INVESTIGATION INTO DUST EXPOSURES AND MINING PRACTICES IN MINES IN THE SOUTHERN APPALACHIAN REGION

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ABSTRACT

Recent NIOSH published information has shown an increase of rapidly progressive coal workers' pneumoconiosis (CWP) in the southern Appalachian coal region (SAR) of the U.S., despite the fact that compliance data indicates that most coal miners have been exposed to coal mine dust concentrations below the statutory limit of 2.0 mg/m³. While the exact cause of these elevated CWP levels in the SAR has not been established, several factors may be contributing to the increase in occupational lung disease among coal miners. The mining of high rank coal is known to lead to higher CWP rates, and this type of coal is mined in a portion of this region. Also, a high percentage of the mines in the region are on reduced dust standards because of the high silica content of the airborne dust resulting in miners possibly being exposed to excessive amounts of respirable silica dust. Exposure to excessive amounts of respirable silica dust can lead to silicosis, a disabling and potentially fatal lung disease. NIOSH's Respiratory Hazards Control Branch has been investigating the possible causes that would account for the observed higher trends in disease progression through literature review, data analysis, and in-mine surveying.

The investigation to date has revealed that underground mines are faced with cutting large amounts of rock in order to maintain haulage clearances. Cutting rock not only increases the potential for silica exposure, it increases the requirement for machine maintenance which was a concern observed during dust surveys conducted by NIOSH. Over half of the mines operating in the SAR are on reduced standards due to high silica content. Adequate face ventilation of the continuous miner and roof bolter and limited down-wind operations from the miner are also issues of concern and items which require the constant attention of miners operating in these conditions.

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INTRODUCTION

The Federal Coal Mine Health and Safety Act of 1969 was passed to protect the safety and health of coal miners. It included provisions to mitigate the harmful effects of respirable coal mine dust by mandating airborne respirable dust standards. Therefore, since December 30, 1972, the amount of respirable coal mine dust allowed in the mine air that miners breathe has been limited to 2.0 mg/m³ for a working shift. This standard is further reduced when the respirable dust contains more than 5 percent quartz since this presents an additional health hazard. If the silica content on the filters exceeds 5% by weight as determined by MSHA's P7 infrared method, the 2.0 mg/m³ standard is reduced using the formula 10 ÷ % quartz (Parobeck and Tomb, 2000; U.S. Code of Federal Regulations, 2008). The Federal Coal Mine Health and Safety Act of 1969 also established the U.S. National Coal Workers' X-ray Surveillance Program (CWXSP) to screen underground coal miners for coal workers' pneumoconiosis (CWP) and to document the general trends and patterns in the prevalence of x-ray evidence of pneumoconiosis among working coal miners. Under this medical monitoring program, administered by NIOSH, coal mine operators are required to offer a free chest x-ray to each underground miner at the time of hire and again three years later; and in the event the second x-ray shows evidence of the development of CWP, the miner, if still engaged in mining, must be offered an additional x-ray two years later. This program also provides miners an opportunity to participate voluntarily in subsequent health screenings every five years following the initial screenings.

Data was combined with the latest round of x-rays in this surveillance program and from the Miners' Choice Program, a special program sponsored by MSHA which offered targeted free health screenings to both surface and underground coal miners between 1996 - 2002. Analysis by the NIOSH Division of Respiratory Disease Studies showed that from 1970 - 1995, the tenure-related prevalence of CWP was on the decline, however from 1999 - 2008; the tenure-related prevalence of disease has doubled. (WoRLD Report, 2008) New cases of CWP are still occurring among miners who have worked exclusively under current dust exposure limits (Antao et al., 2004). The study by Antao et al. identified 886 cases of CWP among 29,521 miners examined from 1996 - 2002, or approximately one in 20 miners with CWP. Among these, 35.4% were identified with rapidly progressive CWP, which included 41 miners with pulmonary massive fibrosis. When comparing the rapidly progressive CWP cases against the cases without the progression, Antao et al. discovered that the miners with the rapidly progressive CWP had reported to have worked at the mining face longer, were younger, and had worked at smaller (fewer than 50 employees) mines. Also observed was the clustering of the CWP "hotspots" in the SAR. The CWP hotspots include counties located in western Virginia, eastern Kentucky and southern West Virginia, which include MSHA coal districts 4, 5, 6, and 7. MSHA district 4 is made up of counties in southern West Virginia. District 5 comprises the entire state of Virginia. District 6 is the counties of eastern Kentucky and district 7 is made up of counties in central Kentucky and the states of North Carolina, South Carolina and Tennessee.

For this investigation, we sought to identify mining conditions and exposures which may explain the increased CWP prevalence that has been observed among underground coal miners from the SAR.

METHODS

NIOSH researchers utilized Mine Safety and Health Administration (MSHA) inspector compliance sampling data in the MSHA Standardized Information System (MSIS) database to identify mines of interest. An analysis of the MSIS database was conducted for each MSHA district in the SAR region. The data were filtered to only include compliance samples from underground coal mines. An analysis of all sampled occupations was conducted for the calendar years 2000 - 2005. Also, a separate analysis of only the continuous miner operator was performed since this occupation may be exposed to high concentrations of dust. The data were filtered to tabulate the number of compliance samples over the 2.0 mg/m³ standard. The number of samples exceeding the reduced dust standard due to high silica content was also calculated. A ratio comparing the frequency the 2.0 mg/m³ standard was exceeded to the overall number of data entries for the particular mine was calculated. A second ratio was calculated to determine the number of times the mine exceeded the reduced dust standard. The percentage of samples that exceeded the dust standards were compared with other mines percentages in the district to determine the targeted mines for this study. Figure 1 is an example of an MSIS graph for district 4. This example identifies the mines exceeding the current applicable standards.

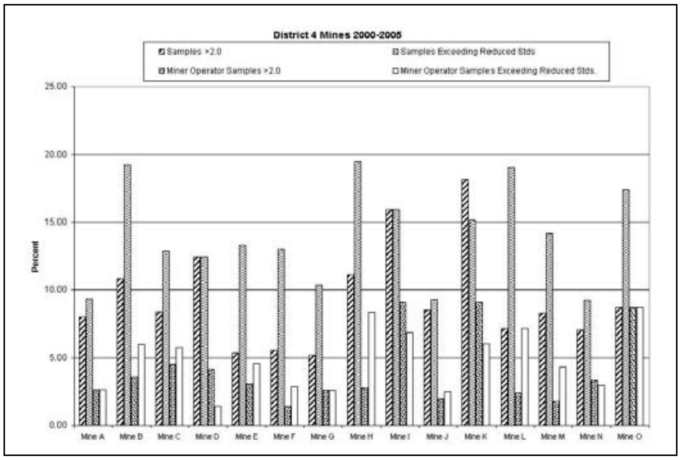

Figure 1. MSIS graph showing target mine percentages of samples exceeding the standards.

The mines targeted for this study not only consisted of mines with high percentage exceeding the applicable standard but also those mines with low percentages of samples that exceeded the applicable standard. A 5% criterion was utilized to identify a number of mines from each district for further evaluation. Those mines that had 5% or above incidences where they exceeded the applicable standard were listed as target mines. The MSIS analysis proved to be a useful method to identify targeted mines for this study; however difficulty in finding active mines for follow-up presented a problem. Initial runs of the database included data from calendar years 1990-2005 however, upon further research of targeted mines, many of the subject mines were no longer operating. A subsequent analysis of the MSIS database for the calendar years 2000-2005 resulted in an increase in active mines. In addition to identifying active mines, the rationale behind the 2000-2005 timeframe was to target mines utilizing current dust control technology and methods. A list of targeted mines was compiled for each MSHA district.

NIOSH researchers also included the mines listed on MSHA's Respirable Dust Emphasis Program (RDEP). The RDEP list identifies mines experiencing compliance problems having been cited at least two or more times during the previous fiscal year for excessive dust. Several of the mines identified through the MSIS analysis were on the RDEP list.

MSHA DOCUMENTATION REVIEW

The next step in the investigation involved visits to selected MSHA District Offices to examine the inspector reports and dust control plans for the targeted mines. These reports contained detailed information regarding the mine's operation, equipment, and dust control practices that were observed at the time of the sampling inspection. The most recently completed MSHA Form 2000-86, Respirable Dust Sampling and Monitoring Data, was examined for each of the targeted mines. These completed forms contain information such as the mine conditions, mining equipment utilized, the number of times that the mine entity or the mine was cited for excessive dust, water spray pressures, ventilation types, air measurements and equipment maintenance schedules. Many of the targeted mines had more than one mechanized mining unit (MMU) report in their files. Each MMU report for the particular mine was reviewed.

RESULTS OF MSIS DATA AND MSHA DOCUMENTATION REVIEW

Table 1 shows the number of mines identified in each selection category for each MSHA district. Antao et al. stated that the miners who had developed the rapidly progressive CWP were more likely to have worked in "small mines" with fewer than 50 employees (Antao et al., 2004). MSHA defines a "small mine" as one having fewer than 20 employees. While the MSIS study does show a higher percentage of mines with number of employees below 50, it should be noted there were several large operations that exceeded the applicable dust standards and there were several small mines with low employment numbers that had very few occurrences where their dust samples exceeded the applicable dust standards. It should be noted that small mines (<50 employees) are the majority of the active underground coal mines in districts 4, 5, 6, and 7. Table 2 shows the number of active underground small mines and the total number of active underground mines for each district.

Table 1. Number of mines per category for each MSHA district.

MSHA Coal District	Mines Exceeding the Applicable Standards	RDEP Mines	Mines in Compliance with the Applicable Standards
4	7 (43%<50 employees)	7 (57%<50 employees)	7 (43%<50 employees)
5	5 (90%<50 employees)	3 (50%<50 employees)	8 (50%<50 employees)
6	6 (83%<50 employees)	4 (50%<50 employees)	8 (75%<50 employees)
7	4 (66%<50 employees)	3 (33%<50 employees)	5 (80%<50 employees)

Table 2. Number of active small (<50 employees) and total number of active underground coalmines in MSHA districts 4, 5, 6, and 7. Source: MSHA Oracle database December, 2008

MSHA District	Number of Small Underground Mines	Total Active Underground Mines
4	85	148
5	39	53
6	88	105
7	50	70
Total	262	373

The documents reviewed at MSHA district offices revealed some interesting information concerning mining conditions in the SAR. The documents listed the dust control parameters in the approved mine ventilation plan, ventilation measurements, curtain setback, machine maintenance, operational sprays, and scrubber airflows at the time of the MSHA sampling inspection. What did stand out was the amount of rock being cut at these mines. On average, MSHA inspectors recorded a ratio of 20 to 30 percent rock to overall roof height. Figure 2 shows the average percentages of rock cut as compared to the roof height for each MSHA district targeted mine category.

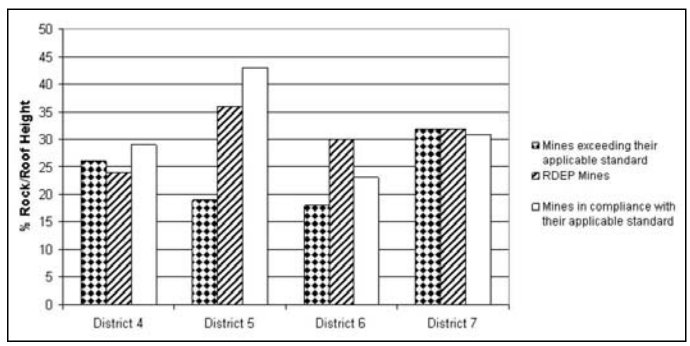

Figure 2. Percentage of rock cut to mine roof height for targeted mines.

It should be noted that according to MSHA's compliance data, several of the mines were successfully meeting the applicable standards under the same difficult mining conditions. Many of these mines also had fewer than 50 employees; suggesting that some "small" mines are capable of maintaining dust concentrations within applicable standards even with limited equipment and personnel resources. Table 3 lists the number of active mines in each of the MSHA districts and those on a reduced standard as of April 2, 2008. Districts 4, 5, 6, and 7 clearly have more active mines than the other MSHA districts. Also, these districts account for the highest percentage of mines on reduced standards.

Table 3. Mines on Reduced Standards for MSHA districts as of April 2, 2008. Source: US Department of Labor, Mine Safety and Health Administration, Program Evaluation and Information Resources, MSHA Standardized Information System, Arlington, VA.

District	Underground[1]		
	Active Status	w/Reduced Stds	
		#	%
1	10	3	30%
2	31	14	45%
3	31	5	16%
4	130	73	56%
5	57	38	67%
6	86	39	45%
7	62	36	58%
8	16	5	31%
9	22	6	27%
10	9	1	11%
11	7	6	86%
All	**461**	**226**	**49%**

[1] Mines with one or more MMUs/Roof Bolter Designated Areas on a reduced dust standard.

MSHA data shows that operations mining an extended cut utilized flooded-bed scrubbers. All of the MMUs reviewed in district 4 were using scrubbers. Besides utilizing flooded-bed scrubbers, mines may also use continuous ripper miners equipped with directional spray systems or spray fan systems utilizing hollow cone water spray manifolds. However, MMUs with spray fan systems are prohibited from taking extended cuts. The water sprays become effective air movers as the water pressure increases, but this airflow can create turbulence that can push dust towards the miner operator and increase the operator's exposure (Jankowski et al., 1987). There were four MMUs in district 5 utilizing fan spray systems, two of which were at mines exceeding the applicable standards. One was on the RDEP list, and the other was at a mine in compliance with their applicable standard. The other 14 MMUs examined in district 5 were utilizing scrubbers. District 6 had only one MMU listed as using a fan spray system which was at a mine on the RDEP list. The other 24 MMUs examined in district 6 had miners equipped with scrubbers. District 7 had two MMUs listed as using a fan spray systems at a mine in compliance with their applicable standard. The other 19 MMUs examined were using scrubber equipped miners.

Table 4 lists the face ventilation types used by the mines in this study. While exhaust curtain appears to be the preferred method, there were numerous MMUs operating with both exhaust and blowing face ventilation. A clear pattern of face ventilation types versus mines exceeding their applicable standard or mines in compliance with their applicable standard was not readily apparent.

Table 4. Face ventilation types utilized in targeted mines.

MSHA District	Mines Exceeding Their Applicable Standard	RDEP Mines	Mines in Compliance With Their Applicable
4	(13 MMUs) 8 Exhaust Curtain 2 Blowing Curtain 3 Both	(10 MMUs) 7 Exhaust Curtain 1 Blowing Curtain 2 Both	(12 MMUs) 9 Exhaust Curtain 1 Blowing Curtain 2 Both
5	(10 MMUs) 10 Exhaust Curtain	(2 MMUs) 2 Exhaust Curtain	(6 MMUs) 6 Exhaust Curtain
6	(12 MMUs) 6 Exhaust Curtain 1 Blowing 5 Both	(7 MMUs) 2 Blowing 5 Both	(6 MMUs) 1 Blowing 5 Both
7	(5 MMUs) 1 Blowing 4 Both	(6 MMUs) 6 Both	(9 MMUs) 9 Both

DUST SURVEYS

Mine dust and ventilation surveys were scheduled at cooperative mines to investigate and confirm findings from the district reports, as well as, to indentify operating conditions not obvious in the reports. Surveys focused on measuring the dust exposure of the continuous miner operators, roof bolters, and shuttle car operators and area sampling of the intake and return of continuous miner and roof bolter. The surveys typically consisted of three consecutive days of sampling and observation during normal production. Time studies were conducted to track continuous miner cuts, shuttle car and roof bolter locations, and various other operations which may influence dust exposure readings. Curtain setback and configuration were noted for each cut. Face ventilation measurements were taken with a vane anemometer at the beginning of all cuts.

Thermo MIE Personal Data RAMs (pDR™) were utilized to record dust concentrations during the surveys. The pDR is a real-time aerosol monitor with logging capability. The typical sampling package consisted of a pDR and two MSA[1] Elf™ sampling pumps (calibrated to 2 liters per minute) with pre-weighed 37-mm MSA[1] filters and 10-mm nylon cyclones. The pDR provided a relative measure of dust levels and by utilizing two gravimetric samplers on the sampling rack, a correction factor was calculated for the pDR measurements. The MSA filters were post-weighed for dust concentration and then sent to an independent laboratory for silica analysis. Prior to each cut, the sampling packages were set in the intake and return of the targeted machine(s). The sampling pumps were run for the duration of the cut or operation of the machine and placed on hold during the move to the next cut. The pDR monitors were left in logging mode since they had real-time capability. This procedure enabled the NIOSH researchers to analyze dust generation on a cut by cut basis and observe real-time dust levels at the specified sampling locations. Utilizing time study observations, researchers were able to associate dust levels with the machine/individual operations.

A personal dust monitor (PDM) (Thermo Fisher Scientific Corporation, Franklin, MA)[1] was placed on the miner and bolter operator(s) and the shuttle car operator(s) to provide end-of-shift measurements of their dust exposure. Various maintenance tasks such as bit replacement, scrubber maintenance, bolter dust box cleaning, and spray maintenance were observed and noted. Also, water spray types were noted and water spray pressures were measured at the spray nozzle.

SURVEY RESULTS AND DISCUSSION

NIOSH has completed six surveys to date at targeted mines in MSHA districts 4, 5, 6, and 7. The mines varied in size from very small operations with crew sizes of approximately 8 men to large operations utilizing super sections where two continuous miners were operating sequentially and were developing panels for longwall mining. On a super section, only one miner was operating at a given time.

While these mines varied as far as crew size, equipment types and sizes, and production rates, all mined through substantial rock layers. Rock thickness for 5 of the mines surveyed varied from 15.2 cm (6 in.) to 30.48 cm (1 ft.). One mine was cutting 0.9 m (3 ft.) of sandstone in order to maintain the roof height. The roof rock conditions encountered at this mine changed the status of this mine from a mine in compliance with their applicable standard to a mine exceeding their applicable standard and faced with complying with a reduced standard. Figure 3 is a box and whisker plot of the PDM gravimetric sampling concentration ranges obtained from the dust surveys. While the median values are below 2.0 mg/m³ for all of the occupations, the higher ranges of the continuous miner operator may have been due to operator positioning or dust roll-back. There are two points on the plot of the shuttle car operator which are shown as outliers.

MSHA P7 silica analysis results have been received on the area sampler filters of four of the six mines surveyed. Figure 4 is a box and whisker plot of the percent alpha quartz results from four of the mines surveyed.

Mining through rock requires not only controlling respirable dust at lower concentrations, but also increased maintenance of extraction equipment due to the hardness of rock compared to coal. Cutting bit life is drastically reduced whenever severe rock conditions are encountered. As the bits wear, more dust is generated (Khair et al., 1999) and scrubber maintenance soon becomes an issue. Figure 5 is a picture of two continuous miner bits. The bit on the left was retrieved after a bit change on a continuous miner during a recent dust survey. The bit on the right is a new bit which clearly shows the carbide cutting tip.

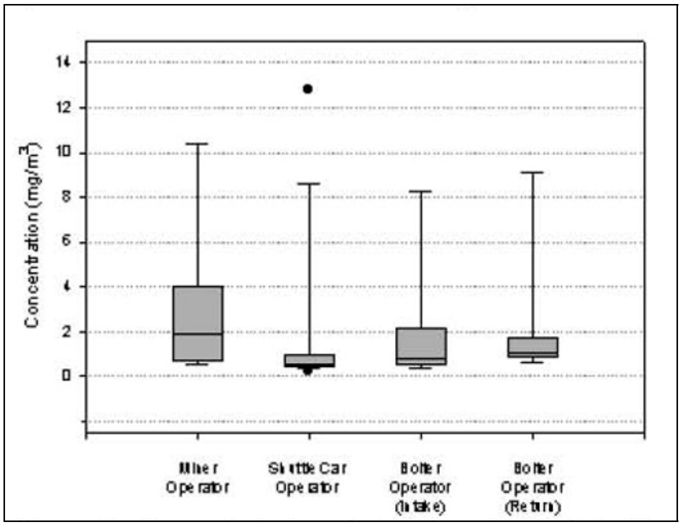

Figure 3. Box and whisker plot of the end-of-shift PDM gravimetric sampling concentrations.

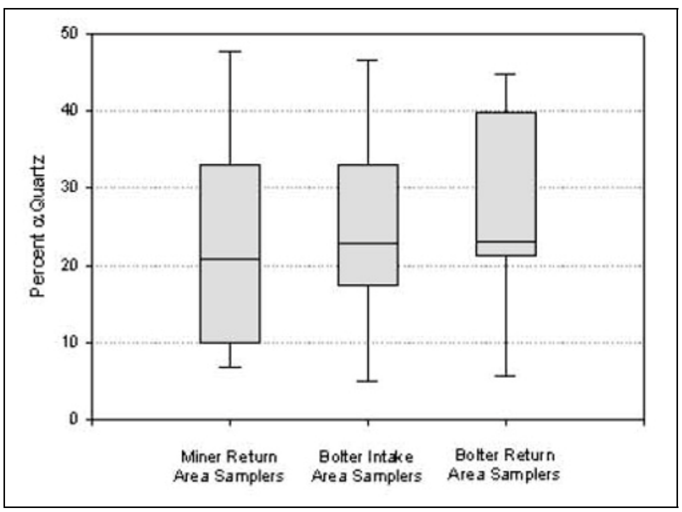

Figure 4. Box and whisker plot of the percent alpha quartz from the continuous miner return, bolter intake, and bolter return area samplers.

When bits become worn below the carbide tip, they no longer cut, they grind. Grinding generates more airborne dust, often in quantities that the sprays and scrubber cannot keep up with, leading to increased exposure of miners. Attention to bit wear is critical when mines are cutting rock. Bit changes, clearing clogged water sprays and scrubber maintenance may be required every time the miner relocates to another cut. While this may seem excessive, it is necessary to adequately control dust when mining in the conditions observed during these six surveys.

Another common observation during these mine surveys was the frequency of roof bolters working downwind of the continuous miner. In these conditions, roof bolters may very easily be exposed to unacceptable dust concentrations. Mines must minimize if not eliminate downwind bolting where results from respirable dust samples demonstrate high quartz percentages as seen in Figure 4.

Also common to the bolter operations of the mines surveyed was inadequate ventilation of the bolter faces. The dust control plans for these mines listed the minimum airflow to the bolter face to be 84.96 m^3/min. (3,000 cfm.). There were numerous periods noted where the bolting face had very limited if any airflow to the face. The use of line curtains to direct the air through the working area and reduce the dust concentrations was recommended during these surveys. There were several mines observed that took the time and effort to properly install and anchor the line curtains and as a result, had lower dust exposure to the miners.

Figure 5. Comparison of worn miner bit to a new bit.

SUMMARY

A majority of mines located in the SAR are faced with difficult mining conditions that may be contributing to an increase in rapidly progressive CWP. The "easy" coal of yesterday has already been mined. The mines of today are faced with mining thick layers of quartz-bearing rock, which rapidly wears miner bits and creates maintenance problems for the machine and dust control systems. MSHA inspector reports that were reviewed have shown the mining of rock to be a common occurrence in the mines identified through the MSIS study. As a result, MSHA districts 4, 5, 6, and 7 account for the highest percentage of mines on reduced standards due to the presence of high quartz levels in the working environment.

Dust surveys were conducted at six targeted mines to observe their operations and examine their dust control equipment and methods to determine commonalities or note any differences that were not evident from the inspector reports. The surveys to date have confirmed the findings of the inspector reports concerning the amounts of rock that the mines are cutting. As the proportion of rock cut increases, a corresponding increase in machine preventative maintenance must occur. An increase of bit, scrubber, and spray maintenance will likely be required to control the dust levels encountered by these mines operating in these conditions.

Another common occurrence noted during the surveys was the lack of proper ventilation at the bolting faces. This deficiency is made more critical given the frequency of bolter crews working downwind of the continuous miner. The ventilation of the bolting face is often overlooked because high volumes of dust are not visible as compared to a continuous miner face. Thus, a false sense of security may exist. Bolting face ventilation and maintenance of the bolter's dust control system is critical to protect the miners working in these areas. Dust samples with high quartz percentages are prevalent in the SAR. Efforts must be made to protect the workers who are drilling into quartz-bearing strata and are working directly in the continuous miner return air path.

NIOSH is continuing this study at other targeted mines throughout the SAR and in the interim, mines must be cognizant of the increased health hazards which follow mining excessive amounts of rock. Mines overall, must be aware that maintenance of their dust control systems, worn bit replacements, scrubber maintenance, proper ventilation, and the reduction of down-wind operations is crucial in order to protect their miners from dust related illnesses and stop this increasing CWP trend.

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