A REVIEW OF OCCUPATIONAL SILICA EXPOSURES ON CONTINUOUS MINING OPERATIONS

Gerrit V.R. Goodman, Jeffrey M. Listak, and John A. Organiscak

Pittsburgh Research Laboratory
National Institute for Occupational Safety and Health

ABSTRACT

Data on dust control practices, geology, and occupational exposures were gathered for approximately eighty underground continuous mining units. Despite silica contents in excess of 5%, nearly forty units successfully maintained silica concentrations at or below 100 $\mu g/m^3$ on a majority of occupational dust samples while the remainder had difficulty maintaining this level. These two sample sets were termed group A operations and group B operations, respectively.

Analyses of productivities, geologies, and dust control parameters revealed only minor differences between these two groups. Subsequent analyses of face ventilation design showed considerable differences in silica exposure and silica content between group A and group B at the continuous mining machine and roof bolter operator occupations. These differences were minimal when using exhaust curtain ventilation with a dust scrubber. This face ventilation system may benefit operations having difficulty controlling silica dust exposure and silica dust content.

Finally, the collected data showed that occupational samples from group B operations possessed generally higher silica exposures and silica content than similar samples from group A. The single head roof bolter (helper) possessed among the highest silica exposures and silica contents in both groups.

INTRODUCTION

The Federal Coal Mine Health and Safety Act limits the respirable dust exposure of mine workers to a time weighted average of 2.0 mg/m^3 for a working shift (1). If the respirable dust sample contains more than 5 percent silica by weight, the dust standard is reduced according to the formula 10 ÷ (%silica). This maintains silica dust levels at or below 100 $\mu g/m^3$.

The process of adjusting the respirable dust standard is discussed by others (2-4) and is based upon the silica content of dust samples collected by coal mine operators and by Mine Safety and Health Administration (MSHA) coal mine inspectors. Such sampling is conducted for eight hours at 2.0 liters/min using a 10-mm nylon cyclone preseparator. On continuous mining operations, samples analyzed for silica content are typically collected at mining machine operator and roof bolter operator occupations.

Typically the dustiest occupation at each production unit, mining machine operator samples are used to adjust the respirable dust standard for the entire mining unit with the understanding that the reduced standard will protect all other occupations. Due to a variety of factors (5), however, silica dust levels at roof bolter occupations often can exceed silica levels found at the continuous mining machine. To provide additional protection, MSHA may require more frequent sampling of roof bolter occupations by the mine operator.

A number of studies have defined trends in silica dust exposures for the underground coal mining industry (2,3). These analyses revealed that for the period July 1991 through 1992, more than 40% of the continuous mining machine operator and machine helper samples exceeded 5% silica. Between 25 and 30% of the operator and helper samples exceeded 100 Fg/m^3 for respirable silica. For this same period, roughly 50 to nearly 70% of the roof bolter operator and helper samples exceeded 5% silica. Thirty to forty percent of the samples exceeded 100 Fg/m^3.

Comparisons of two groups of operations provided insight into potential causes of silica dust exposures. One group, despite high silica dust content, successfully controlled occupational exposures. The second group could not successfully control exposures. This required examinations of dust control practices, work practices, geologic conditions, and corresponding occupational exposures for operations in each of these two groups.

Such information was available at MSHA field offices. Data on approved dust control practices and work practices were part of the dust control plan established for each underground coal operation. Actual operating conditions plus corresponding occupational exposures were found in reports filed by MSHA coal mine inspectors after sampling at these operations. This study only used exposure data from MSHA compliance sampling in lieu of exposure data from mine operator compliance sampling.

The two groups were identified through examinations of the MSHA coal mine silica data base that contains all compliance samples analyzed for silica after 1981. Nearly 97,000 silica records are represented in the period 1982-1996. Each sample record contains considerable information, such as MSHA mine identification number, mining unit designation, sample date, sampling time, occupation sampled, pre and post filter weights, and silica percentage. From this data, respirable dust and respirable silica dust concentrations were calculated.

Due to the large number of underground coal mining operations represented in the database and the need to gather dust plan and MSHA exposure data from each operation, only a very small subset of these operations could be considered for the study. For this reason, several restrictions were placed on the selection of a particular mining operation.

Only operations in southern West Virginia, southwestern Virginia, northeastern Kentucky, and southeastern Kentucky were considered. Prior to the start of this study, MSHA suggested that these areas be considered due to their high prevalence of silica exposure.

When this survey began, October 1997 compliance sampling data was the most current available from MSHA. Identification of operations for this study was based upon the results of MSHA compliance sampling at the continuous mining machine operator and roof bolter operator occupations for the period January 1997 to October 1997. Pre-1997 sampling data was not used to keep this information as current as possible.

For this study, two groups of operations were identified in each area. The first group contained those operations with a majority of samples exceeding 5% silica and having silica dust concentrations less than or equal to 100 Fg/m^3 (group A operations). The last group contained those operations with a majority of samples exceeding both 5% silica and 100 Fg/m^3 (group B operations). Eighty operations initially were considered in this study, forty able to maintain respirable silica dust levels on a majority of compliance samples at or below 100 Fg/m^3 and forty unable to maintain a majority of samples below this level. During visits to the various MSHA field offices, we discovered that some operations were no longer producing. Because current exposure data was not available for these operations, they were dropped from further consideration. The study examined 39 underground coal mining operations in group A and 36 operations in group B. These operations were selected from a population of nearly 700 operations in these geographic areas.

MSHA field offices were visited and data gathered from the approved dust control plan for each of the selected underground mining operations in that district. MSHA mine inspector reports for each operation were reviewed to note dust control practices and to note corresponding occupational exposures to respirable silica and coal mine dusts (table I). The data gathered from these visits produced a history of occupational exposure for these mining operations from January 1997 to an approximate end date of June 1998 to October 1998 (end dates differed because the districts were not visited in the same month).

Table I. Distribution of occupational exposures for two sample groups

Occupation sampled	Number of occupational samples in group A operations		Number of occupational samples in group B operations	
	≤ 100μg/m^3	> 100μg/m^3	≤ 100μg/m^3	> 100μg/m^3
Continuous miner operator	177	60	63	88
Twin head roof bolter (return side operator)	60	8	11	34
Twin head roof bolter (intake side operator)	50	11	11	35
Single head roof bolter (operator)	58	12	22	39
Single head roof bolter (helper)	15	4	5	14

EVALUATION OF GENERAL CHARACTERISTICS

General characteristics for group A operations and group B operations are given in table II. These include daily tonnage produced, coal thickness mined, and rock thickness mined during sampling by the MSHA mine inspector. Also given are values for various dust control parameters (face ventilation quantity, scrubber quantity, spray count, and water pressure) as measured by the coal mine inspector during sampling.

Maximum, minimum, and median values categorize the distribution of values for each characteristic. Differences in sample size between group A and B operations are attributed to the number of operations in each group and the extent of sampling at each operation.

Table II. Characteristics of operations in two sample groups

Characteristic	Group A Operations			Group B Operations		
	Number of samples	Range of values	Median value	Number of samples	Range of values	Median value
Production (tons)	384	96-2700	600	226	85-2520	572
Coal thickness (inches)	318	4-108	48	162	0-126	42
Rock thickness (inches)	315	0-60	8	162	0-96	8
Face ventilation flow (cfm)	325	1080-49500	6462	203	2024-45360	6500
Scrubber flow (cfm)	133	3000-11600	5034	53	2580-13099	5600
Spray count	313	18-50	27	188	14-58	25
Spray pressure (psi)	313	50-280	90	195	50-260	85

Notes:

1. Face ventilation flow is amount of air flowing to the continuous miner.
2. Spray count is the number of water sprays on the continuous mining machine.

This data shows small differences in dust control parameters and geologic conditions for operations in groups A and B. Group A operations produced roughly 5% more than Group B operations. Ranges of coal and rock thicknesses were greater for Group B operations than Group A operations. The range of face ventilation values was greater for group A than group B although median values were similar. While the range of scrubber airflows was similar, the median value was greater for B operations than group A operations. Water spray count and spray pressure were consistent between the two groups.

Although data was available on rock thicknesses, little information was available on the composition of rock present at the cutting face. Previous work (6,8) showed that the silica content in the roof, floor, or parting material could influence the amount of respirable silica generated during the mining process.

Previous work showed that a number of factors could potentially impact occupational silica dust exposures and silica dust contents in underground coal mining. Dust control practices such as ventilation airflow, flooded-bed dust scrubber quantity, water spray quantity and pressure, and water spray configuration influence silica dust exposures (4). Dust control practices operating in the ranges given in table II have more effect on silica exposures than silica contents. With MSHA's presence during sampling, it is likely that good execution of the dust control plan occurred. When evaluating the collected data, silica exposures were assumed as indicators of dust control effectiveness on that mining unit.

Work practices affect silica content, for instance, using a modified cutting scheme to avoid grinding of parting rock (4), avoiding the use of worn cutting bits (5), minimizing the time the roof bolter works downwind of the continuous mining machine (6), and maintenance of dust control systems. Geologic conditions at the mining unit (such as rock parting type, thickness, and silica content) affect silica content (7,8). For these analyses, silica content was assumed as an indicator of either work practices or geologic conditions on the mining unit.

ASSESSMENTS OF FACE VENTILATION

Four basic types of face ventilation systems were noted in reviews of MSHA mine inspector reports.

1. Exhaust ventilation curtain with dust control provided by a machine-mounted flooded-bed dust scrubber.
2. Exhaust ventilation curtain with water sprays on the mining machine arranged in either a sprayfan or other directional face spray design.
3. Combination system using intake curtains to ventilate faces on one side of the section belt entry and exhaust curtains to ventilate faces on the other side. This system reduced the number of drive-through check curtains between each face and the feeder-breaker in the belt entry. Dust control provided by a flooded bed dust scrubber.
4. Intake or blowing ventilation curtain with a flooded-bed scrubber for dust control. However, this face ventilation scheme was not widely represented in the accumulated data and, for this reason, was not evaluated further in this study.

Occupational exposures were noted when the continuous mining machine operator was sampled concurrently with the roof bolter operator. Table III compares minimum, maximum, and median values for silica dust exposure and silica content at the mining machine operator occupation for group A and group B operations.

This data in table III shows that all face ventilation designs were equally represented in group A operations while group B operations used combination curtain face ventilation by nearly two-to-one margin over other ventilation schemes. Group A silica exposures generally were much less for all face ventilation schemes with the exception of the exhaust curtain with dust scrubber. For group B operations, silica exposures were less using this ventilation scheme. Silica content levels were much less for group A operations than for group B operations.

Table III. Distribution of silica exposures and silica contents at continuous mining machine operator occupations for groups A and B operations.

Ventilation Scheme	Number of samples	Group	Silica exposures ($\mu g/m^3$)		Silica contents (%)	
			Range of values	Median value	Range of values	Median value
Exhaust curtain with scrubber	59 31	A B	16-312 1-532	90 150	1-17 0-16	6 9
Exhaust curtain with directional spray designs	57 31	A B	2-260 20-946	100 210	0-14 2-25	8 11
Combination curtain system	62 55	A B	3-549 40-571	90 180	2-14 7-22	8 11

These data suggest that dust control effectiveness for group A operations generally was superior to that for group B operations for all face ventilation schemes except when using exhaust curtain with a scrubber. The high silica contents of group B show that this group of operations likely suffered from poor work practices or inferior geologic conditions compared to group A operations.

Roof bolter exposures were more difficult to assess because their position could change with respect to the fresh airflow of the face ventilation curtain. While being sampled by the MSHA mine inspector, the roof bolter(s) could move upstream or downstream of the continuous mining machine, thus changing environmental conditions for roof bolter occupations. Unfortunately, information of this type was seldom available from MSHA reports.

A comparison of silica exposures and contents at roof bolter occupations for group A and B operations is given in table IV. This data show that, for all three face ventilation designs, bolter occupation silica exposures were highest for group B operations. The difference between A and B operations was greatest when using exhaust curtain face ventilation with directional sprays or combination curtain face ventilation. Differences were less when using exhaust curtain ventilation with a scrubber. Silica contents for roof bolter occupations in group A operations were less than those measured in group B operations. This suggests improved work practices or geologic conditions for group A operations.

Table IV. Distribution of silica exposures and contents at roof bolter occupations for group A and B operations.

Ventilation Scheme	Number of samples	Group	Silica exposures ($\mu g/m^3$)		Silica contents (%)	
			Range of values	Median value	Range of values	Median value
Exhaust curtain with scrubber	59 31	A B	0-364 17-381	80 150	0-24 5-21	9 11
Exhaust curtain with directional spray designs	57 31	A B	0-259 20-1771	80 210	0-14 5-77	8 14
Combination curtain system	62 55	A B	20-303 40-571	90 190	2-16 7-28	10 12

The data show that differences in group A and group B silica exposures for mining machine and roof bolter operator occupations were minimized when using exhaust curtain face ventilation with a dust scrubber. Using either exhaust curtain ventilation with directional sprays or combination curtain ventilation, group B operations were unable to control occupational silica exposures at either the mining machine or roof bolter occupations. It appears that operations able to control silica exposures for mining machine operator occupations were able to control exposures for roof bolter occupations.

The data also suggest that operations having difficulty controlling silica dust exposures may benefit from using exhaust curtain ventilation with a dust scrubber. This scheme is not affected as much by high intake air velocities as is blowing curtain ventilation. Past work showed that high air velocities issuing from the mouth of a blowing curtain could disrupt capture of respirable dust by blowing the dust cloud around the mining machine (9). Also, positioning of the mining machine operator is not as critical to controlling this person's occupational exposure when using exhaust curtain ventilation. The operator has some latitude in movement as long as this person remains outby the curtain mouth. However, the operator must remain within the mouth of the blowing curtain to control occupational dust exposures (10). Three, exhaust curtain ventilation with a dust scrubber does not produce high dust gradients around the mining machine as can occur with the sprayfan system. These high dust gradients also can affect occupational exposures of the roof bolter operator when working downwind.

ASSESSMENTS OF OCCUPATIONAL EXPOSURES

Data on silica exposures and silica percentages were categorized according to worker occupation for group A and B operations (table V). Much of the exposure data is given for the continuous mining machine operator. The remaining roof bolter occupations, with exception of the single head roof bolter helper, had similar numbers of samples in this study. Silica data were available for other non-bolting occupations. However, these samples were not very numerous and, consequently, were not reported.

Table V. Distribution of silica exposures and contents for continuous mining and roof bolting occupations in group A and B operations.

Occupation	Number of samples	Group	Silica exposures ($\mu g/m^3$)		Silica contents (%)	
			Range of values	Median value	Range of values	Median value
Continuous mining machine operator	321 192	A B	1-664 1-1149	90 100	0-37 0-34	8 9
Twin boom roof bolter (intake side operator)	77 52	A B	8-340 10-583	70 150	1-23 1-74	10 12
Twin boom roof bolter (return side operator)	70 54	A B	10-329 4-653	70 200	2-21 0-27	9 13
Single boom roof bolter operator	86 67	A B	0-263 1-1771	80 200	0-35 0-39	8 14
Single boom roof bolter (helper)	22 20	A B	7-644 4-740	90 280	1-17 2-21	9 14

This data show that silica exposures and silica contents at all occupations were higher for group B operations than group A operations. Variations in exposures and contents suggest that these differences were attributable to changes in dust control effectiveness, work practices, and geologic conditions.

The single head roof bolter (helper) possessed among the highest silica exposures and silica contents in group A and B operations. This suggests less effective dust controls, inappropriate work practices, and poorer geologic conditions at this occupation for group A and B operations. It is also possible that the bolter helper engaged in activities that put this person at risk for increased exposure to silica. These would include emptying the dust box and cleaning the dust filters.

SUMMARY

Data on dust control parameters, geology, and corresponding silica exposures was gathered for nearly forty operations that, despite silica content in excess of 5%, were able to maintain silica dust levels in a majority of occupational samples at or below 100 $\mu g/m^3$. Approximately forty other operations were identified that were unable to maintain a majority of occupational samples less than or equal to100 $\mu g/m^3$. These two subsets were termed group A and group B operations, respectively.

Evaluations of geologic and dust control parameters generally revealed only minor differences between group A and group B operations. Subsequent assessments of face ventilation design showed that group B operations suffered from higher silica exposures and contents at continuous mining machine and roof bolter occupations. However, these differences were minimized when using exhaust curtain ventilation with a dust scrubber. This face ventilation system may benefit those operations having difficulty controlling occupational silica exposures.

These evaluations also revealed that occupational silica exposures and silica contents were higher for group B operations than group A operations. In both groups, the single head roof bolter (helper) occupation possessed among the highest silica exposures and silica contents. It is possible that this occupation engaged in activities that put this individual at risk for overexposure to respirable silica.

REFERENCES

1. Mineral Resources. Code of Federal Regulations Title 30, Parts 70 and 75, U.S. Government Printing Office.

2. Tomb, TF, Gero AJ, Kogut J [1995]. Analysis of quartz exposure data obtained from underground and surface coal mining operations. Appl. Occup. Environ. Hyg.10(12): 1019-1026.

3. Ainsworth SM, Gero AJ, Parobeck PS, Tomb TF [1995]. Quartz exposure levels in the underground and surface coal mining industry. Am. Ind. Hyg Assoc. J., 56(10):1002-1007.

4. Jankowski RA, Niewiadomski GE [1987]. Coal mine quartz dust control, an overview of current U.S. regulation and recent research results. Proceedings, Intl. Symp. on Coal Mining and Safety, Soeul, Korea, pp. 303-313.

5. Colinet JF, Shirey GA, Kost JA [1985]. Control of respirable quartz on continuous mining sections. Contract J0338033, US Bureau of Mines, June, 90 pp.

6. Organiscak JA, Khair AW, Ahmad M [1995]. Studies of bit wear and respirable dust generation. Soc. Mining Eng. Transactions 298:1874-1879.

7. Organiscak JA, Page SJ, Jankowski, RA [1990]. Sources and characteristics of quartz dust in coal mines. Information Circular 9271, US Bureau of Mines, 21 pp.

8. Taylor LD, Thakur PC, Riester, JB [1986]. Control of respirable quartz on continuous mining sections. Contract J0338077, US Bureau of Mines, 67 pp.

9. Schultz MJ, Fields KG [1999]. Dust control considerations for deep cut mining sections. SME Annual Mtg, Denver, CO, Preprint 99-163, 4 pp.

10. Goodman GVR, Listak JM [1999]. Variation in dust levels with continuous miner position. Min. Eng. 51(2): 53-58.