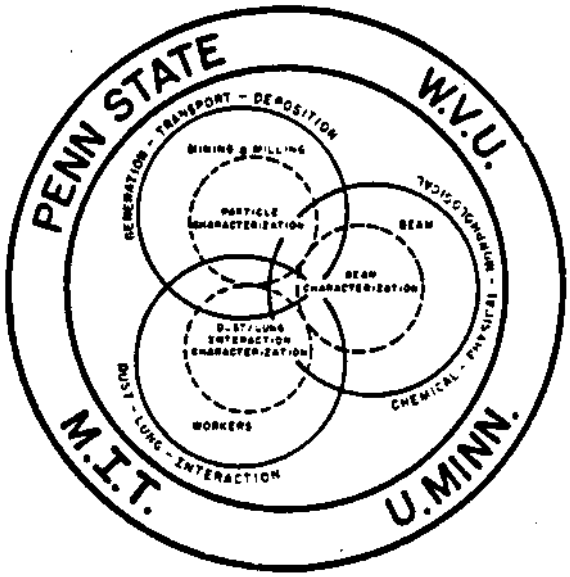
GENERIC MINERAL TECHNOLOGY CENTER FOR RESPIRABLE DUST

The Pennsylvania State University
West Virginia University
University of Minnesota
Massachusetts Institute of Technology
Michigan Technological University



STATUS REPORT 1990

Edited by
Robert L. Frantz and Raja V. Ramani

Submitted to
Office of Mineral Institutes
U.S. Bureau of Mines
Washington, D.C.

September 30, 1990

Volumes of the Respirable Dust Center

VOLUME 1	Status Report, 1984-1988
VOLUME 2	Report to the Committee on Mining and Mineral Resources Research,1987
VOLUME 3	Publications, 1984
VOLUME 4	Publications, 1985
VOLUME 5	Publications, 1986
VOLUME 6	Publications, 1987
VOLUME 7	Respirable Dust Center Research Program Review
VOLUME 8	Publications, 1988
CONFERENCE PROCEEDINGS	Coal Mine Dust Conference West Virginia University Morgantown, West Virginia October 1984
CONFERENCE PROCEEDINGS	Respirable Dust in the Mineral Industries: Health Effects, Characterization and Control The Pennsylvania State University University Park, Pennsylvania October 1986

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INTERACTION OF DUST AND LUNGS

RELATIONSHIP OF MINE ENVIRONMENT, GEOLOGY AND SEAM CHARACTERISTICS TO DUST GENERATION AND MOBILITY

FOREWORD

This report has been prepared by the Generic Mineral Technology Center for Respirable Dust, The Pennsylvania State university, University Park, PA 16802. This research has been supported by the Department of the Interior's Mineral Institute program administered by the Bureau of Mines through the Generic Mineral Technology Center for Respirable Dust under grant number G1135142.

This report is a compilation of the status of the various research projects and activities of the Generic Mineral Technology Center for Respirable Dust (GTCRD) during year 1989 to 1990. It was submitted by the Center on September 30, 1990.

The assistance and co-operation of Dr. Ronald Munson, Chief, Office of Mineral Institutes, in providing timely advice and authorization for the Center's activities are gratefully acknowledged. Particular thanks are extended to the members of the Research Advisory Council of the Center for their valuable inputs. The co-operation extended to the center investigators by the Bureau of Mines, Mine Health and Safety Administration, National Institute for Occupational Safety and Health, and numerous private and public organizations in the mining industry is appreciated.

The Center co-directors express their sincere thanks to Dr. Richard A. Bajura, Dr. John Elliot, Dr. John Johnson, Dr. Virgil Marple and Dr. Z. T. Bieniawski for their co-operation in the administration of the Center. It is recognized that the strength and accomplishments of the Center are derived from the investigators and students who tirelessly perform to achieve the research and educational goals of the Center.

The primary goal of the Center is to reduce the incidence and severity of respirable dust disease through advancement of the fundamental understanding of all aspects of respirable dust associated with mining and milling and the interaction of dust and lungs through:

- Research
- Graduate and Undergraduate Studies
- Training Engineers and Scientists
- Technology Transfer
- Reference Center

A co-ordinated and integrated research effort to study the scientific, engineering and medical components of the respirable dust problem in the following five areas are underway:

- Dust Generation
- Dust Dispersion and Dilution
- Dust Characterization
- Interaction of Dust and Lungs
- Relationship of Seam Characteristics to Dust Generation and Mobility

The Center's research program explores these concerns with the objective of refining existing strategies and developing new respirable dust control techniques that are consistent with the fundamental dust-lung interaction processes that lead to mine worker disability. The fundamental aspects of this work are applicable to the control of respirable dust problems in both hard rock mines and coal mines and to other dusts such as diesel-generated.

The status reports details in a summary manner, the objective, scope and progress in the various research projects in the Center. There has been significant accomplishments in the understanding of the scientific, medical and engineering aspects of the respirable dust problems.

The research performed in the Generic Mineral Technology Center for Respirable Dust has definitely established that varying coal dust characteristics do result in varying responses in a variety of experiments, and as such are being incorporated into medical investigations. Research findings developed by scientists in the Center relate important variants, such as "stale" versus "fresh" dust and superoxide release. The findings are believed to be related to the potential for the reduction of the incidence and severity of black lung disease.

Three coal samples (Anthracite, Lower Kittanning, Pittsburgh Seam) having widely varying characteristics have been selected to provide the unique common thread of a suite of characterized dust samples--anthracite and bituminous coal, limestone rock dusts, fireclay and silica--for investigations by Center researchers. Medical personnel are utilizing this suite of samples to perform a variety of medical experiments on small animal lung cells in such areas as lung damage (fibroblasts), immunology (chemical mediators) and mucus generation (silica damage). A unique project to investigate the response of non-human primate pulmonary macrophages as compared to those of rats and guinea pigs is in progress. This unique concerted medical/primate animal effort is necessary to translate as rapidly as possible to human benefit the biochemical changes observed in small animal studies.

New equipment, instrumentation and test procedures for fracture toughness determination to assess the relative dust generation potential of various coals for engineering design has been developed. A variable response in the wetting rates and efficiency of surfactants related to the effectiveness of dust suppression utilizing water sprays in the mines has been determined for various coals.

Significant benefits have resulted from the synergism and rapid dissemination of research results embedded in the Center's program of scientific, engineering and medical research.

September 30, 1990
University Park, PA

Robert L. Frantz
Co-Director, Generic Mineral
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THE RESPIRABLE DUST CENTER

Excerpted From The

1988 UPDATE TO THE NATIONAL PLAN FOR RESEARCH IN MINING AND MINERAL RESEARCH

Report to: December 15, 1987

The Secretary of the Interior
The President of the United States
The President of the Senate
The Speaker of the House of Representatives

Section 9(e) of Public Law 98-409 of August 29, 1984, (98 Stat. 1536 et seq.) mandates that the Committee on Mining and Mineral Resources Research submit an annual update to the National Plan for Research in Mining and Mineral Resources: "Improving Research and Education in Mineral Science and Technology through Government-(Federal, State and Local), Industry, and University Cooperation."

.....

Respirable Dust (centered at Pennsylvania State U. and West Virginia U., with affiliates at U. of Minnesota and Massachusetts Institute of Technology): brings together experts concerned with particles causing potentially disabling or fatal diseases, including pneumoconiosis ("black lung"), silicosis, and asbestosis, the latter of deep concern not just to workers in the mineral sector of the economy but also to the general populace.

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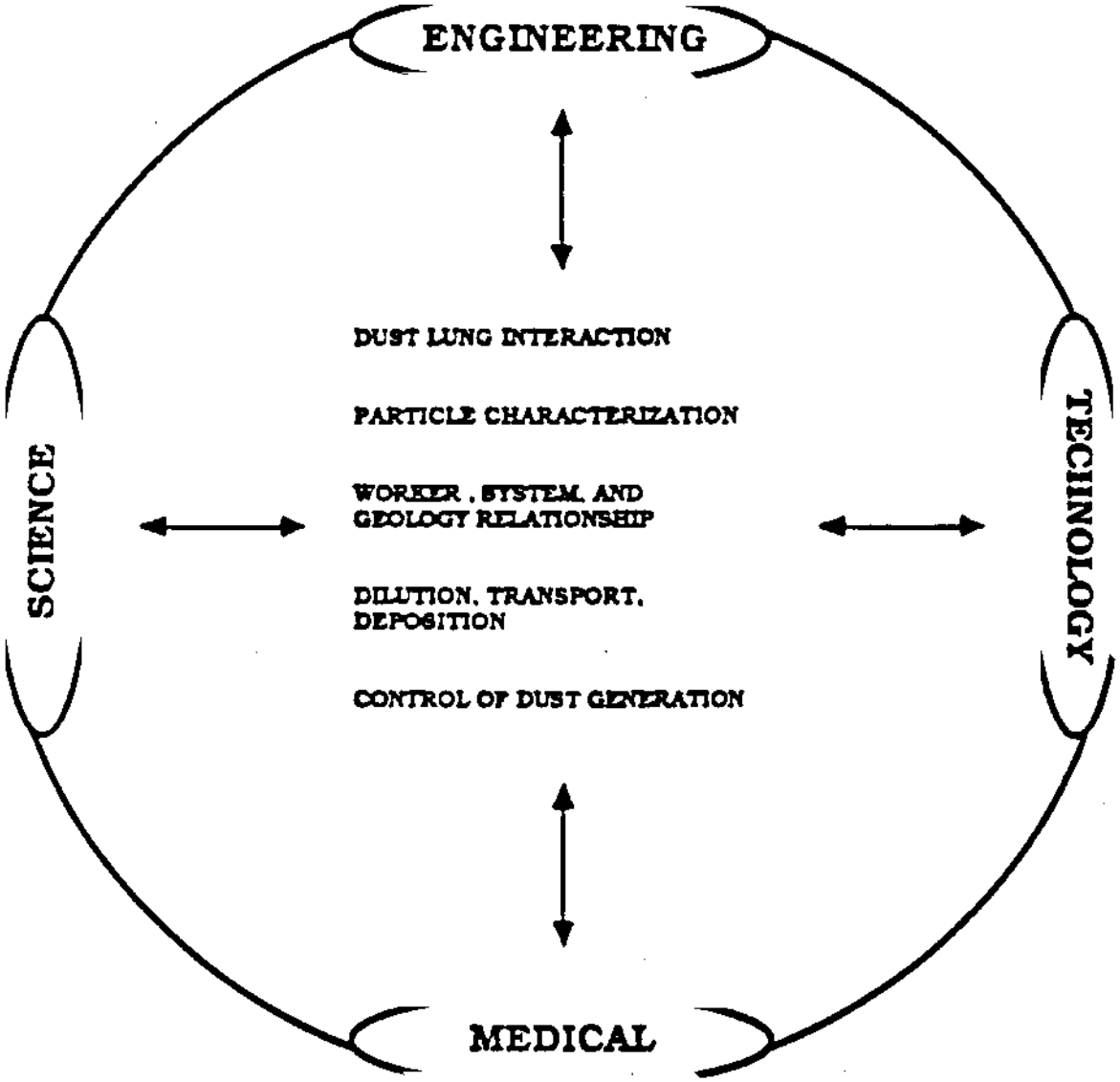


Standardized protocols for Respirable Dust Research in scientific, engineering, and medical areas.

RESEARCH

CONTROL OF GENERATION

- Amount
- Fracture

DILUTION, TRANSPORT AND DEPOSITION

- Concentration
- Size Consist
- Modeling

MINE WORKER, MINING SYSTEM, SEAM GEOLOGY

- Seam Sections
- Silica
- Trace Elements
- System Configuration
- Worker Location

- Coal Data Bank
- Mine Samples

SUITE OF GENERATED RESPIRABLE DUSTS

- Anthracite
- Medium Volatile Bituminous
- High Volatile Bituminous
- Silica
- Fireclay
- Rock Dust

CHARACTERIZATION

- Size/Shape/ Composition
- Surface/Functional Groups
- Particle Interaction

DUST LUNG INTERACTION

- Medical/Cellular
- Medical/Animal
- Medical/Human
- Medical/Engineering

TRAINING

Train engineers, scientists, medical personnel, graduate students and undergraduate students in the interdisciplinary aspects of respirable dust.

The Generic Mineral Technology Center for Respirable Dust

SUITE OF CHARACTERIZED DUST SAMPLES	SAMPLING AND DUST GENERATION METHODS	SUITE OF MEDICAL TESTS
1. Anthracite (Low Volatile)	Dust/Lung Interaction	1. Rats
2. Bituminous (Medium Volatile)	Particle Characterization	2. Guinea Pigs
3. Bituminous (High Volatile)	Mine Workers Mining System Seam Geology Dust Relationships	3. Dogs
4. Fireclay	Respirable Dust Dilution Transport and Deposition	4. Non-Human Primates
5. Silica	Control of Dust Generation	5. Black Lung Patients
6. Rockdust		6. Healthy People

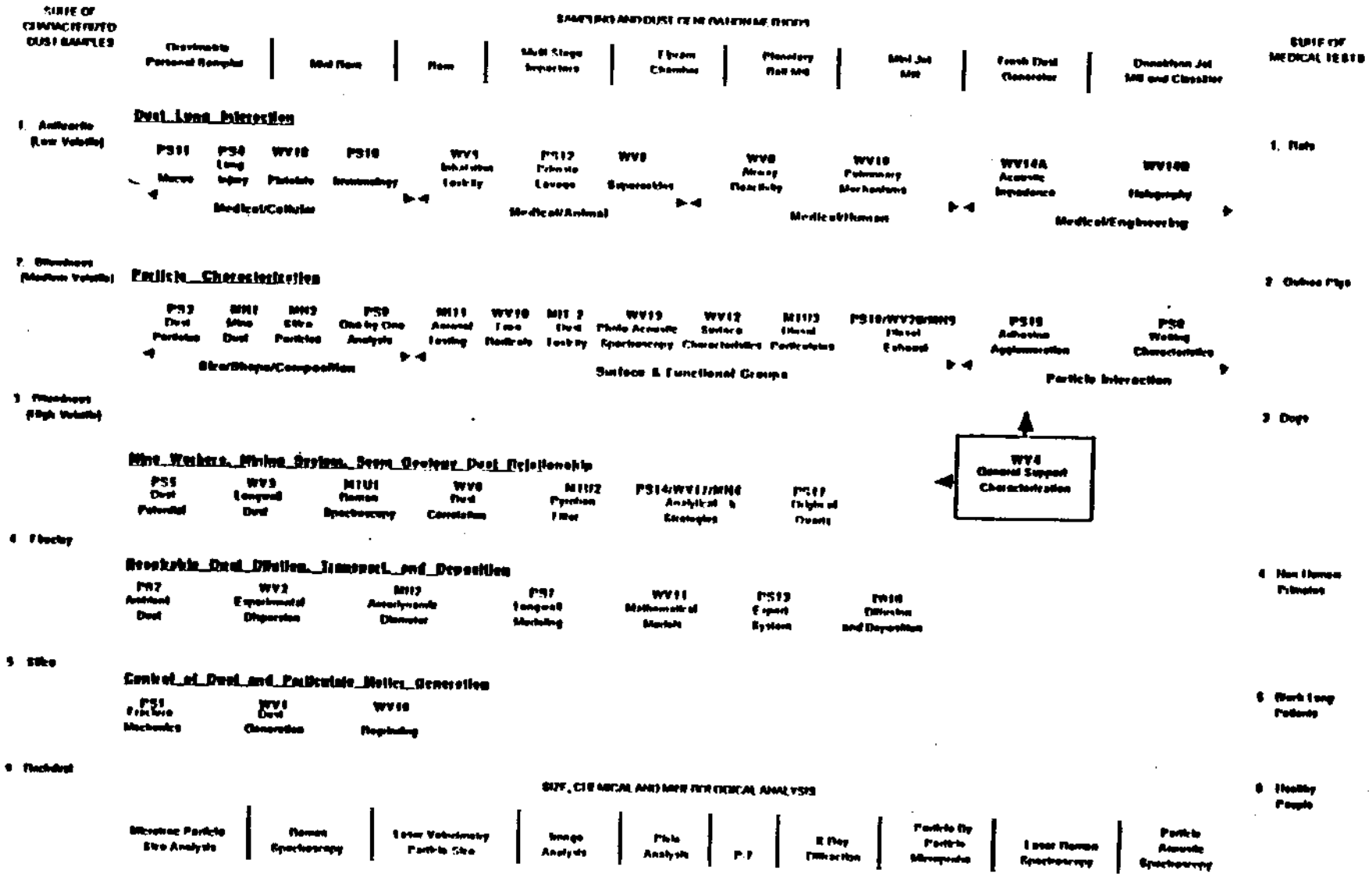
SIZE, CHEMICAL AND MINERALOGICAL ANALYSIS

STATEMENT OF GOAL

The primary goal of the Generic Mineral Technology Center for Respirable Dust is to reduce the incidence and severity of respirable dust disease through advancing the fundamental understanding of all aspects of respirable dust associated with mining and milling and the interaction of dust and lungs.

The holistic approach to standardized protocols and procedures.

1988



The integration of scientific, engineering, and medical research findings into on-going projects.

INTRODUCTION

The U.S. Bureau of Mines (USBM) established on August 15, 1983, a Generic Mineral Technology Center for Respirable Dust (GTCRD) within the Mining and Mineral Resources Research Institutes (MRIs) at The Pennsylvania State University (PSU) and West Virginia University (WVU) in association with participating MRIs at Massachusetts Institute of Technology (MIT) and the University of Minnesota (UMN). In 1986, Michigan Technological University (MTU) was awarded a grant through the GTCRD. The Center's research program has been developed with recognition of the stated objective of the Federal Mine Safety and Health laws which is to "... permit each miner the opportunity to work underground during the period of his entire adult working life without incurring any disability from pneumoconiosis or any other occupation-related disease ..." The Center's program is designed to permit an accelerated attach on the fundamental research problems for the control of respirable dust in mining and milling.

MISSION

The mission of the Respirable Dust Center is to enhance the health, safety and productivity of the miners through advancing the fundamental understanding of all aspects of respirable dust associated with mining and milling and the interaction of dust and lungs for reducing the incidence and severity of respirable dust disease.

All Dust Center activities are focussed to be responsive to this mission which is shared by several federal agencies closely associated with the Generic Mineral Technology Center for Respirable Dust such as USBM, MSHA, and NIOSH, and the mining industry. While significant progress has been achieved in making mine atmospheres cleaner and healthier, respirable dust disease remains the nations worst industrial hazard.

GOALS

The goals of the Respirable Dust Center have been formulated to recognize the diverse scientific, engineering and medical aspects of respirable dust as well as the need to enhance the interaction, education and technology transfer in the respirable dust area.

The Center goals are to:

1. Enhance the understanding of the scientific, engineering and biological characteristics of fine and respirable mineral particles, fibers, organic aerosols, and complex particles found in the mining and milling atmospheres.
2. Advance the understanding of the physical behavior of airborne respirable dust particles in flowing streams under different stimuli during mining and milling.
3. Advance fundamental understanding of the causative mechanisms for the occupationally related lung impairments and the airway diseases of mine and mill workers.

4. Establish the relationship between natural and cultural factors (mine geology, mineralogy, mining and milling methods, equipment and control measures) in the generation, exposures, and pathogenic properties of fine particles.
5. Contribute to the development of control mechanisms for reducing ambient respirable dust concentrations, worker exposure, the incidence and severity of dust related lung disorders and disease prevention in mining and milling atmospheres.
6. Enhance functional integration among the various research personnel in the Center, as well as, with other groups, such as MSHA, NIOSH and USBM involved in respirable dust research and control.
7. Develop technically trained personnel for employment in the mineral industry for respirable dust research and control.
8. Enhance the availability of respirable dust-related information utilizing several technology transfer avenues.

RESEARCH PROGRAM

The original charge to the Respirable Dust Center included research in the five areas of:

1. Control of Dust Generation.
2. Dilution, Dispersion and Collection in Mine Airways.
3. Characterization of Dust Particles.
4. Interaction of Dust and Lungs.
5. Relationship of Mine Environment, Geology, and Seam Characteristics to Dust Generation and Mobility.

The research program has been formulated to also address the recommendations of the National Academy of Sciences (NAS) Study, Measurement and Control of Respirable Dust in Mines.

The purely research aspects of the Center address the first five goals and the last three goals of the Center are more responsive to the interaction, education and technology transfer activities. There is a strong relationship not only between the specific research projects and the goals (see Table I), but also between groups of projects enhancing the synergistic benefits of the co-ordinated research program.

The Center has developed a number of working groups of several investigators researching on related topics including:

1. Diesel particulates in mine atmospheres.
2. Longwall Respirable Dust
3. Dust characteristics and sampling.
4. Fresh vs stale dust.
5. Biomedical interest group.

At the present time in the Dust Center, there are 33 principal investigators and over 100 other investigators including graduate students, working on 33 projects. In this status report, the following informations are provided:

Table 1. The relationships between the goals of the Center and the research projects.

Table 2. A table summarizing a number of relevant statistics with regard to the projects currently underway in the Center.

A one page status report on each project currently underway in the Center.

The strategic plan of the Center is to continue in the five areas of research identified above. The specific investigations to be pursued depend on the criticality of the problem, and the manner in which it is being addressed by the various investigative groups in the Center and outside. At least for the immediate future, the Center will continue to concentrate on the following specific topics:

1. Understanding and controlling dust problems in high production longwalls.

2. Understanding and controlling diesel particulates in mine atmospheres.

3. Understanding and controlling respirable dust capture mechanisms.

4. Understanding and characterizing mine airborne particles for medical research.

5. Understanding and controlling the source and sink relationship of silica in mine atmospheres.

6. Understanding and controlling the genotoxicity of the mine airborne particulates.

7. Understanding and controlling the injury to the lungs.

8. Understanding and enhancing the lung injury prevention/mitigation mechanisms.

9. Designing, developing, and conducting technology transfer activities including education, publications, seminars and symposiums.

The Dust Center program includes all phases of dust generation, dust transport, dust characterization, interaction of dust and lungs, and worker location and mining systems relationships. The medical research encompasses experiments in small animals, non-human primate models and humans, including both coal mineral and healthy volunteers. Other research includes a variety of scientific, engineering and technological experiments. These have established that varying coal dust characteristics do result in varying responses. The following is a summary of selected accomplishments in the Center:

- Pulmonary alveolar macrophages (PAMs) are a key component of the lung's response to inhaled particulates, and they play several important roles in pulmonary inflammatory and repair processes. A consistent pattern of response has been seen following in vitro exposure of human PAMs to coal dusts. The pattern is generally "proinflammatory", meaning that the other components of the lung will respond as if there has been tissue injury.

- A nonhuman primate (monkey) animal model is developed for studies of dust-lung interactions. These animals are considered a useful experimental "bridge" between the small laboratory rodent models (which can be used only once, and which may differ from humans in unknown ways) and humans (in which intentional exposures and controlled experiments are difficult or impossible). Equipment and procedures have been standardized for bronchoscopy and alveolar lavage of PAMs from monkey lungs, and a variety of experiments established.

- Electron spin resonance (ESR) and cytotoxicity measurements on coal and quartz dusts show that freshly generated dusts (such as in mining atmospheres) are more toxic than old (i.e., stored) dusts from the same stock. The underlying biochemical mechanism appears to involve free radicals and/or other active centers on the surface of the dust particles. This finding provides a fundamental understanding of the biochemical mechanism of mining dusts' cytotoxicity and, hence, a possible new approach for combating pneumoconioses and related occupational diseases.

- The research on diesel particulates is developing and validating monitoring systems for both mine atmospheres and mine worker exposure and will be useful to the implementation of proposed diesel regulations.

- Fundamental data collection and understanding of such important topics as dust control techniques with water sprays, the role of surfactants, transport and deposition of dust, the trace elements in coal seams and airborne coal dust, and worker location and mining system configuration have been achieved. These will lead to reducing the severity of worker exposure to airborne contaminants.

At the present time in the Center there are thirty-three principal investigators and over one-hundred other investigators including graduate students working on thirty-three projects.

TABLE I

MATRIX OF GOALS AND PRIMARY PROJECT RELATIONSHIP

GOALS	PROJECTS						
1. Enhance the understanding of the scientific, engineering and biological characteristics of fine and respirable mineral particles, fibers, organic aerosols, and complex particles found in the mining and milling atmospheres.							
a. Improved Characterization of the Size, Shape and State of Aggregation of Respirable Particles found in mines and mills.	2601	2701	2702	4203	4223	5404	5411
b. Increased Understanding of the Chemical/Mineralogical Composition of Airborne Particulates.	2501	2703	4203	4208	4226	5404	5412
c. Establishing the Surface Properties of fine particles, including electrical charge, structure and composition of particle surfaces, surface films, free radicals, nature and bonding of surface species.	5404	5409	5411	5423			
d. Characterization of the Biochemical and Biomedical activity of dust particles and particle surfaces.	2521	5404	5423	5427			
e. Characterization of viable and nonviable organic materials in mine and mill atmospheres.							

Project Code
2500 Series - M.I.T.
2600 Series - M.T.U.
2700 Series - U.M.
4200 Series - P.S.U.
5400 Series - W.V.U.

Table 1 - Continued

MATRIX OF GOALS AND PRIMARY PROJECT RELATIONSHIP

GOALS	PROJECTS					
2. Advance the understanding of the physical behavior of airborne respirable dust particles in flowing streams under different stimuli during mining and milling.						
a. Understand the spatial and temporal behavior of mine and mill airborne dust particles.	4202	4206	5402	5403	5410	
b. Understand the Fundamental aspects of particle/particle and particle/surface interactions in mine and mill atmospheres.	4207	4223	4224			
3. Advance fundamental understanding of the causative mechanisms for the occupationally related lung impairments and the airway diseases of mine and mill workers.						
a. Better definition of the role of various aspects of the lung environment (e.g. surfactant, the mucociliary system) in the disposition and toxicity of respirable dust.	4210	4211	5424			
b. Comprehensive characterization of the role of the PAM and its secretory products on the development of dust related lung disorders.	4209	4229	5408	5424	5431	
c. Development of improved detection methods and more effective models for increased understanding and control of dust related lung disorders	4211	5405	5407	5413A	5413B	5429
d. Increased search for methods for reducing the toxicity of respirable dust, both prior and subsequent to its entry into the lung.	4209	4229	5430			

Table 1 - Continued

MATRIX OF GOALS AND PRIMARY PROJECT RELATIONSHIP

GOALS	PROJECTS							
4. Establish the relationship between natural and cultural factors, (mine geology, mineralogy, mining and milling methods, equipment and control measures) in the generation, exposures, pathogenic properties of fine particles.								
a. Understand the fundamental mechanisms of respirable dust generation.	4201	4225	5401					
b. Understand the relationship between geology, mining system, worker location and respirable dust.	4205	4227	5403	5406A	5406B			
c. Determine the effect of mining operative variables on the amount of dust produced.	4228	5401	5421					
5. Contribute to the development of control mechanisms for reducing ambient respirable dust concentrations, worker exposure, the incidence and severity of dust related lung disorders and disease prevention in mining and milling atmospheres.								
a. Understand fundamental aspects of respirable dust capture in flowing air streams.	4207							
b. Development of approaches to keep respirable dust away from workers or workers away from dust.	4221							
c. Development of improved sampling and sample preparation methodology for scientific, engineering, medical and epidemiologic studies.	2601	2722	4222	5422				
d. Development of sampling technology to monitor and control respirable contaminants other than coal dust in mine atmospheres.	2601	2627	2722	2727	4222	4227	5422	5427

TABLE 11

USBM Grant Number: G1135142 -- Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1989

Penn State Projects

USBM Account Number	GTC Number	Title	PI	Initial* funding	Amendments No. 1** funding	Amendments No. 2*** funding	Amendment No. 3**** funding
4200	PS6	Information Exchange & Dissemination Indirect Rate on Subgrants	Frantz/ Ramani	$ 26,130 29,356	$ 16,523	---	$ 24,996
4201	PS1	A Fracture Mechanics Study of Crack-Propagation Mechanism in Coal Utilizing Fracture Toughness and Fracture Velocity Concepts	Bieniawski	120,105	---	---	89,487
4202	PS2	Prediction of Ambient Dust Concentrations in Mine Atmospheres	Ramani	121,688	---	---	52,800
4203	PS3	Characterization of Dust Particles	Hogg/Luckie	180,347	23,895	---	103,585
4204	PS4	Characterization of the Mechanism of Lung Injury by Coal Mine Dusts	Bartlett	129,999	20,000	---	118,000
4205	PS5	Establishment of Standard Procedures for Characterization of Respirable Coal Mine Dust Potential	Mutmansky/ Bise	178,396	196,021	---	150,314
4206	PS7	Computer Modeling of Longwall Face Ventilation	Ramani	---	55,598	---	---
4207	PS8	Wetting Characteristics of Dust Particles in Relation to Dust Abatement	Aplan/ Chander	---	77,295	---	---
4208	PS9	Analysis of Coal Particles on a One-by-One Basis Using an Automated, Computer-Controlled SEM with X-ray Fluorescence	Austin	---	76,348	---	---
4209	PS10	Investigation of the Role of Polymorphonuclear Leukocytes (PMN's) in the Dust Lung Interaction	Demers	---	130,000	---	---
			Total	$786,021	$595,680	---	$539,182

* Initial funding - August 1983
** Amendment No. 1 funding - July 1984
*** Amendment No. 2 funding - September 1984
**** Amendment No. 3 funding - July 1985

Table 11 - Continued

USBM Grant Number: G113542 Generic Technology Center For Respirable Dust

August 15, 1983 - September 30, 1989

Penn State Projects

USBM Account Number	GTC Number	Title	PI	Amendment No.4 - 5 funding	Amendment No.6-7 funding	Amendment No. 8 funding	Total
4200	PS6	Information Exchange & Dissemination Indirect Rate of Subgrants	Frantz/ Ramani	$ 31,101	---	---	$128,106
4201	PS1	A Fracture Mechanics Study of Crack-Propagation Mechanism in Coal Utilizing Fracture Toughness and Fracture Velocity Concepts	Bieniawski	---	67,544	---	$277,136
4202	PS2	Prediction of Ambient Dust Concentrations in Mine Atmospheres	Ramani	140,000	---	---	$314,488
4203	PS3	Characterization of Dust Particles	Hogg/Luckie	---	65,206	68,865	$441,898
4204	PS4	Characterization of the Mechanism of Lung Injury by Coal Mine Dusts	Bartlett	110,843	48,619	104,525	$531,986
4205	PS5	Establishment of Standard Procedures for Characterization of Respirable Coal Mine Dust Potential	Mutmansky/ Bise	50,000	65,000	---	$639,731
4206	PS7	Computer Modeling of Longwall Face Ventilation	Ramani	70,000	100,348	---	$225,946
4207	PS8	Wetting Characteristics of Dust	Aplan/Chander	89,986	79,932	70,000	$317,213
4208	PS9	Analysis of Coal Particles on a One-by-One Basis Using an Automated, Computer-Controlled SEM with X-ray Fluorescence Particles in Relation to Dust Abatement	Austin	75,000	55,000	---	$206,348

Table 11 - Continued

USBM Grant Numbers: G113542 Generic Technology Center For Respirable Dust
August 15, 1983 - September 30, 1989

Penn State Projects

USBM Account Number	GTC Number	Title	PI	Amendment No.4-5 funding	Amendment No. 6-7 funding	Amendment No.8 funding	Total
4209	PS10	Investigation of the Role of Polymorphonuclear Leukocytes (PMN's) in the Dust Lung Intertaction	Demers	75,000	80,000	80,930	$365,930
4210	PS11	Biochemical Alternations in Mammalian Respiratory Mucus by Coal Mine Dust	Bhavanandan	75,616	82,142	75,017	$232,775
4211	PS12	Interactions with Nonhuman Primate Lungs	White	75,454	62,210	66,409	$204,073
		Total		$793,000	$756,001	$465,746	$3,885,630

*Amendment No. 5 funding - October 1986

Amendment No.6-7funding - October 1987

Amendment No. 8 funding - October 1988

Table 11 - Continued

USBM Grant Numbers: G117542 Generic Technology Center For Respirable Dust
October 1, 1987 - September 30, 1989

Penn State Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 6-7 funding	Amendment No. 1 funding	Total
4220	PS6	Information Exchange & Dissemination	Frantz Ramani	50,000	29,909	$ 79,909
4221	PS13	Knowledge Based Expert System for Planning Mine Ventilation Systems	Ramani	86,687	66,560	$153,247
4222	PS14	Formulation, Evaluation and Verification of Improved Dust Sampling and Analytical Strategies for Use at Coal Mines (jt.proj.)	Mutmansky	73,855	68,043	$141,898
4223	PS15	Adhesion, Agglomeration and Deposition of Respirable Dust	Chander/Hogg	133,321	100,000	$233,321
4224	PS16	Diffusion Coefficient and Deposition Rate of Respirable Dust in Mine Airways	Ramani	---	51,595	$ 51,595
4225	PS17	Breakage Porcesses and the Origin of Quartz in Airborne Coal Mine Dusts	Mutmansky	---	60,025	$ 60,025
4226	PS18	Silica Analyses Procedures for Bulk Coal and Host Rock Samples	Ramani	---	30,000	$ 30,000
4227	PS19	Characterization and Control of Diesel Exhaust Contamination of Mine Airways	Mutmansky Ramani	---	69,300	$ 69,300
		Total		$ 343,863	$ 475,432	$ 819,295

Amendment No. 6-7 funding October 1987
Amendment No. 1 funding October 1988

Table 11 - Continued

USBM Grant Numbers: G119542 Generic Technology Center For Respirable Dust
October 1, 1989 - September 30, 1991

Penn State Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 1 funding	Total
4203	PS3	Characterization of Dust Particles	Hogg/Luckie	$ 65,171	65,171
4207	PS8	Wetting Characteristics of Dust	Aplan/Chander	68,907	68,907
4209	PS10	Investigation of the Role of Polymorphonuclear Leukocytes (PMN's) in the Dust Lung Intertaction	Demers/Kuhn	85,500	85,500
4210	PS11	Biochemical Alternations in Mammalian Respiratory Mucus by Coal Mine Dust	Bhavanandan	85,428	85,428
4211	PS12	Interactions with Nonhuman Primate Lungs	Griffith	71,419	71,419
4220	PS6	Information Exchange & Dissemination	Frantz/Ramani	70,000	70,000
4221	PS13	Knowledge Based Expert System for Planning Mine Ventilation Systems	Ramani	76,098	76,098
4223	PS15	Adhesion, Agglomeration and Deposition of Respirable Dust	Chander/Hogg	59,566	59,566
4224	PS16	Diffusion Coefficient and Deposition Rate of Respirable Dust in Mine Airways	Ramani	70,979	70,979
4225	PS17	Breakage Porcesses and the Origin of Quartz in Airborne Coal Mine Dusts	Mutmansky	44,932	44,932
4227	PS19	Characterization and Control of Diesel Exhaust Contamination of Mine Airways	Mutmansky Ramani	75,326	75,326
4228	PS20	Support Generated Dust by High Production Longwalls	Suboleski	50,696	50,696
4229	PS21	Human Alveolar Macrophage and Coal Mine Dust Interaction	Demers	110,800	110,800
		TOTAL		$934,822	$934,822

Table 11 - Continued

USBM Grant Number: G1135142 -- Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1989

West Virginia Projects

USBM Account Number	GTC Number	Title	PI	Initial* funding	Amendments No. 1** funding	Amendments No. 2*** funding	Amendment No. 3**** funding
5400	WV7	Information Exchange & Dissemination	Bajura	$ 10,000	$ 11,866	$ 24,418	$ 25,000
5401	WV1	Experimental Study of the Mechanisms of Dust Generation and Entrainment	Khair	194,000	---	---	98,000
5402	WV2	Experimental Studies of Dispersion and Transport of Respirable Dusts in Mine Atmospheres	Wang	119,103	---	---	---
5403	WV3	Measurements and Construction of Dust Distribution Maps for Longwall Faces	Peng	64,860	76,950	---	---
5404	WV4	General Support Characterization	Bajura	50,000	70,000	33,107	---
5405	WV5	Pulmonary Inhalation Toxicity of Respirable Coal Mine Dusts: A Morphometric Study	Hinton	150,000	---	---	94,980
5406	WV6	Correlations of Respirable Dust Characteristics to Coal Seams, Worker Positions and Mining Methods	Peng/ Stobbe	150,000	80,000	40,313	89,200
5407	WV8	Dust-Lung Interaction in Coal Miners	Lapp	---	50,599	---	---
5408	WV9	Effects of Respirable Dust on Release of Superoxide from Pulmonary Alveolar Macrophages	Cilento	---	86,663	---	---
5409	WV10	Magnetic Resonance Spectroscopic Characterization of Paramagnetic Irons and Free Radicals in Coal Dust, Black Lung Tissue and Lung Tissure Under Controlled Dust Exposure	Dalal	---	---	131,567	60,400
5410	WV11	Development of Mine Dust Distribution Models for Working Faces	Wang/Peng /Chiang	---	---	---	79,978
5411	WV12	Shape and Surface Characterization of Respirable Mine Dust Particles	Meloy	---	---	---	80,000
			Total	$737,963	$376,078	$229,405	$527,558

* Initial Funding - August 1983
** Amendment No.1 funding - July 1984
*** Amendment No.2 funding - Sept. 1984
****Amendment No.3 funding - July 1985

Table 11 - Continued

USBM Grant Number: G1135142 Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1989

West Virginia Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 4-5 funding	Amendment No 6-7 funding	Amendment No. 8 funding	Total
5400	WV7	Information Exchange & Dissemination	Bajura	30,000	---	---	$ 101,284
5401	WV1	Experimental Study of the Mechanisms of Dust Generation and Entrainment	Khair	1,466	---	---	$ 293,466
5402	WV2	Experimental Studies of Dispersion and Transport of Respirable Dusts in Mine Atmospheres	Wang	---	---	---	$ 119,103
5403	WV3	Measurements and Construction of Dust Distribution Maps for Longwall Faces	Peng	---	---	---	$ 141,810
5404	WV4	General Support Characterization	Bajura	196,195	---	---	$ 349,302
5405	WV5	Pulmonary Inhalation Toxicity of Respirable Coal Mine Dusts: A Morphometric Study	Hinton	82,585	181,986	152,000	$ 661,551
5406	WV6	Correlations of Respirable Dust Characteristics to Coal Seams, Worker Positions and Mining Methods	Peng/ Stobbe	40,000	85,420	---	$ 484,933
5407	WV8	Dust-Lung Interaction in Coal Miners	Lapp	60,034	59,388	99,015	$ 269,036
5408	WV9	Effects of Respirable Dust on Release of Superoxide from Pulmonary Alveolar Macrophages	Cilento	72,973	60,667	63,000	$ 283,303
5409	WV10	Magnetic Resonance Spectroscopic Characterization of Paramagnetic Irons and Free Radicals in Coal Dust, Black Lung Tissue and Lung Tissue Under Controlled Dust Exposure	Dalal	79,182	83,398	72,997	$ 427,544
5410	WV11	Development of Mine Dust Distribution Models for Working Faces	Wang/Peng /Chiang	50,007	---	---	$ 129,985
5411	WV12	Shape and Surface Characterization of Respirable Mine Dust Particles	Meloy	139,742	103,680	77,000	$ 400,422

Table 11 - Continued

USBM Grant Number: G1135142 Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1989

West Virginia Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 4-5 funding	Amendment No. 6-7 funding	Amendment No. 8 funding	Total
5412	WV13	Determination of Biologically Active Silica Using Photoacoustic Spectroscopy	Seehra	77,841	66,004	64,000	$ 207,845
5413	WV14	Acoustic Impedance and Topographic Laser Holography for the Early Detection of Black Lung	Sneckenberger	148,000	124,964	70,000	$ 342,964
			Total	$978,025	$795,507	$598,012	$ 4,212,548

*Amendment No. 5 funding - October 1986
*Amendment No.6-7 funding - October 1987
*Amendment No. 8 funding - October 1988

Table 11 - Continued

USBM Grant Number: G1175142 Generic Technology Center for Respirable Dust
October 1, 1987 - September 30, 1989

West Virginia Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 6-7 funding	Amendment No. 1 funding	Total
5420	WV15	Information Exchange & Dissemination	Bajura	30,000	30,000	$ 60,000
5421	WV16	Augmentation of Dust Owing to Regrinding at the Face	Khair	63,934	62,000	$125,934
5422	WV17	Dust Sampling and Analytical Strategies	Stobbe	53,395	59,999	$113,394
5423	WV18	Platelet-Activating Factor in Etiology of Pneumoconioses	Van Dyke	22,578	63,440	$ 86,018
5424	WV19	Immunological and Inflammatory Pulmonary Mechanisms Associated with Chronic Coal Dust Inhalation in Coal Mines	Lapp	---	90,495	$ 90,495
5427	WV20	Characterization and Control of Diesel Exhaust Contaminationof Mine Airways	Gautam	---	77,135	$ 77,135
			Total	$139,907	$383,069	$552,976

Amendment No. 6-7 funding - October 1987
Amendment No. 1 funding - October 1988

USBM Grant Number: G1195142 Generic Technology Center for Respirable Dust
October 1, 1989 - September 30, 1991

West Virginia Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 1 funding	Total
5405	WV5	Pulmonary Inhalation Toxicity of Respirable Coal Mine Dusts: A Morphometric Study	Hinton	$180,000	$180,000
5406	WV6	Correlations of Respirable Dust Characteristics to Coal Seams, Worker Positions and Mining Methods	Peng/ Stobbe	60,000	60,000
5407	WV8	Dust-Lung Interaction in Coal Miners	Lapp	70,000	70,000
5408	WV9	Effects of Respirable Dust on Release of Superoxide from Pulmonary Alveolar Macrophages	Cilento	63,000	63,000
5411	WV12	Shape and Surface Characterization of Respirable Mine Dust Particles	Meloy	70,000	70,000
5412	WV13	Determination of Biologically Active Silica Using Photoacoustic Spectroscopy	Seehra	63,000	63,000
5413	WV14	Acoustic Impedance and Topographic Laser Holography for the Early Detection of Black Lung	Sneckenberger	67,000	67,000
5420	WV15	Information Exchange & Dissemination	Bajura	23,908	23,908
5423	WV18	Platelet-Activating Factor in Etiology of Pneumoconioses	Van Dyke	102,000	102,000
5427	WV20	Characterization and Control of Diesel Exhaust Contaminationof Mine Airways	Gautam	99,000	99,000
5429	WV21	Mediators of Early Lung Injury as an Aid to the Detection of Dust Induced Occupational Lung Diseases	Lapp	68,065	68,065
5430	WV22	Targeted Delivery of Tetrandrine to Alveolar Macrophages for Treatment of Silicosis	Ma	56,970	56,970
5431	WV23	Macrophage Growth Factors in Fibroblast Activation After Coal Dust Exposure	Dey	74,537	74,537
		TOTAL		$997,480	$997,480

USBM Grant Number: G1135142 -- Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1989

Minnesota Projects

USBM Account Number	GTC Number	Title	PI	Initial* funding	Amendments No. 1** funding	Amendments No. 2*** funding	Amendment No. 3**** funding
2701	MN1	Coal Mine Dust Characterization	Marple	$100,016	---	---	---
2702	MN2	Experimental and Theoretical Aerodynamic Diameter Analysis of Coal Dust	Marple	---	$125,000	---	---
2703	MN3	Determination of Silica Particle Concentrations in Respirable Size Ranges	Marple	---	---	---	$85,700
			Total	$100,016	$125,000	---	$85,700

MIT Projects

USBM Account Number	GTC Number	Title	PI	Initial* funding	Amendments No. 1** funding	Amendments No. 2*** funding	Amendment No. 3**** funding
2501	MT1	Respirable Dust Testing in Metal, Non-Metal Mines and Metallurgical Operations	Ring	$200,000	$125,000	---	---
			Total	$200,000	$125,000	---	---
GRAND TOTAL -- GENERIC TECHNOLOGY CENTER FOR RESPIRABLE DUST				$1,824,000	$1,221,758	$229,405	$1,152,440

* Initial funding - August 1983

** Amendment No. 1 funding - July 1984

*** Amendment No. 2 funding - September 1984

**** Amendment No. 3 funding - July 1985

Table 11 - Continued

USBM Grant Numbers: G1135142 Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1989

Minnesota Projects

USBM Account Number	GTC Number	Title	PI	Amendment No.4-5 funding	Amendment No.6-7 funding	Amendment No. 8 funding	Total
2701	MN1	Coal Dust Characterization	Marple	$180,000	---	---	$280,016
2702	MN2	Experimental and Theoretical Aerodynamic Diameter Analysis of Coal Dust	Marple	---	178,144	150,000	$453,144
2703	MN3	Determination of Silica Particle Concentrations in Respirable Size Ranges	Marple	---	---	---	$ 85,700
			Total	$180,000	$178,144	150,000	$818,860

MIT Projects

USBM Account Number	GTC	Title	PI	Amendment No.4-5 funding	Amendment No. 6-7 funding	Amendment No. funding	Total
2501	MT1	Respirable Dust Testing in Metal, Non-Metal Mines and Metallurgical Operations	Ring		---	---	$325,000
			Total		---	---	$325,000

Amendment No. 4-5 funding October 1986
Amendment No. 6-7 funding October 1987
Amendment No. 8 funding October 1988

Table 11 - Continued

USBM Grant Numbers: G1175142 Generic Technology Center for Respirable Dust
October 1, 1987 - September 30, 1989

Minnesota Projects

USBM Account Number	GTC Number	Title	PI	Amendment No.6-7 funding	Amendment No.1 funding	Total
2722	MN4	Dust Sampling and Analytical Strategies	Marple Rubow	$ 30,000	$ 30,000	$ 60,000
2727	Mn5	Characterization and Control of Diesel Exhaust Contamination of Mine Airways	Marple Rubow	---	23,565	23,565
			Total	$ 30,000	$ 53,565	$ 83,565

MIT Projects

USBM Account Number	GTC	Title	PI	Amendment No.6-7 funding	Amendment No. 1 funding	Total
2521	MT2	Effect of Physical Properties of Respirable Dust on their Toxicity	Elliott	$ 56,216	$100,000	$156,216
			Total	$ 56,216	$100,000	$156,216

Amendment No. 6-7 funding October 1987

Amendment No. 1 Funding October 1988

Table 11 - Continued

USBM Grant Numbers: G1195142 Generic Technology Center for Respirable Dust
October 1, 1989 - September 30, 1991

Minnesota Projects

USBM Account Number	GTC Number	Title	PI	Amendment No. 1 funding	Total
2701	MN1	Coal Mine Dust Characterization by Improved Instrumentation	Marple Rubow	$144,537	$144,537
2727	MN5	Characterization and Control of Diesel Exhaust Contamination of Mine Airways	Marple Rubow	48,633	48,633
		TOTAL		$193,170	$193,170

MIT Projects

USBM Account Number	GTC	Title	PI	Amendment No. 1 funding	Total
2521	MT2	Effect of Physical Properties of Respirable Dust on their Toxicity	Elliott	$100,000	$100,000
		Total		$100,000	$100,000

Table 11 - Continued

USBM Grant Numbers: G1135142 - G1175142 Generic Technology Center for Respirable Dust
August 15, 1983 - September 30, 1988

Michigan Technological University Projects

USBM Account Number	GTC Number	Title	PI	Amendment No.4-5 funding	Amendment No.6-7 funding	Amendment No.1 funding	Total
2601	MTU1	Quantitative Analysis of Diesel Particulate Matter in Respirable Coal Dust by Raman Spectroscopy	Johnson	66,639	---		$ 66,639
2651	MTU2	Monitoring and Control of Diesel Particulate in an Underground Coal Mine	Johnson	---	83,384	120,005	$203,389
			Total	$ 66,639	$ 83,384	$120,005	$270,028

Amendment No. 4-5 funding - October 1986
Amendment No. 6-7 funding - October 1987
Amendment No. 8-1 funding - October 1988

Table 11 - Continuted

USBM Grant Number: G1195142 Generic Technology Center for Respirable Dust
August 15, 1989 - September 30, 1991

Michigan Technological University Projects

USBM Title Number	GTC Number	TITLE	PI	Amendment No.1	Total
2623	MTU 3	Development of Collection and Measurement Techniques to Monitor and Control Underground Mine Diesel Emissions	Johnson	41,605	41,605
2627	MTU 4	Diesel Exhaust Contamination of Mine Atmospheres	Johnson	82,923	82,923
		TOTAL		$124,528	$124,528

Initial Funding	1983	Grant G1135142	$ 1,824,000
Amendment No. 1	1984	" "	1,221,758
Amendment No. 2	1984	" "	229,405
Amendment No. 3	1985	" "	1,152,440
Amendment No. 4-5	1986	" "	2,017,664
Amendment No. 6-7	1987	" "	1,649,652
Amendment No. 8	1988	" "	1,213,758
Amendment No. 6-7	1987	Grant G1175142	683,370
Amendment No. 1	1988	" "	1,132,071
Amendment	1989	Grant G1195142	2,350.000
Total Funding	Grants G1135142 - G1175142-G1195142		$ 13,474,118

INFORMATION EXCHANGE AND DISSEMINATION

PS6/USBM 4220 - WV7/USBM 5420

Co-Directors: Professor Robert L. Frantz
Dr. Raja V. Ramani
Dr. Richard A. Bajura

The objective in this area is to exchange information between the Generic Mineral Technology Center for Respirable Dust (GTCRD) participants and the Advisory Council and to disseminate information to the industry.

Arranged and participated in the Respirable Dust Center Review Meeting held in Morgantown, WV on May 13 - 15, 1990.

A principal activity was the ongoing review and revisions to proposals and budgets for continuation and new proposals on the basis of the Research Council's action, and establishing sub-contracts with other affiliated institutions. Research review of continuing and new proposals were conducted by the co-directors of the GTCRD during the month of October. A total of 22 current projects were reviewed. The co-directors also reviewed 11 new proposals for submission for research under the GTCRD program for funding under the year (8) program. Assembled all proposals from all the universities in the GTCRD and prepared the final proposal submission to the Office of Mineral Institutes for the year (8) funding.

The eight volumes prepared for the Generic Mineral Technology Center Reference Center now includes:

Volume (1) Research Program and Status Report 1984-1988

Volume (2) Report to the Committee on Mining and Mineral Resources Research

Volume (3) Respirable Dust Center Publications 1984

Volume (4) Respirable Dust Center Publications 1985

Volume (5) Respirable Dust Center Publications 1986

Volume (6) Respirable Dust Center Publications 1987

Volume (7) Respirable Dust Center Research Program Review 1988

Volume (8) Respirable Dust Center Publications 1988

Participated in the preparation of the USBM Technology Transfer publication U.S. Bureau of Mines Respirable Dust Program, An Overview of Accomplishments and Future Research Needs.

The co-directors attended the annual meeting of the Mineral Institute Directors that was held in Washington, D.C. on February 14, 15, 1990 and Professor Frantz attended the Generic Center's National Advisory Committee Meeting, in Rolla, Missouri on September 12, 1990.

Sent notices to all P.I.'s in the center in regard to the Annual Review meeting of the GTCRD Advisory Committee that was held on May 14-15, 1990, at the Sheraton Lakeview Inn, Cheat Lake, West Virginia. Made the arrangements for the Research Council and all Center P.I.'s for the meeting. At this meeting, the principal investigators within the Center presented the progress of their individual projects.

Planned and attended the 1990 Symposium Planning Committee Meeting held in Pittsburgh, Pa. on May 16, 1990. Planned and co-ordinated the 1990 Symposium on Respirable Dust in the Mineral Industries to be held on October 16-19, 1990 at Pittsburgh, Pa.

Assisted in the co-ordination and arrangements of joint research study group activities involving P.I.'s and graduate students in the various universities.

Prepared a statement of selected Respirable Dust Center accomplishments for USBM personnel.

Worked on the development of the Generic Technology Center for Respirable Dust Goals and Objectives statement for the USBM.

The Pennsylvania State University has a Center for Industrial Research for all the Research Centers within the University. GTCRD is a member of this Center. As such, GTCRD responds to inquiries for information regarding the Dust Center.

The center co-ordinated the activities for the submission of progress reports, continuation proposals, and informed the affiliated institutes of the call for continuing and new proposals. The center reviewed the requests for budget modification, no-cost extensions requests, and equipment acquisitions and forwarded them to the Office of Mineral Institutes.

CONTROL OF DUST PARTICLE GENERATION

MAJOR ACCOMPLISHMENTS ON THE PROJECT OF "CORRELATION OF DUST DUE TO REGRINDING AT THE FACE" WV5421

A hydraulically powered chain saw was designed and fabricated to cut coal in underground coal mines since it is very difficult to obtain large blocks by any other means. Four specially designed coal block containers were also fabricated and used to retrieved coal blocks.

The modification of ARCCS was completed. This modification included: 1) allow the experimenter to vary bit spacing from o.5 in. to 3.0 in. and the number of bits that can be mounted on cutting head increased from 7 to 22; 2) a cowl to hold a coal block at the bottom of the confining chamber. This cowl has built-in hydraulic cylinders which will advance the coal blocks upwards toward the cutting head, thus simulating the downward movement of cutting head; 3) a hopper like feeder to be used in feeding a predetermined size of coal on to the entire width of the cutting head in order to simulate regrinding mechanism; 4) an enclosure to completely cover up the cutting head. Such enclosure enables the investigator to collect the airborne dust and total product; 4) The 25 hp motor was replaced by 40 hp motor. The start-stop unit and the electrical system for the ARCCS were upgraded.

The principle of regrinding was analyzed. A mathematical model, which describes the relationship between product size distribution and feed material size distribution in matrix form, was established. The major factors influencing regrinding were analyzed. These factors would be coal properties. rpm, depth of sump, the amount and size distribution of feed material. An experimental program is developed using orthogonal fractional factorial experimental design technique to evaluate factorial effect on correlation matrix of size distribution.

Large coal blocks were obtained with chain saw from three coal seams, namely, Waynesburg, Pittsburgh, and Lower Kittanning. The physical and mechanical properties were determined. The block sample and feed sample were prepared from these coal. The experiments are carried out utilizing Automated Rotary Coal Cutting Simulator (ARCCS). Experiments on Waynesburg coal and Pittsburgh coal had been completed by May, 1990. The mechanism analysis and preliminary experimental result has been published on the 3rd respirable dust symposium.

The experiments on Lower Kittanning coal were started at the end of May, 1990 and 8 experiments have been conducted. The laboratory experiments were suspended because of the moving of the College of Mineral and Energy Resources to new building. The equipments have been set up in the new building and the remained experiments on Lower Kittanning coal will be completed in November 1990. A final report will be prepared after laboratory experiments are completed. Experimental result will be published on health and safety symposium to be held in Phonix, Arizona, February, 1992.

DILUTION, DISPERSION AND COLLECTION IN MINE AIRWAYS

PS2/USBM 4202

Prediction of Ambient Dust Concentration in Mine Atmospheres

Principal Investigator: Dr. Raja V. Ramani

Graduate Student: Sachin Shankar

Project Status Summary

The objective of this project is to understand the spatial and temporal behavior of airborne dust particles in underground mine airways. Prediction of ambient dust concentration would lead to improved sampling strategy, improved ventilation practices, better operating practices and aid in the development of dust suppression devices - these all would help in reducing worker exposure to dust.

Theoretical and experimental studies investigating the dominant mechanisms affecting dust transport and deposition in mine airways have been completed. Mechanisms modeled include turbulent and gravitational deposition, coagulation and dispersion. In the later part of the project detailed study of the re-entrainment phenomeon was undertaken.

A literature search was conducted to identify factors affecting re-entrainment of dust and the key observations have been compiled. A wind tunnel was designed and constructed at the Particle Technology Laboratory of the Mechanical Engineering Department at University of Minnesota. A total of 36 preliminary experiments were performed using twelve samples and three velocity settings.

Work in the last six months involved completion of all laboratory experiments. The final experiments were performed in the same wind tunnel as the preliminary experiments at University of Minnesota. In all, 72 experiments were performed with two types of coal dust (bituminous and anthracite), at three velocity settings and for three different duration of time periods. Samples were collected at two stations and at five locations along a vertical height at each station. The mass concentration data has been calculated and tabulated. Experiments to determine the size distribution of some of the samples out of a total of 720 samples are being carried out at present. Densities of the samples have already been determined. Once all the data are tabulated, analyses would be carried out to establish relationships among the major parameters, eg., air velocity, types of coal dust, density, size distribution, mass concentration as a function of height and distance from the source and duration of exposure of coal dust to moving air. A video recording has been done of an experiment in the wind tunnel.

PS7/USBM 4206
Computer Modeling of Longwall Face Ventilation
Principle Investigator: Dr. Raja V. Ramani
Graduate Student: Jianmin Qin

Project Status Summary

The purpose of this research project is to aid in the design and analysis of longwall face ventilation schemes. The major objective is the development of a mathematical model for longwall face ventilation incorporating characteristics of airflow and airborne dust in the face. Despite the tremendous strides made in the development of improved equipment and operational procedures to control the dust levels at longwall faces, it is still difficult to bring some longwalls into compliance with the federal standard of 2.0 mg/m^3 without loss of production.

Extensive experimental studies have been carried out to document the spatial and temporal characteristics of dust flow at longwall faces and derive parameters for theoretical model development. The sampling plan was carefully designed. The experiments were performed in six operating longwall faces in eastern U.S. representing different coal seams. Two experiments were performed in each of the six longwalls. Data on the cross-section areas and airflow velocities, gravimetric respirable and total airborne dust samples, instantaneous respirable dust concentrations, and time study of the shearer activities were collected. A simulated longwall face was set up in D-drift of Lake Lynn Laboratory mine of U.S. Bureau of Mines. Experiments under controlled air velocities, dust generation rate, source speed etc. were performed in the simulated longwall face.

The data obtained from operating longwall faces as well as the simulated longwall show that there is a definite discernible relationship among dust concentration, air velocity, and distance from headgate. Specifically, the dust concentration increases and air velocity decreases with distance from headgate for the first half of the face. Towards the tailgate, the air velocity increases with increasing distance but the dust concentration levels off with some variation. The data obtained from the simulated longwall face show that a higher dust generation rate results in higher dust concentration. But, what is more important is that the rate of increase of airborne dust concentration is higher than that of dust generation rate at higher velocities.

A theoretical model incorporating the theory of aerosol sciences and technology has been developed. Currently, the data from experimental studies are being used for the validation of the model. Potential applications of the model include identification of the role of longwall ventilation schemes on dust levels, better ventilation planning to minimize dust levels at the face, and descriptions and prediction of average airborne dust concentrations at different places in the face.

PS13/USBM 4221

A Knowledge Based Expert System for Planning Mine Ventilation Systems

Principal Investigator: Dr. R V Ramani

Graduate Student: K V K Prasad

Project Status Summary

The objective of this research project is the development of a knowledge based expert system for aiding the planning and designing of mine ventilation systems. The major thrust of this research is the integration of expert systems with a large, algorithmic mine ventilation network analysis program. The work on this project involves four phases: Phase I - Evaluation of various expert system shells in the market and development of input output interfaces to PSUMVS. Phase II - Development of knowledge representation schemes for the analysis and interpretation expert systems. Phase III - Computer implementation and execution of the analysis and interpretation expert systems. Phase IV - Validation of the system.

Phases I and II of this project are complete. Previous work on this project includes evaluation of PC based shells for this problem, development of interactive input / output interfaces to PSUMVS and development of knowledge representation schemes for the analysis and interpretation expert systems. The interactive PSUMVS have been tested not only on example networks but also on two real world ventilation system design and modification case studies. This aspect helps the interactive, user friendly creation and modification of data files for use with PSUMVS.

The development and implementation of the analysis expert system along with several interfacing modules: PSUMVS - User Interface, Analysis Expert System (AES) - User Interface and AES - PSUMVS interface has been completed. The analysis expert system has also been tested with satisfactory results on some representative test cases derived from literature. Results of this work were presented at the 22nd. APCOM Symposium in Berlin. Work on the computer implementation of the interpretation expert system and associated modules - Interpretation Expert System (IES) - User Interface, IES - PSUMVS interface is in progress. The IES will also be tested using example networks for staisfactory performance. Evaluation of new commercial expert system products and delivery environments has been a continuing endeavor within the project scope of work.

Future work on this project involves the validation and demonstration of the developed system to users in industry and government. The feedback obtained will be used to refine the system to address user oriented issues.

PS/16 - USBM/4224 USDI DCDR

DIFFUSION COEFFICIENT AND DEPOSITION RATE OF RESPIRABLE DUST IN MINE AIRWAYS

Principal Investigator: Raja V. Ramani Graduate Student: Klaus Bode

The objective of this study was to provide a better understanding of airborne dust flow in mine airways with regards to the diffusion coefficients and the deposition rates. The study had four components: 1) a review of literature concerned with diffusion and deposition in the field of aerosol science and literature related to mining engineering; 2) an experimental study in a wind tunnel to obtain concentration and deposition patterns of dusts typically found in coal mines; 3) an experimental study in a mine airway to gather similar information on concentration and deposition, and real-time concentration data; and 4) a comparative analysis of the data obtained in the wind tunnel and the mine airway, and related findings in the literature survey.

A thorough review of theoretical and experimental studies revealed that most of the available studies on diffusion in mine airways were concerned with diffusion of gases. Literature available in the field of aerosol science were reviewed for particle deposition.

Experiments were carried out in a suitable wind tunnel at the Particle Technology Laboratory, University of Minnesota. Particles (anthracite coal, bituminous coal and clay), each fractionated into four narrow size ranges were instantaneously dispersed into the wind tunnel at three air velocities. Samples were collected at two locations down stream through ten isokinetic gravimetric samplers and were also collected on deposition plates laid along and across the floor of the wind tunnel.

Experiments were also performed in the Lake Lynn Laboratory Mine of the USBM. The same three dust types, unfractionated, were dispersed continuously at three different velocities, and were sampled with real-time aerosol monitors (RAM-1) and gravimetric samplers.

For the wind tunnel experimental conditions studied, diffusion coefficient values obtained with Taylor's formula vary between 0.0263 and 0.0764 m^2/s. The average values calculated with Skobunov's equation vary between 1.40 and 4.05 m/s. In the mine airway it is observed that the diffusion coefficient increases along the airway and appears to be linearly dependent on air velocity.

In the wind tunnel it is observed that particles larger than 3 μm has deposition velocities which increase with both particle size and Reynold's number but below 3 μm the particles tend to show increased deposition velocities. In the mine airway it is observed that the deposition velocities increase with air velocity (or Reynold's Number). The increase is more obvious for the coal types than for clay. Clay also show fairly low deposition rate.

The data obtained during this study and the results observed would help us significantly in the fundamental understanding of the deposition phenomena and in the development of deposition velocity database for mine airways.

Study of Support Generated Dust by High Production Longwalls

Principal Investigator: Dr. Stanley Suboleski Graduate Student: Wilson Miola
Co: Principal Investigator: Dr. Jan M. Mutmansky

1990 Project Status Report and Summary

Objective

This study proposes to examine dust generation caused by shield supports in high-production longwalls, quantifying the magnitude of the problem and better understanding the mechanisms of dust generation, to analyse the relationship between roof support types and operating methods to the amount of dust generated under specific roof and floor conditions, modelling the dust generation, developing and testing control methods and to recommend abatement procedures.

Approach

The project is divided in two phases: Phase I - first year - preparatory phase beginning with a literature survey in order to develop a sampling technique to quantify cumulative effect of support dust over the course of a work shift, to measure particle size distributions and accurate mass concentrations. The sampling strategy defined will be applied to a set of mines selected from the literature survey and data from U.S. mines. A decision will be made at the end of this phase to define if the project should continue. Phase II- second year - comprising data analysis, laboratory dust generation and control, operating methods, support types, suppression devices and dust supression recommendations.

Results to Date

The literature survey and a preliminary selection of mines is being carried out. Over 60 publications have been analysed. The selections of mines was based on previous data from sampling by the USBM. A sampling strategy and preliminary experimental design was established and performed in one of the mines. The procedure involves 10 fixed RAMs, roving RAMs, one upwind and another downwind of the shield being moved, 1 total and 1 respirable sampler for each RAM and a double sampling from the intake. A detailed time study of the shearer and shields movement was performed. The objectives of the experiment are: 1) to analyse closely the behaviour of the dust along the working face; 2) to evaluate the possibility of isolating the dust from shields in continuous sampling data from RAMs; 3) to correlate dust from shields to the cutting sequence and shields movement; 4) to evaluate the possibility of mathematicall modelling for the calculation of a reliable work-shift average dust concentration from shields for compliance purposes; 5) to evaluate the relevance of the problem. The data analysis is being performed. The main problem is the availability of a model for dust behaviour that take into account all the parameters, which are still under development.

CHARACTERIZATION OF DUST PARTICLES

PS3/USBM 4203

Characterization of Dust Particles

Principal Investigators: Richard Hogg, Peter Luckie
Graduate Students: P. Bunnaul, E. Kaya

Project Status Summary

The principal objectives of this project are to prepare and characterize standard respirable coal dust samples and to develop and evaluate techniques and procedures for the characterization of respirable dust. Characterization of the distributions of particle size and composition is of particular interest. An additional objective is to provide service to other projects and research groups in the areas of dust sampling and characterization, preparation of special synthetic dusts, etc.

A suite of standard respirable dusts has been prepared from coals representing the western (high volatile A bituminous), central (medium volatile bituminous) and eastern (anthracite) mining areas of Pennsylvania, as well as quartz and kaolin clay which represent important mineral constituents of coal dust. Extensive characterization studies have been performed on the samples to evaluate chemical and mineralogical composition and the distributions of particle size and specific gravity. Samples of these standard dusts have been made available to research groups concerned with respirable dust in mines.

Complete physical/chemical characterization of the heterogeneous mixtures of coal, minerals, etc., which comprise respirable dust in coal mines is generally impractical. The approach we have adopted is to make limited measurements by three different levels: the bulk sample, individual size classes, and particle-by-particle. The information so obtained is combined to provide as complete a description as possible.

In previous project years, we have developed and evaluated procedures for the determination of the distributions of particle size, shape and chemical/mineralogical composition. A laser diffraction/scattering instrument has been adopted as a practical working standard for particle size analysis, backed up as needed by more absolute measurements using centrifugal sedimentation. An SEM image analysis based scheme has been developed for shape characterization. Simple single- or two-parameter shape descriptors have been defined for characterizing particle angularity.

Specific gravity fractionation procedures for estimating the distribution of chemical/mineralogical composition by size have been developed. These can be augmented, where necessary, by SEM/EDS analysis of individual particles.

Current research efforts are aimed especially towards the evaluation and quantification of the extent to which airborne dusts exist as agglomerates. Studies conducted under projects PS8/USBM 4207 and PS15/USBM 4223 have revealed that aerosolized synthetic dusts and dusts produced directly by single particle crushing are highly agglomerated. Some evidence has also been found for extensive agglomeration in airborne dust in mines. Various techniques for determining the extent of agglomeration in the laboratory are being evaluated. These include comparisons of cascade impactor data with direct laser diffraction/scattering measurements and analysis of liquid-dispersed particles following deposition on individual cascade impactor stages. The latter approach is especially attractive for application to real mine dusts.

PS8/USBM 4207

Wetting Characteristics of Dust Particles In Relation to Dust Abatement

Principal Investigators: Dr. S. Chander Graduate Student: Q. Hu
Dr. F. F. Aplan

Project Status Summary

The main objective of this project is to find ways to increase the collection efficiency of sprays used to capture dust particles. Dust suppression in coal mines using water sprays is inherently difficult because of the nature of the coal seam, as mined. The raw coal particles show a great variation in their degree of hydrophobicity due to such factors as coal rank, oxidation and contained mineral matter (silica, clays, carbonaceous shales, etc.). The successful development of a surfactant-containing dust suppression system would offer the user an additional degree of freedom in controlling, especially, those dusts not readily wettable by water alone.

The capture of dust particles by a water spray may be visualized as composed of three sequential sub-processes: 1) collision between water droplets and dust particles, 2) adhesion of the dust particles to the droplets, and 3) spreading of water on a particle and the engulfment of the particle by the droplet. The use of a surfactant offers the possibility of improving the dust capture efficiency of these sub-processes.

Using a modified Walker sink test and the initial rate of wetting, it has been demonstrated that the rate of wetting of coal particles with ethoxylated alkyl phenols (the Triton and Tergitol wetting reagents) is a function of coal rank and the type of surfactant. With a nonyl phenol containing 9.5 moles of ethylene oxide, the wetting rate of coal by rank is: HVA Bit > anth > sub-Bit while with octyl phenol, containing the same amount of ethylene oxide, the wetting rank is: anth > HVA Bit > sub-Bit. Note in both cases the sub-Bit coal is the most difficult to wet with this sirfactant-containing water solution.

Our studies show that at fixed levels of liquid consumption, the collection efficiency increases significantly with a decrease in droplet size. Experiments with air atomized nozzles indicate that the presence of surfactants generally make the droplets larger requiring higher spray pressures to obtain droplet sizes comparable to those made using water alone. To determine the role of surface charge on collection efficiency, a device was set-up to measure the charge on droplets. This charge was found to be a strong function of surfactant type and concentration.

A theoretical analysis of the process of dust capture has shown that the maximum benefits of surfactant would occur when sprays are used in areas of high dust concentration. To test this hypothesis the aerosol generator was modified to obtain higher dust concentrations in the spray chamber. Studies so far confirm this hypothesis. Additional studies are in progress.

PSIS/USBM 4223

Adhesion, Agglomeration and Deposition of Respirable Dust

Principal Investigators: S. Chander, R. Hogg
Graduate Students: Mary Koban, Hurriyett Polat

Project Status Summary

The objective of this research program is to determine the factors which control the effectiveness of the processes of adhesion, agglomeration, deposition and re-entrainment of particles. Considerable evidence exists to suggest that a significant portion of the adhesion and agglomeration occurs within a short time after fragmentation has occurred. Since it is known that freshly created surfaces undergo a variety of aging processes including atomic rearrangements, adsorption of water vapor and other gases from the environment, etc., it is important to specify the age of the dust and, if possible, to evaluate the nature and time scale of the aging processes. To carry out these investigations, we have designed and fabricated a fresh dust generator. This device can be used to produce particles for which the time of generation is precisely known, and which are available for study within a very short time. We have used this fresh dust generator to determine the effects of such variables as humidity, mineral type and coal rank, on the amount and size of the airborne dust.

The size distribution of airborne dust measured by an in-situ light scattering device, was much coarser than the size distribution of particles collected by an impactor. The size distribution obtained by impactor was similar to the distribution when particles were dispersed in a liquid. From this observation it was concluded that the airborne particles are highly agglomerated. The presence of agglomerates was confirmed by high speed microscopy of airborne particles and by scanning electron microscopic observation of samples collected on a substrate.

The difference between the size distribution of dust in air and dispersed in liquid was used as a measure of the extent of agglomeration. We have used this procedure to determine the effect of material type and humidity on the extent of agglomeration.

Since surface charge was expected to influence the extent of agglomeration, an apparatus was set-up to measure surface charge on particles. The results show that the particles carry different quantities of charge which is a function of material type and humidity. Using a different set-up, the potential on large fragments was also measured. The results are currently being analyzed.

Procedures have been developed for investigating the aging process and its effects on adhesion and agglomeration. We have studied changes in surface charge as particles age. Longer term aging effects will be evaluated by comparative studies of fresh dust and regenerated dust. For this purpose a device to redisperse dust has been fabricated and tested. Since adhesion, agglomeration and deposition occur simultaneously in many situations, the results are being analyzed so as to separate contributions from each of these effects.

WV10/USBM 5409

Magnetic Resonance Characterization of Paramagnetic Ions and Free Radicals in Coal Dust and Lung Tissue Under Controlled Dust Exposure

Principal Investigator: Professor Naresh Dalal
NIOSH collaborator: Dr. Val Vallyathan
Research Associates: P.Cevc, Mee Han
Graduate Students: X. Shi, H.Paul, X-Y Sun

Project Status summary (1989)

The overall objective of this project is to gain an understanding of the role of chemical properties of the surface of freshly broken coal and quartz particles in pneumoconiosis. This research is important because mine workers are exposed to coal and quartz particles within seconds or minutes of their generation. Our hypothesis is that carbon-,or silicon-centered free radicals are generated at the instance of severage of the particles from the lumps of coal and quartz, respectively. In order to test this hypothesis, we developed electron spin resonance and biochemical cytotoxicity assays suitable for dust studies, and the results obtained strongly indicated that freshly made dusts of both quartz and anthracite coals are significantly more cytotoxic than their 'old' (i.e., air-stored) dusts [1-3]. Another significant finding was that in aqueous media, fresh quartz dust produces hydroxyl radicals which are known to initiate lipid peroxidation [4,5], a necessary step for fibrosis. While these results have suggested a new mechanism for pneumoconiosis, the biochemical mechanism of the radical production is still not clear. Since the knowledge of this mechanism could lead to important clues to future strategies for the biochemical control of pnenmocoriosis, this year's effort is focused on elucidating this mechanism. We are currently developing techniques for controlling the radicals in direct relationship to their cytotoxicity and lipid peroxidation properties[6,7].

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WV13/USBM 5412

Determination of Biologically Active Silica using Photoacoustic Spectroscopy

Principal Investigator: Dr. M. S. Seehra, Research Associate: Dr. R. S. Pandurangi

Co Investigator: Dr. W. E. Wallace

Project Summary

During this year, we focussed on the particle size effects in the quantitative determination of silica by FTIR/Photoacoustic Spectroscopy, on establishing a correlation between the surface silanol species and cytotoxicity of silica, and on comparing quartz, cristobalite, tridymite and amorphous silica in terms of their hemolytic abilities and quantitative determination.

The particle size effects in PAS (photoacoustic spectroscopy) [1] results in much higher signal for smaller particles than that for larger particles of the same mass. These results are understood in terms of a recent theory by McGovern et al. A similar but smaller effect has been reported in FTIR spectroscopy. In PAS, surface and bulk IR modes are affected differently [2]. An important implication of these findings is that mass of smaller particles tend to get overestimated by IR techniques.

In another work involving cytotoxicities studies and FTIR/PAS of silica particles, we have established a correlation between the hemolytic ability of silica and the surface silanol species, Si-OH [3,4]. A critical examination of the literature has led us to conclude [4] that to first order, quartz, cristobalite and tridymite have nearly equal long-term hemolytic abilities but much larger than that of amorphous silica when compared on per unit surface area basis. Also a one-to-one correlation appears to be valid between hemolysis and fibrosis studies. Finally, criteria are established to distinguish between quartz, cristobalite and tridymite using x-ray diffraction and IR spectroscopy [5].

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PS/19-USBM/4227/2727/5427

Characterization and Control of Diesel Exhaust Contamination of Mine Atmospheres (Formerly titled as Diesel Haulage Investigations)

Investigators
R. V. Ramani, Penn State University
Virgil A. Marple, University of Minnesota
John Johnson, Michigan Tech
M. Gautam, West Virginia University
Kenneth L. Rubow, University of Minnesota
Jan M. Mutmansky, Penn State University

Project Summary

This project is oriented toward the characterization and control of diesel exhaust particulates in underground coal mines. West Virginia University is orienting their research work toward laboratory studies involving a diesel engine test bed and integrating this facility with an animal exposure facility. Their involvement will be summarized elsewhere. The remaining institutions will be working on field studies and their research activity is outlined in the paragraphs below.

Two meetings of the diesel project team were held during the past year with the first being held at the Pittsburgh airport on February 9 and the second held at the Respirable Dust Center review meeting in Morgantown, West Virginia, on May 16. These meetings were held mainly to plan various aspects of the field work and to coordinate activities of the participating institutions.

Four sampling and data gathering trips to coal mines utilizing diesel-powered equipment were completed during the past twelve months with most of the trips completed with personnel from two ore more of the participating institutions. Two of these trips were made to eastern coal mines and two were made to western coal mines. In addition, a trip to the Midwest set for August was cancelled when the mining company withdrew its support for the project. That field trip, which was to involve all of the participating institutions plus MSHA and the Bureau of Mines, has been rescheduled for December at a western coal mine.

Between field sampling trips, the individual institutions worked on analysis of the data gathered and on continued development of instrumentation to be used for assessing the diesel particulate concentrations in underground mine openings. The University of Minnesota has been concentrating its efforts on expanding their data base on size distribution and concentration of coal mine dust and diesel exhaust particles, on evaluating personal diesel samplers for underground environments and in continued development of a sampler for separating diesel particles from coal dust particles. Minnesota is also working with MSHA personnel in field evaluations with these samplers.

Personnel at Michigan Tech have completed the analysis of the Pierrepont mine data and have continued their development of an improved on-board emission measurement apparatus for use on underground diesel equipment. Their primary efforts during the past year have been oriented toward designing an improved emission measurement apparatus for use in analyzing diesel engines while used in their normal productions environment. Two different designs have been considered with choice of the final design to be made soon.

At Penn State University, the work performed during the past year has been oriented toward the analysis of time study data from underground diesel coal mines, the relationship between diesel particulate concentrations and the equipment usage, and the contributions of section and outby equipment to the overall diesel particulate matter. In addition, efforts have been made at assessing the advantages and disadvantages of the use of diesel equipment for use in underground coal mines.

RESPIRABLE PARTICULATE GENOTOXICANT DISTRIBUTION IN DIESEL EXHAUST AND MINE ATMOSPHERES

Principal Investigator	:	Mridul Gautam
Co-Investigators	:	Bill Wallace, Nigel Clark, Michael Keane, Nar Dalal, Tong-Man Ong,
Research Fellows	:	Gao Hong-Guang, Sui-Guang Xing
Graduate Students	:	David Nussear

Mutagenic activity of a diesel soot dispersed in three phospholipid surfactants, and initial findings of higher tier genotoxic activity of surfactant dispersed soot were published ("Mutagenicity of Diesel Exhaust Soot Dispersed in Phospholipid Surfactants", in "ENRIRONMENTAL HYGIENE, II", 1990, Eds., Seemayer, N.H. and Hadnagy, W., Springer-Verlag, ISBN 0-387-52735-4). These results had been the subject of an invited presentation at the Second European Environmental Hygiene Meeting.

The non-dissolved fraction of lecithin surfactant dispersed diesel soot from the Lovelace test unit was found to express SCE activity in the V79 mammalian cell line. A report on this has been accepted for publication in MUTATION RESEARCH ("Genotoxicity of Diesel Exhaust Particles Dispersed in Simulated Pulmonary Surfactant"). The surfactant dispersed soot has also been found to induce chromosomal aberrations and micronucleus formation in the mammalian cell line. The results are in review ("Mutagenicity and Clastogenicity Studies of Diesel Emission Particles in Mammalian Cells"). This surfactant preparation also is active for unscheduled DNA synthesis, related in a draft paper ("Induction of Unscheduled DNA Synthesis by Diesel Particles in V79 cells").

These results together have developed and demonstrated a method to perform first and second tier genotoxicity assays on diesel exhaust and the manner representing bioavailability in the lung. This provides a unique capability for physiologically reasonable in-vitro assays of diesel soot and complex diesel - mine dust respirable particles.

Design and fabrication of the multitube-type dilution tunnel is completed and the entire system is being set-up in the Engine Research Center. The CVS system is unique in that it can be used for both steady state tests as well as testing engines in the transient mode of operation. The system consists of an exhaust splitter in-line with a surge tank, a 1 m long, 10 cm diameter mini-dilution tunnel, a CVS and filter for inlet dilution air. In addition to the mini-dilution tunnel, an 18-inch total-exhaust double dilution tunnel with a CVS (using critical flow venturis) has been designed and is currently under fabrication. The system has been designed to handle 1000 cfm to 4000 cfm depending on the dilution requirements. An exhaust analysis bench capable of taking in samples from three separate probes (HC, NO_x, CO/CO_2) is being fabricated using Beckman Analyzers for continuous and bag sampling.

Electron Spin Resonance (ESR) measurements were made on diesel soot samples and all of them exhibited free radical activity. The plot of the free radical concentration versus sample mass was found to be quite linear.

MN1/USBM 2701

Coal Mine Dust Characterization

Principal Investigators: Dr. Virgil A. Marple
Dr. Kenneth L. Rubow

Graduate Students: Bernard Olson
Rodney Weber
Zhixin Xu

Project Status Summary

The objectives of this project are the development of instrumentation and protocols for the measurement of particulate matter found in underground mines. Efforts during the past year have been concentrated in three areas. The first is the continued development of personal diesel exhaust samplers to be used for determining the concentrations of diesel exhaust and mineral dust in respirable mine aerosols. These samplers use size selective sampling to separate diesel exhaust particles from mineral dust particles. The second area is the basic studies of, and improvements to, the microorifice uniform deposit impactor (MOUDI). The last area involves basic studies of virtual impactors.

Three different personal diesel exhaust samplers have been designed, built and field tested. These samplers consist of three stages. The first stage is a preclassifier that allows only the respirable dust fraction to be drawn into the sampler. This preclassifier is either a respirable cutoff impactor or a 10 mm nylon cyclone. The second stage is either a multiple nozzle impactor or a cyclone with a cut-size at 0.8 μm. The third stage is an afterfilter. This design allows the respirable fraction of the mine aerosol to be separated into two size fractions at 0.8 μm. The premise is that most of the material less than 0.8 μm is diesel exhaust particulate matter while most of the portion greater than 0.8 μm is mineral matter. The samplers operate at either 2 or 4 L/m and are intended to be used with personal sampler pumps. Laboratory evaluation of the sampler involved determining the size separation characteristics of the 0.8 μm cut impactor and cyclone. The impactor and cyclone were found to have sharp particle cutoff characteristics with cutpoints at 0.8 μm. These samplers are currently undergoing field evaluations. To date they have been used in more than 6 underground coal mines in joint studies with USBM and MSHA personnel.

The MOUDI studies have included development of a 0.8 μm cutpoint impactor stage, a parametric study of the impactor operating characteristics for the microorifice stages and general improvements for ease of use and improved performance. The 0.8 μm cutpoint impactor stage was developed for use in the coal mines using diesel powered equipment. Other MOUDI additions and improvements include development of a 0.032 μm cutpoint stage and use of drilling rather than chemical etching for the microorifice nozzles.

The use of virtual impactor techniques for sampling mine related dust aerosols is being investigated. In virtual impactors the impactor collecting surface is replaced with a receiving tube through which a small fraction of the airflow passes. Particles larger than the cut-size for the impactor remain airborne, thereby eliminating the potential problem of particle bounce from the solid collection surface in a real impactor. The objectives of the current study is to investigate the minimum fraction of flow required in the receiving tube and parameters affecting particle loss on the receiving tube.

MN3/USBM 2703

The Determination of Silica Particle Concentrations in the Respirable Size Range

Principal Investigators: Dr. Virgil A. Marple
Dr. Kenneth L. Rubow

Graduate Student: Ye Tao

Project Status Summary

The objective of this project is to investigate techniques to determine the respirable quantity of silica particulate matter in mine dust. The primary effort has been devoted to techniques capable of determining silica content as a function of particle size. A technique has been developed for determining the mass concentration and particle size distribution of silica particles in the respirable size range in a joint project between the University of Minnesota and Mine Safety and Health Administration (MSHA). The technique uses the microorifice uniform deposit impactor (MOUDI) for in-mine particle sampling followed by silica analysis of the collected material. The MOUDI, which has a sampling flowrate of 30 L/m, collects 15 times more dust per unit time than either the standard personal respirable dust sampler or the Marple personal cascade impactor. Both of the latter two samplers, which usually sample at a flow rate of 2 L/m, have been used by other investigators to obtain dust samples for silica analysis. Respirable dust samples are usually used to determine the overall silica concentration rather than the concentration as a function of particle size. Personal cascade impactors have been used to collect dust samples for subsequent particle size distribution analysis of the silica dust. However, the particle size resolution is limited, since the particle deposits from several impactor stages must be combined to obtain sufficient material for analysis. The MOUDI, operating at a higher sampling flow rate, collects sufficient particle mass on most stages for silica mass analysis. The MOUDI size fractionates the particle sample into 9 size intervals ranging from 0.1 μm to 18 μm on the basis of aerodynamic diameter. Particles less than 0.1 μm are collected on an afterfilter. With the MOUDI, the overall mass size distribution of the dust aerosol is determined through gravimetric analysis of the collected sampled prior to silica analysis. Silica analysis on each stage was performed by MSHA using Fourier transform infrared spectrophotometric and X-ray diffraction analyses. Protocols has been developed to redeposit the collected dust particles from the MOUDI collection substrates onto filters compatible with each silica analysis method. In the case of the infrared spectrophotometry, the particles are washed from the substrates using xylene, filtered with Nuclepore filters, ashed, deposited onto Gelman Metricel filters and analyzed for silica content. For X-ray defraction analysis, the particles are washed from the MOUDI substrates using methylene chloride, filtered through silver membrane filters and then analyzed for silica content.

Dust samples were collected in 3 underground coal mines during the past year. These samples together with those collected during the previous 2 years provide a data base of 9 underground mines: 7 coal, 1 shale and 1 quartzite. All MOUDI dust samples were collected in the working sections. Both the overall dust and silica dust data were analyzed to determine the silica mass fraction of the overall respirable dust and to determine the particle size distribution of each dust. The silica fraction in the respirable dust ranged from 0.2% to 5.9% for the coal mine, 6.3% to 12.5% for the quartzite mine and 5.4% to 5.6% for the shale mine. The particle size distribution of the silica dust was similar to that of the overall dust. The ratio of the mass medium diameter for the silica size distribution to that of the overall dust size distribution range from 0.75 to 1.38.

INTERACTION OF DUST AND LUNGS

Status Report
PS04/USBM 4209

Alveolar Macrophage and Polymorphonuclear Leukocytes in the Dust/Lung Interaction

Principal Investigator: Laurence M. Demers, Ph.D.

This project is designed to characterize the effect of mineral dust on the production of key mediator of the inflammatory response by the alveolar macrophage (AM). Utilizing AM from rats and monkeys, we have assessed the effect of various mineral dusts on the production of the oxygenated deviatives of arachidonic acid, the eicosanoids. The goal of the project is to determine if intervention directed at eicosanoid production by AM could serve to reduce the incidence and severity of mineral dust-induced lung disease.

In vitro studies suggest that freshly ground coal dust is more active than "stale" coal dust in eliciting alterations in AM eicosanoid production. In addition, silica is more effective than "fresh" coal dust. These findings are similar to those produced in other in vitro assays of dust toxicity (eg. red blood cell hemolysis assay) and suggest that the chemical characteristics of dust is an important factor in its biological activity. Additional studies with dipalmityl lecithin suggest that the toxic potential of mineral dust can be reduced by lung surfactant. We have assessed the effects of general and specific inhibitors eicosanoid production in order to determine if dust-induced changes in AM eicosanoid production can be normalized. The nonsteroidal anti-inflammatory compound, suprofen, inhibited the increase in AM eicosanoid production caused by in vitro exposure to silica. The specific thromboxane (Tx) synthesis inhibitor, UK38,485 (Pfizer) inhibited the induced increase in AM Tx production but had no effect on prostaglandin E_2 (PGE_2) or leukotriene B_4 (LTB_4 production). Interestingly, the prostaglandin analogue, cicaprost (Shering AG) also selectively inhibited Tx production in silica-exposed AM. Pre-incubation of AM with the biological antioxidant, å tocopherol, also inhibited eicosanoid production in AM exposed to silica. These findings suggest that the dust-induced release of pro-inflammatory eicosanoids by AM can be reduced by pharmacological intervention and provide a basis for further studies to determine if the inflammatory and fibrotic response to inhaled mineral dust can be reduced by inhibitors of eicosanoid production.

We have compared eicosanoid production in AM from monkeys and humans in order to determine if the monkey may serve as a valid model for aspects of dust-induced lung disease in the human. We have exposed monkey and human AM to coal and silica dust in vitro and have found that both qualitative and quantitative aspects of dust-induced eicosanoid production in AM from these species are virtually identical. These findings suggest that the non-human primate model of dust-induced lung disease may adequately reflect the pro-inflammatory response of AM in the human.

PS11/USBM 4210

Biochemical Alterations in Mammalian Respiratory Tract Mucus Caused by Coal Mine Dust

Principal Investigator: Dr. V. P. Bhavanandan

Project Status Summary

Objective of this project is to understand the influence of the coal dust exposure on the quantity and/or quality of respiratory secretions. The alterations in the mucus production are determined under both *in vitro* and *in vivo* conditions using metabolic labeling with ^{3}H-$GlcNH_2$ and/or ^{14}C-leucine. The radiolabel incorporated into the mucin fraction is estimated after purification from the culture medium. For *in vivo* studies tracheal secretions, explants and epithelial cells are obtained from rats exposed to coal dust in inhalation chambers. The long term objective is to understand the role played by the alterations in respiratory mucin secretion in predisposing the coal miner to chronic bronchitis and pneumoconiosis.

Our studies demonstrated that exposure of *in vitro* tracheal explant outgrowth cultures to coal dust caused 30 to 50% decrease in mucin production. The results were reproducible in three independent experiments. Similar effects (20 to 30% decrease) on mucin synthesis were also noted in the trachea of rats exposed to coal dust in *in vivo*. While the advantage of the tracheoexplants is that it attempts to mimic the *in vivo* conditions of the trachea and is likely to maintain control on the differentiation of the outgrowth cells, the disadvantages are that it contains a number of different cell types and it is not possible to estimate cell death.

Experiments with airway epithelial cell culture systems were then conducted to examine the effect of coal dust without the complexity introduced by the presence of mixed cell types and to determine cell death. The results indicate that rat epithelial cell cultures exposed to coal dust *in vitro* produced 70-80% more mucin compared to controls. Rat tracheal cells derived from rats exposed to dust *in vivo* (inhalation chambers) also produced more mucin (~40%) compared t cells from control animals. We also measured the mucin concentration in the lung lavages by direct ELISA using an antibody raised against monkey lung mucin and which was cross reactive with rat tracheobronchial mucin. Compared to controls, rats exposed to fresh and stale coal dust for 1 month had 63% and 49% less cross-reactive material, respectively in their lung lavages. Experiments are underway to determine the mucin content of the lung lavages by chemical analysis.

Monkey tracheobronchial mucin have been purified and its physical and chemical properties studied. The information obtained would be extremely valuable in utilizing monkeys as a model for studies on the effect of coal dust and various other environmental pollutants on the respiratory tract secretions of humans. Polyclonal antibodies were produced and used to measure mucin levels in lung lavages of monkeys. Intratracheal coal dust instillation caused increases in the amount of mucin in the monkey lung as detected by competitive ELISA. These antibodies are being tested in preliminary experiments for their utility in molecular biological investigations of the alterations in respiratory tract mucus due to inhaled particulate and gaseous toxicants.

September 1990

PS12/USBM 4211

INTERACTION OF COAL MINE DUSTS AND NONHUMAN PRIMATE LUNGS

Principal Investigator: James W. Griffith, D.V.M.

Research Assistant: Sarah Childe

Project Status Summary

The goal of this project is to determine the effects of characterized respirable dusts on a selected area within lungs of nonhuman primate monkeys. When respirable dust is placed within alveoli it may cause changes in the alveolar free cell population, the alveolar surface proteins, the quantity of surfactant secreted by the alveolar type II cells, and eventually pulmonary fibrosis.

These changes can be studied in monkeys who have had dust placed into their lungs, and in miners with pneumoconiosis, by using bronchoalveolar lavage to recover materials for laboratory analysis. Factors such as the physical characteristics of the dusts, the amount of dust, the time dust is in contact with alveoli, cigarette smoking, and the quality of the ambient air, food, and water can be controlled during experiments using monkeys.

By placing dust into only one lung lobe and recovering materials from affected and unaffected lung lobes, each animal serves as it's own source of normal and abnormal materials. By identifying the differences in these materials we hope to: determine mechanisms of fibrosis, develop treatments for fibrosis, and refine bronchoalveolar lavage into a more precise diagnostic tool for characterizing pneumoconiosis.

The first phase of investigation was to determine if the experimental dusts would produce focal pulmonary lesions in monkeys comparable to lesions found in man. Bituminous, anthracite, and quartz dust were tested, and each caused a marked accumulation of alveolar and interstitial macrophages which were detectable by lavage findings, radiographs, at gross necropsy, and histologically.

The dust caused a marked focal increase in the number of macrophages characterized by examination of lavage and histologic specimens. The macrophages were filled with dust, and clusters of macrophages within the interstitium were associated with increased connective tissue when examined at necropsy after 12 months. High levels of dust had been administered over a 10 month period and focal necrotic lesions similar to progressive massive fibrosis were identified in animals exposed to quartz dust, but not anthracite or bituminous dusts.

Experiments will soon begin in collaboration with Drs. Demers, Kuhn, and Schengrund where bronchoalveolar materials will be further characterized regarding cell types, eiconsanoids, peptides, and surfactant. I hope to increase interactions with Drs. Stauffer and Reynolds regarding refinements in the diagnostic abilities of bronchoalveolar lavage in pneumoconiosis of man and animals.

Status Report
PS04/USBM 4229

Human Alveolar Macrophage and Coal Mine Dust Interaction
Principal Investigator: Laurence M. Demers, Ph.D.

Inflammation and interstitial fibrosis are the predominant features of pneumoconiosis and silicosis. The alveolar macrophage (AM) is the primary defensive cell in the lung which, when activated by exposure to inhaled mineral dust, secretes potent inflammatory and fibrotic mediators. Among these, the eicosanoids (oxygenated derivotives of arachidonic acid) and cytokines (peptide intercellular messengers) appear to play a major role in dust-induced lung disease. The goal of this project is to characterize the production of eicosanoids and cytokines by human AM exposed to coal dust in vitro and in vivo.

We have studied the in vitro response of AM from normal human volunteers to coal and silica dust. AM are harvested by bronchoalveolar lavage (BAL) and maintained in cell culture. The results of these studies suggest that the AM response to coal and silica is biphasic with low doses of dust (<100 ug/5 x 10^5 cells) inhibiting eicosanoid production while higher doses stimulate eicosanoid production. Silica elicits changes in AM eicosanoid production at a 10-fold lower concentration than does coal dust. The production of interleukin-1 (IL-1) and tumor necrosis factor (TNF) are stimulated by silica at concentrations greater than 10 ug/5 X 10^5 cells. A 10-fold higher concentration of coal is required to elicit similar changes in cytokine production.

We have compared basal eicosanoid and cytokine production by AM harvested from non-smoking normal volunteers and from active and former coal miners. The 9 coal miners in this initial study had an average exposure of over 25 years but had no significant impairment of lung function or radiographic evidence of lung disease. The production of eicosanoids and cytokines by AM from coal miners was not significantly different from AM from normal volunteers. However, a significantly greater number of AM were harvested from the lungs of coal miners than control subjects suggesting that the total lung burden of eicosanoids and cytokines may be greater in coal miners. Further studies to evaluate eicosanoid and cytokine production by AM from miners with significant lung disease are in progress.

In addition, we assessed the effect of various inhibitors of eicosanoid production on cytokine release by miners' AM in order to determine if the reciprocal relationship which has been demonstrated between PGE_2 and IL-1 production (ie PGE_2 down-regulates IL-1 production in activated AM) in vitro, exists in the chronically stimulated AM of the coal miner. Several general and specific inhibitors of eicosanoid production reduced eicosanoid release by miners' AM but no effect on cytokine production could be demonstrated. The results of these studies suggest that eicosanoid and cytokine release are not linked in chronically activated AM. However, the ability of selective eicosanoid inhibitors to reduce the production of inflammatory and chemotactic eicosanoid by AM indicates that it may be possible to reduce the recruitment of immune cells into the lung thereby reducing total lung burden of eicosanoids and cytokines.

WV5 / USBM 5405

INHALATION TOXICITY OF RESPIRABLE COAL MINE DUSTS : A MORPHOMETRIC STUDY

Charles Stanley, Naresh Dalal, Henry Abron, Richard Dey, Art Pavlovic

89-90 Project Status Summary

SCIENTIFIC RATIONALE

The overall objective of this project is to provide a small animal inhalation facility to study the effects of inhalation of respirable coal mine dusts on animal lungs. The working hypothesis is :

" A relationship exists between the physical and chemical makeup of the inhaled dusts and the alterations in the lung caused by dust inhalation. Therefore, by controlling and knowing the physical and chemical makeup of the inhaled dusts, the important factors which lead to pulmonary injury following inhalation of coal mine dusts can be determined and detoxification or intervention techniques can be developed. "

Our existing research has concentrated on evaluating free-radical activity of fresh coal mine dust as an important factor leading to pulmonary injury by exposing animals in the WVU Inhalation System.

Arrangements were made to supply these animals to Dr. Eugene Cilento , BOM 5408 , to examine superoxide release from pulmonary alveolar macrophages ; Dr. Richard Dey, BOM 5431 , to examine macrophage growth factors in fibroblast activation ; Drs.Larry Demurs and Douglas Kuhn , BOM 4209,4229, to evaluate arachidonic acid metabolism in the alveolar macrophage.)

Testing is not complete, but relevant preliminary results are summarized below.

a) Morphometric analysis of rats exposed to stale and fresh 20 / 20 coal mine dusts for two week periods has shown no significant differences in the alveolar interstitium. However a longer, 12 -week exposure has been completed, and results should be available in 1990.These results might necessitate exposures with durations greater than 12 weeks.

b) Drs. Larry Demurs and Douglas Kuhn (Hershey Medical Center) used rats exposed in our facility to demonstrate changes in arachidonic acid metabolism in rats exposed to fresh 20 / 20 dust made in a jet-mill compared to rats exposed to stale 20 / 20 dust collected at the mine site. However, when comparisons were made between rats exposed to fresh 20 / 20 dust and to dust made the same way (using a jet-mill) but allowed to become stale (relative to the free radical activity), no differences were seen. In perspective, however, it is noted that this result was based on only a two-week exposure and considered only arachidonic acid metabolism as an indicator.

c) To continue examining the effects of particle shape/size, we produced respirable titanium oxide for Dr. Kuhn to use in initial in-vitro studies.

d) A test of the effects of particle feed rate, initial particle size, and supply air pressure to the jet-mill on the size and shape of respirable dust produced is being made.

WV08/USBM 5407 AIRWAY REACTIVITY IN COAL MINERS

Principal Investigator: Henry L. Abrons, M.D.
Associate Investigator: Edward L. Petsonk, M.D.

This longitudinal investigation follows coal miners and a matched control group of industrial workers for 5 years. The objective of this study is to determine if the occurrence of respiratory tract symptoms or variability in lung function is related to the degree of nonspecific airway responsiveness in coal miners compared to nonmining controls. Alternatively, is airway responsiveness itself influenced by current and previous underground coal mine employment, cigarette smoking, and other factors. Upon completion of the final two years of this project, our analysis will determine if airway reactivity testing can predict the development of symptoms and decreasing ventilatory capacity in coal miners and whether prolonged coal mine dust exposure leads to increased airway reactivity.

Analysis of cross-sectional data has revealed the following trends regarding symptoms, smoking and mining tenure. Subjects who indicated symptoms that would suggest an atopic disposition (hay fever or seasonal rhinitis) and who were cigarette smokers displayed both higher prevalences of methacholine responsiveness and higher levels of responsiveness than nonsmokers. A similar trend was seen with mining: methacholine responsiveness was significantly more prevalent in miners with atopic symptoms compared to miners without symptoms. In the nonminers, the proportion of responders was similar irrespective of these symptoms.

No clear evidence was found regarding an association of nonspecific airway responsiveness with work tenure in underground coal mining. We found miners with the longest tenures in dusty jobs to have the lowest prevalence of methacholine responsiveness. An effect of mining on airway responsiveness, however, cannot be excluded based on these data. Participation rates or self-selection both between jobs in the mines, and into and out of the industry, are likely to have prevented detection of any such effect, if present.

Age and length of employment data for workers who were eligible but chose not to participate at each mine and control group testing site were analyzed. No selection biases were apparent. Three industrial hygiene surveys have been completed at two mines and two of the series of three have been completed at the third mine in the study. A database has been established and verified for all dust samples and mine working conditions received to date from the industrial engineers who conducted the survey. A random sample of spirometry graphs has been selected for quality control analysis through hand calculation.

Verification of our follow-up pulmonary function database is complete to April 1990. Arrangements have been made to begin final testing, which includes methacholine challenges and pulmonary symptoms questionnaire administration, at one mine and two control groups. Semi-annual testing continues. In an effort to reduce participation attrition, another motivational item has been designed, and telephone contact with subjects is ongoing. Over 1,500 motivational letters and spirometry results letters were disseminated in the past year. We now have at least 7 separate lung function results, representing three years of follow-up, on 62% of the study group. Four years of follow-up have been obtained on 133 members (28%) of the group. To date, 3,056 complete spirometry tests have been conducted.

US BOM #5408 (WV09) September 26, 1990

EFFECTS OF RESPIRABLE DUST ON SUPEROXIDE RELEASE FROM SINGLE PULMONARY ALVEOLAR MACROPHAGES

Submitted by: Eugene V. Cilento
Technical Liaison: Wayne Duerr, USBOM
September 25, 1990

Studies are being done to measure superoxide release ($O_2^{\cdot}$) from individual PAM during in vitro or in vivo exposure to fresh and stale respirable dusts (quartz, CMD). The major objective this year have been to determine the effects of surfactant coated dusts on PAM superoxide release under different conditions of exposure.

In Vitro Studies. In vitro experiments consisted of stimulation with freshly sheared or aged quartz. Dust particles were either coated or non-coated with the surfactant dipalmitoyl lecithin (DPL). Superoxide release and the number of particles phagocytized by each cell were estimated from video-recorded images of quartz exposed PAM. Results show that freshly sheared quartz significantly increased (381%) biological activity. DPL-coated quartz particles (fresh or stale) delayed release until 180 min. The data support the hypothesis that the prophylactic DPL coating was slowly being removed by intracellular lysosomal enzymes. A dose effect also was observed; stale quartz below 250 µg/ml did not significantly increase release, with fresh quartz again being more reactive. However, phagocytosis of quartz particles was the same for fresh or stale dusts, independent of coating.

In Vivo Studies. In vivo exposures consisted of using freshly sheared or aged CMD for an acute exposure of 12 hr, or for 2 and 11 weeks. PAM then were lavaged immediately after, or 3, 10, or 31 d post-exposure. Results are as follows: (a) after 12 hours fresh CMD induced a 62% increase in release compared to control cells or stale CMD which did not stimulate cells; (b) after 2 weeks no significant differences in production were observed between fresh and stale CMD with both exhibiting significant increases upto 10 d post-exposure (highest at 0 d). Particle frequency distributions for the stale CMD suggested there was cell turnover between 3 and 10 d post-exposure, probably due to recruitment of macrophages in response to the exposure. In contrast, for fresh CMD increased numbers of cells with less particles phagocytized were observed immediately after 2 weeks exposure. The combined observations suggested fresh CMD induced a more intense cell recruitment; (c) 11 weeks of exposure showed that lavaged cells contained many more monocytes, floating dust, and lysed cells compared to stale CMD. Between 3 and 10 d post-exposure there was increased production for fresh CMD suggesting that the recruited monocytes might have been conditioned while for stale CMD cells were not conditioned as demonstrated by the low production of $O_2^{\cdot}$. In summary, fresh CMD exhibited a higher biologic toxicity and induced earlier, enhanced cell recruitment. Data also suggested that chronic exposure to fresh CMD could be particularly harmful to lung tissue. These data are now submitted to American Review of Respiratory Diseases.

USBM 5413 / WV14A

TRACHEAL ACOUSTIC IMPEDANCE OF LUNG AIR PASSAGES

Dr. John Sneckenberger, Dr. Charles Stanley
Timothy Whitmoyer, Jing Tian, Jerry Legg, Kumar Kushal, Nadia El-Ayouby

The main objective of this research has been to systematically develop a method for clinically assessing biomechanical changes within the human respiratory system caused by lung-dust interactions. This diagnostic tool will non-invasively detect an abnormal respiratory airway condition from a measurement of the person's tracheal impedance.

A prototype clinical facility that incorporates a two-microphone impedance tube technique capable of measuring acoustic impedance at frequencies higher than previously reported in the literature has been further developed. The ergonomical design of a commercial facility that is compact and portable with clinically meaningful results being computed within five minutes has been proposed.

Equivalent airway area functions recovered from tracheal acoustic impedance measurements have been computationally analyzed for a group of normal human subjects to assess their upper lung volume as a function of depth into the lung. The upper airway area functions into the bronchi were typical of the lung area function for a normal person. The upper lung volume results, when assessed relative to the results obtained from traditional spirometry and helium dilution methods for the same human subjects, were found to reasonably extrapolate to their total lung volumes. A subsequent human subject study has been formulated to assess the repeatability and to further quantify the results of the tracheal acoustic impedance measurements.

Computational interpretation of the airway area function that is recovered from the measured tracheal acoustic impedance has been integrated with the theoretical lung modeling endeavors. An experimentally detected lung dysfunction can be mathematically associated with physiological airway wall parameters. A previously derived acoustic-mechanical model of the lung enables the tracheal acoustic impedance to be expressed in terms of biomechanical airway wall tissue parameters. This three-section responding wall model has been used to parametrically study and clinically appreciate the effect of lung airway changes. Recovery of rat lung wall parameters at various stages of inflation or deflation has been completed. Initial laboratory facility design has been pursued to experimentally obtain enhanced biomechanical property values for lung airway tissue.

Experimental results have been obtained from tests on a three-generation Y-tube branched lung model and lined straight-tube airway models. The impedance tube method was able to detect changes in both the termination condition of the branched lung model and the wall condition of the straight airway model. Study of a Weibel-type branched lung model is underway, as are extensions of the method to detect other dysfunctions of the human upper respiratory system.

Title of Project: The Role of Platelet-Activating Factor in the Etiology of Coal or Silica-Induced Pneumoconioses and the Effects of Fresh Cleavage Planes on this Response

Project Number: WV USBOM Subaccount Number: 5423

Institution: West Virginia University

Principal Investigator: Knox Van Dyke, Ph.D.
Pharmacology/Toxicology
(304) 293-5449

Co-Investigators: Vincent Castranova, Ph.D.
Val Vallaythan, Ph.D. Division of Respiratory Disease studie National Institute for Occupational Safety and Health

Summary of Project:

Inhalation of dusts from coal mines causes lung diseases of miners. The coal dust or its silica-laced counterpart overcome the protective phagocytic/cellular systems normally present in lung. The processes which in most cases are helpful to the body are activated to produce inflammatory reactions which ultimately attempt to detoxify, wall off or isolate the toxic particles. This can result in problems such as emphysema, black lung or fibrosis depending on the composition of the insulting particles.

We have identified freshly cleaved silica as a major toxic component in the mines. This problem is well understood in anthracite mining. However, toxic concentrations of silica can be encountered in soft coal mines in roof bolting for structural support when drilling occurs in hard rock. In addition, when sand is thrown on the track for extra traction of the cars hauling coal from site of production additional silica toxicity can occur. In addition some soft coal seams can be interwoven with hard rock containing silica. Our data indicate that freshly cleaved silica is much more toxic than silica broken days or weeks previously. Therefore we have developed a chemical mechanism using a water soluble organo-silane concentrate (Prosil 28%) which when used in conjunction with water cooled drills can decrease the toxicity of particles at the point of particle generation. This coating mechanism deactivates the surface free radical present on silica namely (SiO) and (Si) .

In addition we have shown that silica activates the lipoxygenase mechanism present in phagocytic cells which apparently ultimately is linked to cytokines and growth factors causing fibrosis. Using antilipoxygenase drugs, either direct or indirect lipoxygenase inhibitors, we are able to stop this toxic reaction. Tetrandrine which is known to be antisilcotic/antifibrotic appears to be acting as an indirect lipoxygenase inhibitor. This is a second method to detoxify the key reaction caused by silica.

Furthermore we have shown that the phospholipid hormone platelet activating factor (PAF) is a major inflammatory substance. It has both direct activating effects on phagocytic cells, neutrophils and macrophages and it produces a potentiating or magnifying effect on the inflammatory process caused by coal dust and/or silica. We have found that anti PAF inhibitors help in decreasing the exacerbation of the inflammatory process.

In summary we have developed three different methods to lessen the toxicity of dusts from coal mines and other hard rock drilling situations.

BOM 5424/WVU 21

Immunological and Inflammatory Pulmonary Mechanisms Associated with Chronic Coal Dust Inhalation in Coal Miners.

Principal Investigator: N. LeRoy Lapp, M. D.
Co-Investigators : Marvin Balaan, M. D.
Vincent Castranova, Ph. D.
Daniel Lewis, Ph. D.

The aim of this project is to study the number and types, function, and biological activity of immune effector and inflammatory cells obtained by bronchoalveolar lavage (washing) from nonsmoking coal miners exposed to respirable dust and compare these findings to control subjects of comparable age. The study is composed of several of several parts.

Subjects Studied

Since October, 1989, we screened an additional 12 subjects, 3 controls and 9 miners. This brings to a total number of subjects screened to 38, of which 31 completed the entire protocol including bronchoalveolar lavage. The 31 are distributed as 19 control subjects and 12 miners.

Metabolic State of the Cells Harvested

There were no significant differences between the spontaneous release of superoxide (toxic) radicals in the miners and the controls. Similarly, liquid stimulation of the cells of miners and controls produced increased amounts of superoxide radicals, but the results were not different. In contrast, the miners' cells released significantly less superoxide when stimulated by particulates.

Cell Morphology

The alveolar macrophages from miners demonstrated significantly more surface ruffling than the cells from control subjects. When examined by electron microscopy, the miners' cells were filled black particles. These were identified morphologically as coal dust particles.

Immunological Studies

The total amount of protein recovered in the alveolar fluid was significantly lower in miners than controls. No significant differences were found in the immunoglobulins IgA and Igm.

Major Conclusions Thus Far

While most indices of inflammation from bronchoalveolar lavage in miners, the <u>decrease</u> in particle-stimulated chemiluminescence and the <u>increased</u> ruffling suggest the beginnings of particle overload of the alveolar macrophage clearance system in the lungs.

<u>Reports</u>

The preliminary data from this study have been summarized and are being presented as follows:
Oral presentation at Respirable Dust Meeting in Pittsburgh, PA, October 17, 1990. Manuscript submitted for publication.
Poster presentation at American College of Chest Physicians meeting in Toronto, Ont, October 23, 1990.

WVU 20/USBM 5430
Targeted Delivery of Tetrandrine to Alveolar Macrophages for Treatment of Silicosis

Principal Investigators: Joseph K.H. Ma; C.J. Malanga, V. Castranova; J.Y.C. Ma

Research Associates: C.G. Mo; D.H. Chao; J.K. Kang

Project Status Summary

Tetrandrine, a bisbenzylisoquinoline (BBIQ) alkaloid, has been used in Chinese Clinics in the treatment of silicosis. The objective of this research is to provide more insight on the mechanism of drug action and the role of alveolar macrophages in the fibrotic process, and to develop an emulsion system for targeted delivery of tetrandrine to the lungs. Drug targeting, which offers the advantages of increased efficacy at the targeted site and reduced systemic toxicity, can be used to maximize the therapeutic index of the drug.

It has been well demonstrated that the macrophage-orchestrated inflammatory sequel following lung injury, manifested by macrophage respiratory burst and/or production of fibrogentic mediators, is central to the fibrotic process. Tetrandrine and other BBIQ alkaloids are known to exhibit varying degree of antifibrotic activity against silicosis. Our studies indicate that tetrandrine and methoxyadiantifoline interact with alveolar macrophages and inhibit the cellular release of reactive oxygen. In contrast, compounds such as curine and tubocurine, which have little or no effect on silicosis, do not interact with alveolar macrophages. These results suggest that the antifibrotic action of the BBIQ alkaloids depends on their ability to interact and, thus, to inhibit the abnormal inflammatory activities of alveolar macrophages associated with fibrotic lung injury. Binding of the BBIQ alkaloids with alveolar macrophages occurs only with live cells at the cellular plasma membrane, which can be partially blocked by cytochalasin B or vinblastine. It is postulated that the cellular drug action involves drug binding to the microtubule and microfilament systems, which play an important role in the rapid dynamic control of cellular transport and membrane potential. Using a microscopic fluorometric technique, we further demonstrated that the tetrandrine binding results in an decrease in intracellular free Ca^{++}. Since the intracellular Ca^{++} mobilization is associated with fibrotic stimulation as well as the phagocytotic responses of the cells, the effect of the BBIQ alkaloids may be to interfere with the Ca^{++}-triggered transmembrane signal transduction.

Tetrandrine was found to be toxic to alveolar macrophages on prolonged incubations. For effective drug targeting to the lung region, multiple water/oil/water emulsions containing tetrandrine were prepared using Tween 80 and Triton X-100 at concentrations nontoxic to the cells. These emulsion systems were found to exhibit high affinity to alveolar macrophages for drug uptake and provide reduced drug toxicity but increased efficacy on drug activity. In vivo studies of drug distribution showed that increased drug distribution in the lung 24 hours after administration may be achieved with the emulsion system in comparison with free drug solutions.

PROGRESS REPORT 1989-90

Project Number: WV 5431

Project Title: Role of macrophage growth factors in fibroblast activation after coal dust exposure.

Principal Investigator: Richard D. Dey, Ph.D. Department of Anatomy, WVU Health Sciences Center

Co-investigators: Vincent Castranova, Ph.D., Director, Section of Biochemistry, NIOSH, and Department of Physiology, WVU; Kent Vrana, Ph.D., Department of Biochemistry, WVU Health Sciences Center.

STATEMENT OF OVERALL OBJECTIVES

The major objective for this project is to characterize pulmonary macrophage responses to coal mine dust. We hypothesize that macrophages in the alveoli act as target cells initiating the pulmonary response to inhaled dusts. It is well known that inhalation of dust into the lung may lead to pulmonary inflammation and fibrosis. Our investigation will evaluate the possibility that inflammation and fibrosis occur as a result of mediators released from macrophages. These mediators then activate fibroblasts resulting in increased collagen synthesis and fibroblast proliferation, characteristic features of pulmonary fibrosis. Although macrophages can be stimulated to release mediators in response to toxic agents such as silica and bleomycin, their release by mine dusts has not been demonstrated. Thus, the involvement of macrophage mediators in the production of lung inflammation and fibrosis remains to be established.

During the first year of funding on this project, we have accomplished the following:

1. Developed methods for the isolation and purification of fibroblasts from rat lungs and for the maintenance of alveolar macrophages and pulmonary fibroblasts in culture.
2. Performed control experiments which indicate that we are able to demonstrate PDGF-stimulated proliferation of fibroblasts using the thymidine-incorporation technique.

DELIVERABLE:

a. Reist, R., K. Bryner, P. Wearden, J. Blackford, K. Vrana, V. Castranova, and R. Dey. Development of a cell culture system as a bioassay for pulmonary cell production of fibrogenic factors. Presented at Respirable Dust in the Mineral Industries, October 17-19, 1990, Pittsburgh, PA.

b. Full manuscript of above presentation submitted to Toxicological Methods for peer-reviewed publication.

3. Developed biochemical assay for human and rat PDGF:
   a. Measured PDGF release from normal and silica exposed rat alveolar macrophages. No changes found in preliminary studies.
   b. Detected high levels of PDGF in lung lavage fluid of control human subject. This is the first subject of a collaborative study with Dr. Lapp to compare PDGF levels in lavage fluid from normal subjects and from coal miners.

Directions in following years are as follows:

Year 2: Examine the effects of <u>in vivo</u> and <u>in vitro</u> exposures to selected coal mine dust and silica on release of PDGF from macrophages and on fibroblast proliferation response to macrophage supernatants.

Year 3: Examine the effects of exposures on release of additional mediators: tumor necrosis factor-alpha (TNF), fibroblast growth factor (FGF) and interleukin-1 (IL1). Use antibodies to mediator in fibroblast proliferation assay to inhibit mediator action as a way to assess the action of specific mediators.

Year 4: Investigate the role of free radicals in mediator release from macrophages and fibroblast proliferation response to macrophage supernatants.

RELATIONSHIP OF MINE ENVIRONMENT, GEOLOGY AND SEAM CHARACTERISTICS TO DUST GENERATION AND MOBILITY

PS5/USBM 4205

Establishment of Standard Procedures for Characterization of Respirable Coal Mine Dust Potential

Principal Investigators: Dr. Jan M. Mutmansky
Dr. Christopher J. Bise
Prof. Robert L. Frantz

Graduate Students: Lijun Xu
Sriram Padmanabhan

Project Status Summary

The work on characterization of coal samples from the various coal-producing regions of the United States and its relationship with coal workers' pneumoconiosis (CWP) has progressed and is nearly at an end. A statistical analysis of the overall data set based upon 99 impactor dust samples from 18 mines in 7 states has been completed. A variety of patterns exist in the data that may have a relationship with CWP. Some of these are outlined below.

Study of the dust physical properties shows that mines using diesel equipment contain a large percent of submicron dust particles in their intake airways. The mass concentration and size distribution vary significantly in the different sampling locations. Dust particles in the respirable size range are likely to be transported through the working area.

Significant size effects on the elemental and mineral contents are shown. Elemental concentrations decrease as size decreases. However, mineral contents have a negative relationship with dust size. Regional variations of elemental and mineral contents are also significant. Quartz and kaolinite contents are small in regions with low incidences of CWP, and elements Cu and Zn may have the effect of protecting against the disease.

The relationship between the mineral contents in dust and in mined material indicates that mineral content in airborne dust can be predicted by mineralogical data in channel samples. Association among the three dust properties gives a better understanding of the characteristics of airborne coal mine dust.

NIOSH data on CWP occurrences was sought during the project to provide a relationship between the dust characteristics and the incidence of CWP. Citing confidentiality restrictions, NIOSH provided only data aggregated by state. This data was not considered to be useful for the analysis. This research effort has pointed out the need for better data on the incidence and progression of the disease. Currently, the data available to researchers does not suffice.

Finally, work is still progressing on the evaluation of a scanning electron microscope for determining the shape and mineralogical makeup of a coal dust. Preliminary tests have been made and initial results are favorable. The project will be terminated after this topic on dust characteristics is investigated and analyzed.

PS14/USBM 4222/5422/2722

Formulation, Evaluation and Verification of Improved Dust Sampling and Analytical Strategies for Use at Surface and Underground Coal Mines

Faculty Participants:
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R. L. Frantz

Graduate Assistants:
Jianliang Li
Hyunwook Kim
Shiquan Yuan
Satyendra Sunkavally

Project Summary

The primary thrust of this project is the provision of better sampling and analytical technology for application to the sampling and characterization of respirable coal mine dusts. A research team comprised of Penn State, West Virginia University and University of Minnesota researchers was assembled for this effort. During the past year, the project team has been continuing its efforts toward the writing an assessment report on the dust sampling and analytical strategies for use in mines. In addition, each of the institutions has pursued an individual line of research that will support the project goals and increase the level of knowledge or technology in a specific area of sampling or analysis.

The research being pursued at West Virginia University is oriented toward a field study of the coefficient of variation that occurs during dust sampling in underground mines. Their research effort has resulted in the design of an experiment to be performed on a longwall operation. The sampling experiment involves eight sampling sites on the longwall section with four samplers per site to investigate the sources of dust and the coefficients of variation that were encountered. The field experiments were to take place during the summer but were postponed due to labor problems in the eastern coal fields.

At the University of Minnesota, the specific research pursued has been oriented toward the collection of dust samples in a lung surfactant as a means of preserving the dust characteristics in medical and scientific research. To perform this task, an official protocol has been established with the University of Minnesota Medical School to extract animal lung surfactants and procedures developed for the use of the electron spin resonance method to measure free radicals in the experimental dusts collected.

Penn State University has been orienting its research effort toward the generation of coal dusts for medical and scientific research that possesses all of the natural physical properties of in-mine airborne dust. To perform this effort, a variety of coal grinding equipment is being tested to compare the resulting dust product with in-mine airborne coal mine dust on the basis of shape and size characteristics. The equipment includes pulverizers, a hammer mill, a roller mill, a jet mill and two versions of a ball mill. Size and shape analysis of the dusts created is continuing with conclusions to be outlined by the end of the project.

PS/17 - USBM/4225

Breakage Processes and the Origin of Quartz in Airborne Coal Mine Dusts

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The primary emphasis during the last year of research on this project has been analysis of the airborne and channel samples collected during the previous year at three underground room and pillar coal mines for identification of the petrography of the mined materials, the quartz content of the coal and rocks, the specific morphology of the quartz in the host rocks and the airborne dust, and the statistical analysis of the resulting data. The quartz content for each of the samples was obtained by the infrared method, the X-ray powder diffraction method, and compared with the percentage of quartz particles found using the scanning electron microscope. Preliminary results have indicated that the quartz in the rocks associated with the coal seams sampled were in the range from 5% to 27% by weight of the rock mass.

The results of the petrographic analysis indicated that all the rocks associated with the three mines sampled were shales or mudstones with a variety of identifiable minerals. The quartz particles isolated from the source rocks appeared to be well-rounded even for the smallest particles. This appears to be a result of transport and abrasion of the rock particles before they were deposited. This finding was a fortuitous one because it makes the detection of quartz particles in the airborne dust that are fractured during the mining process an easy task.

The results of the scanning electron microscope investigation of specific quartz particles indicated that many of the quartz grains in the source rocks were being released cleanly from their matrix, i.e., without fracturing. However, about the same number of particles retain some attached matrix, primarily clay. The cost significant finding is that very few of the particles showed any evidence of fracturing during the mining process and that this pattern was consistent throughout the mines studied. The results of this aspect of the study will be presented by project personnel at the Third Symposium on Respirable Dust in the Mineral Industries in a paper entitled "Quartz Particulate Behavior During the Mechanical Mining of Coal Seams."

One additional aspect of the research that still needs completing at the present time is the statistical analysis of the size difference between the quartz particles and the coal particles in the airborne dust samples and the statistical comparison of the quartz contents as determined by the infrared and the X-ray powder diffraction methods. These statistical analyses will be completed and will be the subject of a second paper to be published as a result of this project. This proposed paper will be published in a refereed journal.

WV6A/USBM 5#06A

Correlation of Respirable Dust Characteristics to Coal Seams, Worker Positions and Mining Methods--Longwall Mining

Principal Investigators: R. L. Grayson
W. E. Wallace

Research Staff: J. Harrison
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Graduate Student: L. Zhao

The objective this past year has been to develop and apply a methodology for the semi-automated depth profiling of respirable dust particles using an SEM interfaced with an EDX spectrometer. In previous research, Dr. Grayson found that the higher rank seams appeared to have more pure quartz material than lower rank seams. Dr. Wallace, in his previous research, discovered that many of the quartz-assayed particles from a clay mine were coated with a layer of clay. This conclusion was reached after extensive analysis of many particles at different accelerating voltages.

The first part of this year was devoted to developing the methodology for depth profiling coal mine dust particles. Experimentation focused on ensuring 1) the elimination of artifacts on the mounting substrate, 2) the proper tracking of particles in a field as the accelerating voltages are varied from 11 keV to 5 keV (four steps), 3) the accurate determination of the minimum detection limits for the existence of elements, 4) the proper times for analysis of particles at different accelerating voltages , 5) the accurate identification of changing mineral phases in a particle, and 6) the stability and repeatability of results. The analysis is semi-automated for a field at a particular accelerating voltage, with approximately 15-20 particles being analyzed per field.

The methodology was developed after six months and has now been applied to a respirable dust sample taken from the Pocahontas No. 6 coal seam, to one of Dr. Wallace's clay mine samples, and to some low-temperature-ashed MSHA samples. Thus far we have seen just about any single- and multiple-phase combination of coal and minerals imaginable in the respirable coal mine dust sample. Representative data for different models has been generated, although only 250 coal seam particles have been analyzed thus far. Clay coatings on quartz-assayed particles have been detected in the unaltered coal mine dust, the clay mine dust, and the low-temperature-ashed MSHA dusts. Interestingly, quartz phases have been detected on the surface of nonquartz-assayed particles. All of this data indicates the very complex nature of the surfaces of respirable dust particles, which bulk analysis procedures cannot detect. The inhibitory effect of clay minerals on the fibrogenicity of quartz can now be explained. What needs to be determined yet is the existing trends of the phase compositions of particles across the U.S. coal fields.

MIT2/USBM 2521

Effect of Physical Properties of Respirable Dusts on Their Toxicity

Principal Investigator: Prof. J. F. Elliott

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Project Status Summary

The principal objectives of this project are:

(1) To identify specific physical and chemical properties of certain respirable size dust particles that make them particularly toxic, and thus a health hazard to persons engaging in mining and mineral processing operations.

(2) To develop methods for identifying the properties most related to toxicity and to extend methods of detection to a broad range of materials (silica, mine dusts, asbestos, etc.).

(3) To identify the most hazardous features of respirable dust particles, to suggest better methods for monitoring, warning, and abatement, thus minimizing exposure to hazardous conditions.

In the earlier phase of the project, research was conducted on the relationship between the crystalline and surface structures and morphology of respirable silica particles and their biological activity. It was established that the concentration of surface silanol groups was directly related to the degree of biological activity of these particles as measured by erythrocyte hemolysis. Experiments were conducted which led to an indication of an oxidative mechanism of cell membrane damage. It was established, through a joint research effort with Prof. Seehra of WVU that the silanol group concentration in dust samples could be measured semi-quantitatively by FTIR techniques.

During the past year (Oct. 1989 - Sept. 1990), the project has been oriented toward testing the application of criteria established for silica to respirable dusts obtained from the coal mining environment. Tests have been conducted on over two hundred samples of mineral dusts from coal mine respirators (supplied by MSHA) and on dust samples from roof-bolter dust box samples from coal mines. It has been found that, as in pure silica, the hemolytic activity of the mineral dusts is related to the presence of surface silanol groups; however, little or no correlation has been found between the mass fraction of silica present in the dust and its hemolytic activity. Mineral dust samples from roof-bolter boxes of different mines show large differences in hemolytic activity. These results have shown that the surface structure of the dust particle is a prime physico-chemical property of interest for biological activity. Work is continuing on improving methods for quantifying the concentration of active surface groups, for modifying dust particle surfaces by physical and chemical treatment, and for relating dust surface properties to geology and seam characteristics of the source.

Publications:

"Surface and Bulk Infrared Modes of Crystalline and Amorphous Silica: A Study of the Relation of Surface Structure to Cytotoxicity of Respirable Silica". R.R. Pandurangi, M.S. Seehra, B.L. Razzaboni, and P. Bolsaitis in Environmental Health Perspectives, v.86, pp.327-336, 1990.

"Clay Occlusion of Respirable Quartz Particles detected by Low Voltage Scanning Electron Microscopy-X-Ray Analysis", W.E. Wallace, J. Harrison, M.J. Keane, P. Bolsaitis, D. Eppelsheimer, J. Poston, and S.J. Page, in Annals of Occupational Hygiene, v.34, pp.195-204, 1990.

"Evidence of an Oxidative Mechanism for the Hemolytic Activity of Silica Particles", B.L. Razzaboni and P. Bolsaitis, in Environmental Health Perspectives, v.87, pp. 337-341, 1990.

"A Micro-hemolysis Assay for Monitoring Mineral Dusts", B.L. Razzaboni, L. Rainey, W.E. Wallace, V. Vallyathan, and P. Bolsaitis, Symp. Respirable Dust in the Mineral Industries, Pittsburgh, PA (Oct 16-19, 1990).

MTU2/USBM 2651

Improved Methods for Monitoring and Control of Diesel Particulate in an Underground Mine.

Principal Investigators:	Staff and Grad. Students:
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This MTU research is a part of the joint Pennsylvania State University project "Diesel Exhaust Contamination of Mine Atmospheres". The major thrust is the engineering control of airborne particulate and gaseous pollutants in a diesel underground coal mine. The MTU research is directed at the development of both measurement and control techniques.

The measurement methods under study include the single-engine load and speed tailpipe emissions measurement apparatus (EMA2) and the on-board all-engine load and speed tailpipe emissions measurement apparatus (EMA3). Both are designed to measure diesel particulate matter (DPM), CO_2, CO, NO, and NO_2. Continued development of the Laser Raman Quantitative Analysis (LRQA) method to distinguish diesel from coal particulate has also taken place. The particulate control research has been directed at ways to analyze and interpret mine air and tailpipe concentration measurements to identify diesel vehicle engine faults and evaluate emissions controls that affect mine air concentrations.

Emissions Measurement Apparatus. Evaluation of EMA2 has continued during the past year. A repeat comparison to Bureau of Mines laboratory instruments using improved laboratory procedures has shown that the apparatus accurately dilutes and measures tailpipe pollutants. DPM concentrations differed at one of six conditions, and while indications are that this difference may also be attributed to the laboratory procedures, we plan to make another comparison at this condition to determine the cause.

Two designs for EMA3 have been developed. Both involve sampling at a rate proportional to the flow rate of exhaust out the tailpipe. One would obtain a single average measurement for the time period covered. While this would quantify in-production tailpipe emissions for the period covered, it would not provide emissions rates that are tied to engine loads and speeds as required for detailed engine diagnostics. The other design would continuously read out concentrations along with the engine data necessary for diagnostics, but would be very bulky and difficult to develop in an intrinsically-safe package as required for use on vehicles that operate near the coal mine face. The selection of one of these designs for continued development is presently in progress.

Laser Raman Quantitative Analysis Method. DPM and respirable coal dust are being quantitatively distinguished using this method. Recent studies have shown that DPM accounts for 40 to 80% of the 'respirable coal dust' measured by the standard method in diesel underground coal mines. The past years research involved measurement of diesel fractions in an eastern thin seam mine. Comparison with size selective personal samplers (MOUDI and personal samplers) and with earlier mine results has been continued. Good agreement has been observed between these three methods. A new Raman instrument has been purchased and recently set-up. Faster measurement with this instrument (ca. 90 times faster than the current 5 hours per sample) will make application of this method more efficient and practical.

Control of Underground Diesel Emissions. Airborne concentrations from three underground coal mines using diesel vehicles have been analyzed and interpreted to bring out differences due either to engine faults or controls; and, a paper has been prepared and submitted for publication at the October 1990 Symposium on Respirable Dust in the Mineral Industries. Methodology and equations are presently being developed by which to diagnose engine faults from mine vehicle tailpipe measurements.

We are continuing to cooperate with TCRC, the U. of Minnesota (UM), and the Colorado Mining Association in the in-mine evaluation of new control technology although none of the laboratory research has progressed sufficiently during the past year to warrant mine testing.

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