# CHAPTER 6. OCCUPATIONAL EXPOSURES

This chapter presents data on occupational exposures from several sources. Data from compliance samples obtained by MSHA inspectors are presented in table 6-1 for coal mine dust and silica dust, and in tables 6-2 through 6-6 for metal fumes. Since these samples were taken for compliance monitoring rather than as part of a survey of the industry, it is difficult to predict how well they indicate actual exposures for all mining operations.

In the coal industry, 7.8% of all respirable dust samples during 1986-1995 were above the permissible exposure limit (PEL). Of silica dust samples obtained during the 10-year period, 23.7% were above the PEL in coal, 16% in metal, 10.8% in nonmetal, 9.1% in stone, and 7.6% in sand and gravel. Of metal fume samples, silver samples showed the largest percentage above the PEL—approximately 48% of samples in both metal and nonmetal.

Tables 6-7 and 6-8 present data on noise exposures from the MSHA "dual threshold" survey, which was published in the *Federal Register* [61 Fed. Reg. 66347 (1996)] as part of a proposed rule change for occupational noise exposure in mining. This study examined a group of samples obtained during 1991-1995 and compared the percent of samples that were above two separate specified limits. The first limit was the current noise standard, a time-weighted average of 90 dBA, calculated to include only exposures at 90 dBA and above. The second limit was a time-weighted average of 85 dBA, calculated to include exposures at 80 dBA and above.

Tables 6-8 and 6-9 refer to musculoskeletal overload conditions examined in the National Occupational Health Survey of Mining (NOHSM) [NIOSH 1996]. Table 6-8 shows the operational definitions for each condition; table 6-9 shows the percentage of the workforce potentially exposed, by commodity. Across all commodities, a large proportion of workers were exposed to musculoskeletal overloads due to positioning of the neck and back; positioning and motion of the forearms, arms, and shoulders; heavy lifting; and positioning and movement of the lower limbs.

The recorded overloads were defined in the survey and did not exceed any NIOSH, MSHA, or OSHA guidelines for musculoskeletal overloads. Further information on this survey appears in appendix A.

**Table 6-1.—Dust samples, 1986-1995. Number of samples, number and percent under permissible exposure limit (PEL), number and percent 1-2 times PEL, and number and percent 2 or more times PEL.**

| Sample type | Total samples | Samples under PEL | | Samples > PEL and <2 × PEL | | Samples >2 × PEL | |
|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % |
| Coal respirable dust | 194,682 | 179,584 | 92.2 | 11,751 | 6.0 | 3,347 | 1.7 |
| Coal silica dust | 49,044 | 37,434 | 76.3 | 7,213 | 14.7 | 4,397 | 9.0 |
| Metal silica dust | 9,044 | 7,593 | 84.0 | 873 | 9.7 | 578 | 6.4 |
| Nonmetal silica dust | 10,347 | 9,230 | 89.2 | 668 | 6.4 | 449 | 4.3 |
| Stone silica dust | 45,608 | 41,453 | 90.9 | 2,435 | 5.3 | 1,720 | 3.7 |
| Sand and gravel silica dust | 34,924 | 32,275 | 92.4 | 1,487 | 4.3 | 1,162 | 3.3 |

Source: Mine Safety and Health Administration data.

**Table 6-2.—Metal industry: metal fume samples, 1986-1995. Number of samples, number and percent under permissible exposure limit (PEL), number and percent 1-2 times PEL, and number and percent 2 or more times PEL.**

| Fume type | Total samples | Samples < PEL | | Samples > PEL and < 2 × PEL | | Samples > 2 × PEL | |
|---|---|---|---|---|---|---|---|
| | | Number | Percent | | | Number | Percent |
| Aluminum oxide | 778 | 776 | 99.7 | 0 | 0.0 | 2 | 0.3 |
| Arsenic | 379 | 379 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Beryllium | 465 | 464 | 99.8 | 1 | 0.2 | 0 | 0.0 |
| Cadmium oxide | 495 | 494 | 99.8 | 0 | 0.0 | 1 | 0.2 |
| Chromic acid/chromate | 444 | 419 | 94.4 | 15 | 3.4 | 10 | 2.3 |
| Cobalt | 483 | 481 | 99.6 | 0 | 0.0 | 2 | 0.4 |
| Copper | 858 | 812 | 94.6 | 16 | 1.9 | 30 | 3.5 |
| Fluoride | 4 | 4 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Iron oxide | 1,038 | 1,008 | 97.1 | 13 | 1.3 | 17 | 1.6 |
| Lead | 797 | 757 | 95.0 | 22 | 2.8 | 18 | 2.3 |
| Magnesium oxide | 743 | 743 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Manganese | 793 | 793 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Mercury | 156 | 137 | 87.8 | 10 | 6.4 | 9 | 5.7 |
| Molybdenum | 453 | 452 | 99.8 | 1 | 0.2 | 0 | 0.0 |
| Nickel | 559 | 559 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Silver | 248 | 129 | 52.0 | 25 | 10.1 | 94 | 37.9 |
| Titanium dioxide | 602 | 601 | 99.8 | 1 | 0.2 | 0 | 0.0 |
| Vanadium | 512 | 511 | 99.8 | 1 | 0.2 | 0 | 0.0 |
| Zinc oxide | 698 | 697 | 99.9 | 1 | 0.1 | 0 | 0.0 |

Source: Mine Safety and Health Administration data.

**Table 6-3.—Nonmetal industry: metal fume samples, 1986-1995. Number of samples, number and percent under permissible exposure limit (PEL), number and percent 1-2 times PEL, and number and percent 2 or more times PEL.**

| Fume type | Total | Samples < PEL | | Samples > PEL and < 2 × PEL | | Samples > 2 × PEL | |
|---|---|---|---|---|---|---|---|
| | | Number | Percent | Number | Percent | Number | Percent |
| Aluminum oxide | 2,460 | 2,454 | 99.8 | 2 | 0.1 | 4 | 0.2 |
| Arsenic | 1,309 | 1,309 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Beryllium | 1,550 | 1,547 | 99.8 | 3 | 0.2 | 0 | 0.0 |
| Cadmium oxide | 1,513 | 1,512 | 99.9 | 1 | 0.1 | 0 | 0.0 |
| Chromic acid/chromate | 1,467 | 1,297 | 88.4 | 65 | 4.4 | 105 | 7.2 |
| Cobalt | 1,609 | 1,607 | 99.9 | 2 | 0.1 | 0 | 0.0 |
| Copper | 2,453 | 2,378 | 96.9 | 29 | 1.2 | 46 | 1.9 |
| Iron oxide | 3,220 | 3,148 | 97.8 | 39 | 1.2 | 33 | 1.0 |
| Lead | 1,941 | 1,898 | 97.8 | 25 | 1.3 | 18 | 0.9 |
| Magnesium oxide | 2,555 | 2,555 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Manganese | 2,824 | 2,761 | 97.8 | 40 | 1.4 | 23 | 0.8 |
| Mercury | 113 | 94 | 83.2 | 10 | 8.8 | 9 | 8.0 |
| Molybdenum | 1,532 | 1,531 | 99.9 | 1 | 0.1 | 0 | 0.0 |
| Nickel | 1974 | 1,967 | 99.6 | 4 | 0.2 | 3 | 0.2 |
| Silver | 249 | 130 | 52.2 | 25 | 10.0 | 94 | 37.8 |
| Tin oxide | 3 | 3 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Titanium dioxide | 2,182 | 2,181 | 100.0 | 1 | 0.0 | 0 | 0.0 |
| Vanadium | 1,593 | 1,590 | 99.8 | 3 | 0.2 | 0 | 0.0 |
| Zinc oxide | 2,099 | 2,097 | 99.9 | 2 | 0.1 | 0 | 0.0 |

Source: Mine Safety and Health Administration data.

**Table 6-4.—Stone industry: metal fume samples, 1986-1995. Number of samples, number and percent under permissible exposure limit (PEL), number and percent 1-2 times PEL, and number and percent 2 or more times PEL.**

| Fume type | Total samples | Samples < PEL | | Samples > PEL and < 2 × PEL | | Samples > 2 × PEL | |
|---|---|---|---|---|---|---|---|
| | | Number | Percent | Number | Percent | Number | Percent |
| Aluminum oxide | 1,164 | 1,162 | 99.8 | 1 | 0.1 | 1 | 0.1 |
| Arsenic | 538 | 538 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Beryllium | 666 | 666 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Cadmium oxide | 619 | 619 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Chromic acid/chromate | 795 | 667 | 83.9 | 44 | 5.5 | 84 | 10.6 |
| Cobalt | 704 | 704 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Copper | 1,065 | 1,044 | 98.0 | 9 | 0.8 | 12 | 1.1 |
| Iron oxide | 1,512 | 1,478 | 97.8 | 20 | 1.3 | 14 | 0.9 |
| Lead | 708 | 705 | 99.6 | 3 | 0.4 | 0 | 0.0 |
| Magnesium oxide | 1,254 | 1,254 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Manganese | 1,424 | 1,367 | 96.0 | 37 | 2.6 | 20 | 1.4 |
| Mercury | 6 | 6 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Molybdenum | 664 | 663 | 99.8 | 1 | 0.2 | 0 | 0.0 |
| Nickel | 967 | 961 | 99.4 | 3 | 0.3 | 3 | 0.3 |
| Silver | 1 | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Tin oxide | 3 | 3 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Titanium dioxide | 1,085 | 1,084 | 99.9 | 1 | 0.1 | 0 | 0.0 |
| Vanadium | 688 | 686 | 99.7 | 2 | 0.3 | 0 | 0.0 |
| Zinc oxide | 950 | 948 | 99.8 | 2 | 0.2 | 0 | 0.0 |

Source: Mine Safety and Health Administration data.

**Table 6-5.—Sand and gravel industry: metal fume samples, 1986-1995. Number of samples, number and percent under permissile exposure limit (PEL), number and percent 1-2 times PEL, and number and percent 2 or more times PEL.**

| Fume type | Total samples | Samples < PEL | | Samples > PEL and < 2 × PEL | | Samples > 2 × PEL | |
|---|---|---|---|---|---|---|---|
| | | Number | Percent | | | Number | Percent |
| Aluminum | 346 | 346 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Arsenic | 240 | 240 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Beryllium | 254 | 252 | 99.2 | 2 | 0.8 | 0 | 0.0 |
| Cadmium oxide | 250 | 250 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Chromic acid/chromate | 144 | 136 | 94.4 | 3 | 2.1 | 5 | 3.5 |
| Cobalt | 264 | 264 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Copper | 325 | 322 | 99.1 | 2 | 0.6 | 1 | 0.3 |
| Iron oxide | 432 | 427 | 98.8 | 3 | 0.7 | 2 | 0.5 |
| Lead | 271 | 271 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Magnesium oxide | 338 | 338 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Manganese | 387 | 386 | 99.7 | 1 | 0.3 | 0 | 0.0 |
| Mercury | 2 | 2 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Molybdenum | 247 | 247 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Nickel | 280 | 280 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Titanium dioxide | 321 | 321 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Vanadium | 250 | 250 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| Zinc oxide | 303 | 303 | 100.0 | 0 | 0.0 | 0 | 0.0 |

Source: Mine Safety and Health Administration data.

**Table 6-6.—Coal industry: MSHA "dual-threshold" study, 1991-1995. Number of samples by occupation, percent of samples over 90 dBA based on 90-dBA threshold for time-weighted average, and percent of samples over 85 dBA based on 80-dBA threshold for time-weighted average.**

| Occupation | Number of samples | % of samples over 90 dBA with time-weighted average based on 90-dBA threshold | % of samples over 85 dBA with time-weighted average based on 80-dBA threshold |
|---|---|---|---|
| Continuous miner helper | 68 | 33.8 | 88.2 |
| Continuous miner operator | 262 | 49.6 | 96.2 |
| Roof bolter operator (single) | 234 | 21.8 | 85.5 |
| Roof bolter operator (twin) | 92 | 31.5 | 98.9 |
| Shuttle car operator | 260 | 13.5 | 78.5 |
| Scoop car operator | 94 | 18.1 | 74.5 |
| Cutting machine operator | 22 | 36.4 | 63.6 |
| Headgate operator | 20 | 40.0 | 100.0 |
| Longwall operator | 34 | 70.6 | 100.0 |
| Jack setter (longwall) | 25 | 32.0 | 68.0 |
| Cleaning plant operator | 107 | 36.4 | 77.6 |
| Bulldozer operator | 225 | 48.9 | 94.2 |
| Front-end loader operator | 244 | 16.0 | 76.6 |
| Highwall drill operator | 83 | 21.7 | 77.1 |
| Refuse/backfill truck driver | 162 | 13.6 | 78.4 |
| Coal truck driver | 28 | 17.9 | 64.3 |

**Table 6-7.—Metal/nonmetal industry: MSHA "dual-threshold" study, 1991-1994. Number of samples by occupation, percent of samples over 90 dBA based on 90-dBA threshold for time-weighted average, and percent of samples over 85 dBA based on 80-dBA threshold for time-weighted average.**

| Occupation | Number of samples | % of samples over 90 dBA with time-weighted average based on 90-dBA threshold | % of samples over 85 dBA with time-weighted average based on 80-dBA threshold |
|---|---|---|---|
| Front-end loader operator | 12,812 | 12.9 | 67.7 |
| Truck driver | 6,216 | 13.1 | 73.7 |
| Crusher operator | 5,357 | 19.9 | 65.1 |
| Bulldozer operator | 1,440 | 50.7 | 86.5 |
| Bagger | 1,308 | 10.2 | 65.0 |
| Sizing/washing plant operator | 1,246 | 13.2 | 59.7 |
| Dredge/barge attendant | 1,124 | 27.2 | 78.7 |
| Clean-up person | 927 | 19.3 | 71.3 |
| Dry screen operator | 871 | 11.7 | 57.6 |
| Utility worker | 846 | 12.4 | 60.6 |
| Mechanic | 761 | 3.8 | 43.9 |
| Supervisors/administrators | 730 | 9.0 | 32.2 |
| Laborer | 642 | 17.1 | 65.7 |
| Dragline operator | 583 | 34.0 | 82.5 |
| Backhoe operator | 546 | 8.4 | 52.6 |
| Dryer/kiln operator | 517 | 10.5 | 55.5 |
| Rotary drill operator (electric/hydraulic) | 543 | 39.6 | 83.1 |
| Rotary drill operator (pneumatic) | 489 | 64.4 | 89.0 |

**Table 6-8.—Operational definitions for musculoskeletal overload conditions in the National Occupational Health Survey of Mining (NOHSM).**

| | |
|---|---|
| Awkward lifting | Lifting above head level, or lifting while twisting, or lifting while reaching excessively. |
| Heavy lifting | Lifting greater than 50 lb unaided. |
| Frequent lifting | Lifting an object heavier than 25 lb, 5 or more times per minute. |
| Fingers and hands | Forceful finger actions (except grasping with the whole hand), grasping with wet or poorly fitting gloves, tool handles that end in the central part of the palm. |
| Wrist movement | Forceful movements or finger manipulations with wrist bent, using repeated wrist motions, or clothes-wringing motion. |
| Forearms, arms, and shoulders | Elbows unsupported and/or abducted, or forearms resting on sharp edges, or working with hands above the shoulders, or tossing motions at extremes of range of motion. |
| Neck and/or back | Bent forward, or bent to the side, or hyperextended, or twisted neck and back. |
| Lower limb movement | Kneeling, or squatting (bearing the body weight on the knee, flexed to an acute angle), or crawling on hands and knees. |
| Sitting | Sitting in a cramped position, or with feet dangling, or without low back support, or in a seat tilted forward or to one side. |
| Standing | Standing without movement for 4 or more min or operating foot pedals while standing, or standing in a restricted space for 2 hr or more without sitting or leaning. |
| Prone or supine | Lying flat on back, or lying on abdomen, or lying on one side supported by one hip and one shoulder or elbow. |

**Table 6-9.—Percent of workers potentially exposed to musculoskeletal overload conditions by condition and commodity, National Occupational Health Survey of Mining (NOHSM), 1984-1989.**

| | Percentage of workforce potentially exposed | | | | |
|---|---|---|---|---|---|
| Musculoskeletal overload condition | Coal | Metal | Nonmetal | Stone | Sand and Gravel |
| Awkward lifting | 22 | 29 | 16 | 17 | 19 |
| Heavy lifting | 41 | 37 | 24 | 30 | 21 |
| Frequent lifting | 9 | 3 | 8 | 8 | 5 |
| Fingers and hands | 24 | 35 | 24 | 14 | 12 |
| Wrist movement | 21 | 29 | 16 | 12 | 11 |
| Forearms, arms, and shoulders | 44 | 39 | 30 | 25 | 23 |
| Neck and/or back | 42 | 50 | 35 | 34 | 30 |
| Lower limb movement | 31 | 26 | 15 | 16 | 13 |
| Sitting | 19 | 10 | 8 | 9 | 11 |
| Standing | <1 | 2 | 3 | 1 | 4 |
| Prone or supine | 10 | 5 | 5 | 4 | 3 |

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# APPENDIX A. SOURCES OF DATA

## National Occupational Mortality Surveillance (NOMS) System

The National Occupational Mortality Surveillance (NOMS) System was developed by NIOSH in collaboration with the National Center for Health Statistics and the National Cancer Institute. NOMS is based on mortality data from the National Vital Statistics system, with the addition of occupation and industry information coded by selected State health departments. The NOMS data include all conditions listed on the death certificate, both underlying and contributing, for each decedent. Additional data include age, race, sex, State, and county of residence at the time of death.

The number of States included in NOMS varies by year. A total of 28 States have contributed data since 1979. The States included in the analyses presented in this report and the years for which those States provided data are: Alaska (1987-88), Colorado (1985-1993), Georgia (1985-1993), Hawaii (1993), Idaho (1988-1993), Indiana (1986-1993), Kansas (1985-1993), Kentucky (1985-1993), Maine (1985-1993), Missouri (1985-1986), Nebraska (1985), Nevada (1985-1993), New Hampshire (1985-1993), New Jersey (1988-1993), New Mexico (1986-1993), New York (1985-1987; New York City excluded in 1985) North Carolina (1987-1993), Ohio (1985-1993), Oklahoma (1985-1993), Pennsylvania (1985-1991), Rhode Island (1985-1993), South Carolina (1985-1993), Tennessee (1985-1988), Utah (1985-1993), Vermont (1986-1993), Washington (1990-1992), West Virginia (1988-1993), and Wisconsin (1985-1993).

## Census of Fatal Occupational Injuries (CFOI)

The Census of Fatal Occupational Injuries (CFOI) was developed by the U.S. Bureau of Labor Statistics (BLS) to compile comprehensive and timely information on fatal work injuries occurring in the 50 States and the District of Columbia. Because no single source of information is capable of identifying all fatalities that occur at work, the CFOI system cross-references nearly 25 different sources of information to compile a complete roster. These sources include (but are not limited to) death certificates, workers' compensation files, motor vehicle reports, the news media, and data collected by State and Federal agencies such as the Occupational Safety and Health Administration, the Mine Safety and Health Administration, and the Employment Standards Administration. To ensure an accurate count of fatal occupational injuries, the program requires that for each case, the injury's work-relatedness be substantiated by at least two independent sources, or a source document and a followup questionnaire.

Data collection is a cooperative process between BLS and the States. The States are responsible for data collection and coding, while BLS concatenates the national database and provides for additional verification of fatality reports that have only one source of information. A work-related case in CFOI is required to meet the following criteria: "The dece-dent must have been employed (working for pay, compensa-tion, or profit or in the family business) at the time of the event and engaged in a legal work activity or present at the site of the incident as a job requirement" [U.S. Bureau of Labor Statistics 1995]. Fatalities that resulted from motor vehicle crashes while driving as part of work and from violent acts at work such as homicide and suicide are included in the data.

## Current Population Survey (CPS)

The Current Population Survey (CPS) is a monthly survey of approximately 60,000 households. The CPS is a probability sample, and the survey is conducted by the U.S. Bureau of the Census for the U.S. Bureau of Labor Statistics. The survey collects information about each employed member of a household, including age and sex, class of worker, and industry and occupation. Data on number of hours worked the week prior to the survey are also collected.

The criteria for reporting number of hours worked changed in 1994. For this reason, rate calculations in this report that use the CPS denominator are based on the number of employees in a particular subgroup, rather than on the number of hours worked.

## Mine and Employment Data: MSHA

These data include all work hours reportable to MSHA. Mine operators must report quarterly all hours worked at any operation where any individual worked during any day in that calendar quarter. Independent contractors must report quarterly hours related to the following activities:

- Mine development, including shaft and slope sinking
- Construction/reconstruction of mine facilities including building/rebuilding preparation plants and mining equipment, and building additions to existing facilities
- Demolition of mine facilities
- Construction of dams
- Excavation or earth-moving activities involving mobile equipment
- Installation of equipment, such as crushers and mills
- Equipment service or repair on mine property for a period exceeding 5 consecutive days at a particular mine

### Accident, Injury, and Illness Data: MSHA

The MSHA accident, injury, and illness database includes all occupational injuries and illnesses reportable to MSHA. For mine operators, reportable occupational injuries include any onsite injury to an employee for which medical treatment is administered or that results in death or loss of consciousness, inability to perform all job duties on any day after the injury, restriction of work or motion, lost workdays, temporary assignment to other duties on any day after the injury, transfer to another job, or termination. First-aid injuries are not reportable provided that there are no lost workdays, restricted work activity, or transfer because of the injury. Reportable occupational illnesses include any illness or disease of an employee that *may* have resulted from work or exposure at a mine or for which an award of compensation is made. Independent contractors working on mine property must report injuries and illnesses in the activities for which they are required to report work hours (listed above).

### 1986 Mining Industry Population Survey (MIPS): U.S. Bureau of Mines

This survey obtained information on job title or occupation, principal equipment operated, work location at the mine, experience at present job, experience at present company, total mining experience, job-related training during the preceding 2 years, age, sex, race, and education.

The MIPS covered all workers employed in anthracite coal (SIC 111), bituminous coal (SIC 121), metal (SIC 101-106, 109, 281), stone (SIC 141, 142, 324, 327), sand and gravel (SIC 144), and nonmetal (SIC 131, 145, 147, 149, 289, 299) mining during March through September 1986. The survey design used a two-stage stratified random sampling. The primary sampling units (first stage) were the mine establishments; the secondary sampling units were the employees within each sampling unit. The characteristics used to stratify the primary units were the industry (anthracite coal, bituminous coal, metal, stone, nonmetal), mine type (underground, surface, plant or mill), employment size class (1-19, 20-49, 50-99, 100-249, 500-999, 1,000 and above), and status code (active, intermittent). The sampling frame used was the 1985 preliminary address and employment file maintained by MSHA.

### Respirable Coal Mine Dust Data: MSHA

These data were obtained from MSHA and represent respirable coal mine dust levels measured by MSHA inspectors at surface and underground mines beginning in 1970. The data include the sample collection date, dust concentration, occupation associated with the sample, an MSHA designator as to the validity of the sample, and the mine at which the sample was obtained.

The MSHA respirable coal mine dust samples are obtained by drawing mine air through a filter at the rate of 2 L/min, with a cyclone used to extract nonrespirable particles prior to the filter. The dust weight collected on the filter is multiplied by 1.38 to complete the conversion to Mines Research Establishment (MRE) units. The "MRE" designation indicates that measurements obtained by MSHA were converted so that they would be equivalent to those obtained with an instrument on which the U.K. standards have been based (Isleworth type 113A gravimetric dust sampler).

### Respirable Coal Mine Quartz Dust Data: MSHA

These data were obtained from MSHA and represent respirable quartz levels derived from respirable coal mine dust samples collected by MSHA inspectors at surface and underground coal mines beginning in 1982. The data include the sampling date, sampling time, initial and final weights, percent quartz, production level during sampling, the occupation associated with the sample, and the mine at which the sample was obtained.

### National Occupational Health Survey of Mining (NOHSM): NIOSH

The National Occupational Health Survey of Mining was designed by NIOSH to characterize health-related agents found at U.S. mines. A sample of mines representing 66 different mineral commodities was surveyed during 1984-1989. A total of 491 mines employing 59,734 miners were surveyed during that period, including 431 metal/nonmetal mines and 60 coal mines. The mines surveyed were selected from a total of 2,131 mines that employed 297,322 miners. Although NIOSH surveyed only a representative sample of mines in each mineral commodity, the data were projected over all of the mines in each of those mineral commodities. Each mine's survey included three phases: questionnaire, chemical inventory, and worksite visit. During the worksite visit, surveyors (1) made observations of the numbers of potential exposures (by sex and occupation of workers) to chemical and physical agents; musculoskeletal overload conditions; welding, brazing, and soldering processes; and abrasive grinding processes; (2) obtained samples of bulk dust from selected worksites within each mine; and (3) made observations of the controls associated with the potential exposures.

# APPENDIX B. METHODS

## Injury and Illness Rates: CFOI Data

Numerator data for these rates came from CFOI data files; denominator data came from the Current Population Survey (CPS). To compute the fatality rates for each year, the total number of deaths that occurred during the year in each industry sector was divided by the number of employees in that sector. For presentation purposes, fatal injury rates were then multiplied by 100,000 to obtain the rate per 100,000 workers.

## Injury and Illness Rates: MSHA Data

Numerator data for the rates came from MSHA accident and injury file. Denominator data came from the MSHA employment files, and for the variable occupation only, from the Mining Industry Population Survey. To compute the average annual rates during 1986-1995, the total number of deaths during the 10-year period was divided by the total number of hours worked during 1986-95 to obtain the injury rate per hour worked for 1986-1995. Average annual rates for subunits were calculated as the total number of deaths in a specified subunit during 1986-1995, divided by the number of hours worked in the subunit during 1986-1995, to obtain the injury rate per hour worked for each subunit. Yearly rates were computed as the total number of deaths in the specified year divided by the total hours worked in that year to obtain the injury rate per hour worked for that year. All injury and illness rates per hour worked were then multiplied by 2,000, the typical number of hours worked in 1 year by an employee working a 40-hr week, to obtain the rate per full-time equivalent worker. For presentation purposes, fatal injury rates and illness rates were then multiplied by 100,000 to obtain the rate per 100,000 full-time equivalent workers; nonfatal injury rates were multiplied by 100 to obtain the rate per 100 full-time equivalent workers. Occupations were grouped into BOC categories. Data on occupation were available for 1986 only. Estimates on the incidence of injury by occupational group for the entire 10-year period were made by determining the proportion of workers in each occupational group in the 1986 data and applying these proportions to the data on hours worked for all years. This type of extrapolation assumes that the proportion of workers in each occupational group was constant over the 10-year period.

## Proportionate Mortality Ratio

The proportionate mortality ratio (PMR) is defined as the observed number of deaths with the condition of interest (mentioned as underlying or contributing cause) in a specified occupation or industry divided by the expected number of deaths caused by that condition. The expected number of deaths is the total number of deaths in the occupation or industry of interest multiplied by the proportion, defined as the number of cause-specific deaths for the condition of interest divided by the total number of deaths in the population. The PMRs in the report have been internally adjusted for age (i.e., 15-34, 35-54, 55-74, and 75 years and over) and for race. Confidence intervals were calculated assuming a Poisson distribution of the data.

## Exposure Data Selection

MSHA respirable coal mine dust samples selected for analysis were restricted to those samples that met *all three* of the following criteria:

(1) Samples obtained in the 50 States or Washington, DC (the U.S. Virgin Islands and Puerto Rico were excluded);
(2) Samples designated by MSHA as valid; and
(3) Samples coded as "designated occupation," "non-designated occupation," or "designated work position" with valid occupation codes, or "designated area" other than "intake air."

MSHA coal mine quartz samples selected for analysis are those samples that met all five of the following criteria:

(1) Samples obtained in the 50 States or Washington, DC (the U.S. Virgin Islands and Puerto Rico were excluded);
(2) Samples designated by MSHA as valid;
(3) Samples with sampling time greater than 0;
(4) Samples with quartz concentration greater than 0; and
(5) Samples coded as "designated occupation," "non-designated occupation," or "designated work position" with valid occupation codes, or "designated area" other than "intake air."

Since December 1972, the PEL for respirable coal mine dust has been 2 mg/m$^3$ MRE unless the quartz concentration at the particular mine has been found in excess of 5%. MSHA has no specific PEL for quartz in coal mines. MSHA's respirable coal mine quartz data are based on its analysis of respirable coal mine dust samples. However, for the period covered by this report, inspector samples with less than 0.45-mg net-weight gain were not analyzed for quartz. When the quartz content has been found to be in excess of 5% in dust from a particular mine, the 2 mg/m$^3$ MRE PEL is reduced based on the following formula:

$$\text{PEL} = \frac{10\ \text{mg/m}^3\ \text{MRE}}{\%\ \text{quartz}}$$

Using this formula, one sees that at 100% quartz the PEL would be 0.1 mg/m$^3$ MRE.

# APPENDIX C. WORK ACTIVITY CATEGORIES USED FOR INJURIES IN MSHA ACCIDENT, INJURY, AND ILLNESS DATABASE

| | |
|---|---|
| Vehicular and Transportation Operations | Conveyer belt (not riding)<br>Forklift<br>Haulage truck<br>Jitney<br>Load-haul-dump<br>Locomotive (air trammer)<br>Mantrip<br>Shuttle car<br>Utility truck<br>Ride equipment<br>Get on or off equipment, machines, etc.<br>Spot cars, drop cars<br>Couple/uncouple mine car/tractor/jeep, etc.<br>Barge, boat, dredge<br>Sprag/block/chock mine cars or other track equipment |
| Using or Operating Tools/Machinery | Drill face/rib/side/down/rise (not roof bolter)<br>Auger (surface mine)<br>Auger (underground mine)<br>Bulldozer<br>Continuous miner<br>Cutting machine<br>Front-end loader<br>Grader<br>Hoist<br>Loading machine<br>Longwall, shear, plow<br>Mucking machine<br>Power shovel/dragline/backhoe<br>Shortwall<br>Slusher<br>Remove or position hydraulic jack<br>Sand fill (backfilling stopes with sand, gob, etc.)<br>Grinding<br>Impactor<br>Mill equipment<br>Blow gun to blow out drilled holes<br>Hand tools (powered)<br>Bar down face, rib, or side, etc.<br>Double jack<br>Hand tools (not powered)<br>Environmental tests/checks<br>Welding and cutting<br>Advance longwall roof support<br>Coal tipple/crusher/cleaning plant/breaker<br>Rock dust machine<br>Scraper (rig), cans, etc. |

| | |
|---|---|
| | Surface equipment, NEC |
| | Underground equipment, NEC |
| | Roof bolter, drilling |
| | Roof bolter, inserting bolt |
| | Roof bolter, NEC |
| Constructing, Repairing, Cleaning | Hang or reposition tubing/pipe/rope/wire, etc. |
| | Lay or repair railroad track/roadbed, switching tracks, etc. |
| | Moving equipment |
| | Set brattice |
| | Set/remove/relocate props |
| | Surface construction, NEC |
| | Timbering (includes lagging and cribbing) |
| | Ventilation (maintenance/installation) |
| | Chute, pull or free |
| | Electrical maintenance/repair |
| | Machine maintenance/repair |
| | Rerail equipment |
| | Skip pocket (pull/free) |
| | Inspect equipment |
| | Brush floor |
| | Clean up |
| | Cement work; gunite crew, etc. |
| | Investigate, enter, or work in bins, tanks, etc. |
| | Wetting down working place |
| Protective Service Activities | Accident recovery (equipment and workers) |
| Materials Handling Operations | Handling supplies or material, load/unload |
| | Working with solvents |
| | Working with chemicals |
| | Working with noxious materials, NEC |
| | Hand load, hand shoveling/mucking |
| | Handling coal, rock, waste, or ore |
| | Handling explosives |
| | Handling timber |
| | Move power cable |
| Bodily Movement | Climb in raise/shaft/manway |
| | Climb scaffolds/ladders/platforms, headframes/derrick/towers |
| | Climb on piled material/ore/rock/ timber/stone |
| | Walking/running |
| | Crawling/kneeling |
| Other, NEC | Office and laboratory work |
| | Blasting; shoot coal |
| | Caging; operate elevator, manlift; etc. |
| | Change house, bathing, changing clothes, etc. |

| | |
|---|---|
| | Cross-over (conveyer)<br>Escaping a hazard<br>Horseplay<br>Idle (eat lunch, coffee break, etc.)<br>Observe operations<br>Supervise<br>Travel to and from work location<br>Other, NEC |
| Activity, Unspecified | Unknown |

# APPENDIX D. U.S. BUREAU OF THE CENSUS OCCUPATION DIVISIONS

## U.S. Bureau of the Census Grouping of Job Titles for Coal Operators

Source: U.S. Bureau of the Census [1982]

| | |
|---|---|
| Executive, Administrative, and Managerial | Mine Foreman/Mine Manager/Mine Owner<br>Fire Boss/Preshift Examiner<br>Inspector<br>Superintendent<br>Union Representative<br>Safety Representative<br>Training Specialist |
| Professional Specialty | Surveyor<br>Engineer—Electrical, Ventilation, Mining<br>Safety Director<br>Education Specialist |
| Technicians and Support | Transit Man |
| Administrative Support | Dispatcher<br>Weighman<br>Timekeeper/Clerk/Office Help |
| Protective Service | Watchman/Guard |
| Mechanics and Repairers | Mechanic/Repairman<br>Belt Vulcanizer<br>Oiler/Greaser<br>Master Mechanic<br>Maintenance Foreman |
| Construction Trades | Electrician<br>Stoping Builder/Ventilation/Mason<br>Wireman/Communications Man/Repairman<br>Brattice Man<br>Mason<br>Carpenter<br>Master Electrician |
| Extractive Occupations | Rock Duster<br>Shotfirer/Shooter/Blaster<br>Timberman/Propman/Jacksetter<br>Trainee<br>Drill Operator<br>Continuous Miner Operator/Mole<br>Cutting Machine Operator/Ripper<br>Headgate Operator<br>Jacksetter/Longwall/Advanceman<br>Longwall Shear Operator/Plow Operator |

| | |
|---|---|
| | Rockman/Hang-Up Man/Chute |
| | Roof Bolter/Rock Bolter |
| | Roof Bolter Mounted |
| | Section Foreman/Shift Boss |
| | Tailgate Operator |
| | Utility Man |
| | Clean-Up Man |
| | Labor Foreman/Bullgang Foreman |
| | Belt Cleaner |
| | Rock Driller |
| | Rock Machine Operator |
| | Miner, NEC/Quarry Worker |
| | Auger Operator |
| | Highwall Drill Operator |
| | Lampman |
| | Assistant Mine Foreman/Assistant Mine Manager |
| | Outside Foreman |
| Precision Production Occupations | Pumper |
| | Shopman/Machinist |
| | Battery Station Operator |
| | Fan Attendant |
| | Boom Operator |
| | Machinist |
| | Preparation Plant Foreman/Mill Foreman |
| Machine Operators, Assemblers, and Inspectors | Coal Sampler |
| | Welder/Cement Man |
| | Welder |
| | Cleaning Plant Operator/Media Plant Operator/Boney Preparation Plant Operator/Crusher Worker |
| | Driver Operator |
| | Fine Coal Plant Operator |
| | Scalper/Screen Operator |
| | Dust Sampler/Laboratory Technician |
| Motor Vehicle and Rail Transport | Brakeman/Rope Rider/Snapper |
| | Motorman/Swamper/Switchman |
| | Driver/Tractor Operator/Jeep Driver |
| | Brakeman/Trip Rider |
| | Truck Driver |
| | Refuse Truck Driver |
| | Water Truck Operator |
| | Yard Engineer Operator/Fireman |
| Material Moving Equipment Operators | Belt/Conveyor Man |
| | Scoop Tram-Load Haul Operator |
| | Haul Loader/Hand Trammer |
| | Loading Machine Operator/St. Joe Shovel Operator |
| | Shuttle Car Operator/Ram Car Operator |

| | |
|---|---|
| | Stall Driver |
| | Scoop Car Operator/Unitrac Operator |
| | Hoistman/Engineer |
| | Transportation Trainee |
| | Skip Tender |
| | Loader Head Operator/Roscoe Operator |
| | Buggy Pusher |
| | Dump Operator |
| | Shuttle Car Operator |
| | Power Shovel Operator/Pitman |
| | Bulldozer Operator/Tractor/Heavy Equipment |
| | Barge Attendant/Boat/Dredge |
| | Car Dropper |
| | Grader Operator/Roadgrader Operator |
| | Crane Operator/Dragline/Backhoe |
| | Highlift Operator/Front-End Loader |
| | Rotary Bucket Excavator Operator |
| | Silo Operator |
| | Stripping Shovel Operator |
| | Tipple Operator/Topman/Binman |
| Handlers, Equipment Cleaners, Helpers, and Laborers | Electrician Helper |
| | Mechanic Helper |
| | Supplyman |

## U.S. Bureau of the Census Grouping of Job Titles for Metal/Nonmetal Operators

Source: U.S. Bureau of the Census [1982]

| | |
|---|---|
| Executive, Administrative, and Managerial | Mine Foreman/Mine Manager/Mine Owner<br>Fire Boss/Preshift Examiner<br>Inspector<br>Superintendent<br>Union Representative<br>Safety Representative<br>Training Specialist |
| Professional Specialty | Surveyor<br>Engineer—Electrical, Ventilation, Mining<br>Safety Director<br>Education Specialist |
| Technicians and Support | Transit Man |
| Administrative Support | Dispatcher<br>Weighman<br>Timekeeper/Clerk/Office Help |
| Protective Service | Watchman/Guard |
| Mechanics and Repairers | Mechanic/Repairman<br>Oiler/Greaser<br>Master Mechanic<br>Maintenance Foreman |
| Construction Trades | Electrician<br>Stoping Builder/Ventilation/Mason<br>Brattice Man<br>Wireman/Communications Man/Repairman<br>Carpenter<br>Master Electrician |
| Extractive Occupations | Shotfirer/Shooter/Blaster<br>Timberman/Propman/Jacksetter<br>Trainee<br>Slusher Operator<br>Drill Operator<br>Continuous Miner Operator/Mole<br>Cutting Machine Operator/Ripper<br>Headgate Operator<br>Jacksetter/Longwall/Advanceman<br>Longwall Shear Operator/Plow Operator<br>Rockman/Hang-Up Man/Chute<br>Roof Bolter/Rock Bolter<br>Roof Bolter Mounted<br>Section Foreman/Shift Boss<br>Tailgate Operator |

| | |
|---|---|
| | Utility Man |
| | Stope Miner |
| | Drift Miner |
| | Raise Miner |
| | Miner, NEC |
| | Contract Miner |
| | Rock Duster |
| | Clean-Up Man |
| | Labor Foreman/Bullgang Foreman |
| | Rock Driller |
| | Rock Machine Operator |
| | Surface Miner |
| | Claw Operator |
| | Drill Operator |
| | Miner, NEC/Quarry Worker |
| | Auger Operator |
| | Highwall Drill Operator |
| | Lampman |
| | Stone Finishing/Sizing Personnel |
| | Dimension Stone Cutter/Polisher |
| | Assistant Mine Foreman/Assistant Mine Manager |
| | Outside Foreman |
| Precision Production Occupations | Pumper |
| | Shopman/Machinist |
| | Battery Station Operator |
| | Fan Attendant |
| | Boom Operator |
| | Machinist |
| | Preparation Plant Foreman/Mill Foreman |
| Machine Operators, Assemblers, and Inspectors | Metal/Nonmetal Sampler |
| | Welder/Cement Man |
| | Welder |
| | Cleaning Plant Operator/Media Operator/ Boney Preparation Plant Operator/Crusher Operator |
| | Driver Operator |
| | Scalper/Screen Operator |
| | Stone Finishing/Sizing Personnel |
| | Dimension Stone Cutter/Polisher |
| | Dust Sampler/Laboratory Technician |
| Motor Vehicle and Rail Transport | Truck Driver |
| | Brakeman/Rope Rider/Snapper |
| | Motorman/Swamper/Switchman |
| | Refuse Truck Driver |
| | Water Truck Operator |
| | Yard Engineer Operator/Fireman |

| | |
|---|---|
| Material Moving Equipment Operators | Belt/Conveyor Man<br>Bobcat Operator<br>Scoop Tram-Load Haul Operator<br>Mucking Machine Operator<br>Hand Loader/Hand Trammer<br>Loading Machine Operator/Joy Loader Operator/St. Joe Shovel Operator<br>Shuttle Car Operator/Ram Car<br>Scoop Car Operator/Unitrac Operator<br>Crane Operator/Dragline Operator/Backhoe Operator<br>Front-End Loader Operator<br>Dump Operator<br>Load-Haul-Dump Operator/Gizmo Operator<br>Grader Operator<br>Hoistman/Engineer<br>Transportation Trainee<br>Skip Tender<br>Loader Head Operator/Roscoe Operator<br>Power Shovel Operator/Pitman<br>Bulldozer Operator/Tractor Operator/Heavy Equipment Operator<br>Barge Attendant/Boat Operator/Dredge Operator<br>Car Dropper<br>Grader Operator/Roadgrader Operator<br>Highlift Operator/Front-End Loader<br>Rotary Bucket Excavator Operator<br>Forklift Operator<br>Silo Operator<br>Tipple Operator/Topman/Binman |
| Handlers, Equipment Cleaners, Helpers, and Laborers | Electrician Helper<br>Mechanic Helper<br>Supplyman<br>Laborer/Faceman/Move-Up Man/Pumpman<br>Grizzly Man/Car Dump Operator<br>Drill Helper<br>Continuous Miner Helper<br>Cutting Machine Helper<br>Loading Machine Helper<br>Roof Bolter Helper/Rock Helper<br>Laborer/Mucking Machine Operator/ Pipeman/Ginman<br>Trackman<br>Cager<br>Supplyman/Supply Truck Driver/ Warehouseman<br>Laborer/Utility Man/Pumper<br>Rodman<br>Cager/Cage Attendant/Aerial<br>Chainman<br>Auger Helper<br>Hoist Operator Helper<br>Highwall Drill Helper |

# APPENDIX E. MSHA ACCIDENT CLASSIFICATIONS

Source: [MSHA 1997]

*Electrical*.—Accidents in which the electric current is most directly responsible for the resulting accident.

*Entrapment*.—Accidents involving entrapment of persons.

*Exploding Vessels Under Pressure*.—Accidents involved with bursting of air hoses, air tanks, hydraulic lines, hydraulic hoses, standpipes, etc., due to internal pressure.

*Explosives and Breaking Agents*.—Accidents involving the detonation of manufactured explosives; includes Airdox or Cardox.

*Falling, Rolling, or Sliding Rock or Material of Any Kind*.—Accidents caused directly by falling material other than materials from the roof or face. Or, if material was set in motion by machinery, by haulage, by hand tools, or while being handled or disturbed, etc., the force that set the material in motion determines the classification. For example, where a rock was pushed over a highwall by a bulldozer and the rock hit another rock that hit and injured a worker—the accident is classified as machinery; machinery (a bulldozer) most directly caused the resulting accident.

*Fall of Face, Rib, Pillar, Side, or Highwall (from in place)*.—Accidents in this classification include falls of material while barring down or placing props; also, pressure bumps and bursts. Not included are accidents in which the motion of machinery or haulage equipment caused the fall either directly or by knocking out support.

*Fall of Roof, Back, or Brow (from in place)*.—Underground only - Accidents that include falls while barring down or placing props; also, pressure bumps and bursts. Not included are accidents in which the motion of machinery or haulage equipment caused the fall either directly or by knocking out support.

*Fire*.—Accidents related to uncontrolled burning of material or mineral in the mine environment. Not included are fires initiated by electricity or by explosion of gas or dust.

*Handling Material*.—Accidents related to handling packaged or loose material while lifting, pulling, pushing, or shoveling.

*Hand tools*.—Accidents related to nonpowered tools.

*Nonpowered Haulage*.—Accidents related to the motion of nonpowered haulage equipment. Included are accidents involving wheelbarrows, manually pushed mine cars, timber trucks, etc.

*Powered Haulage*.—Accidents related to the motion of powered haulage equipment. Included are accidents involving conveyors, front-end loaders, forklifts, shuttle cars, load-haul-dump units, locomotives, railroad cars, haulage trucks, pickups, automobiles, and personnel carriers.

*Hoisting*.—Accidents involving cages, skips, ore buckets, and elevators. The accident results from the action, motion, or failure of the hoisting equipment or mechanism. Included are equipment such as cranes and derricks only when used in shaft sinking; also, suspended work platforms in shafts. Not included is equipment such as chain hoists, come-alongs, and winches.

*Ignition or Explosion of Gas or Dust*.—Accidents resulting as a consequence of the ignition or explosion of gas or dust.

*Impoundment*.—Accidents caused by an unstable condition or failure of an impoundment, refuse pile, or culm bank requiring emergency preventative action or evacuation of an area.

*Inundation*.—Accidents caused by inundation of a surface or underground mine by a liquid (or semisolid) or a gas.

*Machinery*.—Accidents related to the motion of machinery. Included are all electric and air-powered tools and mining machinery such as drills, tuggers, winches, slushers, draglines, power shovels, loaders, and compressors.

*Slip or Fall of Person (from an elevation or on the same level)*.—Accidents include slips or falls while getting on or off machinery and haulage equipment that is not moving, and slips or falls while servicing or repairing equipment or machinery.

*Stepping or Kneeling on Object*.—Accidents are classified in this category only where the object stepped or kneeled on contributed most directly to the accident.

*Striking or Bumping*.—This classification is restricted to those accidents in which an individual, while moving about, strikes or bumps an object, but is not handling material, using hand tools, or operating equipment.

*Other*.—Accidents not elsewhere classified.