RESULTS FROM THE NATIONAL OCCUPATIONAL HEALTH SURVEY OF MINING (NOHSM)

I. INTRODUCTION

A. Field Survey Summary

The National Occupational Health Survey of Mining (NOHSM) was designed by the National Institute for Occupational Safety and Health (NIOSH) to characterize health-related agents found at U.S. mines. A sample of mines representing 66 different mineral commodities was surveyed during the period of May 1984 through August 1989. A total of 491 mines were surveyed during that period, including 431 metal-nonmetal mines and 60 coal mines. The 491 surveyed mines employed 59,734 miners.

B. Previous Similar NIOSH Surveys

NOHSM was similar to two previous NIOSH surveys: the National Occupational Hazard Survey (NOHS) conducted during 1972–1974[1] and the National Occupational Exposure Survey (NOES) conducted during 1981–1982.[2]

C. NOHSM Purpose

NOHSM was developed in response to the U.S. Federal Mine Safety and Health Amendments Act of 1977 for two reasons. First, the Act required that the Secretary of Health, Education, and Welfare (now the Department of Health and Human Services) "*. . . shall, for each toxic material or harmful physical agent which is used or found in a mine, determine whether such material or agent is potentially toxic at the concentrations in which it is used or found in a mine.*"[3] In order to fulfill these requirements of the Act, NIOSH implemented a two-stage plan. The first stage involved the identification of occupational health hazards in the mining industry; the identification of the mining commodities where these occupational health hazards occurred; and the identification of the occupations and the number of workers, by sex, potentially exposed to these occupational health hazards. The second stage, which is not a part of NOHSM, will require air sampling for selected chemicals and dusts to determine the concentrations at which they are used or found. This second-stage effort will rely on information obtained from the first stage in selecting the mining commodities, chemicals, and occupations that are to be sampled. Second, since the Act directed NIOSH to perform research to protect the health of U.S. workers in the mining industry, NIOSH needed to develop a reliable database concerning workers' potential exposures to health hazards. The establishment of this NOHSM database has enabled NIOSH to: (1) estimate the number of miners potentially exposed to occupational health hazards; (2) describe the types of mining commodities and occupational groups where the potential for exposure to these hazards was observed; and (3) document some of mine management's practices and policies toward workers' health.

II. NOHSM SAMPLE SELECTION

A. Commodity Adjustments

The NOHSM covered 66 mineral commodities (Table 1). Twenty-one of the Mine Safety and

Health Administration (MSHA) mineral commodities had no active mining facilities during the period of the NOHSM survey; NOHSM combined Aluminum (Mill) and Aluminum (Ore) into one commodity, Aluminum; the 3 Clay commodities designated by MSHA were combined into one NOHSM commodity, Clay. Those adjustments resulted in 66 mineral commodities being surveyed by NOHSM which are shown in Table 2. A few of the 66 commodities used in NOHSM were divided into geographic strata based on differences in mineral composition and mining methods. When NOHSM began some of the mineral commodities had many inactive mines. In order to allow some of these mineral commodities enough time to recover into a more active operating status, NOHSM was divided into 4 segments. The mineral commodities with the highest operating status as compared to the 1980 year-end version of the Address and Employment file that was maintained by MSHA were surveyed in the first segment. The mines that were surveyed in the second segment belong to the mineral commodities that had the highest operating activity status from the remainder of the commodities that were not surveyed in the first segment, etc. NIOSH obtained information on each mine's operating activity status from MSHA-provided computer tapes that were updated on a quarterly basis. The specific tape that was used for the selection of each mineral commodity is provided in Table 3.

B. Basis of Mine Selection

Mines to be surveyed as a part of NOHSM were selected from a file of mining and milling establishments maintained by MSHA. Sample selection was based on each mine's operating status (NIOSH had specified that NOHSM cover mines that had an active operating status), average yearly employment, MSHA's Standard Industrial Classification (SIC), and geographical area. The MSHA SIC is a five digit coding classification for each mineral commodity that MSHA constructed from the four-digit SIC used in the non-mining industries. The MSHA SIC codes and associated mineral commodities are listed in Table 1.

C. Systematic Sampling Description

NOHSM used systematic sampling with replacement. Each mine in the sample was weighted in proportion to its employment level, with a proportionally heavier weighing going to larger employment mines. A test sample interval was calculated by dividing the total number of workers in a commodity by the number of mines to be surveyed for that commodity. The number of mines to be surveyed for a commodity was calculated by multiplying the sampling percent (initially 15 percent of the mines in a commodity were to be sampled, but this was adjusted before the second segment of NOHSM mines were selected so that no more than 30 mines were selected within any commodity) by the total number of mines in that commodity and rounding up. Any mine with an employment level greater than the sample interval had a 100 percent probability of being selected and a chance of being selected more than once; therefore such mines were pre-selected as a self-representing unit (SRU) and removed from the list of all mines in that commodity. A new sample interval was then calculated and systematic sampling was initiated over the remaining mines in that commodity. Mines which were selected with the new sample interval from the sample with the SRUs removed were called non-self-representing units (NSRUs). Data from NSRUs can be projected over the commodity—remaining mines which were not surveyed, while data from the SRUs can only apply to the individual mine selected and can only be added as a constant to obtain the commodity totals. A document entitled "*Final Report on the Sampling Design for the Occupational Health Survey of the Mining Industry*" provides a thorough description of the NOHSM sample selection.[4] The compendium of the resulting sample of mines is found in Appendix A. Any mineral commodity in Appendix A which lists only SRU mining facilities being surveyed means that every mining facility in that mineral commodity was surveyed under NOHSM. In effect, a census of the commodity was performed.

Table 1

MSHA SIC CODES AND ASSOCIATED MINERAL COMMODITIES

MSHA SIC CODE	MINERAL COMMODITY	MSHA SIC CODE	MINERAL COMMODITY
28191	Alumina (Mill)**	10990	Metal Ores, NEC+
10510	Aluminum Ore**	14994	Mica
10991	Antimony*	10615	Molybdenum
14591	Aplite	10616	Nickel*
14991	Asbestos	14990	Nonmetallic Minerals, NEC+
14720	Barite	13112	Oil Sand*
10992	Beryl	13111	Oil Shale
14741	Boron Minerals	14995	Peat (Before 1979)*
28193	Bromine*	14996	Perlite
14592	Brucite*	14750	Phosphate Rock
32410	Cement	14792	Pigment Mineral
14790	Chemical and Fertilizer, NEC*+	10993	Platinum Group
10611	Chromite*	14742	Potash
14590	Clay, Ceramic & Refractory, NEC**+	14740	Potash, Soda & Borate Minerals, NEC*+
14550	Clay (Common)**	14997	Pumice
14530	Clay (Fire)**	14793	Pyrites
11110	Coal, Anthracite	10994	Rare Earths
12110	Coal, Bituminous	28991	Salt (Evaporated)
10612	Cobalt*	28992	Salt (In Brine)*
10613	Columbium–Tantalum*	14760	Salt (Rock)
10210	Copper Ore	14410	Sand & Gravel
14593	Feldspar	14292	Sandstone (Crushed & Broken)
10610	Ferralloy Ores*	14114	Sandstone (Dimension)
14730	Fluorspar	14596	Shale (Common)
14531	Garnet*	14295	Silica Sand*
14992	Gemstones	10440	Silver Ores
14993	Gilsonite	14293	Slate (Crushed & Broken)
10410	Gold (Lode and Placer)	14115	Slate (Dimension)
14230	Granite (Crushed & Broken)	14744	Sodium Compounds
14111	Granite (Dimension)	14290	Stone, Crushed & Broken, NEC+
14920	Gypsum	14110	Stone, Dimension NEC+
28190	Industrial Chemicals, NEC*+	14794	Strontium*
10110	Iron Ore	14770	Sulfur*
14594	Kyanite	14960	Talc, Soapstone & Pyrophyllite
10310	Lead and/or Zinc Ore	10995	Tin Ore*
29900	Leonardite	10996	Titanium
32740	Lime	14294	Traprock (Crushed & Broken)
14220	Limestone (Crushed & Broken)	14116	Traprock (Dimension)*
14112	Limestone (Dimension)	14743	Trona
14791	Lithium	10617	Tungsten*
14595	Magnesite	10941	Uranium
10614	Manganese	10940	Uranium–Vanadium Ores
14291	Marble (Crushed & Broken)	10942	Vanadium
14113	Marble (Dimension)	14998	Vermiculite
10920	Mercury	10997	Zircon

*NOTE: Commodity inactive during the NOHSM survey period. The source for the MSHA SIC CODES are the technical documentation for the MSHA address and employment file.

**NOTE: NIOSH combined the Alumina (Mill) and Aluminum (Ore) commodities into one commodity, Aluminum; the three Clay commodities into one commodity, Clay.

+NOTE: NEC represents Not Elsewhere Classified.

Table 2

NOHSM MINERAL COMMODITIES AND ASSOCIATED MSHA SIC CODES

MINERAL COMMODITY	MSHA SIC CODE	MINERAL COMMODITY	MSHA SIC CODE
Aluminum	10510	Mica	14994
Anthracite Coal*	11110	Molybdenum	10615
Aplite	14591	Nonmetallic Minerals, NEC+	14990
Asbestos	14991	Oil Shale	13111
Barite	14720	Perlite	14996
Beryl	10992	Phosphate Rock	14750
Bituminous Coal*	12110	Pigment Minerals*	14792
Boron Minerals	14741	Platinum Group	10993
Cement	32410	Potash	14742
Clay	14530	Pumice	14997
Copper*	10210	Pyrites	14793
Feldspar	14593	Rare Earths	10994
Fluorspar	14730	Salt (Evaporated)	28991
Gemstones	14992	Salt (Rock)	14760
Gilsonite	14993	Sand and Gravel*	14410
Gold*	10410	Sandstone (Crushed & Broken)	14292
Granite (Crushed & Broken)	14230	Sandstone (Dimension)	14114
Granite (Dimension)	14111	Shale (Common)	14596
Gypsum	14920	Silver*	10440
Iron Ore	10110	Slate (Crushed & Broken)	14293
Kyanite	14594	Slate (Dimension)	14115
Lead/Zinc*	10310	Sodium Compounds	14744
Leonardite	29900	Stone, Crushed & Broken, NEC+	14290
Lime	32740	Stone, Dimension, NEC*+	14110
Limestone (Crushed & Broken)	14220	Talc, Soapstone & Pyrophyllite	14960
Limestone (Dimension)	14112	Titanium	10996
Lithium	14791	Traprock (Crushed & Broken)	14294
Magnesite	14595	Trona	14743
Manganese	10614	Uranium	10941
Marble (Crushed & Broken)	14291	Uranium–Vanadium Ores	10940
Marble (Dimension)	14112	Vanadium	10942
Mercury	10920	Vermiculite	14998
Metal Ores, NEC+	10990	Zircon	10997

*NOTE: Abbreviated or slight change to name: Coal, Anthracite to Anthracite Coal; Coal, Bituminous to Bituminuous Coal; Copper Ore to Copper; Gold (Lode and Placer) to Gold; Lead and/or Zinc Ore to Lead/Zinc; Pigment Mineral to Pigment Minerals; Sand & Gravel to Sand and Gravel; Silver Ores to Silver; and Stone, Dimension NEC+ to Stone, Dimension, NEC+.

+NOTE: NEC represents Not Elsewhere Classified.

Table 3

MSHA TAPES USED FOR SELECTION OF NOHSM MINERAL COMMODITIES

MSHA TAPE	FIRST SEGMENT COMMODITIES
2nd Quarter 83	Aluminum
	Aplite
	Asbestos
	Beryl
	Boron Minerals
	Gemstones
	Gilsonite
	Gold
	Gypsum
	Leonardite
	Magnesite
	Mercury
	Metal Ores, NEC+
	Nonmetallic Minerals, NEC+
	Perlite
	Potash
	Rare Earths
	Salt (Evaporated)
	Salt (Rock)
	Sandstone (Crushed & Broken)
	Silver
	Sodium Compounds
	Trona
	Vermiculite

MSHA TAPE	SECOND SEGMENT COMMODITIES
4th Quarter 84	Bituminous Coal
	Clay
	Granite (Crushed & Broken)
	Granite (Dimension)
	Manganese
	Slate (Crushed & Broken)
	Slate (Dimension)
	Stone, Crushed & Broken, NEC+
	Stone, Dimension, NEC+

MSHA TAPE	THIRD SEGMENT COMMODITIES
1st Quarter 86	Anthracite Coal
	Feldspar
	Kyanite
	Lignite Coal
	Lime
	Limestone (Crushed & Broken)
	Marble (Crushed & Broken)
	Marble (Dimension)
	Mica
	Phosphate Rock
	Pigment Minerals
	Pyrites
	Sandstone (Dimension)
	Talc, Soapstone & Pyrophyllite
	Traprock (Crushed & Broken)
	Zircon

MSHA TAPE	FOURTH SEGMENT COMMODITIES
2nd Quarter 87	Barite
	Cement
	Copper (Porphyry)
	Copper (Sedimentary)
	Fluorspar
	Iron Ore
	Lead/Zinc (Lead)
	Lead/Zinc (Zinc)
	Limestone (Dimension)
	Lithium
	Molybdenum
	Oil Shale
	Platinum Group
	Pumice
	Sand and Gravel
	Shale (Common)
	Titanium
	Uranium
	Uranium (Solution)
	Uranium–Vanadium Ores
	Vanadium

+NOTE: NEC represents Not Elsewhere Classified.

III. SURVEY DESCRIPTION

The field activities for the NOHSM were carried out by ten surveyors who had been trained to conduct the field portion of the surveys. A maximum of six surveyors were in the field at one time. The ten surveyors included six mining engineers, one chemical engineer, one mineral-processing engineer, and two industrial hygienists. Each NOHSM survey consisted of a questionnaire, an inventory, and worksite observations. Mine management had the right to designate any data from all phases of the NOHSM survey as trade secret. Any NOHSM data which is reported to the public must exclude data that was designated as trade secret by mine management.

A. Questionnaire

The NOHSM questionnaire, reproduced as Appendix B, was administered at each of the 491 facilities in the NOHSM sample, representing 66 mineral commodities. Several of the questions from the NOHSM questionnaire were taken directly from the NOES questionnaire and some of the questions were modified versions of the NOES questions to make them more appropriate to the mining industry.[2] The questionnaire was designed to document certain management practices and policies toward workers' health. The questions were subdivided into four major subject areas. The first of these subject areas consisted of general facility information which characterized sampled facilities by industrial classification, commodities mined or processed, age, and workforce size. The second and third subject areas contained profile information on the provision of medical and industrial hygiene services to employees as a result of management policy. The final portion of the questionnaire addressed the employee health-related record-keeping practices and the geology of the sampled facility. Appendix C contains the definitions, guidelines, and procedures which the NOHSM surveyor followed for preparing and conducting the questionnaire. These guidelines were not given to mine management.

B. Inventory

1. Chemical Substance Definition

   The NOHSM inventory included all chemical substances and trade name products which were present at the mine site. The NOHSM definition of a chemical substance is any substance that can be unambiguously characterized by a specific chemical name or formula. If a substance was coded as a chemical but was not found on the initial list of accepted chemical terms, a NIOSH chemist (with the assistance of the NOHSM surveyors) determined whether or not the unidentifiable chemical should be coded as a chemical substance or a trade name product. The list of NOHSM accepted chemical terms includes generic substances such as sulfuric acid, hydrogen chloride, sodium hydroxide, acetone, creosote pressure treated wood, waste oil, saw dust, portland cement, copper slag, coal tar pitch volatiles, chalk, creosote ties, and gas mixtures such as (argon-90%, methane-10%).

2. Trade Name Product Definition

   If a substance could not be identified by a specific chemical name or formula by the surveyor, it was coded as a trade name product. Trade name products include substances such as Windex Glass Cleaner, WD-40, WD-40 (aerosol), Chevron Sri-Grease No. 2, and Certanium 705 Welding Rod, etc.

3. Product Categories

   This inventory was quite diverse; the following product categories are examples: paints; lubricants, oils, and greases; janitorial cleaning chemicals; welding rods and wires; solders; abrasives such as grinding wheels and grinding discs; lab chemicals; mill reagents; sealants and adhesives; explosives; fuels; and aerosol products. The inventory excluded cosmetics, medical supplies, and food items.

4. Associated Data for Each Inventoried Item

For each inventoried item, the NOHSM surveyor recorded the manufacturer or distributor's name and address, the exact product name or chemical name, a product use term (PUT) which described the mining facility's primary use of the inventoried item, an estimated yearly usage rate in pounds or gallons, the location where the product was stored on the mine property, and whether or not the substance was contained in a pressurized aerosol can. The designation of being contained in an aerosol can was coded because aerosol canned substances usually involve a propellant gas, a solvent or thinner vapor, and a mist. The names of the PUTs, which are listed in Appendix D, were taken directly from the NOES with some additions, deletions, and modifications to make the list more appropriate to the mining industry.[2]

C. Worksite Observations

1. Potential Exposure Definition

During the worksite visit, the surveyors observed and interviewed workers to determine their potential exposures at the worksite. The term **"potential exposure"** had two criteria. First, the NOHSM surveyor must have determined that the health-related agent was in sufficient proximity to a worker such that the agent could have entered or contacted the body of the worker, although the level of exposure was not measured by NIOSH. Second, the duration of the potential exposure must have met the minimum duration guidelines (i.e., a part-time duration was defined as the potential exposure time which was greater than 30 minutes per week [on an annual average] or at least once per week, 90 percent of the weeks of the work year).

2. Categories of Potential Exposures

a. *Physical agent potential exposures*

The definitions, guidelines, and procedures for coding physical agent potential exposures are listed in Appendix E. The physical agents that were recorded during the worksite observations were:

(1) Noise

(2) Heat (whether caused by work processes or generated by underground rock strata).

(3) Radiation (ionizing radiation from ore bodies were recorded as potential exposures when the surveyor was notified of such conditions, but the environmental levels were not assessed).

(4) Vibration (whole-body or segmental).

b. *Musculoskeletal overload potential exposures*

The musculoskeletal overload potential exposures consisted of twelve different types of awkward bending, posture, and lifting. The definitions, guidelines, and procedures for coding musculoskeletal overload potential exposures are listed in Appendix F.

c. *Welding, brazing, and soldering potential exposures*

The elements coded in welding, brazing, or soldering operations, which are listed in Appendix G, were taken from the NOES.[2]

d. *Abrasive grinding potential exposures*

The three elements coded in abrasive grinding operations were the names of the metals being ground, the trade names of the grinding wheels or discs used, and any chemical substances or trade name products attached to the metals that were ground; such as solvents used to clean the metals or lubricants used to lubricate metals prior to grinding.

e. *Chemical substance potential exposures*

Only the chemical substances recorded during the inventory phase of the

NOHSM survey and observed during the worksite observations to meet potential exposure guidelines were recorded as chemical substance potential exposures.

f. *Trade name product potential exposures*

Only the trade name products recorded during the inventory phase of the NOHSM survey and observed during the worksite observations to meet potential exposure guidelines were recorded as trade name product potential exposures.

g. *Bulk dust potential exposures*

At each worksite, approximately 10 cubic centimeters of fine settled dust were collected in a plastic vial. If no fine settled dust was available, coarser bulk dust was collected. Of all the bulk dust samples gathered at each mine, five were selected and analyzed for crystalline silica (quartz, cristobalite, and tridymite), 31 different elements, and asbestos. When fewer than five bulk dust samples were collected, all were submitted for analysis.

3. Potential Exposure Exclusions

Any potential exposures which occurred as a result of non-work activities were not coded. Thus the surveyor did not code the potential exposures which resulted from the personal use of alcohol; tobacco; prescribed, over-the-counter, or recreational drugs; or perfume.

4. Associated Data for Each Potential Exposure

For each potential exposure, the surveyor coded the following information: occupation, operation, location, number of workers involved (by sex), the duration, the controls intended to reduce the effects of that potential exposure, how the product was used at that particular worksite (PUT), and if the product was being combusted (such as diesel fuel or gasoline that is combusted as fuel in engines). The names and definitions of the occupations, operations, and locations were taken directly from an MSHA list of occupations, operations, and locations for metal and non-metal mines (Appendix H) and coal mines (Appendix I). The duration was defined as the approximate length of time that an employee group or occupation was potentially exposed to any of the recordable potential exposures which were previously defined in this report. The potential exposure duration could have been either full- or part-time. A full-time duration was defined as the potential exposure time which was greater than four hours per day and on a daily basis of at least 90 percent of the company's work year or a standard work year. A part-time duration was defined as the potential exposure time which was greater than 30 minutes per week [on an annual average] and not full time, or at least once per week, 90 percent of the weeks of the work year. Surveyors entered worksite PUTs and inventory PUTs. The worksite PUT described how the product was used at that particular worksite where the potential exposure occurred; the inventory PUT described the entire mine's major use of the product. Both the worksite PUTs and the inventory PUTs are also listed in Appendix D. The intended controls were defined as the measures which were intended by management to protect the employees at risk to the potential exposures listed previously. These controls included ventilation, personal protective equipment, administrative measures, and others. The names and definitions of the intended controls for NOHSM, listed in Appendix J, were taken directly from the NOES.[2]

IV. DATA PROJECTION AND VARIANCE CALCULATION FORMULAS

A. Introduction

NOHSM was designed to provide the capability to project the survey data to national statistics and calculate variances for the projections. One major advantage of the NOHSM design is

the simplicity of the projection and variance calculation formulas. After listing the required notation below, the general formula is shown for the projection of a characteristic of the target population. This is followed by the formulas to be used for calculating the variance of the projections.

B. Notation

Let:

L denote the number of commodities

h denote the hth commodity

i denote the ith unit (mine) within commodity h

j equal to 1, denote a self-representing unit (SRU)

j equal to 2, denote a non-self-representing unit (NSRU)

N_{h1} denote the number of self-representing units in commodity h in the population

n_{h1} denote the number of self-representing units in commodity h in the sample (by definition of self-representing $n_{h1} = N_{h1}$)

N_{h2} denote the number of non-self-representing units in commodity h in the population

n_{h2} denote the number of non-self-representing units in commodity h in the sample

π_{hi1} denote the probability of the ith self-representing unit in commodity h being included in the sample (by definition of self-representing $\pi_{hi1} = 1$ for all (h, i, 1))

π_{hi2} denote the probability of the ith non-self-representing unit in commodity h being included in the sample

M_{hi1} denote the number of employees in the ith self-representing unit within commodity h in the population

M_{hi2} denote the number of employees in the ith non-self-representing unit within commodity h in the population

M_{h1} denote the total number of employees in the self-representing units in commodity h in the population

M_{h2} denote the total number of employees in the non-self-representing units in commodity h in the population

Y_{hij} denote the value of the characteristic "Y" for (h, i, j)

$\hat{Y}_{h1}$ denote the projection of the population total for the self-representing units within commodity h for characteristic "Y" ($\hat{Y}_{h1}$ will equal the actual Y_{h1} since the units are self-representing)

$\hat{Y}_{h2}$ denote the projection of the population total for the non-self-representing units within commodity h for characteristic "Y"

$\hat{Y}_h$ denote the projection of the population total for commodity h for characteristic "Y" ($\hat{Y}_h = \hat{Y}_{h1} + \hat{Y}_{h2}$)

$\hat{Y}$ denote the projection of the population total of characteristic "Y"

$\hat{Var}(\hat{Y}_{h2})$ denote the estimated variance of $\hat{Y}_{h2}$

$\hat{Var}(\hat{Y}_h)$ denote the estimated variance of $\hat{Y}_h$

$\hat{Var}(\hat{Y})$ denote the estimated variance of $\hat{Y}$

C. Projection Techniques

$$\hat{Y} = \sum_{h=1}^{L} \hat{Y}_h$$

$$\hat{Y} = \sum_{h}^{L} (\hat{Y}_{h1} + \hat{Y}_{h2})$$

$$\hat{Y} = \sum_{h}^{L} \sum_{i}^{n_{h1}} \frac{Y_{hi1}}{\pi_{hi1}} + \sum_{h}^{L} \sum_{i}^{n_{h2}} \frac{Y_{hi2}}{\pi_{hi2}}$$

Equation (1)

where:

$$\pi_{hi1} = 1 \text{ for all (h, i, 1)}$$

$$\pi_{hi2} = n_{h2} \frac{M_{hi2}}{\sum_{i}^{N_{h2}} M_{hi2}}$$

$$\pi_{hi2} = n_{h2} \frac{M_{hi2}}{M_{h2}}$$

Substituting:

$$Z_{hi2} = \frac{M_{hi2}}{M_{h2}},$$

π_{hi2} can be written as $\pi_{hi2} = n_{h2} Z_{hi2}$.

D. Variance Calculations

The actual variance of $\hat{Y}_h$, denoted by Var $(\hat{Y}_h)$, is given by the expression

$$Var(\hat{Y}_h) = Var\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2} Z_{hi2}}\right)$$

The variance of $\hat{Y}_h$ can be estimated by the expression

$$\hat{Var}(\hat{Y}_h) = \hat{Var}\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{\pi_{hi2}}\right)$$

This expression is independent of the self-representing units, since these units contribute nothing to the variance of $\hat{Y}_h$. Upon substituting $\pi_{hi2} = n_{h2}Z_{hi2}$, this expression can be estimated by the equation

$$\hat{Var}(\hat{Y}_h) = \hat{Var}\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2} Z_{hi2}}\right)$$

$$\hat{Var}(\hat{Y}_h) = \frac{\sum_{i=1}^{n_{h2}} \left(\frac{Y_{hi2}}{Z_{hi2}} - \hat{Y}_{h2}\right)^2}{n_{h2}(n_{h2} - 1)}$$

Equation (2)

where:

$$\hat{Y}_{h2} = \sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{\pi_{hi2}} = \sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2} Z_{hi2}}$$

The variance of $\hat{Y}$ can be estimated by the expression

$$\hat{Var}(\hat{Y}) = \sum_{h} \hat{Var}(\hat{Y}_h) \qquad \text{Equation (3)}$$

where $\hat{Var}(\hat{Y}_h)$ is obtained from the equation (2).

The standard deviation of $\hat{Y}$ can be estimated by the expression

$$Std\ Dev(\hat{Y}) = [Var(\hat{Y})]^{1/2} \qquad \text{Equation (4)}$$

where Var $(\hat{Y})$ can be obtained from Equation (3).

If no response was obtained from some mines in the sample (i.e., the mines were closed), the summations in equations (1) and (2) are understood to include only mines from which survey data were obtained.

The variance estimators for $\hat{Y}_h$ and $\hat{Y}$ using equations (2) and (3) are based on the assumption that the units were sampled with replacement through the procedure of random selection with probability proportional to size. In the design, the units were sampled with replacement using the procedure of systematic selection with probability proportional to size. Because units in each commodity are listed in order of mine ID (which gives an implicit stratification by state and age) the units adjacent in the list will tend to be similar. The variances using systematic sampling with probability proportional to size are smaller than random sampling with probability proportional to size. Consequently, these variance equations

give conservative estimates of the variance; that is, the actual variance will be no larger than the random sampling variance.

The standard deviations for $\hat{Y}$ which are obtained by using equation (4) can provide a rough indicator of the variance about the projection. Many of these standard deviations are quite large, such as the standard deviations for the projections of most of the chemicals listed in Appendix O. It is beyond the scope of this report to provide the projections and standard deviations for all of the data gathered by NOHSM. However, any parties that are interested in the projections and standard deviations for specific agents of interest should direct their requests to the NOHSM project officer listed in the discussion, Section IX of this report, or obtain the NOHSM database that is described in the NOHSM database, Section VI of this report and perform the calculations themselves. A document entitled *"Final Report on the Sampling Design for the Occupational Health Survey of the Mining Industry"* provides a thorough description of the NOHSM data projection and variance calculation equations.[4]

V. NOHSM Commodity Reports

Once the NOHSM data were coded and computerized, commodity reports were generated. The commodity reports identify potential exposures for entire commodities and provide the associated numbers of workers, the occupations of those workers, and the locations on the mine property where the potential exposures were observed. This information is categorized into seven tables: four concerning chemical agents; one concerning musculoskeletal overload conditions; one concerning physical agent conditions; and one concerning welding processes. Estimated annual usage (pounds and gallons) is provided for chemical agents and trade name products. Commodity reports have been provided to MSHA and other interested parties. Appendix K contains the Stone, Dimension, NEC commodity report, which provides an example of the commodity reports produced for NOHSM.

VI. NOHSM Database

A. Processing of Datasets

After the field data were collected and coded, the data were keyed into a facility dataset. This dataset was processed by using the PL/I multipurpose programming language to perform edit checks on the data.[5] After the dataset passed all the edits, it was placed into the NOHSM master file. The master file was then processed by using PL/I and Statistical Analysis System (SAS) programs to create SAS datasets.[6] These datasets include SAS and other types of datasets.

B. Types of SAS Datasets Created

A SAS data file consists of a collection of data values arranged in rectangular form by the SAS software.

1. Inventory dataset: Contains a complete inventory of all the chemicals and trade name products used or stored on the mine property, along with management's estimate of the mining facility's annual consumption and primary use for each item that was recorded. See Section III. B, *Inventory*, for further detail about the data that was gathered during the inventory.

2. Worksite dataset: Contains the potential exposure data that was gathered from each employee group or unique occupation, along with the associated data for each potential exposure. See Section III. C, *Worksite Observations,* for further detail about the data gathered during the worksite observations.

3. Trade name product usage dataset: Contains the trade name product annual usage projections by commodity.

4. Chemical usage dataset: Contains the chemical annual usage projections by commodity.

5. Commodity occupation dataset: Contains the projected number of workers associated with each occupation by commodity.

6. Commodity location dataset: Contains the projected number of workers associated with each location by commodity.

7. Facility occupation dataset: Contains the projected number of workers associated with each occupation by mining facility.

8. Facility location dataset: Contains the projected number of workers associated with each location by mining facility.

C. Other Types of Datasets Created

In addition to the above listed SAS data sets, other data sets were created using various methods. These include:

1. Questionnaire dataset: Contains the responses for most of the 51 questions in the questionnaire answered by a knowledgeable representative of mine management. This is a sequential file (a set of records in consecutive order).

2. Commodity dataset: Contains the information required to associate any NOHSM data with the appropriate commodity, the statistical value used to calculate that commodity's projections, and the projected number of workers for that commodity. This is a SAS data file.

3. Facility dataset: Contains the information required to associate any NOHSM data with the appropriate commodity, the statistical value used to calculate that commodity's projections, and the number of workers for that facility. This is a SAS data file.

4. Chemical dataset: Contains the translation of the chemical hazard codes in the inventory and worksite datasets. This is a sequential data file.

5. PUT dataset: Contains the translation of the product use terms in the inventory and worksite datasets. This is a sequential data file.

6. Trade name product dataset: Contains the translation of the trade name product codes in the inventory and worksite datasets. This is a SAS data file.

7. Manufacturer dataset: Contains the translation of the manufacturer/distributor codes in the inventory and worksite datasets. This is a SAS data file.

8. Metal/non-metal occupation dataset: Contains the translation of the metal/non-metal occupation codes in the worksite dataset. This is a sequential file.

9. Metal/non-metal location dataset: Contains the translation of the metal/non-metal location codes in the worksite dataset. This is a sequential file.

10. Metal/non-metal operation dataset: Contains the translation of the metal/non-metal operation codes in the worksite dataset. This is a sequential file.

11. Coal occupation dataset: Contains the translation of the coal occupation codes in the worksite dataset. This is a sequential file.

12. Coal location dataset: Contains the translation of the coal location codes in the worksite dataset. This is a sequential file.

13. Coal operation dataset: Contains the translation of the coal operation codes in the worksite dataset. This is a sequential file.

14. MSHA chemicals dataset: Contains the chemicals regulated by MSHA. This is a sequential file.

15. NIOSH chemicals dataset: Contains the chemicals that have a NIOSH recommended exposure limit. This is a sequential file.

By using these datasets, the commodity reports were generated. All but the data entry was

accomplished on an IBM 4361 mainframe. The data entry was accomplished on personal computers.

D. PC-based NOHSM Query System

1. Basic Options to Form a Query

In June, 1991, the PC-based NOHSM query system was completed. This system allows queries to be processed against the data collected during the NOHSM survey, after the data has been loaded into a PC. The NOHSM query system was developed to be user friendly so that end-users could process their own queries against the NOHSM data. This was accomplished by making the system key-driven with on-line help and simplifying the query formulation process by minimizing the selections. There are two basic steps in formulating a query. Step one is deciding which data the user wishes to retrieve or how the user wishes to retrieve the data (SELECTION CRITERIA) and step two is deciding what the user wishes to see once the query is processed (OUTPUT VARIABLES). Table 4 shows the NOHSM query system menu options including all of the data elements that can be accessed.

2. Availability of PC-Based Query System

This system was designed using the CA-Clipper software, which creates a stand-alone executable program.[7] This allows end-users to utilize the NOHSM query system without requiring them to purchase or possess the Clipper software. This database is currently available to any interested parties. It requires 300 mega-bytes of hard disk storage capacity to install it on a computer. This database is currently distributed on 30 floppy diskettes. NIOSH has developed a CD-ROM disc with the NOHSM query system included as an alternative for those end-users who do not wish to place the NOHSM query system on a personal computer. Any parties that are interested in special queries from the NOHSM data or a copy of the PC-based NOHSM query system should direct their requests to:

Project Officer
National Occupational Health Survey of Mining
National Institute for
Occupational Safety and Health (NIOSH)
Division of Respiratory Disease Studies (DRDS)
Environmental Investigations Branch
Environmental Surveillance Team
1095 Willowdale Road
Morgantown, WV 26505-2888

3. Query Example

An example of a possible query and the steps taken to create the query and its results are shown below.

Query: What physical agents are mechanics potentially exposed to in the Uranium - Vanadium Ore commodity? Also list the other occupations and the projected number of workers potentially exposed to each physical agent.

Step 1: To select the *"selection criteria"*: Place the highlighted bar in the *"SELECTION CRITERIA"* column by using the left or right arrow.

Step 2: To select the commodity: Place the highlighted bar on the *"Independent Commodities"* option under the *"SELECTION CRITERIA"* column and press the <ENTER> key. Then place the highlighted bar on the *"Uranium–Vanadium Ore"* option and press the <ENTER> key. Press the <END> key.

Step 3: To select the "*mechanics*" occupation: Place the highlighted bar on the *"Job Titles"* option under the *"SELECTION CRITERIA"* column and press the <ENTER> key. To locate the job title that starts with *"MECH"*: Press the <INS> key and enter *"MECH"* (no quotes) in the highlighted space at the bottom of the screen and press the <ENTER> key. The highlighted bar is now on the title *"MECHANIC"*;

press the <ENTER> key and then press the <END> key.

Step 4: To select the *"output variables"*: Place the highlighted bar in the *"OUTPUT VARIABLES"* column by using the left or right arrow.

Step 5: Place the highlighted bar on each of these options and press the <ENTER> key: *"Commodities," "Physical Agents," "Job Titles,"* and *"Number of Workers (Summary)."*

Step 6: Press the <F7> key to produce the report. Table 5 shows the results of this query.

Table 4

NOHSM QUERY SYSTEM OPTIONS AND DATA ELEMENTS

SELECTION CRITERIA	OUTPUT VARIABLES
Independent Commodities	Commodities
Combined Commodities	Chemicals
Chemicals	Trade Names
Trade Names	Manufacturers
Manufacturers	Product Use Terms
Chemicals/Trade Names	Physical Agents
Product Use Terms	Musculoskeletal Overloads
Physical Agents	Welding Processes
Musculoskeletal Overloads	Welding Metals
Welding Processes	Grinding Metals
Welding Metals	Job Titles
Grinding Metals	Locations
Independent Controls	Operations
Combined Controls	Controls
Job Titles	Questions
Locations	Bulk Dust Types
Operations	Number of Workers (Summary)
Questions	Number of Workers (Detail)
Projected Annual Usages	Projected Annual Usage (Summary)
Number of Workers	Projected Annual Usage (Detail)
Bulk Dust Types	Bulk Dust Percent (Summary)
Bulk Dust Percentages	Bulk Dust Percent (Detail)
Welding Chemicals	Number of Workers (All workers)
Welding Trade Names	Number of Workers (Males)
Grinding Chemicals	Number of Workers (Females)
Grinding Trade Names	Count of Chemicals
	Count of Trade Names
	Count of Product Use Terms
	Count of Physical Agents
	Count of Musculo. Overloads
	Count of Welding Processes
	Count of Grinding Metals
	Welding Process Chemicals
	Welding Process Trade Names
	Grinding Chemicals
	Grinding Trade Names
	Employment Level Summary

Table 5

RESULTS OF NOHSM QUERY EXAMPLE

SELECTION CRITERIA/OUTPUT VARIABLES

Independent Commodities:

URANIUM–VANADIUM ORES

Job Titles:

MECHANIC (M/NM 604)

OUTPUT VARIABLES:

Commodities
Physical Agents
Job Titles
Number of Workers (Summary)

Commodity:	URANIUM–VANADIUM ORES	
Phy. Agent:	IONIZING RADIATION	
# of Observed:	42 (All Workers)	
# of Projected:	42 (All Workers)	
% of Workers:	93 (All Workers)	
Job Titles:	9% ADMIN, SUPERVISORY, MGT PERSONNEL	(M/NM 659)
	40% COMPLETE LOAD / HAUL / DUMP CYCLE	(M/NM 728)
	4% LABORATORY TECHNICIAN	(M/NM 514)
	18% LEACHING OPERATIONS WORKER	(M/NM 673)
	13% MECHANIC	(M/NM 604)
	7% SLURRY, MIXING OR PUMPING WORKERS	(M/NM 579)
	2% TRUCK DRIVER	(M/NM 376)
Commodity:	URANIUM–VANADIUM ORES	
Phy. Agent:	NOISE	
# of Observed:	24 (All Workers)	
# of Projected:	24 (All Workers)	
% of Workers:	53 (All Workers)	
Job Titles:	40% COMPLETE LOAD / HAUL / DUMP CYCLE	(M/NM 728)
	13% MECHANIC	(M/NM 604)
Commodity:	URANIUM–VANADIUM ORES	
Phy. Agent:	SEGMENTAL BODY VIBRATION	
# of Observed:	4 (All Workers)	
# of Projected:	4 (All Workers)	
% of Workers:	9 (All Workers)	
Job Titles:	9% MECHANIC	(M/NM 604)
Message:	END OF REPORT	

VII. LIMITATIONS OF THE NOHSM DATA

The following limitations of the NOHSM data must be recognized:

A. Annual Usage Data

The annual usage data for each inventoried item were only a guide to the projected magnitude of usage for those items. The annual usage data were the total amount of gallons or pounds of each inventoried item which the mine used in the 12 months immediately preceding a survey; and were based on estimates which were provided by mine management. It is possible that an item might have been represented as having an annual usage rate of zero with workers observed to be potentially exposed to that item. This might have occurred since annual usage rates were generally based on purchases during the 12 months immediately preceding a survey. Therefore, items purchased prior to that 12 month period might have been represented as having a zero annual usage rate even though potential exposures were observed during the survey. Other items with zero usage rates which could have been observed as potential exposures could have been recyclable items such as catalysts and desiccants, items such as paints and coatings applied prior to the 12 month period but present in the workplace in such a way as to present a potential exposure, and obsolete items no longer actively used on the mine property but to which employees could have still been potentially exposed in the course of their work. Furthermore, all the estimates from mine management were rounded to the nearest whole number, with all quantities between 0 and 1 being reported as 1. Thus, extremely small usage rates may actually be lower than estimated. With this possible exception, NIOSH believes the projected magnitude of the usage rate to be appropriately represented.

B. Large Variances in Projections

The projections of attributes that have previously been described have variances and standard deviations which are dependent on the observed data from NSRUs, however these variances and standard deviations are not accounted for in the projections. Many of these standard deviations are quite large, such as the standard deviations for the projections of most of the chemicals listed in Appendix O.

C. Trade Secret Data Exclusions

Mine management had the right to designate any data from all phases of the NOHSM survey as trade secret. Any NOHSM data which is reported to the public must exclude data that was designated as trade secret by mine management. Seventy-nine of the four hundred ninety-one mines (16 percent) surveyed under NOHSM designated some data from at least one phase of the NOHSM as trade secret.

D. Time Dependency of Data

Since the NOHSM surveys were conducted at one point in time, the data will become outdated due to subsequent changes occurring at surveyed mine sites or in the mining industry as a whole. The data in the NOHSM database may be slightly changed in the future to make the information more applicable to that point in time. For example, the number of employees in each mine at the time the NOHSM sample was selected was used to calculate the commodity projections and variances, but the current number of employees in these mines could be substituted to calculate the commodity projections and variances.

E. Lack of Trade Name Product Resolution

NOHSM has not determined the chemical ingredients for trade name products. When questioning the NOHSM query system for the presence of a chemical, only the single chemical data will appear in the results. Because of the lack of trade name product chemical ingredients, the trade name products cannot be queried for the presence of a chemical.

F. Bulk Dust

For each worker that was observed and interviewed during the worksite visit, approximately 10 cubic centimeters of fine settled dust were collected in a plastic vial. Coarse bulk

dust was collected if no fine settled dust was available. The limitation of bulk dust samples as an indicator of airborne dust must be recognized: bulk dust samples can only be used to estimate the percentage of crystalline silica, trace elements, or asbestos in the worksite dust; but not the concentration of airborne quartz, trace elements, or asbestos. Bulk dust samples may represent an accumulation of dust over many months or dust which was recently deposited. It is possible that a bulk dust sample may have never been airborne. The bulk dust results are reflective of the 491 mines surveyed under NOHSM and should not be projected to other mine sites in the same way that other agents are projected.

VIII. RESULTS

A. Questionnaire

Appendix L contains results for most questions from the questionnaire. Since results for all of the 66 mineral commodities surveyed under NOHSM cannot be conveniently displayed in Appendix L in this report, the 66 mineral commodities have been grouped under the 6 mineral industries which MSHA uses in their annual injury experience information reports: stone mining, nonmetallic mineral mining, sand and gravel mining, anthracite coal mining, bituminous coal mining, and metallic mineral mining.

B. Inventory

The inventory contains 84,939 trade name products and 2,570 chemical substances. Approximately 31 percent of all inventoried items were recorded as having zero usage (not having been used in the 12 months before the mine was surveyed as estimated by mine management). Two hundred fifty-seven (257) MSHA-regulated chemicals were found during the surveys, in addition to approximately 2,197 chemicals that have no NIOSH recommended exposure limit (REL) or MSHA permissible exposure limit (PEL). For each inventoried item, the NOHSM surveyor recorded mine management's estimated annual usage rate in gallons or pounds. Appendices M and N list the 100 chemical substances which had the highest annual usage rate (amount used in the previous 12 months before the NOHSM survey was conducted at the mine) in gallons and pounds. The data in Appendices M and N are mutually exclusive, with some exceptions which are noted with asterisks (*). Any chemical substances that occur in both Appendices M and N have total use projections in both gallons and pounds. For example, sulfuric acid has a total projected usage rate of 4,888,000 gallons **and** 220,659,158 pounds; these numbers were not double-counted. Seven of the ten chemicals with the highest usage rate (by gallons) are fuels: natural gas, methane, acetylene, diesel fuel no. 2, gasoline-unleaded, diesel fuel no. 1, and gasoline-leaded.

C. Worksite Observations

All of the potential exposure results from the worksite observation phase of the NOHSM survey include both full- and part-time potential exposures which were previously defined in the survey description section of this report.

1. Physical Agent Potential Exposures

The health effects of noise, whole-body and segmental vibration, heat stress, and ionizing radiation in the mining industry have been presented in a number of publications.[8, 9, 10, 11, 12, 13, 14, 15, 16] Figure 1 indicates the projected number, and percent, of workers who were potentially exposed to the different types of physical agents recorded under NOHSM. These recorded physical agent potential exposures did not necessarily exceed NIOSH's recommended exposure limits (RELs) or any MSHA or OSHA standards for physical agents. For example, the NOHSM surveyor coded a potential exposure to noise (NL) whenever the surveyor had to raise his/her voice above a normal conversational level to be heard by the person standing next to him/her. The written definitions, guidelines, and procedures to code physical agents which NIOSH established for NOHSM are listed in Appendix E. "*Other*" in Figure 1 includes temperature (underground strata)

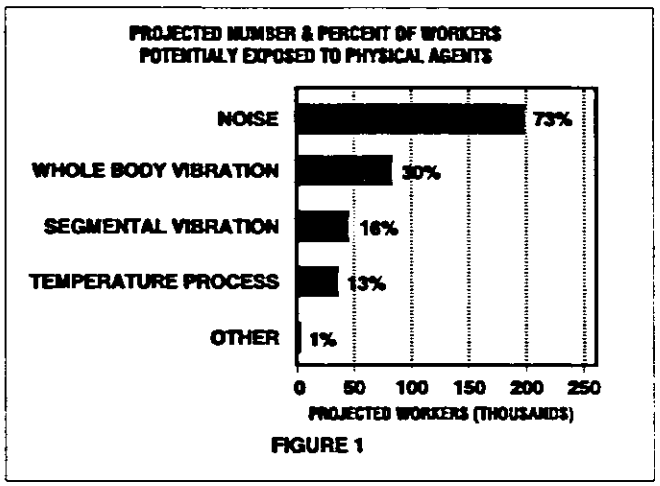

FIGURE 1

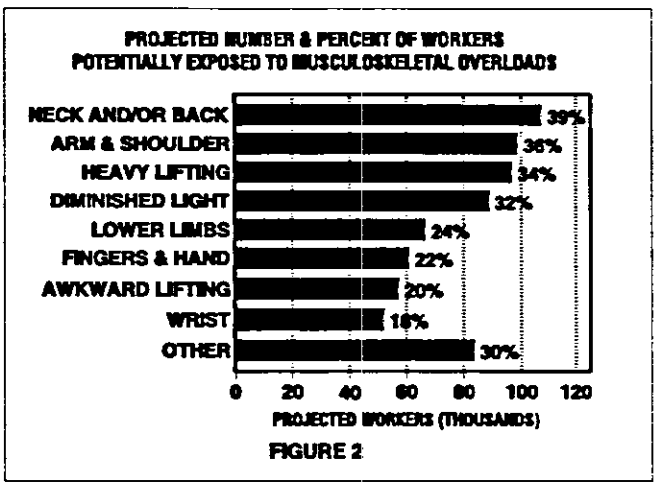

FIGURE 2

and ionizing, ultraviolet, microwave, laser, and miscellaneous radiation.

2. Musculoskeletal Overload Potential Exposures

   The health effects of musculoskeletal overloads in the mining industry have been presented in several recent publications.[17, 18, 19] Figure 2 shows the projected number, and percent, of workers potentially exposed to the different types of musculoskeletal overloads. These recorded musculoskeletal overload potential exposures did not necessarily exceed any NIOSH, MSHA, or OSHA guidelines for musculoskeletal overloads. For example, the NOHSM definition for the heavy lifting musculoskeletal overload was lifting greater than 50 pounds, unaided. The definitions, guidelines, and procedures for coding potential exposures to musculoskeletal overloads which NIOSH established for NOHSM are listed in Appendix F. *"Other"* in Figure 2 includes sitting, frequent lifting, prone or supine lying, and standing. Although diminished light is not a musculoskeletal overload, it was included in the NOHSM survey because it could make work more fatiguing and hazardous.

3. Welding, Brazing, and Soldering Potential Exposures

   The health effects of welding, brazing, and soldering processes have been presented in several recent publications.[20, 21, 22, 23, 24, 25, 26] NIOSH surveyors identified and coded 24 of the 34 different types of welding, brazing, and soldering processes that are shown in Appendix G. These processes included: 18 types of welding, 3 types of cutting, 1 type of brazing, and 2 types of soldering. Approximately 32 percent of the projected number of workers were potentially exposed to welding or cutting processes. Less than 3 percent of the projected number of workers were potentially exposed to brazing and soldering processes. The most common types of welding and cutting processes were shield metal arc welding (with 20 percent of all projected number of workers potentially exposed) and oxy-fuel gas cutting (with 25 percent of all projected number of workers potentially exposed).

4. Chemical Substance and Trade Name Product Potential Exposures

   The Bureau of Mines has found that chemicals in mining are an occupational health concern.[27] In addition, NIOSH's Health Hazard Evaluation Team has conducted approximately 40 investigations which involved occupational health concerns regarding various chemicals in the mining

industry. Several of the chemicals and trade name products used in a mining facility can become airborne throughout an entire facility or over large areas of a facility which can cause a large number of workers to become potentially exposed to them. Some of these products include: rock dust, welding rods, and paints.

a. *Locations with the highest projected number of chemical substance and trade name product potential exposures*

Figure 3 shows the four locations associated with the highest projected number of chemical substance and trade name product potential exposures along with the percent of workers who were potentially exposed to those substances. The names of the locations were taken from the MSHA location codes listed in Appendices H and I. The *"surface shop"* location yielded the highest projected number of chemical substance and trade name product potential exposures (1,104,250). *"Other"* in Figure 3 includes underground shop, coal preparation plant, underground warehouse, underground miscellaneous, surface warehouse, surface laboratory, surface bathhouse, underground mill, surface crushing, surface grinding, surface flotation and reagents, and surface mill.

b. *Projected number of workers potentially exposed to chemical substances and trade name products by location*

Figure 4 shows the projected number, and percent, of workers who were potentially exposed to chemical substances and trade name products in each location listed in Figure 3. Any worker could have been potentially exposed to one or more chemical substances or trade name products, which explains why the projected number of chemical substance and trade name product potential exposures from Figure 3 was greater than the projected number of workers that were potentially exposed to these chemical

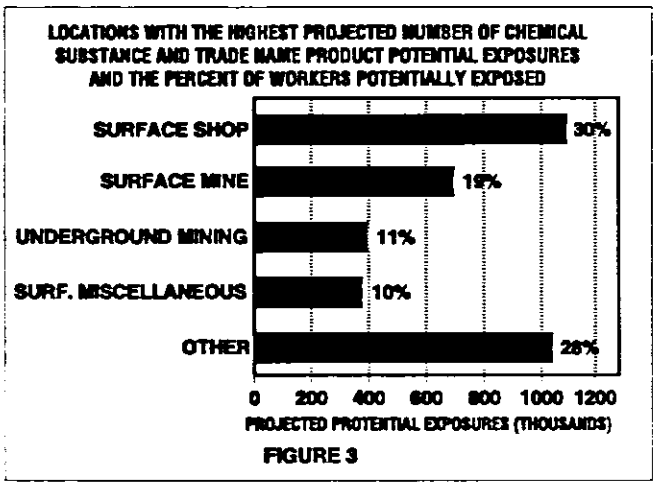

FIGURE 3

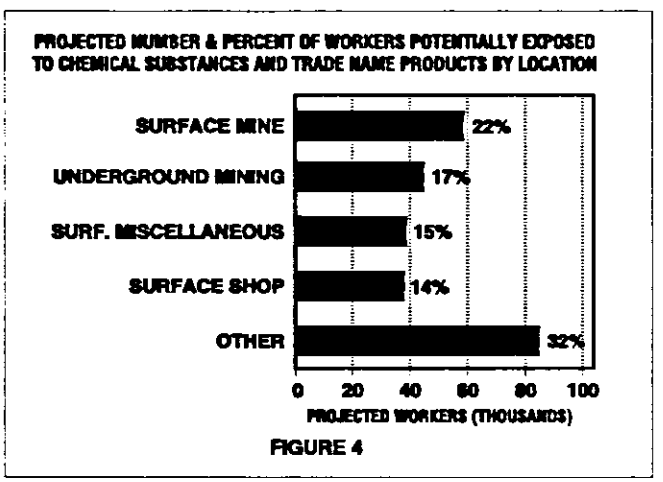

FIGURE 4

substance and trade name products in the locations in Figure 4.

c. *Chemical substance potential exposures*

Appendix O lists the 100 chemical substances with the highest projected number of workers potentially exposed. The number of workers potentially exposed to chemical substances contained in the ore being mined is not reported in Appendix O. Appendix O only reports those chemical substances which were purchased and then used in the mining process. Hence, in Appendix O, coal miners are not listed as being potentially exposed to coal, asbestos miners are not reported as being potentially exposed to

asbestos, and so forth. These potential exposures are listed in Appendix P. The eight chemical substances to which workers were most frequently potentially exposed were all fuels: diesel fuel no. 2, acetylene, unleaded gasoline, leaded gasoline, diesel fuel no. 1, propane, coal, and kerosene.

d. *Trade name product potential exposures*

Appendix Q lists the 100 trade name products with the highest projected number of workers potentially exposed. The chemical ingredients for trade name products have not been determined.

5. Product Use Term (PUT) Potential Exposures

For each potential exposure, the NOHSM surveyor recorded a PUT which indicated how the product was used at that particular worksite. Appendix R lists the 100 PUTs with the highest number of projected workers potentially exposed. The ten PUTs most frequently associated with potential exposures were maintenance-related products: fuel, grease, hand cleaner, hydraulic oil, motor oil, not elsewhere classified oil, gear oil, welding rod, solvent, and penetrant.

6. Bulk Dust Potential Exposures

Out of 7,143 bulk dust samples collected from the NOHSM, 2,075 were analyzed for crystalline silica (quartz, cristobalite, and tridymite), 2,151 for 31 different elements, and 2,152 for asbestos. The bulk dust results are reflective of the 491 mines surveyed under NOHSM and should not be projected to other mine sites in the same way that other agents are projected. NIOSH and other interested parties have access to MSHA's airborne dust compliance data through a number of publications.[28, 29 30] The NOHSM bulk dust data could be used in conjunction with the MSHA airborne dust compliance data for future research efforts.

a. *Quartz*

The NIOSH analytical method #7500 was used to determine the percentage of quartz in the bulk dust samples.[31] This method uses x-ray powder diffraction as a measuring technique. Figure 5 shows the cumulative frequency distribution of the percent quartz contained in bulk dust samples. Nearly 30 percent of the 2,075 analyzed samples were equal to or less than 1 percent quartz. Approximately 50 percent of all samples had a quartz percentage of 5 or greater. Approximately 38 percent of the samples contained greater than 10 percent quartz. If one assumes that the one to five bulk dust samples analyzed for each mine represents the percent quartz for the entire mine and that the average of all analyzed samples for a given commodity is representative of that commodity then, approximately 214,000 miners were potentially exposed to bulk dust which had an average quartz percentage greater than 5. MSHA begins to reduce exposure standards based on quartz content of greater than 5 percent.[32] While this is not a *"projection"* in the context described in Section IV, it is an index of how widespread potential exposures to quartz may be in the mining industry.

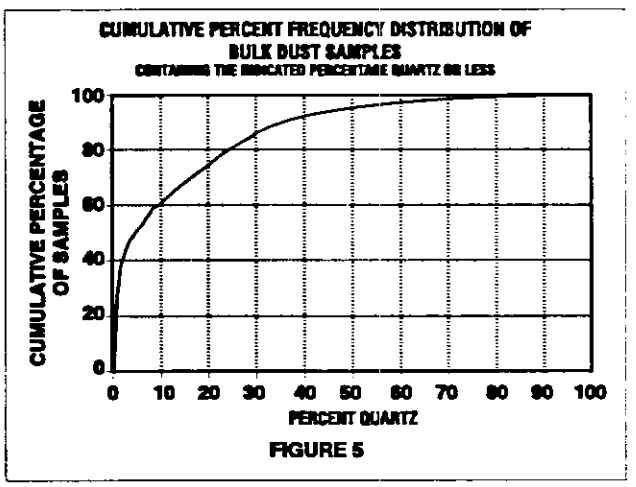

FIGURE 5

b. *Elements*

The NIOSH analytical method #7300 was used for the trace element analysis of the NOHSM bulk dust samples.[31] This method uses inductively coupled argon plasma-atomic emission spectroscopy (ICP-AES) as a measuring technique. Table 6 shows the median, maximum, and the mean percentage of the 31 different elements analyzed from 2,151 NOHSM bulk dust samples. The average element content ranged from 0.01 percent to 5.25 percent. Calcium (5.25 percent), Iron (4.34 percent), Aluminum (2.52 percent), Sodium (1.59 percent) and Magnesium (1.11 percent) had the highest mean percentage of element content out of the 31 different elements analyzed from the NOHSM bulk dust samples. Although Table 6 shows that the average percentage of arsenic was only 0.01 percent from the 2,151 NOHSM bulk dust samples which represented all of the 491 mines surveyed under NOHSM, Table 7 shows that the bulk dust samples collected from the Rare Earths and Zircon commodity mines yielded averages of 0.93 percent and 0.17 percent of arsenic in their respective bulk dust samples. Although it may appear that these commodities were under-represented since only one facility was surveyed for each of these com-

Table 6

BULK DUST ELEMENTS RESULTS

ELEMENT	MEDIAN	MAXIMUM	MEAN
Aluminum	1.72%	33.30%	2.52%
Antimony	0.01%	92.00%	0.06%
Arsenic	0.01%	4.21%	0.02%
Barium	0.02%	3.57%	0.08%
Beryllium	0.01%	0.49%	0.01%
Cadmium	0.01%	0.84%	0.01%
Calcium	0.87%	38.50%	5.25%
Chromium	0.01%	6.35%	0.05%
Cobalt	0.01%	2.12%	0.01%
Copper	0.01%	27.90%	0.13%
Iron	1.93%	49.10%	4.34%
Lanthanide	0.01%	4.94%	0.01%
Lead	0.01%	28.80%	0.10%
Lithium	0.01%	0.94%	0.01%
Magnesium	0.22%	31.10%	1.11%
Manganese	0.04%	21.50%	0.19%
Molybdenum	0.01%	48.20%	0.06%
Nickel	0.01%	10.50%	0.04%
Phosphorous	0.04%	33.20%	0.20%
Platinum	0.01%	0.28%	0.01%
Selenium	0.01%	0.17%	0.01%
Silver	0.01%	0.10%	0.01%
Sodium	0.26%	44.50%	1.59%
Strontium	0.01%	2.12%	0.03%
Tellurium	0.01%	0.10%	0.01%
Thallium	0.01%	0.10%	0.01%
Titanium	0.16%	6.25%	0.28%
Vanadium	0.01%	11.10%	0.02%
Yttrium	0.01%	0.08%	0.01%
Zinc	0.01%	22.50%	0.18%
Zircon	0.01%	1.71%	0.01%

modities, only one active Zircon mine and three active Rare Earths mines existed in the United States for these commodities at the time the NOHSM survey was conducted.

c. *Asbestos*

The NIOSH analytical method #9002 was used to analyze the bulk dust samples for seven forms of asbestos: actinolite asbestos, amosite (cummingtonite-grunerite), anthophyllite asbestos, chrysotile, crocidolite (riebeckite), tremolite asbestos, and amphibole asbestos. This method uses polarized light microscopy and dispersion staining as a measuring technique.[31] Five forms of asbestos were found: actinolite asbestos, amosite (cummingtonite-grunerite), anthophyllite asbestos, chrysotile, and amphibole asbestos. Table 8 summarizes the bulk dust analysis for asbestos. The locations of NOHSM commodities where bulk dust samples containing asbestos were collected, are listed in Table 9.

Table 7

COMMODITIES WITH HIGHEST PERCENT ARSENIC IN BULK DUST SAMPLES

COMMODITY	#MINES SURVEYED	#SAMPLES	MAXIMUM	MEAN
Rare Earths	1	5	4.21%	0.93%
Zircon	1	5	0.67%	0.17%
Silver	11	44	2.39%	0.11%
Gold	20	72	0.37%	0.08%
Metal Ores, NEC*	2	4	0.14%	0.04%

***NOTE:** NEC represents Not Elsewhere Classified.

Table 8

BULK DUST ASBESTOS RESULTS

ASBESTOS VARIETY	NUMBER OF FACILITIES[2]	MAXIMUM PERCENTAGE FOUND	NON-ASBESTOS[3] COMMODITY ASSOCIATED MAXIMUM PERCENTAGE FOUND[4]
Actinolite	9	35.0	Vermiculite
Amosite	19	1.0	Several[5]
Anthophyllite	2	1.5	Talc, Soapstone, & Pyrophyllite
Chrysotile	18	4.0	Vermiculite
Other[1]	1	<1	Salt (Rock)

[1]Laboratory analysis reported *amphibole* for one sample.

[2]491 facilities were surveyed; one facility could appear in the counts for more than one variety of asbestos.

[3]Asbestos mines yielded percentages of actinolite (max=1.5%); amosite (max=7.5%); and chrysotile (max=90%).

[4]The *association* indicates the commodity being mined or processed at the facility which yielded the highest percentage of a given variety of asbestos. The sample may not be representative of the ore being mined or processed.

[5]Following non-asbestos commodities all yielded at least one sample which contained 1% amosite: aluminum, anthracite coal, bituminous coal, clay, gold, limestone (crushed & broken), manganese, nonmetallic minerals/ not elsewhere classified, perlite, salt (rock), sandstone (crushed & broken), slate (crushed & broken), traprock (crushed & broken), and vermiculite.

TABLE 9

LOCATIONS WITHIN NOHSM COMMODITIES WHERE BULK DUST SAMPLES CONTAINING ASBESTOS WERE COLLECTED

COMMODITY	LOCATION(S) ASSOCIATED WITH THE SAMPLE(S)
Aluminum	Surface Mill
Anthracite Coal	Surface Shop
Asbestos	Surface Mill, Surface Shop, Surface Mine, Surface Miscellaneous
Bituminous Coal	Underground Mine, Underground Miscellaneous
Clay	Surface Mill
Copper	Underground Mine, Underground Shop
Gilsonite	Surface Grinding, Surface Mill
Granite (Crushed & Broken)	Surface Mine, Surface Miscellaneous
Gold	Surface Shop
Limestone (Crushed & Broken)	Surface Shop, Surface Crushing
Limestone (Dimension)	Surface Mill
Manganese	Surface Crushing, Surface Mill
Nonmetallic Minerals, NEC*	Surface Mine, Surface Mill, Surface Miscellaneous
Perlite	Surface Mill
Salt (Rock)	Underground Mill, Surface Shop
Sandstone (Crushed & Broken)	Surface Crushing, Surface Mill
Silver	Surface Miscellaneous
Slate (Crushed & Broken)	Surface Crushing, Surface Mill
Stone, Crushed & Broken, NEC*	Surface Mine, Surface Shop, Surface Crushing
Talc, Soapstone, & Pyrophillite	Underground Mine, Surface Shop, Surface Grinding, Surface Miscellaneous, Surface Mill
Traprock (Crushed & Broken)	Surface Shop, Surface Crushing, Surface Miscellaneous, Surface Mill
Vermiculite	Surface Mine, Surface Shop, Surface Miscellaneous, Surface Mill

*NOTE: NEC represents Not Elsewhere Classified.

IX. DISCUSSION

The information presented in this report provides an indication of the range of occupational health-related agents found at U.S. mining facilities. This information is only a small portion of the NOHSM information which is available. NIOSH has constructed a database which makes the data from the NOHSM survey available to any interested party. NIOSH plans for use of these data in the future include:

- Encourage MSHA to use the NOHSM data in combination with other data (exposure data) to set regulatory priorities and write improved health standards; and to identify and determine research needs and priorities;
- Select the appropriate chemicals, mineral commodities, and occupations that require air sampling to determine the concentrations at which they are used or found; as required by Section 201 of the 1977 Federal Mine Safety and Health Amendments Act;
- Assist in setting priorities for mine-related occupational health research;
- Respond to questions from other parties regarding occupational health aspects of the mining industry; and
- Provide potential exposure data for use in NIOSH reports.

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