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Noise Exposure and Hearing Conservation in U.S. Coal Mines—A Surveillance Report

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This study examines the patterns and trends in noise exposure documented in data collected by Mine Safety and Health Administration inspectors at U.S. coal mines from 1987 through 2004. During this period, MSHA issued a new regulation on occupational noise exposure that changed the regulatory requirements and enforcement policies. The data were examined to identify potential impacts from these changes. The overall annual median noise dose declined 67% for surface coal mining and 24% for underground coal mining, and the reduction in each group accelerated after promulgation of the new noise rule. However, not all mining occupations experienced a decrease. The exposure reduction was accompanied by an increase of shift length as represented by dosimeter sample duration. For coal miners exposed above the permissible exposure level, use of hearing protection devices increased from 61% to 89% during this period. Participation of miners exposed at or above the action level in hearing conservation programs rapidly reached 86% following the effective date of the noise rule. Based on inspection data, the occupational noise regulation appears to be having a strong positive impact on hearing conservation by reducing exposures and increasing the use of hearing protection devices and medical surveillance. However, the increase in shift duration and resulting reduction in recovery time may mitigate the gains somewhat.

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

INTRODUCTION

Mining of *in situ* minerals requires highly energetic extraction methods, exposing miners to high noise levels. In 1981, the United States Environmental Protection Agency (EPA) estimated that 255,000 miners were exposed to daily noise levels above 85 decibels on the A-weighted scale (dBA).[(1)] This represented about 47% of miners, including employees and contractors. In a subsequent assessment[(2)] performed from 1984 to 1989 by the National Institute for Occupational Safety and Health (NIOSH), the National Occupational Health Survey of Mining (NOHSM) estimated that 108,264 (87.8%) of miners in the bituminous coal and lignite Standard Industrial Classification code were occupationally exposed to noise. Both of these estimates demonstrated widespread exposure to elevated noise levels and the associated increased risk of developing noise-induced hearing loss (NIHL) in the mining industry. However, these estimates may not accurately represent the current coal mining work force, which from 1987 to 2004 has decreased by 57% for coal, excluding office workers.[(3)] In addition, mining technologies have changed and noise reduction controls have become available.

The purpose of this report is to describe patterns of noise exposure in the coal mining sector using compliance samples collected by Mine Safety and Health Administration (MSHA) inspectors. A secondary objective is to provide a baseline for future review of the impact of the MSHA Occupational Noise Exposure regulation on noise exposures in coal mining.

Federal Regulation of Occupational Noise Exposure in Mining

Before 2000, MSHA enforced a permissible exposure level (PEL) for noise exposure in coal mining that was derived from the Walsh-Healy Public Contracts Act. The PEL was an 8-hour, time-weighted average (TWA_8) of 90 dBA, and unless a citation was issued for overexposure to noise, hearing conservation programs were not mandated. The prior MSHA noise regulations did not specify engineering and administrative controls as the primary methods to reduce coal miners' noise exposures.

MSHA internally reviewed the effectiveness of its noise standard and determined that the risk of developing NIHL from exposures at or above the PEL was unacceptably high, and some residual risk of NIHL remained for miners exposed below the PEL.[(4)] MSHA analyzed the impact of alternative compliance strategies to reduce the NIHL risk to miners including reducing the PEL to a TWA_8 of dBA, and the doubling rate from 5 dB to 3 dB for noise exposure measurements.

MSHA determined that reducing the PEL to 85 dBA would require 75% of coal mine operators to install engineering controls or use administrative controls while changing the doubling rate to 3 dB would double the percentage of noncompliant measurements. MSHA thus concluded that these changes were not technologically or economically feasible for the mining industry.[5]

As a result of its review, MSHA issued a final occupational noise exposure rule codified at 30 CFR 62 in 1999 that became effective in September 2000 and included several significant changes:

1. The compliance requirements for the metal and nonmetal mining sector (not included here) and coal were made the same.
2. Primacy of engineering and administrative noise controls in both sectors was established.
3. Mine operators were required to implement a monitoring system to evaluate the noise exposures of miners.
4. A TWA_8 action level (AL) of 85 dBA (a dose of 50%) was established.
5. Enrollment in a hearing conservation program was required for miners exposed at or above the AL, and
6. A statutory definition for hearing loss cases that must be reported to MSHA based on audiometric testing was established (a deterioration in hearing sensitivity of 25 dB or more at 2000, 3000 and 4000 Hz in either ear, relative to the appropriate baseline audiogram).

The MSHA noise regulation specifies that the PEL measurement includes all sound pressure levels (SPLs) from 90 dBA to at least 140 dBA, whereas the AL measurement includes all SPLs from 80 dBA to at least 130 dBA.[6] Both measurements use a 5-dB doubling rate, a reference time of 8 hours, a reference SL of 90 dBA, and slow response.

METHODS

Compliance samples collected using personal noise dosimeters were downloaded from MSHA's inspection database from 1986 (the start date of the database) through 2004. Dosimetry results are reported in dose percent.

MSHA maintains two data repositories for coal sector noise exposure samples. One repository contains records for the period from 1986 through 1999 and is maintained by the MSHA Safety and Health Technology Center in Bruceton, Pennsylvania; the other is the active MSHA management information system, and it contains noise exposure records from 2000 onward. Noise exposure-related data were extracted from both repositories. No information that would permit personal identification of either MSHA inspectors or mine employees was retrieved.

The two data sets were formatted into separate data files using SPSS 12.0 for Windows. The two data files had differing structures because MSHA's inspection and data collection practices changed in response to the September 1999 promulgation of the occupational noise exposure regulation. However, the key variables used for this analysis (i.e., exposure dose percent, occupation, sample date, and sample duration) were present in both datasets. These key variables were assigned identical names and formats, whereas all other variables were retained and the two data files were merged.

The combined file included 148,813 noise exposure records. The data were edited to exclude potentially invalid samples prior to the analysis. Records were excluded if any of the following criteria were met:

- There were duplicate cases.
- No value for survey date was given, or the survey date was before January 1, 1987, or after December 31, 2004.
- No value for the PEL dose was given.
- The PEL dose exceeded the AL dose (where dual-channel dosimeters were used to simultaneously measure PEL and AL doses).
- The occupation was invalid or missing.
- No sample time was recorded, or the sample time was less than 6 hours or greater than 16 hours.

A small number (22) of records had extremely high PEL doses (e.g., 9999%). These doses were considered transcription errors and were excluded. Similarly, sample durations of less than 6 hours (0.8% of all records) and greater than 16 hours (0.03% of all records) were considered nonrepresentative and were also excluded.

Based on the above criteria, 6,281 records (4.2%) were excluded, resulting in 142,735 exposure records that were used for analysis.

MSHA's *Coal Mine Health Inspection Procedures Handbook* specifies the procedures to be followed during a noise compliance inspection.[6] American National Standards Institute (ANSI) Type II noise dosimeters are used to collect personal noise exposure measurements. Dosimeter parameters (threshold level, criterion level, doubling rate, etc.) are specified for action level and permissible exposure level measurements, and dosimeters and calibrators are laboratory calibrated annually to assure conformity to ANSI standards for Type II instruments. MSHA inspectors perform pre- and postsampling field calibration checks on the dosimeters. If a dosimeter is not within ±1.0 dB of the calibration value, the dosimeter or the collected exposure data is not used and is not included in the database.

Shift length is not specifically recorded in the MSHA databases; however, sample duration is used in this analysis as a surrogate measure of shift length because MSHA's policy is to collect full-shift "portal-to-portal" noise samples.

The noise exposure databases include both a measured noise dose and, for samples collected prior to 2000, an adjusted noise dose when hearing protection devices (HPDs) were worn by the monitored miners. This allows an examination of the patterns of HPDs use. In the pre-rule period (before 2000), information

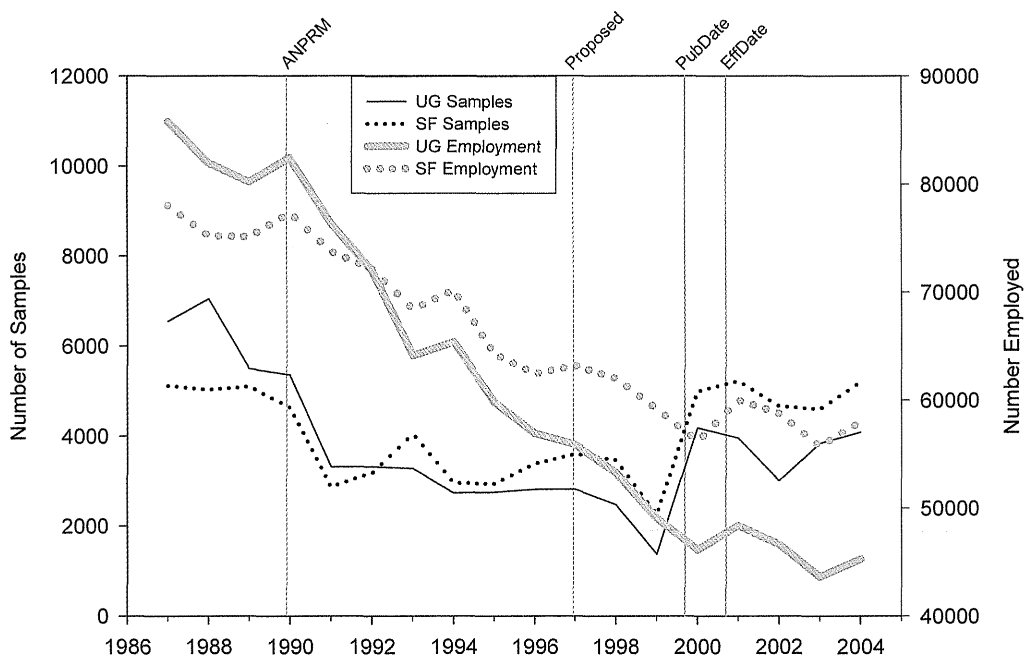

FIGURE 1. *Coal mine noise sampling and employment trends 1987–2004*

about the use of HPDs among coal miners was collected to adjust the measured noise dose based on the protection provided by the HPD, in accordance with the prevailing coal mine health inspection procedures. No information about the type of HPD used was documented. For this analysis, where the pre-rule exposure record contains a value for adjusted dose that is less than the measured dose, it is assumed that the miner wore hearing protection during the sampling event. Only unadjusted (measured) noise dose values are used to represent miner exposure in this analysis.

The data sets were examined for normality. The Lilliefors Komolgorov-Smirnov test rejected normality for the PEL and AL noise dose data ($p < .001$), and the natural log transform of the PEL and AL dose data ($p < .001$).

The post-rule (after 1999) data contain a small number of extreme values of dose (>2000%); rendering means an inappropriate statistic to represent the data. Consideration was given to censoring the extreme values prior to analysis, but this approach was not supported by any available information. Consequently, medians of dose are used to characterize central tendency, and the interquartile range is used to represent the spread in the data.

The trends in exposure were determined using linear regression of the annual median PEL dose on calendar year for the pre-rule (1987–1998) and post-rule (2000–2004) periods. Calendar year 1999 is excluded from the analysis because the final rule took effect during the year, causing differing criteria to apply in parts of the year. For the AL, only the period from 2000 through 2004 was analyzed. Linear regressions were performed using SAS v. 9.1; figures were generated with SigmaPlot 2004 for Windows v. 9.01.

RESULTS

The average annual number of PEL noise samples recorded increased during the years after the occupational noise exposure regulation was issued in 1999. The average annual number of workers' exposures recorded in the 4-year period from 1995 to 1998 was 6098. The average annual number for the 2000 through 2004 period was 8839, a 45% increase. The number of exposure records in 1999 was unusually low because very few were recorded in September and October of that year; for this reason, 1999 is not included in the sample count comparison.

Annual noise sample counts and employment totals are presented in Figure 1. Vertical reference lines have been overlaid on each figure to represent the occurrence of significant events in the development of the noise regulation. The definitions of these reference lines are: ANPRM—advance notice of proposed rulemaking (12/04/1989); Proposed—publication of the proposed noise regulation (12/17/1996), PubDate—publication date of the final noise regulation (09/13/1999); and EffDate—effective date of the final noise regulation (09/13/2000).

The number of operating coal mines and the fraction of operating mines surveyed by year is presented in Figure 2. The number of mines inspected for noise exposures per year generally declined from 1987 to 1999. Based on MSHA's published data,[7] the fraction of operating coal mines inspected remained relatively constant before the final rule but has increased since the final occupational noise exposure rule has been in effect.

The increase in sampling activity matched a reduction in the annual median PEL dose from 62.2% in 1998 to 34% in 2004

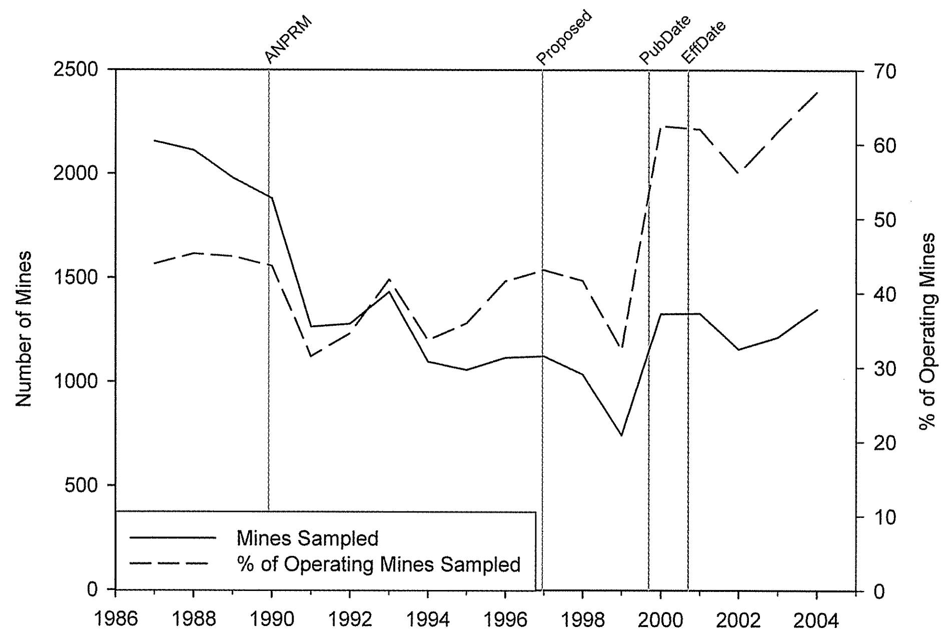

FIGURE 2. Number and percent of operating coal mines receiving an MSHA noise inspection 1987–2004

(1999 is excluded because the final rule took effect within that calendar year). Reductions are seen in both the annual median PEL dose for noise samples taken on underground occupations (74% to 50%) and surface occupations (48.8% to 20%) (Table I). Annual means and standard deviations are included in Table I to provide additional description of the data. The means of the underground and surface occupation doses for the 1987–1989 and the 2000–2004 periods were significantly different by the Mann-Whitney U test ($p < 0.001$ for both).

TABLE I. PEL Dose Sample Descriptive Statistics by Year and Location

	Surface					Underground				
		PEL Dose Percent					PEL Dose Percent			
Year	N	Mean	SD	Median	IQ Range	N	Mean	SD	Median	IQ Range
1987	5117	101.8	144.3	61.0	90.0	6549	72.4	55.4	65.8	62.6
1988	5028	86.2	117.2	55.0	76.0	7049	72.9	57.6	65.0	57.0
1989	5100	88.0	115.4	62.0	81.0	5501	67.9	46.3	63.0	55.8
1990	4632	90.2	119.8	63.0	75.3	5356	71.3	52.8	65.4	52.5
1991	2870	88.3	121.1	59.0	81.0	3318	75.3	53.6	69.4	56.4
1992	3181	85.5	112.7	54.2	79.7	3322	80.8	61.2	73.4	56.6
1993	4049	89.8	121.7	63.0	77.2	3280	83.4	68.7	74.9	57.0
1994	2961	92.6	120.3	67.0	82.6	2737	83.2	65.4	76.0	58.2
1995	2937	80.9	106.5	58.9	74.7	2755	75.5	66.5	68.0	53.7
1996	3386	76.4	89.5	60.0	70.4	2818	79.0	76.7	69.3	54.2
1997	3596	79.6	114.7	56.5	69.1	2821	83.1	81.2	73.0	54.3
1998	3468	81.3	125.8	48.8	77.9	2479	87.3	96.4	74.0	55.3
1987–1998	46,325	87.4	119.32	59.5	77.7	47,985	75.9	63.1	68.1	56.3
2000	4186	67.9	142.3	31.0	72.0	4995	93.4	271.6	63.0	69.0
2001	3957	58.2	197.2	23.0	52.0	5223	80.9	219.1	54.0	63.0
2002	3005	43.4	72.8	22.0	49.0	4666	63.0	53.7	50.0	55.0
2003	3839	47.1	238.9	20.0	43.0	4599	92.6	391.6	52.0	58.0
2004	4084	38.3	60.7	20.0	43.0	5197	80.3	316.1	50.0	52.0
2000–2004	24,680	51.1	157.7	23.0	50.0	19,071	83.0	280.9	53.0	59.0

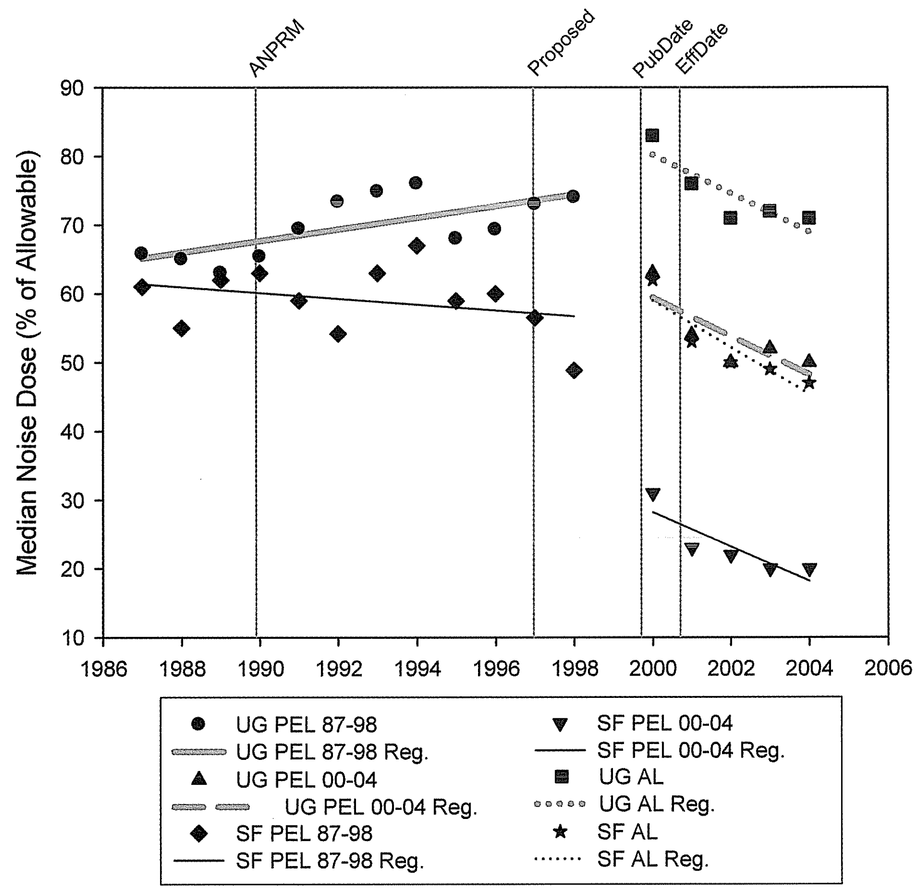

FIGURE 3. Regression of the annual median PEL and AL noise dose on year by surface and underground coal mining occupations during two periods: from 1987 to 1999 and from 2000 to 2004

Converting the median PEL doses to A-weighted sound levels using Eq. 1

$$TWA_8 = 16.61 \times \log_{10}\left(\frac{\text{Dose\%}}{100}\right) + 90 \qquad \textbf{(1)}$$

the reductions in dose represent a decrease in TWA_8 exposure from 87.1 dBA to 82.2 dBA for all samples; from 88.2 dBA to 85 dBA for underground samples, and from 86 dBA to 78.4 dBA for surface samples. The median noise doses in underground and surface occupations and the trends in median doses are presented in Figure 3.

In underground occupations the median PEL noise dose increased at the rate of 0.84% per year from 1987 through 1998 (pre-rule). For the post-rule period from 2000 through 2004, the median PEL noise dose declined at the rate of 2.8% per year. The increase in pre-rule doses appears to be consistent through when the new rule was adopted in 1999. The median AL noise dose in underground occupations decreased at an identical rate of 2.8% per year.

In surface occupations the median PEL noise dose decreased at the rate of 0.40% per year during the pre-rule period. The rate of decline increased in the post-rule period to 2.5% per year. The median AL noise dose in surface occupations decreased at the rate of 3.4% per year.

The median PEL doses in surface and underground in 1987 were of similar magnitude; however, by 1998 the PEL doses were substantially different. During the post-rule period, the median underground PEL noise doses also dropped substantially but not as much as the drop in surface PEL noise doses during the same period. The rate of change is similar for both underground and surface, but the PEL noise doses are substantially less in surface occupations than in underground occupations. The trends in surface and underground median AL noise doses during the post-rule period are similar to the trends and differences noted in the median PEL noise doses.

Occupation Data

MSHA lists 201 occupations that are used to describe the primary activity performed by a miner during a sampling event.[8] The list of occupations has been relatively stable over the period examined by this report; a few new occupations were added when new production technologies were introduced. The number of noise samples collected in each occupation varied widely; no samples were collected in nine occupations. For sampled occupations, the number of samples per occupation ranged from one (nine occupations) to 15,942 (high lift operator/front end loader operator). The median number of samples per occupation was 71.5; the mean number of samples was 743.4. Not all occupations were sampled each year, and the number of samples per year in any occupation was variable.

Underground Occupations

Twenty-five underground occupations were represented by at least 100 samples in both the pre- and post-rule periods. Of these occupations, the median PEL dose in the 2000–2004 period was lower than in the 1987–1998 period in 18 occupations (72%) and was unchanged in one occupation (4%). The median PEL dose increased from the 1987–1998 period to the 2000–2004 period in six occupations (24%) (Table II). The occupations that displayed an increase between the two periods were headgate operator, jack setter (longwall), longwall operator (headgate side), longwall operator (tailgate side), roofbolter (mounted—intake side), and roofbolter (mounted—return side).

Surface Occupations

Twenty-nine surface occupations had at least 100 samples in both the pre- and post-rule periods. For 28 of these 29 occupations (97%), the median PEL dose in the 2000–04 period was less than in the 1987–1998 period. The remaining occupation was unchanged (Table II).

Hearing Conservation Programs

In association with the new noise rule, MSHA inspectors began collecting information during inspections to document enrollment of the monitored miners in hearing conservation programs (HCPs). HCP-enrollment percentages of monitored miners by AL noise dose are presented in Table III. Note that miners with noise dose equal to or greater than the AL were not required to be enrolled in an HCP until the fourth calendar quarter of 2000.

Use of Personal Protective Equipment (PPE)

Approximately 36% (35,603 samples) of pre-rule PEL samples included a reduced adjusted dose, suggesting that only 36% of monitored miners wore HPDs. Of the 36% of miners who wore HPDs less than half (43%) were exposed to noise in excess of the PEL.

During inspections in the post-rule period, MSHA inspectors document the use of HPDs, and specify which of three generic types (cap, muff, or plug) is used by the monitored miner. The descriptions of the types of HPD are: caps occlude the outer opening of the ear canal, muffs cover the entire pinna, and plugs are inserted into the ear canal. Some records indicate that the miner used more than one type in combination (e.g., muff and plug).

The percentage of miners monitored during an inspection in a year and that used any type of HPD was categorized by the PEL noise dose range and presented in Figure 4.

HPD use increased during the period reviewed for sampled miners in all noise dose ranges, although the increase is small for the two highest dose ranges (150% to 199%, and greater than 199%) because HPD use is high throughout the entire period.

Most monitored miners exposed to noise used hearing protection—predominantly the plug type, although 13% of underground miners and 9% of surface miners exposed to greater than 100% PEL noise dose did not use HPDs in 2004. Surface miners were more likely to use HPDs than were underground miners.

In the 5 years for which data are available, plugs are used by a large majority (89%) of monitored miners who used HPDs. Muffs are the second most common choice (10%), and cap type are used by only 1% of miners who used HPDs.

DISCUSSION

MSHA coal mine inspection policies and methods have been relatively constant since the 1980s, permitting comparison of data collected over a long period at locations throughout the United States. MSHA's policy is to conduct annual noise compliance inspections at each producing mine, with follow-up surveys conducted where PEL dosimetry measurements are between 100% and 132%.

Where PEL dosimetry exceeds 132%, an initial follow-up survey is to be conducted after implementation of feasible engineering and administrative controls. A subsequent follow-up survey is to be conducted within 60 days of the initial follow-up survey to assess continuing compliance. The relatively consistent policies and methods over this extended period, as well as the requirements to record all exposures collected, make the database a valuable tool for surveillance of noise exposures in the mining industry. However, there is some variability in the procedures that must be accounted for to interpret the data appropriately. For example, MSHA inspectors are responsible for assessing whether mining operations are in compliance with MSHA regulations; to assess compliance they identify and sample miners with the highest potential noise exposure (worst case). Generally, at least five individuals are sampled during a noise survey, although the selection of occupations to sample is based on procedures in the *Coal Mine Health Inspection Handbook* that specify that the exposures of miner operators, roof bolters, shuttle car operators, and mobile bridge conveyor operators in underground mines will be sampled. In surface mines, bulldozer operators and other heavy equipment operators must be sampled when present in the workplace. The MSHA inspectors may select other occupations exposed to high levels of noise. These MSHA policies result in variability in the number of noise samples collected from the various occupation codes.

The number of samples collected per year increased after 1999. This increase in samples collected can be attributed to several factors. MSHA has performance objectives related to reduction of health hazards, including noise exposure, defined within its strategic plan developed pursuant to the Government

TABLE II. Median PEL Doses of Coal Mining Occupations Sampled at Least 100 Times

	1987–1998		2000–2004	
Occupation Code and Description	N	Median	N	Median
Underground Occupations				
001 Belt man/conveyor man	271	44.0	110	32.0
002 Electrician	178	31.7	225	25.0
004 Mechanic	454	36.0	236	24.0
012 Roof bolter (twin head) (intake side)	2479	71.3	1548	59.0
014 Roof bolter (twin head) (return side)	2319	70.3	1617	59.0
019 Roof bolter (mounted) (intake side)	310	94.7	104	126.5
034 Coal drill operator	1235	52.4	183	25.0
035 Continuous miner helper	2324	79.0	337	72.0
036 Continuous miner operator	8866	93.0	3617	93.0
038 Cutting machine operator	1113	77.0	147	43.0
040 Headgate operator	425	98.0	184	101.5
041 Jack setter (longwall)	596	77.0	242	81.0
043 Loading machine operator	606	98.5	100	94.5
044 Longwall operator (tailgate side)	374	121.1	173	151.0
046 Roof bolter (single head)	7146	69.0	1461	53.0
048 Roof bolter (mounted) (return side)	427	93.7	156	109.0
049 Section foreman	353	46.7	244	32.5
050 Shuttle car operator (standard side)	6490	53.0	3388	44.0
053 Utility man	498	40.1	276	38.0
054 Scoop car operator	3413	41.6	1671	27.0
064 Longwall operator (headgate side)	273	120.8	140	128.0
072 Mobile bridge operator	1477	74.0	708	56.0
073 Shuttle car operator (off standard)	2557	49.3	752	38.0
074 Tractor operator/motorman	495	55.9	234	46.0
101 Belt man/conveyor man	297	37.0	260	27.0
Surface Occupations				
302 Electrician	458	38.6	317	28.0
304 Mechanic	1970	25.7	980	18.0
307 Blaster/shooter/shotfirer	139	27.5	111	23.0
310 Scrapper operator	880	79.3	163	43.0
313 Cleanup man	370	80.2	156	64.5
316 Laborer/blacksmith	1598	45.0	736	27.0
318 Oiler/greaser	837	92.0	328	53.0
319 Welder (shop)	297	27.0	100	24.0
324 Backhoe operator	654	33.7	704	9.0
328 Utility man	797	38.7	868	19.0
341 Belt man/conveyor man	254	49.5	131	31.0
343 Car trimmer/car loader	297	16.0	121	16.0
345 Crusher attendant	290	59.5	152	28.0
357 Washer operator	308	82.0	128	36.5
368 Bulldozer operator	8869	92.1	5198	41.0
370 Auger operator	557	176.0	338	71.0
371 Auger helper	458	160.4	254	76.0
374 Cleaning plant operator	1126	64.0	707	37.0
375 Road grader operator	572	39.1	345	21.0
376 Coal truck driver	938	42.0	474	15.0
378 Crane operator/dragline operator	883	27.0	390	7.5
380 Fine coal plant operator	569	95.4	335	68.0
382 Highlift operator/front end loader	10,207	51.3	5193	16.0
384 Highwall drill operator	2416	70.5	1181	19.0
386 Refuse truck driver/backfill truck driver	4343	49.0	2746	18.0
387 Rotary bucket excavator operator	133	38.7	185	8.0
391 Stripping shovel operator	273	30.0	185	6.0
392 Tipple operator	1767	48.0	507	20.0
393 Weighman	233	8.0	112	2.5

TABLE III. Coal Miner Hearing Conservation Program Enrollment

Action Level Dose Range (%)	Enrollment in HCP				
	2000 (%)	2001 (%)	2002 (%)	2003 (%)	2004 (%)
0–49	9	68	76	76	77
50–99	7	74	84	85	85
100–149	7	81	91	89	88
150–199	3	77	90	91	89
>199	5	70	87	85	82
Subtotal ≥50	6	76	87	86	86
Total	7	73	82	82	82

Performance and Results Act of 1993. MSHA's strategic plan in part drives how its compliance activities will be directed, and the increase in noise sample collection is partially a result of this planning. In addition, after the publication of the new noise rule and before it became effective, MSHA delivered substantial technical support to the coal mining industry to assist with identification of noise sources that resulted in exposures greater than the AL and/or PEL. Some of this assistance took the form of additional targeted sampling to evaluate noise exposures and identify sources. A third possible contributing reason may be the evaluation of additional exposure situations for compliance with the new action level.

Before 2000, the median PEL noise doses were increasing slowly for underground miners and decreasing slowly for surface miners. The increase in the median PEL dose for underground miners reversed and the decrease in noise exposures for surface miners accelerated when the MSHA final occupational noise exposure rule became effective, suggesting that the noise rule may have catalyzed actions that resulted in a reduction in miners' noise exposures.

The reduction in median noise dose can be attributed to several factors. One factor is actions taken by coal mine operators motivated by the new rule's requirements specifying administrative and engineering controls as the primary means to reduce noise exposure. Examples of actions operators may have taken include retiring old, noisy equipment; retrofitting equipment with noise controls; and implementing administrative controls to reduce exposure. Whereas the period between the publication of the rule and its effective date is 1 year, the history of the noise rule legislation is considerably longer (Figure 3). MSHA published an Advance Notice of Proposed Rulemaking (ANPRM) for the noise rule in December 1989 and issued a proposed noise rule in December 1996. The final rule was published in September 1999 with an effective date of September 2000. This multiyear period gave coal mine operators adequate notice of the likely changes to be implemented and permitted deliberate introduction of feasible engineering and administrative controls to reduce noise exposure.

Another potential contributor to the observed decreases in PEL noise dose is the compliance assistance sampling performed by MSHA inspectors between September 1999 and September 2000. If compliance assistance samples were collected during this period on a variety of processes and

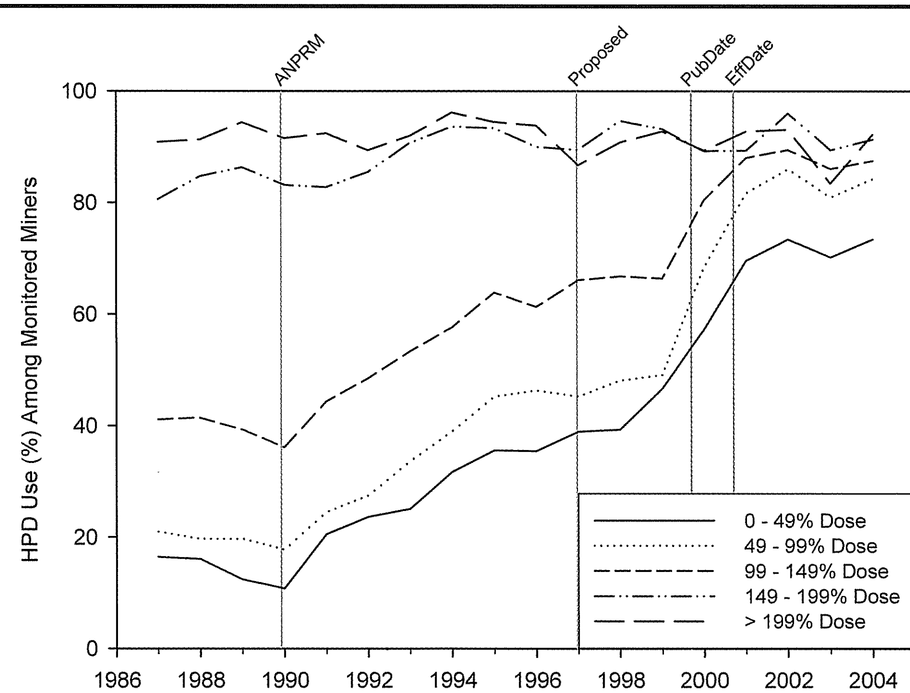

FIGURE 4. Use of hearing protection devices by monitored coal miners during MSHA inspections by PEL dose range and year

occupations that previously were not sampled because they were anticipated to have exposures below the PEL and the exposures were lower, the annual median for 1999 and 2000 would have been reduced. This pattern is not observed for 1999 but appears to contribute to the substantial drop in median PEL noise dose in 2000–2004.

The seemingly permanent drop in noise PEL dose in 2000–2004 may have been caused at least in part by the inclusion of processes and occupations that were sampled during 2000–2004 because exposures are anticipated to be at or above the AL but were not sampled previously because their exposures were below the PEL. Therefore, the observed noise exposure reduction since the new rule was adopted may not be exclusively a result of an overall reduction in noise exposures. However, the slopes of the regression lines suggest that some reductions in noise exposure are occurring. The reduction in overall noise exposure shown by the MSHA data may, if it continues, result in reduced incidence of NIHL among coal miners.

A potential factor impeding the reduction of NIHL risk is an increase in miners' exposure time. The annual mean sample duration of coal miners increased from 8.22 hours in 1987 to 9.35 hours in 2004, a 13.8% increase. For the miners in occupations with decreased noise dose but increased shift length, the increase in shift length may partially or wholly offset the benefit from the declining annual median noise exposure if the "equal energy equal hearing loss" hypothesis that the same amount of energy produces the same hearing loss is pertinent. The increased shift length is particularly concerning because it may result in greater temporary threshold shift (TTS)[9] during the work shift among miners who may not be able to return to baseline hearing ability by the time work is begun again and the noise exposure resumes. Under the theory that a greater TTS results in greater permanent hearing loss,[10] the increased shift length may result in increased rates of permanent NIHL. For miners in occupations with increased noise dose and increased shift length, an increase in NIHL incidence can be anticipated unless they are included in an effective hearing conservation program.

An important aspect of the hearing conservation program specified by the final noise rule is the establishment of a standard definition for hearing loss that must be reported to MSHA by the mine operator. Formerly, hearing loss was reported when a miner was awarded compensation for NIHL through a workers' compensation system, or was diagnosed with a hearing loss. Differing standards used by the various state-based compensation agencies and inconsistent definitions used by medical professionals caused confusion for mine operators regarding which cases of hearing loss should be reported. The inconsistent definitions also reduced the usefulness of the data that were reported to characterize the extent and severity of NIHL in the mining industry. MSHA's standardized definition for reportable hearing loss should substantially increase the reporting rate of cases by mine operators, as well as improve the quality and usefulness of the data submitted.

In addition to decreasing the ambient noise levels to which miners are exposed, miners' hearing may be conserved through the application of a hearing conservation program, including hearing protection, audiometric examinations, and worker training. MSHA's final noise rule requires mine operators to include miners exposed at or above the AL in a hearing conservation program. In addition to these steps to conserve hearing, additional steps to prevent hearing loss such as those described by NIOSH[1] are recommended.

In 2000, only 6.5% of the monitored miners exposed at or above the AL were included in a hearing conservation program, but by 2004, 86% of sampled miners exposed above the AL were in a hearing conservation program. The percentage enrolled in HCPs did not differ substantially between underground and surface occupations. Mine operators should seek to include the nonenrolled miners as soon as possible to preserve their hearing.

Of some note is the high level of enrollment (77% in 2004) of sampled miners with AL noise dose less than 50%; enrollment of these miners in HCPs is not mandatory. Several potential explanations for this high participation rate include that the miner's assigned duties rotated among occupations with higher noise exposure, the mine operator was not aware of the actual noise dose of some occupations, and the mine operator included a larger population in the HCP as a benefit to miners or as a means to simplify compliance. The available data do not permit further evaluation of these or other explanations.

MSHA's final rule requires the use of hearing protectors by miners when the miner's noise exposure exceeds the PEL during the work period until administrative and/or engineering controls are instituted or if controls do not reduce the exposure to below the PEL. Miners have used HPDs in high noise environments to a greater or lesser extent for many years, although underground miners in particular resisted the use of hearing protection because it reduced their ability to hear "roof talk." Roof talk is sound produced in the disturbed geologic strata, and it can provide information about the stability of the mine roof and walls. The use of HPDs among monitored miners increased from 1987 to 2004 for all exposure ranges except the highest (Figure 4). Substantial increases were observed in the use of HPDs in the 3 years following the adoption of the final rule in dose ranges 0–49%, 49–99%, and 99–149%. In 2004, 13% of sampled underground miners and 9% of sampled surface miners who were exposed to noise in excess of the PEL did not use hearing protection, and methods to increase the use of HPDs should be implemented.

A limitation of the data is related to MSHA's compliance policy prior to the promulgation of the final noise rule, which was to adjust measured noise doses downward to account for protection provided by HPDs. The adjustment calculation resulted in substantial reductions of dose, so much so that inspectors reported that they sometimes chose not to sample miners who used HPDs. For example, a miner with a measured PEL dose of 200% who wore a HPD with a noise reduction rating of 29 dB would have been assigned an adjusted dose of 9.5%, which would not exceed the allowable exposure under the previous compliance policy. Because use of HPDs was the primary noise exposure control in coal mines prior to the current regulation, the mine operator would have been motivated to ensure his/her employees used HPDs in high noise areas. This practice would result in lower pre-rule measured doses because the miners more likely to use HPDs (i.e., those with higher noise exposures) may not have been selected for sampling. This would also skew lower the rates of HPD use prior to 2000.

A second limitation results from the sampling strategy used by MSHA. The data used for this analysis were generated by MSHA inspectors performing compliance assessments. The sampled occupations were not selected randomly, workers may not have been selected randomly within the occupation, and the data include sampling done during follow-up surveys subsequent to identifying overexposures, although follow-up samples are not differentiated in the database records. Consequently, the data may be biased.

A third limitation affects estimates of HPD use and enrollment in HCPs. The estimates reported here may be higher than actual rates and may not reflect HPD/HCP status of the total mining population because the estimates are based on miners who used HPDs and reported HCP enrollment during a compliance inspection. The presence of an inspector in the workplace may have altered the behavior of mine operators and the miners with regard to these issues.

SUMMARY AND RECOMMENDATIONS

MSHA's current policy specifies occupations that must be monitored during noise inspections at surface and underground mines. This policy results in high sampling rates for some occupations with relatively lower noise exposure. MSHA should consider modifying its coal mine health inspection policies on selection of occupations to be sampled for noise exposure. A sampling policy prioritized on more recent historical occupation-based noise exposure data, or a statistically selected sample, may provide more useful information for compliance and epidemiologic assessments of noise exposure and NIHL in the coal mining industry.

The average sound levels during a mining shift are declining for most coal mining occupations, but increasing shift duration makes it difficult to predict the effect reduced sound level will have on the incidence of NIHL among miners.

Surveillance should be implemented to assess the occurrence of NIHL in coal miners using audiometric data collected as part of the hearing conservation programs. Analysis of previously collected audiometric data using the new standard definition of hearing loss may provide baseline information to improve future investigation of NIHL in coal miners.

Miner participation in hearing conservation programs is high based on reports from MSHA inspectors but should be expanded to include all miners exposed to noise in excess of the action level. Use of hearing protection should also be expanded to include all miners where feasible administrative and engineering controls do not reduce noise exposure to less than the PEL.

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