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Respirable Dust Levels in Coal, Metal, and Nonmetal Mines

By W. F. Watts, Jr., and D. R. Parker



UNITED STATES DEPARTMENT OF THE INTERIOR
Donald Paul Hodel, Secretary

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Robert C. Horton, Director

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

L/min	liter per minute	mm	millimeter
mg/m ³	milligram per cubic meter	pct	percent
μg/m ³	microgram per cubic meter	yr	year

RESPIRABLE DUST LEVELS IN COAL, METAL, AND NONMETAL MINES

By W. F. Watts, Jr.,¹ and D. R. Parker²

ABSTRACT

In 1980 the Bureau of Mines developed the Mine Inspection Data Analysis System (MIDAS). MIDAS is a computerized, industrial hygiene data base capable of statistically analyzing environmental data collected in coal and noncoal mines and mills by Mine Safety and Health Administration (MSHA) inspectors or mine operators. The objectives of this report are to describe the current contents of MIDAS, to report analyses of coal and noncoal mine respirable dust samples collected by MSHA inspectors and to evaluate the proposed change in the metal and nonmetal respirable dust standard from a formula based upon the percentage of quartz identified in the sample to $100 \mu\text{g}/\text{m}^3$ of respirable quartz.

Based on samples collected by MSHA inspectors, changing the noncoal respirable dust standard would result in 4 pct fewer samples with dust concentrations exceeding the standard. Analysis of respirable coal dust data collected by MSHA inspectors showed that mines with longwall plows or shears had the highest geometric mean concentrations (1.64 and 1.29 mg/m^3 , respectively). Mine operations using continuous rippers outnumbered longwall mine operations about 10 to 1 and had a geometric mean concentration of 0.66 mg/m^3 .

¹Industrial hygienist, Twin Cities Research Center, Bureau of Mines, Minneapolis, MN.

²Mine safety and health specialist, Mine Safety and Health Administration, U.S. Department of Labor, Arlington, VA.

INTRODUCTION

In 1980 the National Academy of Sciences stated that because of insufficient respirable dust measurements and the paucity of reliable information on the incidence of silicosis, the most critical research need in noncoal mining was a definition of the extent of the health problem associated with silica exposures in noncoal miners. It was further stated that the adequacy of the current standard could not be evaluated when the magnitude of exposures remains unknown (1).³

The Bureau of Mines responded to this report by establishing the Mine Inspection Data Analysis System (MIDAS) as a part of the respirable dust research program. MIDAS is a computerized, industrial hygiene data base developed by the Bureau with the assistance of the Mine Safety and Health Administration (MSHA). It is available, on-line, via the Bureau's telecommunications network to Bureau, MSHA, and National Institute of Occupational Safety and Health (NIOSH) personnel involved in mining research. Since its inception, MIDAS has provided information on the magnitude of respirable dust levels in noncoal mines, which is used to prioritize problems, determine trends in exposure, and to evaluate standards. In 1980 MIDAS contained only environmental industrial hygiene data collected from metal and

nonmetal mines and mills by MSHA inspectors. These samples are collected to determine whether or not the mine or mill is in compliance with MSHA air quality regulations.

The first expansion of MIDAS took place in 1982 when data from a scientific survey of 22 mines were added to the data base. The survey was conducted from 1976 through 1978 in metal and nonmetal mines by MSHA personnel. The most recent expansion of MIDAS occurred in 1985 when coal mine respirable dust data were added to the data base. Unlike the noncoal data, the great majority of these samples were collected by coal mine operators, as opposed to MSHA inspectors. MSHA updates the metal-nonmetal and coal mine compliance data on a yearly basis.

The objectives of this report are to describe the current contents of MIDAS, to report analyses of coal and noncoal mine respirable dust samples collected by MSHA inspectors, and to evaluate the proposed change in the metal and nonmetal respirable dust standard. The report is divided into three major sections: A description of the MIDAS metal and nonmetal subsystem, a description of the MIDAS coal subsystem, and a discussion of results from recent analyses of these data.

MIDAS METAL AND NONMETAL SUBSYSTEM

REGULATORY REQUIREMENTS

MSHA regulates health and safety conditions and practices in metal and nonmetal mines and mills under the authority of the Federal Mine Safety and Health Act of 1977, as amended (2). The specific regulations are found in the Code of Federal Regulations, Title 30 (3). Standards in these regulations for airborne contaminants and physical agents were adopted from the 1973 recommended

threshold limit values (TLV's) of the American Conference of Governmental Industrial Hygienists (ACGIH) (4). Compliance with these regulations is determined by the collection of environmental samples by MSHA inspectors.

DATA DESCRIPTION

Since 1974 over 415,000 environmental samples have been collected by MSHA and records of these samples are edited and stored in MIDAS. Details of the editing procedure have been previously reported (5). MSHA has collected samples for 132 different contaminants, but samples for 10 contaminants account for 91 pct of the

³Underlined numbers in parentheses refer to items in the list of references preceding the appendix at the end of this report.

415,000 records. These contaminants are listed in table 1.

Data from metal and nonmetal sampling are of two types: personal (which are either partial- or full-shift samples collected on individuals) and area (which are short-term "grab" samples collected in the mine environment). Each sample record contains at a minimum the mine identification number, date, contaminant code, contaminant concentration, and standard industrial classification (SIC) code. In addition, the personal samples contain codes to describe the worker's occupation, and location. In 1983 MSHA expanded the number of codes used to describe occupation, location, and commodity. These changes were incorporated into the data base in 1984 by converting the pre-1983 codes to the new codes adopted by MSHA. The new codes for occupation, location, and commodity are listed in appendix tables A-1 through A-3.

An additional 15,000 samples were collected during a survey of 22 metal and nonmetal underground mines. MSHA conducted the survey in order to determine exposures to quartz-bearing dusts and to exhaust emissions produced by diesel engines used underground.

TABLE 1. - Contaminants most frequently sampled in metal and nonmetal mines

Contaminant	Sample		Pct of total
	Type	Number	
Noise.....	FS	112,126	27.0
Respirable dust with >1 pct quartz.....	FS	50,508	12.2
Carbon monoxide.....	ST	39,830	9.6
Methane.....	ST	36,412	8.8
Radon daughters.....	ST	34,910	8.4
Carbon dioxide.....	ST	30,767	7.4
Total dust.....	FS	26,637	3.2
Oxygen.....	ST	21,251	5.1
Respirable dust with <1 pct quartz.....	FS	14,706	3.5
Nitrogen dioxide.....	ST	12,293	3.0
Subtotal.....	NAP	379,440	91.4
Others.....	NAP	35,740	8.6
Total.....	NAP	415,180	100.0

FS Full-shift personal exposure sample.

NAP Not applicable.

ST Short-term sample.

The 22-mine-survey data are the only data stored in MIDAS that were not collected to determine compliance with regulatory standards.

Environmental data from the 22-mine-survey include full-shift, personal samples and short-term grab samples. Full-shift samples were used to measure concentrations of nitrogen dioxide, respirable dust, and total dust. The same miners were sampled for both dust and nitrogen dioxide. Grab samples were analyzed for a wide array of gases including carbon monoxide, carbon dioxide, and trace substances. Details of the survey and the major findings have been reported elsewhere (6-7).

The data base also contains an index of all metal and nonmetal mine properties in the United States. Each property is listed with a unique mine identification number, its location, the property name, company name, approximate number of employees, year-round or other status, mine type, and standard industrial classification code (SIC). Pertinent information from this file is added to the records of environmental samples to assist in grouping similar records for analysis. The index is updated annually by MSHA.

SOFTWARE

Data base software has undergone several phases of development since 1980. Each phase has resulted in the development of more comprehensive and user-friendly computer programs. Currently, software is accessed through one program that asks several questions, which results in the introduction of a sequence of submenus. The submenus list the available programs for the type of data being analyzed and ask the user to select the desired program. Once a program is selected, a description of the program is displayed and the user is asked to specify detailed information. This information includes program options, file names, code groups, and sort order. The results may be immediately retrieved upon completion of data processing, or in cases where large volumes of data are being processed the user may submit a job

for overnight processing. This reduces computing costs and ensures adequate process time. Results can be retrieved the following day.

The software for the metal and nonmetal subsystem was designed to accomplish the following tasks: record selection, file creation, record sorting, data analysis, and reporting of results. Records can be selected based upon user-specified variables from the original master files or from previously created user files, and stored in a new data file. Sorting of records in a preset order is required for the use of certain programs, to ensure the efficient use of computer process time. Sorting requirements are noted in the program descriptions found at the

beginning of each program. Analysis is accomplished using a variety of descriptive statistics such as the geometric mean (GM), the geometric standard deviation (GSD), and the percentage of samples greater than the threshold limit value (>TLV, pct). Graphic aids such as cumulative frequency plots are also available. Results are reported in the form of tables or graphs.

In addition to software designed specifically for MIDAS, the user may select other statistical software from the software library maintained by the Bureau. These programs are capable of calculating a wide array of descriptive and inferential statistics (8).

MIDAS COAL SUBSYSTEM

REGULATORY REQUIREMENTS

In 1970 a mandatory respirable dust standard of 3.0 mg/m^3 was established for underground coal mines under the Federal Coal Mine Health and Safety Act of 1969. This standard was subsequently lowered in 1972 to 2.0 mg/m^3 . Mandatory dust standards for surface work areas of underground coal mines and surface mines also became effective in 1972. These regulations were continued under the Federal Mine Safety and Health Act of 1977 (9), which amended the 1969 coal act and merged coal and noncoal regulations into one law. In the 1969 act, "concentration of respirable dust" was defined as a measurement made with a Mining Research Establishment (MRE, Casella 113A) instrument or such equivalent concentration measured with another device. The 1977 act changed the definition of "concentration of respirable dust" to be the "average concentration of respirable dust measured with a device approved by the Secretary and the Secretary of HEW." The device approved for measuring respirable dust uses a Dorr-Oliver 10-mm nylon cyclone to remove the nonrespirable fraction of dust sampled. Measurements made with this device are converted to equivalent MRE concentrations by multiplying by a constant factor of 1.38 (10). Specific regulations detailing the collection of

respirable dust samples by mine operators are found in the Code of Federal Regulations, Title 30 (3). Since 1970, more than 6 million respirable dust samples have been collected by coal mine operators and MSHA inspectors to determine compliance with the 2.0-mg/m^3 standard.

DATA DESCRIPTION

In 1985 the Bureau received the respirable coal dust data from MSHA. Because of the large volume of data, only the 1981 through 1985 records of samples collected by MSHA inspectors, and the 1985 operator samples, are available in the data base. However records dating as far back as 1970 are stored on tape and can be loaded into the data base upon request.

The MSHA coal dust records had three record formats: one corresponding to samples collected from 1970 to 1980, one corresponding to samples collected from 1980 to 1984 by operators, and one corresponding to samples collected from 1980 to 1984 by inspectors. However, in order to conserve disk storage space and to simplify software development and analysis, the coal dust records were revised to reflect only one record type. Information that was not required for analysis was eliminated. Information that was retained but was not consistent

between the different record types caused the creation of blank fields in some records. Records containing erroneous codes were removed by editing.

Retained information that was recorded in the same manner on all records includes State, mine identification number, sample date, dust concentration, tons of coal produced, and occupation code. Information that appears on all records but with different codes includes mine type, sample type, and mining method. Other information appearing on the records includes mine section or mechanized mining unit number, ventilation code, and the MSHA field office code. Table A-4 lists the most frequently used occupation codes, and tables A-5 through A-7 list the codes used to describe mine type, sample type, and mining method. In addition to the information listed above, every record contains a numerical code

that allows rapid sorting into one of four groups: 1970-80 inspector sample, 1970-80 operator sample, 1980-84 inspector sample, and 1980-84 operator sample.

SOFTWARE

Software is currently being developed to analyze the coal dust data, and wherever possible, software developed for the metal and nonmetal subsystem is being modified for use with the coal subsystem. Examples of software under development include trends programs to compute statistics for years, groups of years, and occupations; table programs to compute statistics for data grouped by occupation, mining methods, and sample types; and graphics programs to produce plots by occupation, mining method, and sample type.

RESPIRABLE DUST ANALYSIS

METAL AND NONMETAL

Since 1974 MSHA inspectors have collected more than 50,000 gravimetric samples for dust containing respirable quartz (RQ). The RQ sample is collected on a filter after the aerosol has passed through a cyclone preclassifier at a flow rate of 1.7 L/min. The TLV for RQ is determined by collecting a respirable dust sample, analyzing for quartz content,⁴ and calculating the TLV by dividing percent RQ plus 2 into 10 when the quartz content (percent RQ) is >1 pct (4). The resultant TLV is expressed in milligrams per cubic meter. The TLV for RQ is inversely proportional to the quartz content of the sample. Thus, for a given exposure level the magnitude of the toxicity is proportional to the quartz content (11). The factor 2 in the TLV formula ensures that dust exposures will not be excessively high when the quartz content is less than 5 pct and effectively limits the dust concentration to 5 mg/m³ when no quartz is identified in the sample.

⁴Quartz content is determined by X-ray diffraction after the filter has been weighed.

In 1983 MSHA proposed to revise many of the existing health regulations (12). Included in these revisions was a proposed change in the RQ standard. The proposed new standard, which is still undergoing review, is 100 µg/m³ of respirable quartz. The effects of changing the RQ standard on compliance determinations are discussed in a subsequent section.

The yearly statistics for RQ are shown in table 2. Data shown in table 2 must be interpreted in the context of MSHA policy and regulatory changes that may have altered sampling strategies. These changes have been discussed in depth elsewhere (13), but warrant a brief review.

MSHA inspectors collect dust samples in order to determine compliance. This is accomplished by sampling workers thought to have the greatest risk of overexposure, and a sample exceeding the standard by 20 pct is considered out of compliance.

The sampling strategy used in metal and nonmetal mines and mills tends to be judgmental in that it is not based on a probability model assuming randomness. This creates a statistical problem: These

TABLE 2. - Yearly statistics for RQ

Year	Samples	>TLV, pct	Concentration, mg/m ³			GM
			GM	Median	GSD	C-TLV
1974.....	284	44.37	0.58	0.54	2.62	0.86
1975.....	2,648	27.95	.49	.47	2.94	.53
1976.....	6,223	25.16	.51	.48	3.08	.45
1977.....	7,566	18.90	.44	.43	2.96	.37
1978.....	7,840	15.46	.40	.38	3.00	.34
1979.....	7,780	13.62	.37	.34	2.98	.31
1980.....	4,744	14.69	.40	.37	2.63	.33
1981.....	4,423	16.69	.43	.40	2.58	.36
1982.....	1,640	17.26	.46	.43	2.72	.39
1983.....	3,399	17.01	.45	.41	2.35	.40
1984.....	3,961	17.22	.45	.40	2.43	.39
Total or average....	50,508	18.04	.43	.40	2.84	.37

GM Geometric mean.

GM C-TLV Geometric mean concentration-to-TLV ratio.

GSD Geometric standard deviation.

TLV Threshold limit value.

data may not be representative of all exposures, so the classical assumptions of randomness, homoscedasticity (homogeneous variance), and normal distribution may not apply. In addition, anything that affects the number of samples collected is important because it alters the sampling strategy. Two examples of such alterations are the Federal Mine Safety and Health Act of 1977 (2), and the temporary removal of stone, sand and gravel, and other commodities from MSHA's jurisdiction for most of fiscal year 1982.

The passage of the 1977 act was followed by an increase in the number of RQ samples collected over previous years until 1980 when internal MSHA policy changes caused a marked reduction in the number of RQ samples. This was followed in 1982 with the temporary loss of jurisdiction over stone, sand and gravel, and other commodities accompanied by a sharp decrease in the number of RQ samples as shown in table 2. With the restoration of MSHA's jurisdiction over stone, sand and gravel, and other commodities in the 1983-84 period, the number of samples reported rebounded close to the level in 1980. Overall, the data in table 2 show that for the more than 50,000 RQ samples over the 1974-84 period, more than 18 pct ($\approx 9,000$) of the samples exceeded the TLV.

Exposures by Mine Type and Occupation

Table 3 shows RQ exposures by mine type for two time periods, 1974-79 and 1980-84. The location groups, underground, surface, and mill, are defined in table A-2, and the commodity groups, stone, metal, nonmetal, and sand and gravel, are defined in table A-3. For each group the table shows the number of samples, geometric mean concentration (GM CONC), geometric mean concentration-TLV ratio (GM C-TLV), percentage of samples exceeding the TLV, and the percentage of workers wearing respirators at the time the sample was collected.

Several mine types have shown substantial improvement from the 1974-79 to 1980-84 sample period. Nonmetal mills have reduced the percentage of samples exceeding the TLV from 40.1 pct to 23.9 pct, while increasing the percentage of workers wearing respirators from 49.9 pct to 64.9 pct. The GM CONC was reduced from 0.84 to 0.66 mg/m³. Overexposures were also sharply reduced at industrial sand mills (32.9 to 22.1 pct), while workers wearing respiratory protection increased 13.7 pct. At both nonmetal mills and industrial sand mills, the product is typically a crushed or ground silica sand with a very high quartz content.

TABLE 3. - RQ exposures by mine type for 1974-79 and 1980-84

Commodity group	1974-79				1980-84			
	UG mine	Surface mine	Mill	Total	UG mine	Surface mine	Mill	Total
Metal:								
Samples.....	2,815	1,604	1,892	6,311	1,548	1,093	1,080	3,721
GM CONC.....mg/m ³ ..	0.57	0.30	0.46	0.45	0.55	0.31	0.37	0.41
GM C-TLV.....	0.46	0.28	0.47	0.41	0.42	0.29	0.35	0.36
>TLV.....pct..	18.3	11.2	24.3	18.3	17.0	11.7	15.9	15.2
PROT.....pct..	39.5	25.9	35.6	34.9	58.3	45.2	50.0	52.1
Nonmetal:								
Samples.....	608	1,820	2,252	4,680	260	612	1,425	2,297
GM CONC.....mg/m ³ ..	0.74	0.43	0.84	0.64	0.58	0.38	0.66	0.56
GM C-TLV.....	0.52	0.39	0.78	0.57	0.43	0.29	0.53	0.44
>TLV.....pct..	26.8	18.7	40.1	30.1	18.5	18.7	23.9	20.6
PROT.....pct..	32.9	39.4	49.9	43.6	58.5	47.9	64.9	59.6
Sand and gravel:								
Samples.....	NAp	4,192	799	4,991	NAp	1,905	1,413	3,318
GM CONC.....mg/m ³ ..	NAp	0.24	0.37	0.26	NAp	0.35	0.38	0.36
GM C-TLV.....	NAp	0.28	0.60	0.32	NAp	0.37	0.50	0.42
>TLV.....pct..	NAp	12.8	32.9	16.0	NAp	14.5	22.1	17.8
PROT.....pct..	NAp	22.6	46.3	26.4	NAp	36.6	59.0	46.1
Stone:								
Samples.....	562	11,347	4,385	16,294	484	5,330	3,014	8,828
GM CONC.....mg/m ³ ..	0.86	0.37	0.58	0.43	0.70	0.39	0.49	0.43
GM C-TLV.....	0.44	0.29	0.49	0.34	0.34	0.29	0.43	0.34
>TLV.....pct..	19.4	13.4	25.7	16.9	14.0	11.9	21.5	15.3
PROT.....pct..	34.9	23.4	42.9	29.1	32.2	35.5	51.0	40.6
Total:¹								
Samples.....	3,985	18,963	9,328	32,276	2,292	8,940	6,932	18,164
GM CONC.....mg/m ³ ..	0.63	0.34	0.58	0.43	0.58	0.37	0.47	0.43
GM C-TLV.....	0.47	0.30	0.55	0.37	0.40	0.31	0.45	0.37
>TLV.....pct..	19.8	13.6	29.5	19.0	16.6	12.6	21.3	16.4
PROT.....pct..	37.9	25.0	43.4	31.9	52.8	37.8	55.3	46.4

GM CONC Geometric mean concentration.

GM C-TLV Geometric mean concentration-to-TLV ratio.

NAp Not applicable.

PROT Respiratory protection.

TLV Threshold limit value.

UG Underground.

¹68 records are excluded because no SIC code was reported.

Overall the table shows that the use of respiratory protection is increasing and that dust levels are decreasing. Seven of the eleven mine types show reduced GM CONC while only four (surface stone quarries, metal mines, sand and gravel mills, and surface quarries) show slightly higher GM CONC. Sand and gravel quarries had a small increase in the percent of samples exceeding the TLV despite a large drop in the number of samples collected.

Table 4 shows the changes in the percentage of samples exceeding the TLV and the GM CONC for 17 frequently sampled occupations for the same time periods, 1974-79 and 1980-84. Nearly 90 pct of the over 50,000 RQ samples are accounted for in the table, and each occupation has a minimum of 200 samples in each time period. The bagging, flotation, jack stoper drill, and trucker occupations had 10 pct fewer samples exceeding the TLV. Stope miner, motorman, and laborer and

TABLE 4. - RQ exposures by metal and nonmetal occupation¹ for 1974-79 and 1980-84

Occupation	1974-79			1980-84			Change >TLV, pct
	Samples	>TLV, pct	GM CONC, mg/m ³	Samples	>TLV, pct	GM CONC, mg/m ³	
Bagging and packing.....	1,384	44.0	0.73	1,360	33.1	0.59	-10.9
Flotation.....	422	19.0	.43	232	8.2	.33	-10.8
Jack stoper drill.....	470	25.5	.84	201	14.9	.67	-10.6
Trucker.....	409	14.2	.37	850	4.2	.33	-10.0
Ball and rod mill.....	1,178	31.4	.62	341	21.7	.43	-9.7
Cleanup man.....	3,344	28.3	.54	1,354	21.2	.49	-7.1
Sizing and washing.....	1,239	23.3	.41	510	17.5	.39	-5.8
Mechanic.....	1,318	14.5	.42	372	8.9	.39	-5.6
Crusher.....	4,894	23.5	.51	3,434	20.0	.48	-3.5
Dryer and kiln.....	1,220	24.1	.46	761	22.7	.46	-1.4
Pneumatic drill.....	703	23.2	.55	344	22.1	.53	-1.1
Bulldozer.....	792	12.9	.30	328	11.9	.32	-1.0
Wagon drill.....	1,030	23.8	.50	331	23.0	.49	-.8
Front-end loader.....	9,254	7.6	.29	4,195	6.9	.34	-.7
Stope miner.....	964	13.0	.47	284	13.4	.51	.4
Motorman.....	743	12.5	.33	344	13.1	.34	.6
Laborer and bulfgang.....	350	18.0	.54	221	19.9	.49	1.9
Total or average....	29,714	21.1	.49	15,462	16.6	.45	-4.5

GM CONC Geometric mean concentration.

TLV Threshold limit value.

¹See table A-1 for complete listing of codes, occupations, and samples.

NOTE.--Selected occupations had at least 200 samples in each period.

bulfgang occupations show slight increases (less than 2 pct) in the percentage of samples exceeding the TLV. The average reduction in the percentage of samples exceeding the TLV was 4.5 pct for the occupations shown in the table. Dramatic changes in the percentage of sampled workers wearing respiratory protection for these occupations are illustrated in table A-8. All 17 occupations experienced an increase in the use of respiratory protection ranging from 5 to 20 pct despite reduction in dust levels. The average respirator wear increase for the occupations was 14 pct. The increase in the use of respiratory protection is attributed to increased worker awareness of health problems associated with respirable dust containing quartz and MSHA's respiratory protection program.

Effect of Changing the RQ Standard

As previously mentioned, MSHA has proposed to change the TLV for RQ from the formula to 100 $\mu\text{g}/\text{m}^3$ of respirable

quartz. MIDAS can be used to evaluate the effect of this change because every respirable dust record has the time-weighted average dust concentration and the percentage of quartz, thus the time-weighted average quartz concentration can be calculated for each record and compared to the proposed standard. Table 5 summarizes the quartz statistics for selected commodities. These commodities account for 46,846 of the 50,400 (92.7 pct) of the samples summarized in table 3.

A previous paper (13) showed that both respirable dust and quartz concentrations approximated log-normal distributions. When a distribution is log-normal, the geometric mean or median and geometric standard deviation are the best measures of central tendency and dispersion. In table 5 both the arithmetic and geometric parameters are shown to facilitate comparisons with other sets of data where only the arithmetic mean (AM) and arithmetic standard deviation were computed. The GM CONC's are all well below the proposed standard, whereas six

TABLE 5. - Quartz statistics for selected commodities¹

Commodity	Samples	Concentration, $\mu\text{g}/\text{m}^3$				Quartz, pct (AM)
		AM	ASD	GM	GSD	
Metal:						
Copper.....	2,240	84	254	30	3	8.6
Gold.....	1,150	93	262	37	4	10.0
Iron.....	2,593	49	121	21	3	9.5
Lead and zinc.....	1,044	74	270	28	3	8.3
Molybdenum.....	600	101	193	50	3	9.1
Silver.....	756	68	137	32	3	9.2
Uranium.....	1,158	50	181	22	3	7.5
Nonmetal:						
Common clay.....	2,792	94	225	40	4	7.7
Fire clay.....	784	98	199	45	3	8.4
Nonmetal, not elsewhere classified.....	881	209	563	55	5	20.7
Phosphate rock.....	531	58	106	29	3	9.1
Sand and gravel.....	8,309	75	284	27	4	13.1
Stone:						
Cement.....	1,232	35	68	16	3	4.0
Granite:						
Crushed.....	3,206	68	238	30	3	11.4
Dimension.....	1,113	102	195	46	3	11.4
Limestone: Crushed.....	13,054	34	121	15	3	4.6
Sandstone:						
Crushed.....	3,421	140	294	52	4	22.9
Dimension.....	434	191	690	44	5	21.7
Stone: Crushed.....	689	120	339	40	4	16.1
Traprock: Crushed.....	869	44	76	21	3	6.8

AM Arithmetic mean.

ASD Arithmetic standard deviation.

GM Geometric mean.

GSD Geometric standard deviation.

¹See table A-3 for complete listing of SIC codes, commodities, and samples.

commodities have AM CONC's exceeding the proposed standard of $100 \mu\text{g}/\text{m}^3$ of respirable quartz.

It would be expected that fewer samples would exceed the new standard. For example, if a worker is sampled during a work-shift and a mass of 0.82 mg of respirable dust is deposited on the filter, then the time-weighted average concentration of dust for that sample is $1.0 \text{ mg}/\text{m}^3$. If the sample contains 9 pct quartz, the allowable respirable dust level is $0.91 \text{ mg}/\text{m}^3$ under the current standard. The time-weighted average respirable quartz concentration is $0.090 \text{ mg}/\text{m}^3$. This sample exceeds the current standard but not the proposed standard of $100 \mu\text{g}/\text{m}^3$ ($0.100 \text{ mg}/\text{m}^3$) of respirable quartz. Table 6 shows the percentage

of samples exceeding both standards for the commodities listed in table 5. The proposed standard would result in the reporting of about 4 pct fewer samples exceeding the TLV, and no mining activity would be adversely affected.

COAL

The objective of respirable dust sampling in coal mines is to ensure compliance with the $2.0\text{-mg}/\text{m}^3$ coal mine dust standard or with the more rigorous standard if the mine dust aerosol contains more than 5 pct quartz. A mine is out of compliance if the arithmetic average of five samples is over the standard. MSHA inspectors and coal mine operators regularly sample miners or areas known to

TABLE 6. - Effect of changing the RQ TLV

Commodity ¹	Samples	>TLV, pct	>100 $\mu\text{g}/\text{m}^3$, pct	Change, pct
Metal:				
Copper.....	2,240	19.1	15.0	-4.0
Gold.....	1,150	22.7	18.4	-4.3
Iron.....	2,593	12.1	9.6	-2.5
Lead and zinc.....	1,044	16.6	12.6	-4.6
Molybdenum.....	600	32.2	26.0	-6.2
Silver.....	756	18.9	13.5	-5.4
Uranium.....	1,158	11.3	7.9	-3.4
Nonmetal:				
Common clay.....	2,792	29.3	21.7	-7.6
Fire clay.....	784	31.9	23.8	-7.8
Nonmetal, not elsewhere classified.....	881	40.1	37.3	-2.8
Phosphate rock.....	531	15.6	11.5	-4.1
Sand and gravel.....	8,309	16.7	14.2	-2.5
Stone:				
Cement.....	1,232	13.0	7.6	-5.4
Granite:				
Crushed.....	3,206	16.9	13.8	-3.1
Dimension.....	1,113	30.0	25.0	-5.0
Limestone: Crushed.....	13,054	9.9	5.8	-4.1
Sandstone:				
Crushed.....	3,421	34.1	31.8	-2.3
Dimension.....	434	30.6	29.3	-1.3
Stone: Crushed.....	689	27.6	25.0	-2.6
Traprock: Crushed.....	869	13.1	9.2	-3.9
All commodities:²				
Total or average.....	50,440	18.0	14.1	-3.9

TLV Threshold limit value.

¹See table A-3 for complete listing of SIC codes, commodities, and samples.

²Includes data for commodities not shown in the table.

have high dust exposure. In underground mines, MSHA inspectors are required to sample specific occupations referred to as designated occupations (DO). A DO is an occupation on a mining operation that is typically exposed to the highest respirable dust concentration. Examples of DO's would include the longwall shearer operator or the continuous miner operator. In addition, the MSHA inspectors sample other underground occupations suspected to have high dust exposures such as roof bolters. These occupations are referred to as nondesignated occupations (NDO's).

The results from the respirable coal dust analysis reported below are restricted to samples collected only by MSHA inspectors from 1981-84, and are for the most part restricted to DO and NDO

samples collected in underground mines. Results reported for surface coal mines are limited to specific occupations. Mine compliance data are not reported, but the percentage of samples exceeding the $2.0 \text{ mg}/\text{m}^3$ standard is reported. It should be emphasized that, in coal mines, a single sample that exceeds the standard does not automatically place the mine in a noncompliance status.

MSHA is required to inspect all underground coal mines four times each year, collecting dust samples twice a year, but the population of mines inspected changes from year to year depending upon the market for coal and other factors. From 1981 through 1984, MSHA inspectors collected about 66,000 full-shift, personal, respirable dust samples in underground coal mines. About 16,500 samples

were collected at approximately 1,550 different underground mines per year. An additional 10,000 samples per year were collected at surface coal mines.

Table 7 shows the yearly trends in exposure for underground DO and NDO samples. The sample size, the mean dust concentration, and the percentage of samples exceeding the 2.0-mg/m³ standard remained relatively constant from 1981 through 1984. Between 10 and 12 pct of the samples exceeded the standard and the GM CONC fluctuated between 0.59 and 0.69 mg/m³. A coal mine is out of compliance only when an average of five

samples exceeds the 2.0 mg/m³ standard, thus there are far fewer mines out of compliance than there are samples exceeding the standard. On average, about 1,800 samples exceeded the standard each year.

Table 8 shows the 1984 statistics for DO and NDO underground mine samples grouped by mining method. The table accounts for more than 98 pct of all underground mine samples, despite the fact that methods of mining with less than 50 samples are not included because of small sample size. Mines with long-wall plows or shears have the highest GM

TABLE 7. - Yearly trends in respirable dust exposure for samples collected in underground coal mines

Statistic	1981	1982	1983	1984
Samples.....	16,233	16,244	16,687	16,452
>TLV.....pct..	11.9	11.0	9.9	11.9
Concentration, mg/m ³ :				
AM.....	1.12	1.12	1.01	1.12
ASD.....	1.88	1.86	1.40	1.97
GM.....	0.66	0.69	0.59	0.65
GSD.....	2.80	2.68	2.85	2.83
Median.....	0.80	0.80	0.70	0.70

AM Arithmetic mean.

ASD Arithmetic standard deviation.

GM Geometric mean.

GSD Geometric standard deviation.

TLV Threshold limit value.

TABLE 8. - 1984 coal dust data by underground mining method

Mining method	Samples	Concentration, mg/m ³		>TLV, pct
		GM	GSD	
Longwall plow.....	151	1.64	2.25	43.7
Longwall shear.....	963	1.29	2.18	25.2
Conventional cut machine.....	1,558	.67	2.69	10.2
Continuous ripper.....	10,946	.66	2.75	10.9
Continuous bore.....	153	.61	3.02	10.5
Continuous auger.....	553	.57	4.06	20.8
Scoop shoot solids.....	525	.54	3.18	9.3
Scoop cut machine.....	997	.47	2.96	7.9
Conventional shoot with loading machine.....	84	.39	2.70	7.1
Hand-load shoot solid.....	258	.38	2.58	3.9

GM Geometric mean.

GSD Geometric standard deviation.

TLV Threshold limit value.

NOTE.--For inclusion in the table there had to be at least 50 samples and the mining methods are ranked by the GM concentration.

CONC (1.64 and 1.29 mg/m³, respectively) and the greatest percentage of samples exceeding the 2.0-mg/m³ standard (43.7 and 25.2 pct, respectively). However, many more samples (10,946) were recorded at mines using continuous rippers, where the GM CONC was 0.66 mg/m³ and 10.9 pct of the samples exceeded the standard. Mines with augers had a lower GM CONC (0.57 mg/m³) but 21 pct of the samples exceeded the standard. Augers also have the highest geometric standard deviation (4.06), which suggests that some of the reported dust concentrations are extremely high.

Table 9 is a cumulative frequency table that compares DO and NDO samples for the auger, continuous ripper, and longwall mining methods. Samples from longwall shears and plows were combined to increase the sample size. Four percentiles are shown--20th, 50th, 80th, and 95th. A fifth value, the percentage of samples exceeding the 2.0-mg/m³ standard (TLV), is also shown. This can be converted to a percentile for each mining method by subtracting the value from 100. The percentiles represent low exposure, median exposure, moderate exposure, and high exposure levels. For instance, at the

95th percentile concentration 5 pct of the samples exceed that value. With one exception the DO percentile values are greater than or equal to the corresponding NDO values. The only exception is the 95th percentile longwall NDO value, which is 0.3 mg/m³ higher than the DO values. This finding confirms MSHA's selection of DO's as those occupations with the highest overall exposures. The auger samples have the highest 95th percentile values (7.8 and 6.0 mg/m³) and the lowest 20th percentile values (0.1 mg/m³). This explains the high standard deviations for auger samples shown in table 8. Figure 1 illustrates the distribution of these data, which is approximately log-normal and different for each mining method and sample type group.

More mines use continuous rippers than any other mining method and these mines have the greatest number of samples exceeding the 2.0-mg/m³ standard. Table 10 shows that the average number of samples collected per year at mines using continuous rippers was 11,036 and that the average number of samples over the standard was 1,120 or 10.1 pct. During any single year between 1981 and 1984 about 43 pct of the mines with continuous

TABLE 9. - Differences between DO and NDO samples for three mining methods

Group	Samples	Percentile concentrations, mg/m ³				>TLV, pct
		20th	50th	80th	95th	
Auger:						
DO.....	116	0.1	0.5	2.7	7.8	28.4
NDO.....	437	0.1	0.5	1.8	6.0	18.8
Continuous ripper:						
DO.....	2,520	0.4	0.8	1.8	3.6	14.2
NDO.....	8,426	0.2	0.7	1.5	2.7	9.9
Longwall:						
DO.....	296	1.1	1.7	2.7	4.0	34.8
NDO.....	818	0.7	1.4	2.2	4.3	25.2

DO Designated occupation.

NDO Nondesignated occupation.

TLV Threshold limit value.

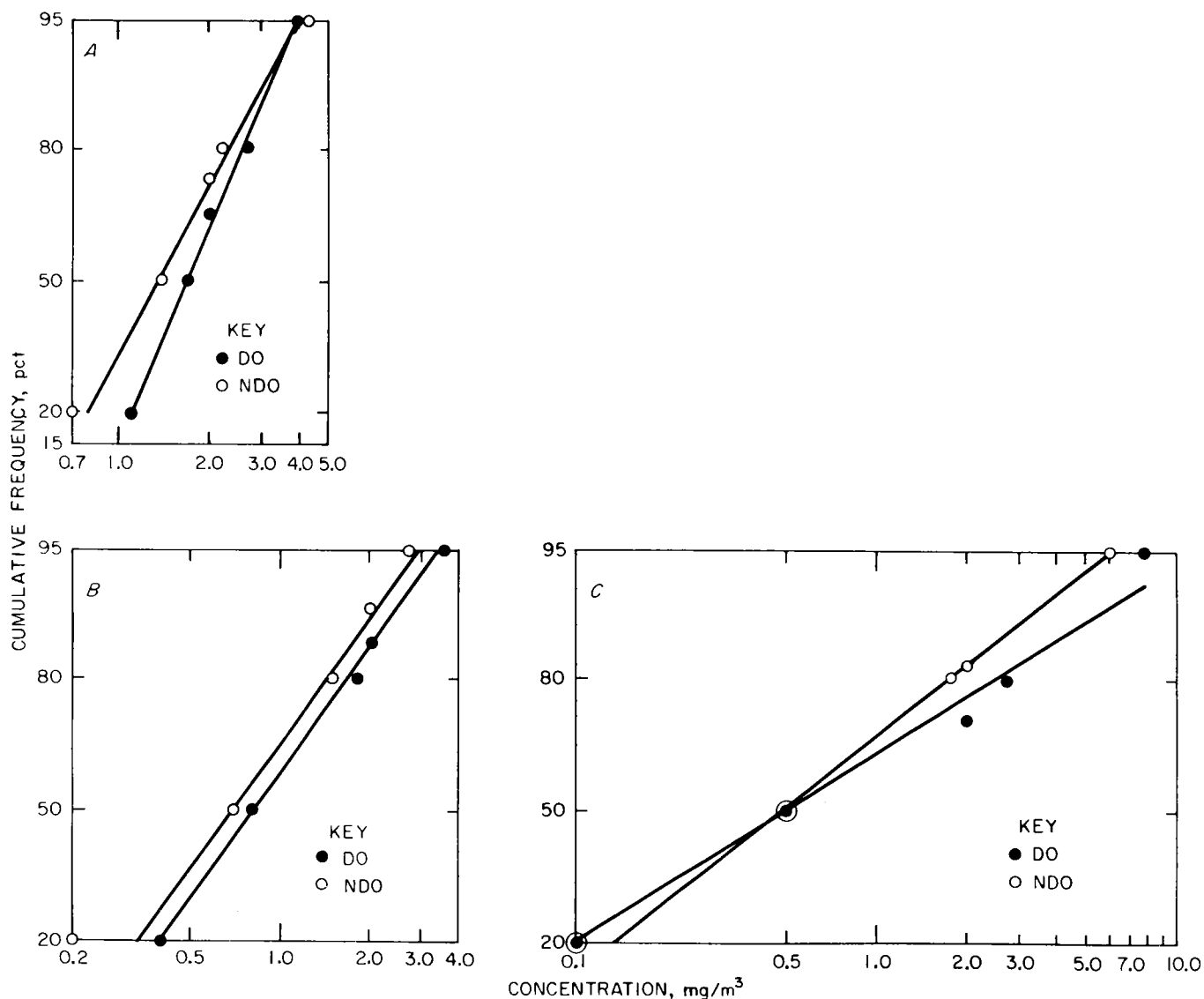


FIGURE 1.—Logarithmic probability plots of longwall (A), continuous ripper (B), and auger (C) samples grouped by designated occupation (DO) and nondesignated occupation (NDO).

rippers had at least one sample exceeding the standard. For mines with longwall shears or plows, only 247 samples per year exceeded the standard at 40 different mines. Every mine reported to have a longwall operation also used continuous rippers for mine development. The dust concentrations were greater at mines with longwall operations but there were nearly

nine times more continuous ripper operations with one or more samples exceeding the 2.0-mg/m³ standard. However, as previously mentioned this does not mean that all of these mines were out of compliance, because compliance with the standard is determined by an average of five samples.

TABLE 10. - Average number of samples exceeding 2.0 mg/m³ for 1981-84 and average number of mines with samples exceeding 2.0-mg/m³ standard

Mining method	Samples			Mines		
	Number	>TLV		Number	>TLV	
		Number	pct		Number	pct
Continuous ripper.....	11,036	1,120	10.1	808	350	43.2
Conventional cut machine.....	1,720	201	11.7	195	74	38.1
Scoop cut machine.....	1,027	76	7.4	151	36	24.1
Longwall shear.....	713	193	27.1	48	33	69.8
Continuous auger.....	530	95	17.9	70	29	41.6
Scoop shoot solids.....	616	50	8.2	107	25	23.4
Longwall plow.....	130	54	41.5	9	7	80.6
Conventional shoot with loading machine..	131	10	7.4	21	4	20.5
Continuous bore.....	91	7	7.7	13	3	21.6
Hand-load shoot solid.....	142	7	4.8	26	3	12.4

TLV Threshold limit value.

NOTE.--The mining methods are ranked by the number of mines with at least 1 sample over the TLV.

Table 11 shows the 1984 coal mine dust data for the most frequently sampled underground and surface occupations. Four occupations, longwall shear or plow operator, return side auger jack setter, longwall jack setter, and surface fine coal plant operator, had more than 28 pct of the samples exceeding the 2.0-mg/m³ standard for a total of 382 samples. In comparison, 558 samples collected on continuous miner operators (14.2 pct) and helpers (13.7 pct), and 420 (11.9 pct) samples collected on roof bolters were over the standard. As previously shown, mines with longwall operations have the highest GM CONC and longwall operators have the highest exposures. However, at the present time there are relatively few longwalls compared to other methods of

mining so occupations not specific to longwall operation, such as roof bolters and continuous miner operators, account for more samples exceeding the 2.0-mg/m³ standard.

Table 12 shows the yearly statistics for five dusty occupations: continuous miner helper, longwall jacksetter, longwall shear-plow operator, and roof bolter. There was a reduction in the GM CONC and the percentage of samples exceeding the 2.0-mg/m³ standard for the longwall shear-plow operator and a reduction in the percentage of samples exceeding the standard for the longwall jack setter. Levels for the other three occupations remained essentially constant over the 1981-84 4-yr period.

TABLE 11. - 1984 coal mine dust data for underground and surface occupations

Occupation ¹	Samples	Concentration, mg/m ³				>TLV, pct
		GM	GSD	AM	ASD	
Underground:						
Longwall tailgate side.....	387	1.66	1.93	2.03	1.45	34.6
Longwall jack setter.....	499	1.50	1.84	1.80	1.30	28.7
Headgate operator.....	136	.87	2.55	1.30	1.24	18.4
Auger jack setter, return side.....	116	.83	4.89	2.44	4.17	36.2
Continuous miner operator.....	2,579	.77	2.83	1.31	2.31	14.2
Loading machine operator.....	283	.76	2.58	1.15	1.30	12.4
Continuous miner helper.....	1,405	.73	2.76	1.15	1.31	13.7
Roof bolter.....	3,451	.69	2.74	1.09	1.24	11.9
Roof bolter helper.....	629	.65	2.80	1.02	.97	12.1
Cutting machine operator.....	516	.64	2.99	1.23	3.05	12.2
Utility man.....	304	.64	2.68	1.17	4.20	9.1
Shotfirer.....	174	.58	2.93	1.00	1.28	10.3
Auger jack setter, intake.....	279	.57	3.81	1.69	5.47	16.8
Section foreman.....	277	.55	2.52	.83	.99	5.4
Shuttle car operator.....	757	.54	2.59	.86	1.22	4.9
Mobile bridge operator.....	136	.53	3.13	1.03	1.45	11.0
Shuttle car operator standard side.....	2,123	.51	2.58	.80	2.00	5.6
Coal drill operator.....	483	.48	2.94	.97	3.02	6.2
Scoop car operator.....	938	.47	2.85	.78	.99	5.6
Mechanic.....	181	.44	2.44	.66	.81	2.8
Motorman.....	148	.41	3.01	.74	.96	6.1
Hand loader.....	117	.30	2.47	.47	.50	4.3
Surface:						
Fine coal plant operator.....	197	1.00	2.85	1.51	1.19	32.0
Highwall drill operator.....	817	.62	3.36	1.29	2.05	17.1
Cleanup man.....	169	.58	2.92	1.04	1.67	10.0
Scalper-screen operator.....	108	.58	2.67	.88	.80	9.3
Cleaning plant operator.....	216	.49	2.90	.88	1.50	6.5
Laborer.....	525	.44	3.11	.97	3.16	7.4
Refuse truck driver.....	634	.38	2.61	.59	.61	3.3
Tipple operator.....	375	.35	2.90	.64	.86	6.4
Mechanic.....	339	.31	2.86	.63	2.19	2.9
Bulldozer operator.....	1,651	.30	2.49	.48	.98	2.0
Scraper operator.....	221	.25	2.54	.43	.69	3.2
Highlift operator.....	1,565	.22	2.29	.34	.43	1.3
Oiler-greaser.....	189	.22	2.30	.32	.35	.5
Coal truck driver.....	179	.22	2.01	.29	.24	0
Coal shovel operator.....	107	.19	2.12	.26	.28	0
Crane-dragline operator.....	232	.17	2.14	.43	3.15	.9

AM Arithmetic mean. GSD Geometric standard deviation.

ASD Arithmetic standard deviation. TLV Threshold limit value.

GM Geometric mean.

¹See table A-4 for complete list of codes, occupations, and samples.

NOTE.--Only occupations with at least 100 samples are included in this table and they are ranked by GM concentration.

TABLE 12. - Trends in exposure for five underground coal mine occupations

Occupation	1981	1982	1983	1984
Continuous miner operator:				
Samples.....	2,196	2,484	2,445	2,579
AM CONC.....mg/m ³ ..	1.30	1.26	1.14	1.31
ASD.....mg/m ³ ..	2.20	2.45	1.21	2.31
GM CONC.....mg/m ³ ..	0.82	0.82	0.73	0.77
GSD.....mg/m ³ ..	2.63	2.52	2.70	2.83
>TLV.....pct..	14.6	13.0	12.4	14.2
Continuous miner helper:				
Samples.....	1,349	1,512	1,413	1,405
AM CONC.....mg/m ³ ..	1.14	1.12	1.01	1.15
ASD.....mg/m ³ ..	1.16	1.06	1.10	1.31
GM CONC.....mg/m ³ ..	0.77	0.78	0.66	0.73
GSD.....mg/m ³ ..	2.61	2.45	2.67	2.76
>TLV.....pct..	12.7	10.7	9.5	13.7
Longwall jack setter:				
Samples.....	269	296	414	499
AM CONC.....mg/m ³ ..	1.72	1.79	1.79	1.80
ASD.....mg/m ³ ..	1.30	1.39	1.65	1.30
GM CONC.....mg/m ³ ..	1.35	1.43	1.40	1.50
GSD.....mg/m ³ ..	2.10	2.00	2.00	1.84
>TLV.....pct..	32.0	40.4	27.5	28.7
Longwall shear-plow operator:				
Samples.....	188	213	328	387
AM CONC.....mg/m ³ ..	2.60	2.16	1.95	2.03
ASD.....mg/m ³ ..	2.49	1.53	1.35	1.45
GM CONC.....mg/m ³ ..	1.88	1.74	1.57	1.66
GSD.....mg/m ³ ..	2.30	1.97	1.97	1.93
>TLV.....pct..	47.9	41.3	34.4	34.6
Roof bolter:				
Samples.....	3,382	3,464	3,624	3,451
AM CONC.....mg/m ³ ..	1.21	1.24	1.00	1.09
ASD.....mg/m ³ ..	2.01	2.43	1.18	1.24
GM CONC.....mg/m ³ ..	0.76	0.77	0.63	0.69
GSD.....mg/m ³ ..	2.70	2.67	2.75	2.74
>TLV.....pct..	13.3	13.0	9.6	11.9

AM CONC Arithmetic mean concentration.

ASD Arithmetic standard deviation.

GM CONC Geometric mean concentration.

GSD Geometric mean standard deviation.

TLV Threshold limit value.

SUMMARY AND CONCLUSIONS

The MIDAS data base stores environmental data collected from coal mines and metal and nonmetal mines or mills. The metal and nonmetal data were collected by MSHA inspectors from 1974 to the present, whereas the coal respirable dust data were collected by both coal mine operators and MSHA inspectors from 1970 to the present. There are about 450,000 records from metal and nonmetal mines and mills and 6.5 million records from coal mines in the data base.

The data base is split into two subsystems--metal-nonmetal and coal. The software used to analyze each subsystem is similar but not identical because of the different record formats and different coding systems used in each. The software is user friendly, menu driven, and requires minimum knowledge of the central computer operating system. Reports are in the form of tables and graphs.

This report also describes results from analyses of the metal and nonmetal respirable quartz (RQ) data and the coal mine respirable dust data gathered by MSHA inspectors from 1981 through 1984. Major findings of these analyses follow.

1. There was a reduction in the percentage of samples exceeding the RQ standard in metal and nonmetal mines from 1974 through 1979, and a slight increase from 14.7 to 17.2 pct from 1980 through 1984. This increase was accompanied by the collection of fewer samples by MSHA and policy changes caused by the passage of the 1977 act and changes in the 1982 appropriation. Overall, 9,000 RQ samples (18 pct) exceeded the RQ standard.

2. The use of respiratory protection among metal and nonmetal mine workers sampled by MSHA increased from 18 pct in 1974 to 47 pct in 1984. Occupations showing the greatest increase in the use of respiratory protection were jack stoper driller (20.4 pct increase),

pneumatic drill operator (20.3 pct increase), and flotation operator (19.7 pct increase).

3. Baggers in nonmetal mills had the highest percent of samples exceeding the RQ standard, but showed the greatest overall improvement with an 11-pct reduction in overexposure from the 1974-79 to 1980-84 period. Flotation operator, truck driver, and jack stoper driller occupations also reduced the percentage of samples over the standard by 10 pct or more for the same time periods. Three occupations, stope miner, motorman, and laborer, showed slight increases in the percent of overexposures for these two time periods.

4. Analysis of metal and nonmetal RQ data collected by MSHA inspectors showed that the net effect of changing the current standard from a formula based upon the percentage of quartz in the sample to a standard of $100 \mu\text{g}/\text{m}^3$ of respirable quartz would be 4 pct fewer samples would exceed the standard.

5. Analysis of coal mine respirable dust data showed that between 1981 and 1984, 10 to 12 pct of the samples exceeded the $2.0\text{-mg}/\text{m}^3$ standard while the geometric mean concentration (GM CONC) fluctuated between 0.59 and $0.69 \text{ mg}/\text{m}^3$. On average, about 1,800 samples exceeded the standard each year. However, far fewer mines were out of compliance because compliance is based on the arithmetic average of five samples exceeding the $2.0\text{-mg}/\text{m}^3$ standard.

6. Designated occupation concentrations are generally higher than the non-designated occupation values at mines using longwall, continuous rippers, or augering as the mining method.

7. Mines with longwall plows or shears have the highest GM CONC (1.64 and $1.29 \text{ mg}/\text{m}^3$) and the greatest percentage of samples exceeding the $2.0\text{-mg}/\text{m}^3$ standard

(43.7 and 25.2 pct). However, many more samples (10,946) were recorded at mines using continuous rippers with 10.9 pct of the samples exceeding the 2.0-mg/m³ limit with a GM CONC of 0.66 mg/m³. The dust concentrations were greater at mines with longwall operations but there were nearly nine times more continuous ripper operations with samples having dust concentrations greater than the Federal standard.

8. Coal mine occupations with the greatest percent of samples exceeding the 2.0-mg/m³ standard were auger jack setter, longwall shear-plow operator, fine coal plant operator, and longwall jack setter. Occupations with the greatest number of samples exceeding the 2.0-mg/m³ standard were continuous miner operator and helper, roof bolter, and highwall drill operator.

REFERENCES

1. National Materials Advisory Board. Measurement and Control of Respirable Dust in Mines. Natl. Acad. Sci., Washington, DC, NMAB-363, 1980, 405 pp.
2. U.S. Congress. Federal Mine Safety and Health Act of 1977. Public Law 91-173, as amended by Public Law 95-164, Nov. 9, 1977, 83 Stat. 803.
3. U.S. Code of Federal Regulations. Title 30--Mineral Resources; Chapter 1--Mine Safety and Health Administration, Department of Labor; July 1, 1984.
4. American Conference of Governmental Industrial Hygienists (Cincinnati, OH). TLV's--Threshold Limit Values for Chemical Substances in Workroom Air Adopted by the ACGIH in 1973. 1973, 54 pp.
5. Watts, W. F., Jr., R. L. Johnson, D. J. Donaven, and D. R. Parker. An Introduction to the Mine Inspection Data Analysis System (MIDAS). BuMines IC 8859, 1981, 41 pp.
6. Sutton, G. W., G. W. Weems, L. A. Schutz, and G. D. Trabant. Summary Report of the Environmental Results of the MSHA and NIOSH Silica/Diesel Exhaust Study. Paper in Industrial Hygiene for Mining and Tunneling. Proceedings of a Topical Symposium sponsored by ACGIH, November 6 and 7, 1978, Denver, CO. ACGIH, 1979, pp. 109-117.
7. Watts, W. F., D. R. Parker, and J. E. Small-Johnson. Gas and Dust Concentrations at 18 Underground, Dieselized, Noncoal Mines. Pres. at Am. Ind. Hyg. Assoc. Meet., May 19-24, 1985, Las Vegas, NV, 17 pp.; available from W. F. Watts, Jr., BuMines, Minneapolis, MN.
8. Dixon, W. J. (ed.). BMDP Statistical Software. Univ. CA Press, 1985, 734 pp.
9. U.S. Congress. The Federal Mine Safety and Health Act of 1977. Public Law 91-173, as amended by Public Law 95-164, Nov. 9, 1977, 91 Stat. 1291 and 1299.
10. Treaftis, H. N., A. J. Gero, P. M. Kacsmar, and T. F. Tomb. Comparison of Mass Concentrations Determined With Personal Respirable Coal Mine Dust Samplers Operating at 1.2 Liters Per Minute and the Casella 113A Gravimetric Sampler (MRE). Am. Ind. Hyg. Assoc. J., v. 45, No. 12, 1984, pp. 826-832.
11. American Conference of Governmental Industrial Hygienists (Cincinnati, OH). Documentation of the Threshold Limit Values. 4th ed., 1980, pp. 364-365.
12. U.S. Mine Safety and Health Administration. Preproposal Draft Air Quality Standards. 1983, 61 pp.; available from Health Div. for Metal and Nonmetal Safety and Health, MSHA, Arlington, VA.
13. Watts, W. F., Jr., D. R. Parker, R. L. Johnson, and K. L. Jensen. Analysis of Data on Respirable Quartz Dust Samples Collected in Metal and Nonmetal Mines and Mills. BuMines IC 8967, 1984, 28 pp.

APPENDIX.--MSHA SAMPLING CODES, DESCRIPTORS, AND SELECTED DATA

TABLE A-1. - Metal and nonmetal occupation codes

Code	Occupation	Samples	Code	Occupation	Samples
28..	Scoop-tram.....	19	612.	Belt vulcanizer.....	0
29..	Mucking machine.....	94	613.	Cleanup man.....	4,712
30..	Slusher.....	290	614.	Sampler.....	27
32..	Brattice.....	0	616.	Laborer and bullgang....	571
34..	Diamond drill.....	76	618.	Greaser and oiler.....	61
35..	Continuous miner helper.....	3	619.	Welder.....	159
36..	Continuous miner operator...	66	622.	Dump operator.....	192
37..	Cutting machine helper.....	0	623.	Surveyor.....	0
38..	Cutting machine operator....	1	634.	Rotary drill.....	74
39..	Hand loader.....	2	649.	Administrator.....	419
41..	Jack setter.....	2	660.	Machinist.....	0
43..	Gather arm loader.....	2	663.	Shaft miner.....	3
45..	Hand and chute blast.....	0	668.	Tractor operator.....	11
46..	Rock and roof bolter.....	96	669.	Puller and truck loader.	138
48..	Roof bolter mounted.....	2	673.	Leaching operations.....	14
53..	Utility man.....	125	674.	Warehouse man.....	376
57..	Stope miner.....	1,248	678.	Dragline.....	11
58..	Drift miner.....	80	679.	Flotation.....	657
59..	Raise miner.....	7	682.	Scraper-loader.....	46
79..	Crusher.....	8,342	706.	Shotcrete man.....	0
134.	Jet-piercer channel.....	110	708.	Ventilation crew.....	1
154.	Belt cleanup.....	21	710.	Ground control.....	98
179.	Ball and rod mill.....	1,523	716.	Cement operations.....	223
216.	Track gang.....	46	726.	Grizzly tender.....	9
234.	Jet piercer drill.....	6	728.	Load, haul, dump cycle..	123
261.	Battery station.....	0	734.	Pneumatic drill.....	1,049
279.	Hammer mill.....	8	739.	Hand trammer.....	4
331.	Clam-shell.....	3	747.	Hand scaling.....	1
334.	Wagon drill.....	1,634	750.	Diesel shuttle.....	10
342.	Bit grinding and sharpening.	0	759.	Raise borer.....	0
344.	Car shakeout.....	6	763.	Shaft repair.....	0
352.	Iron and metal work.....	1	765.	Dry sandfill.....	14
367.	Shovel operator.....	97	766.	Wet sandfill.....	2
368.	Bulldozer.....	1,122	778.	Backhoe.....	2
372.	Barge and dredge.....	64	779.	Pelletizing.....	350
375.	Road grader.....	9	782.	Front-end loader.....	13,463
376.	Trucker.....	1,259	388.	Scalper screen.....	19
378.	Mobile crane.....	11	389.	Forklift.....	28
379.	Dryer and kiln.....	1,982	392.	Top skip and tipple.....	5
385.	Lampman.....	0	393.	Weight and scale.....	8
387.	Rotary bucket excavation....	1	394.	Carpenter.....	1
588.	Sizing and washing.....	1,751	397.	Yard engine.....	3
601.	Conveyor belt.....	25	399.	Stone and rock saw.....	326
602.	Electrician.....	7	413.	Janitor.....	2
603.	Electrician helper.....	0	416.	Salvage crew.....	0
604.	Mechanic.....	1,691	420.	Aerial tram.....	1
607.	Jackhammer.....	112	434.	Churn drill.....	4
608.	Mason.....	0	456.	Engineer.....	263
609.	Supply man nipper.....	6	479.	Hydrating plant.....	4

TABLE A-1. - Metal and nonmetal occupation codes--Continued

Code	Occupation	Samples	Code	Occupation	Samples
488.	Dry screen plant.....	233	850.	Ramcar.....	0
513.	Building repair.....	29	878.	Overhead crane.....	6
514.	Lab technician.....	58	879.	Bagging and packing.....	2,745
516.	Tamping machine.....	0	894.	Painter.....	0
534.	Jack stoper drill.....	675	920.	Cager.....	4
579.	Slurry and mix.....	109	921.	Hoist.....	148
804.	Plumber.....	17	930.	Skip tender.....	17
807.	Powder gang.....	36	934.	Jumbo percussive drill...	50
825.	Bobcat.....	11	950.	Electric shuttle.....	0
833.	Drill helper.....	15	962.	Trip rider swamper.....	0
847.	Mechanical scaling.....	4	969.	Motorman.....	1,087

TABLE A-2. - Metal and nonmetal location codes

<u>Code</u>	<u>Location</u>	<u>Code</u>	<u>Location</u>
Underground:		Surface--Con.	
1.....	Active mining.	49.....	General.
3.....	Exploration and development.	51.....	Construction.
5.....	Travel and haul way.	Mill:	
7.....	Shaft and station.	61.....	Crushing.
9.....	Hoistroom.	63.....	Grinding.
11.....	Ore processing.	65.....	Washing and screening.
13.....	Ore transfer point.	67.....	Dry screening.
15.....	Shops.	69.....	Drying and roasting.
17.....	Office and storeroom.	71.....	Ore transfer point.
19.....	General.	73.....	Shops.
21.....	Construction.	75.....	Office and storage.
Surface:		77.....	General.
31.....	Active mining.	79.....	Flotation and reagents.
33.....	Exploration and development.	81.....	Pelletizing.
35.....	Roads.	83.....	Bagging and packing.
39.....	Tailings pond.	85.....	Construction.
41.....	Ore processing.	Miscellaneous:	
43.....	Ore transfer point.	37.....	Dredges and barges.
45.....	Shops.	99.....	Anywhere.
47.....	Office and storage.		

TABLE A-3. - Metal and nonmetal SIC codes

Code	Commodity	Samples ¹	Code	Commodity	Samples ¹
METAL			NONMETAL--Continued:		
10110	Iron.....	2,593	14750	Phosphate rock.....	531
10210	Copper.....	2,240	14760	Salt rock.....	16
10310	Lead and zinc.....	1,044	14770	Sulfur.....	0
10410	Gold.....	1,150	14790	Chemical fertilizer.....	0
10440	Silver.....	756	14791	Lithium.....	113
10510	Aluminum.....	8	14792	Pigment minerals.....	4
10610	Ferroalloy.....	0	14793	Pyrites.....	0
10611	Chromite.....	0	14794	Strontium.....	0
10612	Cobalt.....	5	14920	Gypsum.....	241
10613	Columbium, tantalum....	0	14960	Talc and pyrophyllite....	183
10614	Manganese.....	20	14990	Nonmetal minerals.....	881
10615	Molybdenum.....	600	14991	Asbestos.....	3
10616	Nickel.....	6	14992	Gemstones.....	7
10617	Tungsten.....	53	14993	Gilsonite.....	2
10920	Mercury.....	11	14994	Mica.....	146
10940	Uranium and vanadium...	275	14995	Peat.....	0
10941	Uranium.....	1,158	14996	Perlite.....	29
10942	Vanadium.....	6	14887	Pumice.....	37
10990	Other metal.....	34	14998	Vermiculite.....	15
10991	Antimony.....	37	28190	Industrial chemicals.....	0
10992	Beryl.....	4	28191	Alumina.....	10
10993	Platinum.....	0	28991	Evaporated salt.....	0
10994	Rare earths.....	23	28992	Brine salt.....	0
10995	Tin.....	1	29900	Leonardite.....	50
10996	Titanium.....	8	STONE		
10997	Zircon.....	0	14110	Other dimension stone....	57
NONMETAL			14111	Dimension granite.....	1,113
13111	Oil shale.....	102	14112	Dimension limestone.....	259
13112	Oil sand.....	0	14113	Dimension marble.....	35
14530	Fire clay.....	784	14114	Dimension sandstone.....	434
14550	Common clay.....	2,792	14115	Dimension slate.....	260
14590	Ceramic clay.....	13	14116	Dimension traprock.....	58
14591	Aplite.....	7	14220	Crushed limestone.....	13,054
14592	Brucite.....	0	14230	Crushed granite.....	3,206
14593	Feldspar.....	252	14290	Crushed stone.....	689
14594	Kyanite.....	27	14291	Crushed marble.....	18
14595	Magnesite.....	0	14292	Crushed sandstone.....	3,421
14596	Common shale.....	326	14293	Crushed slate.....	94
14720	Barite.....	226	14294	Crushed traprock.....	869
14730	Fluorspar.....	142	32410	Cement.....	1,232
14740	Potash, soda, borate...	2	32740	Lime.....	323
14741	Boron.....	21	SAND AND GRAVEL		
14742	Potash.....	2	14410	Sand and gravel.....	8,309
14743	Trona.....	13	UNKNOWN		
14744	Sodium compounds.....	0	0....	Unknown.....	68

¹For respirable quartz.

TABLE A-4. - Occupation codes most frequently used in 1984 by MSHA coal mine inspectors

Code	Occupation	Samples [†]	Code	Occupation	Samples [†]
UNDERGROUND FACE			UNDERGROUND FACE--Continued		
1...	Belt man.....	57	73..	Shuttle car operator (off standard).....	757
4...	Mechanic.....	181	74..	Motorman.....	148
7...	Shotfirer.....	174	SURFACE		
10..	Auger jack setter (intake side).....	279	302.	Electrician.....	87
16..	Laborer.....	63	304.	Mechanic.....	339
34..	Coal drill operator.....	483	310.	Scraper operator.....	221
35..	Continuous miner helper...	1,405	313.	Cleanup man.....	169
36..	Continuous miner operator.	2,579	314.	Coal sampler.....	74
37..	Cutting machine helper....	96	316.	Laborer.....	525
38..	Cutting machine operator..	516	318.	Oiler-greaser.....	189
39..	Hand loader.....	117	319.	Shop welder.....	91
40..	Headgate operator.....	136	367.	Coal shovel operator.....	107
41..	Longwall jack setter.....	499	368.	Bulldozer operator.....	1,651
43..	Loading machine operator..	283	373.	Car dropper.....	92
44..	Longwall (tailgate side)..	387	374.	Cleaning plant operator..	216
46..	Roof bolter.....	3,451	375.	Road grader operator.....	79
47..	Roof bolter helper.....	629	376.	Coal truck driver.....	179
48..	Roof bolter (return side).	78	378.	Crane-dragline operator..	232
49..	Section foreman.....	277	380.	Fine coal plant operator.	197
50..	Shuttle car operator (standard side).....	2,123	382.	Highlift operator.....	1,565
52..	Tailgate operator.....	71	383.	Driller highwall helper..	57
53..	Utility man.....	304	384.	Highwall drill operator..	817
54..	Scoop car operator.....	938	386.	Refuse truck driver.....	634
55..	Auger jack setter (return side).....	116	388.	Scalper-screen operator..	108
72..	Mobile bridge operator....	136	392.	Tipple operator.....	375
			999.	Not designated.....	1,335

[†]Respirable coal dust.

TABLE A-5. - MSHA coal mine codes for mine type

Code	Mine type	Code	Mine type
1970-80:		Post-1980:	
0.....	Surface.	A.....	Surface.
1.....	Development.	B.....	Underground.
2.....	Retreat.		

TABLE A-6. - MSHA coal mine codes for sample type

<u>Code</u>	<u>Sample type</u>	<u>Code</u>	<u>Sample type</u>
1970-80 inspector and operator:		Post-1980 inspector--Continued	
0.....	Surface.	5.....	Part 90 miner.
1.....	High risk.	6.....	Nondesignated area.
2.....	Intake air.	7.....	Intake air.
3.....	Non-high risk.	8.....	Nondesignated work position.
4.....	Nonface.	Post-1980 operator:	
5.....	Part 90 miner.	1.....	Mechanized mining unit.
Post-1980 inspector:		2.....	Nondesignated occupation.
1.....	Designated occupation.	3.....	Designated area.
2.....	Nondesignated occupation.	4.....	Designated work position.
3.....	Designated area.	5.....	Part 90 miner.
4.....	Designated work position.		

TABLE A-7. - MSHA coal mine codes for mining method

<u>Code</u>	<u>Mining method</u>	<u>Code</u>	<u>Mining method</u>
1970-80:		Post-1980--Continued	
1.....	Continuous.	F.....	Continuous shortwall.
2.....	Conventional.	G.....	Conventional with cutting machine.
3.....	Longwall.	H.....	Scoop with cutting machine.
4.....	Other.	I.....	Scoop shoot off solids.
5.....	Surface.	J.....	Conventional shoot with loading machine.
Post-1980:		K.....	Hand load cutting machine.
A.....	Longwall shear.	L.....	Hand load shoot off solids.
B.....	Longwall plow.	M.....	Hand load anthracite.
C.....	Continuous ripper.	N.....	Other (surface).
D.....	Continuous bore.		
E.....	Continuous auger.		

TABLE A-8. - Percentage of metal and nonmetal miners wearing respirators

<u>Occupation</u>	<u>1974-79</u>	<u>1980-84</u>	<u>Change</u>	<u>Occupation</u>	<u>1974-79</u>	<u>1980-84</u>	<u>Change</u>
Jack stoper drill..	38.3	58.7	20.4	Bulldozer.....	25.9	39.9	14.0
Pneumatic drill....	38.7	59.0	20.3	Crusher worker....	32.4	46.0	13.6
Flotation operator.	30.3	50.0	19.7	Motorman.....	30.7	44.2	13.5
Mechanic.....	30.4	49.2	18.8	Bagger.....	60.0	71.4	11.4
General cleanup....	36.9	55.2	18.3	Front-end loader..	21.2	31.6	10.4
Ball and rod mill..	45.8	61.6	15.8	Sizing and washing	36.9	45.5	8.6
Stope miner.....	26.9	41.9	15.0	Truck driver.....	18.6	26.4	7.8
Wagon drill.....	33.5	48.3	14.8	Laborer.....	42.3	47.5	5.2
Dryer and kiln.....	45.4	59.9	14.5	Average.....	35.0	49.2	14.2