels for neutralization potential, N, pyritic sulfur, S, average annual rainfall, R, and coal cleaning process technology, T. The combination (1010), for example, denotes a site category with N and R at level 1 and S and T at level 0.

(3) Six additional possible site combinations (1101, 1100, 1001, 1000, 0101, 0100) were excluded from further consideration since no cleaning plants exist with this combination of variables.

(4) Geographic regions associated with the site categories are denoted by Northern Appalachian (NA), Southern Appalachian (SA), Midwestern (MW), and Western (W).

site category 1, defined at (1111), sampled first; and site category 10, defined as (0000), sampled last. The sampling may be terminated after sampling the first four site categories (Option C), after sampling the first eight site categories (Option B), or after sampling all ten site categories (Option A).

Once existing coal cleaning plants have been classified into these site categories, specific sites within each site category can be selected. The specific sites are intended to yield the maximum information concerning coal cleaning impacts upon environments from a given limited number of sites. Published information, telephone contact, and site visits will be used to provide information on candidate sites.

### Test Plan Development

To date, progress in test plan development has primarily involved selection of test components to the master test plan. Site-independent test elements have been developed for structural geology, water chemistry, air pollution measurement, air pollution modelling, aquatic and terrestrial biota, and noise measurement. These common elements are being integrated into a master test plan. Approximately 15 percent of the work on the master test plan is complete.

## Preoperational Environmental Monitoring

### A Site-Specific Analysis

A major environmental monitoring evaluation has been completed in a study area that included an advanced coal cleaning facility located 2 miles (3.2 km) southwest of Homer City, Pennsylvania. The physical coal cleaning facility is in the final stages of construction at the Homer City Power Station, jointly owned by Pennsylvania Electric Company (Penelec), a subsidiary of General Public Utilities Corporation (GPU), and New York State Electric and Gas Corporation (NYSEG). Nearly all of Battelle's environmental monitoring was conducted within a study area that can be approximately bounded by a circle 4 miles (6.4 km) in diameter with the new coal cleaning facility at the center.

During the period from December 1976 through April 1977, a series of multimedia, grab-sampling campaigns were conducted by Battelle throughout the study area. The intent of this monitoring was to document the abundance or concentrations of selected key parameters in order to evaluate the air, water, and biological quality in the vicinity of the advanced coal cleaning plant. These pre-operational environmental studies, while not sufficiently long-term to be a true baseline analysis, were conducted prior to operation of the cleaning plant as a reference point for future, and more comprehensive, environmental testing planned during operation of the plant.

Fugitive dust was monitored using high-volume samplers at locations verified by a multiple source fugitive dust dispersion model. This model is field-calibrated to the monitoring results and source conditions at the Homer City Station and is able to predict dispersion levels at various distances under a variety of meteorologic conditions.

Mass loadings of fugitive dust were highest in the vicinity of the coal storage pile, especially within 200 meters downwind. However, significant dust concentrations were measured as much as 1,200 meters downwind of the coal pile. At 2,000 meters downwind, which was off the Station property, the measured levels dropped to levels consistent with a good air quality index.

The main results of the fugitive dust chemical analysis revealed two important phenomena. First, there are uncombusted coal dusts 2,000 meters downwind of the coal cleaning plant that exhibit levels of lead, cadmium, arsenic, and mercury higher than those present in the whole-coal or disposed ash. Cadmium and lead values are several orders of magnitude higher than those in the whole-coal or disposed ash. Beryllium and vanadium were not found in the coal dusts but are quite evident in the source coals. Second, it appears that magnification of trace metal compounds may be attributed to the cleavage of the coal along planes where these metal compounds were concentrated. The particles released by fracturing along these planes evidently tend to become airborne due to wind erosion or movement of vehicles over the coal pile.

Water quality in each of the basins monitored is a direct reflection of the types of land uses involved. The five major land uses in the study area affecting stream water are: agriculture, mining, urban, construction, and

power generation. For example, water in Two Lick Creek, which receives acid mine drainage from abandoned strip mines upstream of the study area, is of poor physical and chemical quality. On the other hand, flows which exhibited water quality closest to that of the reference stream (i.e., the highest quality) were the headwater springs discharging to the tributaries north and south of the refuse disposal area and the west tributary to Wier's Run.

The stream sediments of the study area are heavily laden with metal compounds. These streams have a high level of oxygen and, were it not for the pH extremes and suspended solid levels, the streams could begin a rather rapid recovery. As expected in a coal region lithology, the streams had sufficiently high levels of various forms of iron, manganese, sulfur, and calcium to be of some concern.

The aquatic biota reconnaissance involved the sampling of three groups of organisms indicative of the streams' biological quality. These groups were attached algae, bottom-dwelling invertebrates, and fish. Sampling was conducted at 14 locations in eight streams.

The subjective analysis of water quality based on the aquatic biota observed was in close agreement with the water chemistry analysis. Three streams, the tributary to Cherry Run north of the refuse area, the west tributary of Wier's Run, and the upstream portion of the tributary south of the proposed refuse disposal area, were all considered to have good chemical and biological quality. Cherry Run was evaluated as having fair chemical and biological quality. The remaining streams, Wier's Run, the two revines draining the generating station, and the downstream portion of the tributary south of the refuse disposal area, were all considered to have poor chemical and biological quality.

The terrestrial habitats evaluated with a 2-mile (3.2-km) radius of the coal cleaning plant are quite diverse and support animals common to all successional stages, especially those wildlife species associated with the early successional vegetation. Very little wetland habitat exists, and the streams and ponds which do occur in the area are unsuitable for water birds. The observation of particulate matter covering vegetation and leaf litter within 1 mile (1.6 km) of the coal pile suggests that plant biota in that area may soon begin to show signs of stress.

In summary, the ambient environment in the study area appeared to be typical of many western Pennsylvania areas which include coal mining and

handling operations. In many cases, stream water chemistry and biological quality were adversely affected by pollution sources outside of the study area, especially by acid mine drainage. Power complex operations had a negative impact on the chemical and biological quality of a few of the smaller tributaries. Levels of particulates in the air were high in the vicinity of the coal storage pile, but dropped down to relatively good air quality levels off of the power station property. Terrestrial vegetation is presently diverse in the study area. Some of the more sensitive plant species close to the coal pile, however, may begin to show signs of stress due to the accumulation of coal dust and other particulates.

## CONTROL TECHNOLOGY ASSESSMENT

An assessment of pollution control technology for coal cleaning processes must consider control techniques for air pollution, water pollution, and solid waste.

### Air Pollution Control Technology

An evaluation was made of the various air pollution control technologies to determine their applicability for treating emissions from coal cleaning processes. Major factors considered in the evaluation of each control technology are performance, operational constraints and limitations, and costs. Based on this evaluation, cost estimates are given for most applicable control technologies for controlling major emissions for two different sizes of coal cleaning plants: 500 and 1000 tons per hour (tph).

Several types of air pollution control devices are available for application to coal cleaning operations. The choice of the control device depends on the type of pollutant, the properties of the pollutant, and the properties of the conveying medium. Particulate control devices may be broadly classified as dry inertial collectors (gravity settlers and cyclones), filters, wet scrubbers, and electrostatic precipitators. Control devices for the removal of gases or vapors involve adsorption or absorption in a variety of contacting devices.

#### Particulate Control Devices

Dry Inertial Collectors. Dry inertial collection systems utilize either gravitational or inertial forces to separate the particulates from the gas stream. The collection systems are characterized by moderate removal efficiencies,

low energy requirements, low capital and operating costs, and an ability to accommodate high inlet dust loadings and operate at high temperatures.

Cyclones, the most widely used inertial collectors, are chosen for their simplicity of design, ease of operation, and low maintenance, making them one of the more trouble-free particulate collectors available. The major disadvantage of cyclones is low collection efficiencies of minus 10 micron particles.

Fabric Filters. Fabric or bag filters are regarded as one of the simplest and most reliable high efficiency dry collector devices, being capable of 99.9 percent removal of submicron-size particles. They are suitable for a wide variety of dry particulate removal applications.

Electrostatic Precipitators. Due to the explosive nature of coal dust-air mixtures, electrostatic precipitators are not used in coal cleaning plants.

Wet Inertial Scrubbers. The major features that make wet collectors popular dust control devices are their high removal efficiencies, ability to remove gaseous pollutants, tolerance of moisture in the gas, and relatively low capital costs. A major disadvantage of wet collectors is high energy requirements.

The operating constraints and removal efficiencies for each of the different equipment types are outlined in Table 6. Based on the characteristics outlined for the three major emissions from coal cleaning unit operations, and the performance evaluation of the control equipment, those equipment types most appropriate as control equipment for each major emission are presented in Table 7.

## Gaseous Removal and/or Collection Devices

Gaseous removal and/or collection devices are designed to extract specific gaseous compounds from a carrier gas stream. Although not practiced to date, the major potential application for gaseous removal devices in coal cleaning operations is for the removal of $SO_2$ from thermal dryer off-gases. To this

TABLE 6. DUST COLLECTOR CHARACTERISTICS AND APPLICATION CHART

| Dust Collector | Particle Size | Dust Load | Operating Temperature, F | Operating Efficiency | Space Requirement | Remarks |
|---|---|---|---|---|---|---|
| Louver Settling Chamber | 30 microns and up | Medium to heavy | Up to 1,500 | 45% for 30 microns to 99% on flyash | Medium | No moving parts. Will handle heavy surge. Coarse sizes can cause excessive wear. Good as a scalping unit. |
| Low-efficiency Cyclone | 20 microns and up (200 mesh is ideal) | Light to heavy | Up to 1,500 | 75% on all plus 325 mesh | Needs considerable space. | Usually placed out of doors because of bulk. |
| High-efficiency Cyclone | 1 micron and up | Very light to very heavy | Up to 1,500 | 95% on plus 10 micron feed | Small and compact. | No moving parts. Best on plus 20 micron sizes. Good for classifying. |
| Wet Scrubbers (Spray tower and other scrubber types) | All | Light to heavy | Up to 1,500 | 80% in 1 to 10 micron range | Small and compact. | Can handle heavy dust loads. |
| Fabric Filters (unit frame, bag and reverse-jet types) | Minus 200 mesh | Light to medium | Cotton: 175 Wool: 225 Dacron: 275 Fiber-glass: 550 | Up to 100% in 10 micron range | Small to medium. | Excessive moisture will blind fabric. Good on fumes. |
| Venturi Scrubber | All | Light to heavy | Up to 1,500 | 99%+ in 1 to 10 micron range | Small and compact. | Requires large flow rate water supply, up to 1,000 cfm. |
| Electro-static Precipi-tator | Very fine | Light to medium | Up to 550 | 90 to 100 | Small to medium. | Most efficient system for handling extremely fine dust and fumes. Not suitable for use on explosive mixtures. |

TABLE 7. SUMMARY OF APPLICATIONS FOR PARTICULATE CONTROL EQUIPMENT

| Emission Source | Typical Characteristics of Dust | Appropriate Control |
|---|---|---|
| Crushing and Sizing Operations | Dry, submicron up to about 6 microns in size; light dust load, ambient temperature | Cloth filters or high-energy wet scrubbers |
| Pneumatic Cleaners | Dry, submicron up to 48 mesh in size, heavy dust load (>100 gr/dscf), ambient temperature | Primary cyclone-[a] cloth filter or primary cyclone-high-energy wet scrubber |
| Thermal Dryer | High humidity, submicron up to about 100 microns in size, heavy loadings up to 200 gr/dscf, temperature 200 to 250 F. | Primary cyclone-[a] high efficiency wet scrubber |

(a) Not considered as emission control equipment but rather as pneumatic cleaner or thermal drier process equipment utilized to recover coal.

end, two major types of gaseous removal processes, dry adsorption and wet absorption, can be considered for controlling sulfur dioxide emissions. Carbon adsorption is a high-initial-cost process which may be an acceptable technique for use in dry absorption systems. Common wet absorption systems make use of slurries of lime, limestone, or alkalis.

### Estimated Plant Costs - Air Pollution Control Equipment

Costs for air pollution control equipment are presented as installed capital costs and operating costs for various types of hypothetical 500 and 1000 tph coal cleaning plants with the following levels of coal treatment:

Crushing and Sizing Plant (Level 1)

Medium Size Coal Beneficiation Plant with Air Tables (Level 3)

Fine Size Coal Beneficiation Plant with Thermal Drying (Level 4)

The results of this preliminary analysis are presented in Table 8.

## Water Pollution Control Technology

Process and scrubbing water effluents from coal cleaning operations contain two types of pollutants: suspended materials (solid or liquid) and dissolved substances.

### Control of Suspended Materials

Suspended solids may be removed from liquid streams by mechanical dewatering methods, sedimentation, or flotation. Each of these methods produces a solid material which may be processed further in the coal cleaning plant in the case of a coal-rich material, or disposed of as solid waste.

Mechanical Dewatering. Mechanical dewatering devices applicable for removing solid materials from water include centrifuges and various kinds of filters.

The centrifuge has found application as a dewatering device for the land-destined thickener underflow. As a water treatment device, however, a centrifuge is useful for roughing purposes and would be followed by sedimentation, filtration, or some other finishing method.

TABLE 8. ESTIMATED COSTS OF AIR POLLUTION CONTROL EQUIPMENT FOR COAL CLEANING PLANTS

| Plant Type and Emission | Applicable Control Equipment | Installed Cost of Control Equipment, Dollars (1977)/tph | | Annual Operating Cost of Control Equipment,[a] cents/ton | |
|---|---|---|---|---|---|
| | | 500 tons/hr | 1000 tons/hr | 500 tons/hr | 1000 tons/hr |
| Type C,F,G,H, or I (Level 1): Dust from crushing and sizing operation | Dust enclosures with dry bag collectors | 52 | 36 | 0.2 | 0.1 |
| | Dust enclosures with high-efficiency wet scrubbers | 30 | 20 | 0.2 | 0.2 |
| Type C (Level 3): Air tables operating on medium-size coal | Primary cyclones followed by dry bag collectors | 400 | 360 | 2.8 | 2.8 |
| | Primary cyclones followed by high-efficiency wet scrubbers | 220 | 200 | 10.0 | 9.7 |
| Type F,G,H, or I (Level 4): Thermal dryers associated with fine size coal beneficiation | Primary cyclones with high efficiency wet scrubbers | 270 | 250 | 12.5 | 12.2 |
| | Primary cyclones with high-efficiency wet scrubbers followed by limestone scrubbing | 9450 | 9250 | 93.8 | 93.8 |

[a] Excludes capitalization, depreciation, and interest. Based on 180 (2-shift) days.

Vacuum filters are used in the dewatering of fine coal products and fine refuse from wastewater. Although a drum type of vacuum filter is available, the disc type has been the traditional choice in coal cleaning plants.

Granular media filters may either be gravity or pressure filters. In either case the bed of granular filter medium is horizontally oriented; filter media available for use include silica sand (most common), crushed anthracite, diatomaceous earth, perlite, and activated carbon. Pressure filters are generally used in smaller plants where package units are economical or where the additional pressure in the effluent can replace a pump(s) downstream.

Sedimentation. Sedimentation processes, i.e., settling ponds or lagoons and thickeners, allow suspended materials to settle to the bottom of a vessel.

Settling ponds and lagoons comprise the simplest and largest capacity areas to which the wastewaters are routed. Thickeners are available in a variety of configurations, including rectangular, square, round, and inverted pyramidal. Flow through the pyramidal unit is upward, with sludge pumped continuously from the apex (bottom) and clarified effluent overflowing at the top. Round thickeners use radial horizontal flow and rectangular units use parallel horizontal flow; the horizontal flow types all have sloping bottoms, with continuous sediment removal at the lowest point; clarified overflow leaves the top of the tank through a weir.

Flocculants are often used to promote suspended solids removal. Such treatment gives best results in screen and filter systems. The efficiency of sedimentation processes also can be improved by addition of selected flocculating agents to the wastewater.

## Control of Dissolved Materials

The most common problem with dissolved substances in coal cleaning wastewater is excess acidity. Lime neutralization is usually used to control pH.

## Applicability of Wastewater Treatment Processes to Coal Cleaning Process Waste Streams

Applicable treatment processes are matched with each type of water stream

from different types of coal cleaning plants and evaluated with respect to anticipated performance, and capital and operating costs. Water pollution control equipment costs are documented in Table 9 for three types of plants.

## Solid Waste Control Technology

### Properties of Physical Coal Preparation Refuse

Coal preparation refuse can be expected to contain all of the inorganic substances found in the raw coal. Physical coal preparation removes primarily the inorganic sulfur forms, pyrite and marcasite. These may be present in quantities from less than 0.1 percent to as much as 7.1 percent by weight. Trace elements found in coal are not uniformly distributed. A majority of the trace elements found in coal, including Hg, Zr, Zn, Cd, As, Pb, Mn, Mo, Si, Al, Ca, and Fe, tend to concentrate in the mineral matter and, therefore, in the refuse.

Coarse Refuse Disposal. Coarse refuse is considered to be refuse larger than 28 mesh. It is generated by all levels of coal preparation. There have been four major methods of coarse refuse disposal. The method selected depends upon topography, economics, regulations, and other factors.

- Valley-fill dumps
- Side-hill dumps
- Cross-valley fill
- Waste piles.

Fine Refuse Disposal. Fine refuse is considered to be refuse smaller than 28 mesh. It is generated by Level 3 and 4 preparation plants (Types C - I). Disposal of fine refuse will be slurry impoundment, dewatering, or underground disposal.

TABLE 9. ESTIMATED COSTS OF WATER POLLUTION CONTROL EQUIPMENT FOR SELECTED 1000 TPH COAL CLEANING PLANTS

| Plant Type | Effluent | Quantity, gpm | Applicable Control Equipment | Installed Cost of Control Equipment, (1977 Dollars) | Annual Operating Cost of Control Equipment[b] cents/ton |
|---|---|---|---|---|---|
| Crushing and Sizing with Dry Screening and Wet Beneficiation | Process Water Flow- | 3,450 | | | |
| | Suspended Solids | | Radial flow thickener | 345,000 | 0.8 |
| | | | lagoon, or | 108,000 | 0.6 |
| | | | froth flotation | 33,000 | 0.7-1.4 |
| | Dissolved Solids | | Absorption-activated carbon treatment | 1,700,000[a] | 2.0 |
| Crushing and Sizing with Wet Screening and Wet Beneficiation | Process Water Flow- | 7,650 | | | |
| | Suspended Solids | | Mechanical dewatering- | | |
| | | | hydroclones, | 150,000 | 1.4 |
| | | | microscreens, or | 230,000 | 1.0 |
| | | | pressure filters | 310,000 | 1.8 |
| | | | Thickener or | 510,000 | 1.2 |
| | | | lagoon | 160,000 | 0.8 |
| Fine Size Coal Beneficiation with Hydroclones and Thermal Drying | Process Water Flow- | 9,250 | | | |
| | Suspended Solids | | Radial flow thickener | 560,000 | 1.3 |
| | | | or lagoon | 180,000 | 0.9 |

(a) Adsorption is not presently used to treat coal cleaning process water, and would not be necessary for treating the recirculating process water for any plant with a closed water circuit.

(b) Including depreciation and interest on capital.

## Potential Problems from Land Disposal of Coal Preparation Refuse

Generally, the problems caused by land disposal of coal wastes fall into these categories: aesthetics, blowing dust and debris, gas generation, fire potential, erosion, leachate, and final land use.

The refuse generated by a coal preparation plant contains considerable quantities of fine particles, leading to potentially serious fugitive dust emissions. This problem may be controlled by site selection and use of crusting agents. As there is a considerable amount of organic matter in the refuse, fire resulting from spontaneous combustion in the refuse banks is a matter of continuing concern.

Particle sizes of refuse are such that it is particularly susceptible to water erosion. Diversion ditches to minimize flow of water over the refuse surface, as well as siltation basins to capture eroded material, are essential. Leachate can be expected to exhibit high metal ion concentrations. It is possible to minimize leachate production from a disposal facility by (1) diverting away all surface drainage, (2) applying a cover material to prevent infiltration of rainfall, (3) grading to promote rapid runoff, (4) minimizing the open area, and (5) applying a vegetative cover upon completion of an area.

## Present and Future Limitations Imposed by State and Federal Laws

The Resource Conservation and Recovery Act of 1976 (RCRA) authorized financial and technical assistance to state, regional, and local agencies to develop comprehensive programs for environmentally disposing of solid waste. The U.S. EPA is to establish criteria for determining which materials fall into the category of hazardous wastes. If coal preparation refuse is found to be hazardous, additional requirements beyond the applicable nonhazardous waste disposal requirements will be necessary. The principal changes will be in the management/permit system and in the degree of leachate control needed.

## Reclamation of Waste Disposal Area

It is estimated that the coal waste piles and impoundments accumulated between 1930 and 1971 in the United States cover approximately 225,000 acres of land. The most positive approach to preventing pollution from disposal areas is through reclamation similar to mine spoil bank reclamation.

## Costs of Disposal and Reclamation

It is estimated that refuse disposal costs would range from 13 to 39 cents per ton-mile, spreading and compacting from 4 to 28 cents per ton, and soil covering and planting from $1,070 to $2,319 per acre. These costs do not include the cost of installing or operating leachate collection or surface drainage collection and treatment facilities.

## Waste Utilization

Because the potential pollution problems associated with refuse disposal are so great and because coal refuse offers significant combustion heat content and other mineral values, serious consideration is being given to its utilization as a raw material. Some possible uses for coal refuse are: as construction landfill, as road base material, as a raw material for cement and bricks, as fuel for thermal drying of coal fines, and as a source for aluminum and transition metals.

## Additional Data Needs

Further data are needed on the amounts of fine coal being disposal with coarse refuse and in slurry ponds. Leachate characteristics need to be further determined. More data are needed on physical characteristics of refuse. In addition, costs should be updated to include refuse drainage collection and treatment systems.

## ENVIRONMENTAL ALTERNATIVES ANALYSIS

Environmental alternatives analysis is one of the most important requirements in environmental impact assessment. However, it is also one of the last activities undertaken in a program. Hence, Battelle's activity in the first year in this area was limited to a preliminary pollutant ranking and the modification of a computer model for evaluating process technology.

### Pollutant Ranking

When the initial group of approximately 1000 potential pollutants from coal cleaning processes was identified, it was recognized that all were not of equal importance and that priorities had to be established. However, it was also recognized that attempts to rank them serially in order would be a meaningless academic exercise. Thus, ranking efforts have sought only to classify pollutants by priority groups. As described in an earlier section, a Priority I group of about 75 pollutants regarded as most important was selected (Table 2). The basis of selection of pollutants, which was not a rigorous one, reflected such factors as toxicity, abundance, classification as a named hazardous substance, and appearance in environmental standards.

For purposes of developing and testing environmental assessment methodology on actual substances, a "short Priority I list" of 12 pollutants was drawn from the Priority I group. They are:

| | |
|---|---|
| Arsenic | Manganese |
| Beryllium | Selenium |
| Cadmium | Sulfate sulfur |
| Iron | Sulfur dioxide |
| Mercury | Nitrate nitrogen |
| Lead | Nitrogen oxides |

No particular ranking significance is attached to this short list. Twelve was a convenient number to test, and the pollutants selected possess a spread of characteristics desirable for testing. They do rank among the most important pollutants and will rank high on any list of pollutants.

Prioritization of pollutants, on a group basis, can be carried further as more data on emissions and estimated permissible concentrations are developed.

## Modification of Computer Models For Evaluating Process Technology

### Introduction

A modeling effort, involving the review and modification of existing computer programs in the area of coal preparation simulation, was undertaken to aid in the evaluation of an advanced coal cleaning facility being constructed at Homer City, Pennsylvania, and for use in trade-off studies later in the Coal Cleaning Program. Four computer programs were surveyed:

(1) A U.S. Bureau of Mines coal preparation plant simulation model, version 4 (CPSM4)

(2) A program to perform complete coal washability and froth flotation calculations and to plot automatically all washability curves

(3) Coal cleaning programs developed by PEDCo-Environmental

(4) A computer simulation model for coal preparation plant design and control.

Each of these programs contained unique features which hopefully will be available at some future date in a single program. The coal preparation plant simulation model (CPSM4) was sufficiently flexible to be directly usable in the evaluation of the Homer City plant and was, therefore, selected for modification.

The goal of this research effort was not to simulate a representative configuration; rather it was to simulate a particular plant - the Homer City plant. Actual design curves describing the expected performance of units of equipment in the plant were available. Eventually, actual performance curves will also be made available as the plant becomes operational.

The goal set for the program was to generate results which agreed as closely as possible with the material balance prepared by the design team for the plant

Modifications Made to Program

The modification effort was divided into five phases. The overall purpose of the first phase was to make the program easily usable on Battelle's Cyber 73 computer. In particular, three types of changes were planned: (1) to reduce the core requirements of the program; (2) to simplify the logic of the program; and (3) to develop a notation to aid in the structuring of input to the program. As a result of this phase, the program runs in $60000_8$ words of core (versus $202000_8$) and the processes of unit summarization, normalization, size bridging, etc., were unified into single routines. Also, a block diagram notation was developed for describing plant configurations which greatly simplified structuring the input to the program.

The second phase of the modification effort had as its goal to begin making the program actually usable for the Homer City application. After modifications, a set of runs was made for the Homer City plant and the results of and assumptions made in these runs were reviewed in great detail with the individuals responsible for the design and operation of the plant.

The objective of the third phase in the modification effort was to make changes as determined by the above review, so as to model more accurately the expected performance of the plant. At the end of this phase, another review was conducted. As a result of this second review, it was concluded that the present version of the program seemed capable of representing the plant, and plans were made to make some data modifications and to do extensive sensitivity runs.

The fourth phase effort for the program modifications started at the beginning of the task and was completed with the preparation of a user handbook. Its purpose was to fully describe and document the program and its logic so that it could be used as an effective and understandable tool. Initially, a basic description of the mathematical approach to the program was written and reviewed, then a detailed user handbook and program description was written and distributed to the following along with a program deck and sample data deck:

(1) Pennsylvania Electric Company, Johnstown, Pennsylvania

(2) New York State Electric and Gas Corporation, Binghamton, New York

(3) Versar, Incorporated, Springfield, Maryland

(4) U.S. Bureau of Mines, Pittsburgh, Pennsylvania.

To date, no serious problems have been reported by any of the above in their attempts to make CPSM4 operational on their computers.

The fifth phase effort is continuing to date. Its purpose is to modify CPSM4 to provide a tool to:

(1) Evaluate effects of coal and equipment variables on circuit and plant performances, and

(2) Compare alternative coal cleaning systems with respect to environmental impact, energy recovery, and cost.

Simulation of Homer City Plant

To date, three input decks which relate to the Homer City plant have been prepared, run, and reviewed. These are as follows:

(1) The initial plant configuration (for power plant Units #1 and #2)

(2) The final plant configuration (for power plant Units #1, #2, and #3)

(3) The material balance flowsheet.

By far the most important of these is the material balance flowsheet run. A comparison of results from CPSM4 with the plant design material balance indicated quite similar results.

## TECHNOLOGY TRANSFER

Activities relating to the advancement of technology transfer include (1) preparation of the Monthly Current Events Summary and a quarterly Coal Cleaning Environmental Review, (2) the implementation, development, and operation of a Coal Cleaning Information Center (CCIC), (3) support to the Organization for Economic Cooperation and Development (OECD), (4) US-USSR information exchange, and (5) evaluation of physical coal cleaning as an $SO_2$ emission control strategy.

### Newsletter Status Reports

#### Monthly Current Events Summary

The Monthly Current Events Summary covers the following topics related to coal cleaning.

(1) Calendar of meetings and short courses
(2) Annotated literature citations
(3) Organizational news
(4) New contract awards
(5) Requests for proposals
(6) Topics of general interest

The first issue of the Monthly Current Events Summary was included in the monthly progress report for June, 1977, and it is planned that the preparation of this monthly summary will continue throughout the contract period.

#### Coal Cleaning Environmental Review

The Coal Cleaning Environmental Review provides descriptions of current research results and new developments in (a) coal cleaning processes, (b) related environmental effects, and (c) applicable pollution control technology.

In addition, the latest calendar of meetings and short courses from the Monthly Current Events Summary and pertinent items from various sections of all issues of the Summary during the quarter will be included in the Coal Cleaning Environmental Review. The first issue of the Coal Cleaning Environmental Review is scheduled for completion by January, 1978.

## Coal Cleaning Information Center (CCIC)

The Coal Cleaning Information Center (CCIC) was implemented in September, 1976. The most important functions and services of the CCIC and the work accomplished during the past 13 months are summarized in the following sections.

### Data Base Development

Data base development for the CCIC was accomplished through searching of commercial- and government-operated data bases, screening of multiple information sources, and acquisition of the identified articles and reports. Logging of new articles and reports, the assignment of accession numbers, and preparation of a title card and an input processing form for each item was followed by review for selection of index terms. All information from the input processing forms and all selected index terms were processed onto tape and into the CCIC computer data base.

### Contacting Organizations Conducting Ongoing Research

Searches of the SSIE (Smithsonian Science Information Exchange) data base and the ERDA/RECON data bases provided summary information of many ongoing research projects of interest to the coal cleaning program. Telephone and letter contacts with organizations conducting many of these ongoing research programs has resulted in the acquisition of a number of additional research reports.

## Document Storage and Retrieval

As of September 30, 1977, there had been approximately 900 items processed into the CCIC data base which are coded as to bibliographic data and index terms. The actual hard copies of these 900 items are stored in the CCIC in accession number order, by year of processing.

Identification and retrieval of items of interest can be accomplished by a search of the CCIC data base via remote terminal. Computer printout listing all citations identified through the computer search can be prepared.

## Preparation of User Guide for Data Base Searching

In May, 1977, a CCIC On-Line User Guide was prepared. Detailed information is provided the user on log-in procedures, query build-up, display of CCIC records, off-line printing, retrieval/display aids and log-out procedures. An abbreviated instruction page on the use of the CCIC data base is included.

After completion of the user guide, CCIC user names and passwords were established for data base searching. Six user names and passwords were forwarded to the EPA Project Officer and two user names and passwords were retained for use by BCL project personnel. It is expected that the EPA Project Officer will allocate CCIC user names and passwords for use within EPA and to selected EPA contractors.

# Other Activities

## Support to Organization for Economic Cooperation and Development (OECD)

In December, 1976, Battelle participated in a workshop on coal desulfurization organized by OECD and held in Paris. The purpose of this workshop was to initiate the preparation of a draft report on coal desulfurization in western Europe and the United States.

A letter report, dated May 20, 1977, on "Desulfurization of Coal" was prepared and submitted to the Organization for Economic Cooperation and Development, Paris, France, for use in preparing a report for its 24 member

countries on "Clean Fuel Supply". The following six topics were addressed in this report:

(1) Description of technologies available for desulfurization of coal which can be used between now and 1985

(2) Estimates of capital and operating costs versus plant capacity and quantity of sulfur removal for these technologies for the U.S.

(3) Estimates of the time frame to construct and shakedown coal desulfurization plants

(4) Estimates of the quantity of coal now being desulfurized in the United States and the quantity of sulfur that would be removed in 1985

(6) Constraints preventing or delaying the use of coal desulfurization technologies.

US-USSR Information Exchange

The exchange of information on coal utilization with the USSR has been continuing for the last three years. The information which has been exchanged has been in two general areas--coal preparation and the use of coal in complex advanced energy generation systems.

Until the most recent meeting, the coal preparation activities have been concerned primarily with the use of flotation for the removal of pyritic sulfur. The transfer of that activity to the Energy Agreement led to a shift in emphasis on coal preparation at the July, 1977, meeting in Moscow. The activities now will focus upon the environmental consequences of coal preparation. It has been proposed that the initial activities be to conduct a bilateral symposium on "Discharges and Controls for Coal Beneficiation Plants".

The USA and USSR delegations have met on two occasions during the past year to pursue the exchange of information on the utilization of coal in complex advanced energy generation systems--in the U.S. during December, 1976, and in the USSR during July, 1977. The principal activity during both meetings was the exchange of technical material which will be used in a joint report which will be issued in 1978. The delegations will meet in November, 1977, and twice in 1978 to finalize the joint report.

Evaluation of Physical Coal Cleaning as an $SO_2$ Emission Control Strategy

This effort has had two related but separate components. The first objective was to provide a report to the Office of Air Quality Planning and Standards (OAQPS) incorporating technical information on coal cleaning needed by OAQPS in its evaluation of possible revisions in the New Source Performance Standards (NSPS) for $SO_2$. The second component involves a much broader effort to determine the technological, environmental, institutional, economic, and social factors which affect the adoption by industries of physical coal cleaning (PCC) as an $SO_2$ emission control strategy, and to analyze optional initiatives designed to overcome barriers to PCC commercialization.

Report to OAQPS. The objectives of this portion of the task were: to define available coal supplies by location and sulfur content for raw and for physically-cleaned coal, to assess the impact of sulfur variability and averaging times for determination of compliance on coal availability, to assess the impact of alternative standards for utility boilers on coal markets and supplies, and to describe existing and emerging technologies to abate $SO_2$ emissions from coal burning. A draft report was submitted June 30, 1977, and a revised draft was completed October 14, 1977.*

The results of this evaluation indicate the following conclusions:

(1) Physical coal cleaning alone will be of limited value in meeting optional New Source Performance Standards for utilities.

(2) Flue gas desulfurization or other control techniques with comparable higher sulfur-removal effectiveness will be required, if much more stringent $SO_2$ emission standards are imposed.

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* Hall, E.H., Hoffman, L., Hoffman, J., and Schilling, R.A., "Physical Coal Cleaning for Utility Boiler $SO_2$ Emission Control", Report No. EPA-600/7-78-034, U.S. Environmental Protection Agency, IERL, Research Triangle Park, N.C. (February 1978).

(3) If the practicality of coal distribution from one region to another region were ignored, and if it were assumed that the coal reserves were available for use anywhere in the United States, compliance with the most stringent regulations would still be impossible without supplementary flue gas desulfurization or comparable control techniques.

(4) Since the potential for conversion from oil and gas to coal would increase the demand-pull for coal by only 6 percent, this by itself would only cause a ripple effect in the coal availability results.

Initiatives Study. The second portion of the effort is directed toward the identification of barriers to commercialization of physical coal cleaning and initiatives for overcoming these barriers. The study involves: assembly of information on coal supply, demand, reserves, and cleanability; review of coal cleaning technology and costs; comparative analysis of alternative sulfur removal options; review of environmental impacts of alternative sulfur removel strategies; summary of air quality factors and emission control strategies; identification of barriers: identification of initiative alternatives; assessment of environmental, energy, and economic trade-offs; and impact assessment.

An interim progress report was submitted in September, 1977, which included progress reports on the several areas under study with respect to barriers and initiatives. A draft final report will be issued by March, 1978.

## FUTURE EFFORTS

The following sections briefly describe Battelle's currently authorized and/or planned efforts for the remainder of the contract period ending June 30, 1979.

### Current Process Technology Background

#### Technology Overview - Subtask 211

The draft report entitled "Technology Overview of Coal Cleaning Processes and Environmental Controls" will be revised to include information on economics of coal cleaning, potential of coal cleaning technology for meeting state implementation plans and regulations, limitations of washability data, and other topics to be determined by EPA.

#### Revised Technology Overview - Subtask 291

The final report entitled "Technology Overview of Coal Cleaning Processes and Environmental Controls", prepared on Subtask 211, will be revised approximately during the last half year of the program to include updated information obtained from both the outputs of other Subtasks of this program and a continuing review of the literature.

### Current Environmental Background

#### Develop Assessment Criteria - Subtask 241

Little further effort is anticipated on identifying additional potential pollutants; however, some effort will be made in characterizing the mode of occurrence and transformations of pollutants already identified.

An updated summary of pollution control regulations related to coal cleaning processes will be prepared. This effort will involve revising Appendix A to Battelle's April 8, 1977, preliminary report on "Development of Environmental Assessment Criteria" to include new regulations proposed and promulgated since the report was submitted.

The extent of further investigation and compilation of health/epidemiological literature and dose/response data will depend upon the results of the methodology development for estimated permissible concentrations. It is expected that primary reliance will be on the RTI compilations, with only limited investigation of a few specific substances, where additional data may be needed.

Work on transport models will be continued and expanded; this will include physical transport (including initial dispersion) and biological transport. Initially, the models will be delineated for the 12 pollutants on the "short Priority I list". The results from these efforts can be used to extend the modeling to additional pollutants in the Priority I group.

## Environmental Objectives Development

### Develop Assessment Criteria - Subtask 241

The principal objective continues to be to develop an improved methodology for estimating permissible environmental concentrations of pollutants acceptable for the health and well-being of man on the basis of a long-term continuous exposure. Also necessary to this effort is a parallel development of improved methods for interconverting and extrapolating a wide variety of animal test results to man for use when the usual $LD_{50}$ values for the rat are absent.

## Environmental Data Acquisition

### Development of Environmental Test Plan - Subtask 411

The report on this subtask has been submitted for review and all that remains to be done is final revision following receipt of comments.

Selection of Evaluation Sites - Subtask 421

Upon approval of the site selection scheme, coal cleaning plants will be classified into site categories. Information will be gathered on plant characteristics from literature, government agencies, and site visits to make site selections. Information on selected sites will be submitted for site approval before field work begins. A total of ten sites will be recommended as a prioritized list.

Development of Experimental Techniques - Subtask 431

Future effort on Subtask 431 will be to provide detail on experimental procedures to be used in the site evaluations. The detail will consist of work descriptions of procedures or reference to well-known standards, flow charts showing the sequence of how samples may be divided, and diagrams of equipment where appropriate. Quality assurance and control aspects of Level I sampling and analysis will be addressed. Inadequacies in current practices of sampling and analysis, such as in the determination of leachable materials in refuse piles, will be indicated and discussed.

Test Support Development - Subtask 441

Appropriate equipment and instruments will be acquired as needed to conduct the field and laboratory samplings and analyses in the field test program.

Test Plan Development - Subtask 451

A master test plan, which is now being prepared, and which will encompass the general requirements for testing all selected sites and coal cleaning processes will be submitted. As individual evaluation sites are selected, specific test plans will be prepared to add the details of sampling location, kinds of samples, etc. that are unique to each site.

### Testing - Subtask 461

As test sites are selected and approved, the field testing program will be implemented. Sampling, testing, and laboratory analyses will be carried out in accordance with the test plans prepared in Subtask 451 and the analytical procedures outlined in Subtask 431.

### Data Reporting - Subtask 471

Data will be compiled, analyzed, and reported for each test site as the programs at that site are completed.

## Control Technology Assessment

### Detailed Process Descriptions - Subtask 222*

In an effort to secure the previously defined additional information, required to prepare the final report on "Pollution Control Technology for Coal Cleaning Processes", visits are being conducted to vendors of pollution control equipment, engineering consulting firms, and selected coal cleaning plants.

### New Control Technology Studies - Subtask 271

Studies will be undertaken to generate preliminary conceptual designs for improved pollution control systems for coal cleaning processes. This task will utilize results from other subtasks including 211 (Technology Overview), 222 (Detailed Process Descriptions), 232 (Process Data Acquisition), 241 (Development of Assessment Criteria), 251 (Trade-Off Studies), and 461 (Testing).

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* Process Data Acquisition - Subtask 232 provides input data for this subtask and is not reported separately.

Conceptual designs of control systems for air pollution, water pollution, and solid waste will be developed. Advanced control technology will be examined for possible application to various types of coal cleaning processes. The major emphasis will be on control technology for physical coal cleaning processes, although control technology applicable to chemical coal cleaning processes also will be addressed. Preliminary consideration will be given to pollution control for biological coal cleaning processes.

## Control Technology Development Status

Battelle-Columbus has no planned contractual activities in this area.

## Environmental Alternatives Analysis

### Detailed Process Descriptions - Subtask 222

Existing computer programs will be modified for utilization in performing pollution control trade-off studies on Subtask 251. The major effort in this area will involve further modifications to the U.S. Bureau of Mines Coal Preparation Simulation Model Version 4 (CPSM4), as previously modified by Battelle for use in evaluating the advanced coal cleaning facility at Homer City, Pennsylvania.

The primary types of computer program modifications to be accomplished for the trade-off studies include providing the capability of (1) modeling additional equipment types and/or operations, primarily related to pollution control, coal handling, and end use, (2) analyzing capital and operating costs for various configurations of coal cleaning plants including pollution control systems, and (3) comparing alternative coal cleaning systems, including various pollution control options, with respect to environmental impact, energy recovery, and cost.

### Pollution Control Trade-Off Studies - Subtask 251

Studies will be performed to establish cost and performance trade-offs associated with various pollution control techniques for coal cleaning processes. These studies will be used to identify the pollution control

equipment and configurations which provide systems for minimal environmental impact and/or minimal cost in coal cleaning plants.

Using information on existing and projected Federal and state regulations for the control of pollutants from coal cleaning processes, an assessment will be made of the costs (energy and economic) and effectiveness of both existing and recently developed applicable pollution control technologies. Capital and operating costs, equipment life, maintenance requirements, and performance will be evaluated for each technology. This information will be integrated to construct a cost-performance profile as a function of size for the various control technologies.

### Revised Process Descriptions and Impact Assessments - Subtask 381

A detailed review will be made of information pertaining to performance and costs of pollution control technology. Results from other subtasks, including 251 (Pollution Control Trade-Off Studies), will be utilized to revise and update process descriptions in the report entitled "Pollution Control Technology for Coal Cleaning Processes", originally prepared on Subtask 222. Emphasis will be placed on the relative advantages and disadvantages of each control technology and the trade-offs related to environmental impact, costs, and energy utilization.

A comprehensive assessment of the environmental consequences of coal cleaning processes will be provided. This environmental assessment will be based on the assessment criteria developed on Subtask 241 and the field test results from Subtask 461.

## Technology Transfer

### Coal Cleaning Information Center - Subtask 821

Newsletter Status Reports. It is planned that the preparation of both the Monthly Current Events Summary and the Coal Cleaning Review (Quarterly) will continue throughout the current contract period.

Information Centers. It is anticipated that the routine operations of data base development, document storage and retrieval, and the contacting of organizations conducting ongoing research, will continue throughout the current contract period for the Coal Cleaning Information Center (CCIC).

In addition to the continuation of routine operations of CCIC during future months, there is the possibility that two additional assignments will be assumed by the CCIC. These new assignments, which were described within the draft of Technical Directive (TD) No. C2-2 (822), dated May 18, 1977, are as follows:

If funding is available in future months, it is possible that annotated bibliographies will be prepared for the EPA. It is planned that these bibliographies will be printed from the CCIC data base in alphabetical order by personal or corporate author.

When resources are available, the service of both manual and computer searches of the CCIC data base as well as computer searches of commercial- and govenment-operated data bases can be made available to EPA and to selected EPA contractors.

Remote terminal access to the CCIC data base is already possible by EPA and EPA contractors as described in the CCIC On-Line User Guide. Assignments to perform searches of commercial- and government-operated data bases could be accepted by CCIC if directed by EPA.

## Coal Cleaning Demo Planning - Subtask 813

The U.S. Bureau of Mines CPSM4 program, as modified by Battelle, will be used in the evaluation of the Homer City coal cleaning plant. The following types of tasks are envisioned in this effort.

(1) Adjust the equipment specifications for the Homer City configurations as input to program CPSM4 to obtain agreement with experimental results.

(2) Using data obtained from equipment performance tests which will be conducted to measure the sensitivity of that performance to coal properties and operating variables, further adjust program CPSM4 and/or its input data to achieve agreement with these results.

(3) Perform trade-off studies using CPSM4 to identify changes in operating conditions and coal blends which will maximize Btu recovery and pyritic sulfur removal and which can be used to operate the plant for extended periods of time.

(4) Incorporate changes into CPSM4 which would allow the program to estimate detailed coal washability data given only a limited number of experimental data values (probably about 20 points).

(5) Using a newly developed cost model within CPSM4 and available cost data, incorporate a cost component into the trade-off studies.

US-USSR Information Exchange - Subtask 841

Meetings of US-USSR delegations are anticipated in November, 1977, and twice during 1978 to finalize a joint report on the utilization of coal in complex advanced energy generation systems.

Evaluation of Physical Coal Cleaning as an $SO_2$ Emission Control Strategy - Subtask 851

Work on this task is scheduled to be completed with revision of the draft report on "Initiatives Study" due December, 1977. Some discussions have been conducted regarding additional modeling work required after completion of this effort, however, no work has been directed, and none has been incorporated in future planning at this time.

Other Activities

It is anticipated that a symposium on the environmental aspects of coal preparation will be planned and held.

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

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15. SUPPLEMENTARY NOTES IERL-RTP project officer is James D. Kilgroe, Mail Drop 61, 919/541-2851.

16. ABSTRACT The report gives results of the first year's work on an environmental assessment of coal cleaning processes. A strong base of engineering, ecological, pollution control, and cost data is being established through data gathering and systems analysis efforts. In addition to program management, three task areas are defined: system studies, data acquisition, and general program support. Early availability is anticipated for draft reports of progress for three subtasks: (a) developing information on on coal cleaning process technology; (b) defining the technological and cost status of the control of pollutants from coal cleaning and refusal disposal; and (c) establishing criteria for meeting environmental goals. (A fourth subtask, acquiring process data, was terminated to avoid duplication.) Progress has been made on data acquisition subtasks, aimed at the planning needed as the forerunner of the anticipated environmental field testing program: (a) developing and describing the overall environmental test program; (b) developing the rationale for selection and selecting the evaluation sites; (c) specifying the experimental testing techniques to be used; and (d) developing the master site test plan. (Ten site categories have been specified for testing.) General program support includes: (a) obtaining background environmental data, and (b) operating a coal cleaning information center.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group | |
|---|---|---|---|---|
| Pollution | Sulfur | Pollution Control | 13B | 07B |
| Assessments | Sulfur Oxides | Stationary Sources | 14B | |
| Coal Preparation | | Environmental Assessment | 08I | |
| Waste Disposal | | | | |
| Mathematical Models | | | 12A | |
| Emission | | | | |

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