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Quartz Dust Sources During Overburden Drilling at Surface Coal Mines

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	min	minute
h	hour	mm	millimeter
mg	milligram	pct	percent
mg/m^3	milligram per cubic meter	s	second

QUARTZ DUST SOURCES DURING OVERBURDEN DRILLING AT SURFACE COAL MINES

By S. D. Maksimovic [1] and S. J. Page [2]

ABSTRACT

The Bureau of Mines identified and evaluated major sources of quartz dust during overburden drilling at a surface coal mine. The relative contribution of each source to the total dust hazard was estimated, using personal gravimetric and instantaneous dust-sampling devices. No attempt was made to determine actual dust generation rates.

The major sources of dust at the drill rig during dry drilling operations were the collector dump, drill shroud leakage, and drill stem seal leakage. These sources contributed 90 pct of the respirable dust and 89 pct of the respirable quartz dust generated during drilling. The collector dump cycle (21.6 pct of total drilling time) accounted for 38 pct of the respirable dust and 41 pct of the respirable quartz dust, with peak dust concentrations reaching 68 mg/m^3. Shroud and drill stem leakage contributed 28 and 24 pct of the respirable dust and 32 and 16 pct of the respirable quartz dust, respectively. A dragline and second drill rig contributed the remaining 10 pct of dust and 11 pct of quartz dust.

Gravimetric dust samples collected inside the drill cab and outside, near the cab door, averaged 1.65 and 1.43 mg/m^3, respectively, with 6 pct respirable quartz.

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INTRODUCTION

The U.S. Mine Safety and Health Administration (MSHA) regulations require that respirable dust exposures do not exceed 2.0 mg/m^3 in surface coal mine operations where the respirable quartz content of the dust is 5 pct or less. If the respirable quartz content of the dust is greater than 5 pct, the amount of allowable dust is reduced and is calculated by the formula

$$\frac{10 \text{ mg/m}^3}{\text{pct quartz}}.$$

Complying with reduced-dust standards due to a quartz content in excess of 5 pct is a significant problem in surface mining. As of July 1984, there were more than 550 designated work positions (DWP's) on reduced-dust standards. The average standard for these surface operations was 0.8 mg/m^3.

According to MSHA data, the occupations with the greatest exposure to quartz are, in order of severity, (1) highwall driller, (2) drill helper, (3) truck driver, and (4) bulldozer operator.

The highwall driller and drill helper receive the greatest quartz exposure since they are concerned only with overburden removal. Drilling through various rock formations naturally presents a strong potential for quartz dust generation; this is substantiated by the fact that many drills are on reduced standards ranging from 0.1 to 0.5 mg/m^3. To date, no research has been performed that quantifies and ranks the sources of quartz dust and how they affect the respirable dust exposure of the above-mentioned occupations.

The objective of this study was to identify and investigate the respirable quartz dust sources and to estimate the respirable dust levels in the vicinity of these sources during the drilling of overburden material at surface coal mine operations. Inasmuch as dust generation rates were not determined, the study was semi-quantitative in nature.

PROCEDURE

The overburden materials in the mine area selected for study consisted of alluvial material, which includes brown, gray, and dark shale, clay, limestone, and sandstone. The thickness of the alluvial material ranged from 4 to 8 ft, and the total overburden from 64 to 117 ft. The depth of the holes drilled during the field studies ranged from 25 to 100 ft. Hole diameter was 6-3/4 in.

Approved personal gravimetric sampling devices with 10-mm nylon cyclones were operated during the work shift for 2 to 6 h (determined by drill operating time) at dust sources and around the drill rig. In general, a package of three samplers was located at each sampling point, and five to seven sampling points were used daily (fig. 1). Gravimetric samplers were located inside the drill cab, near the cab door, between the drill rig and dragline, between the drill rigs when a second rig was in operation, and at the collector discharge, drill stem, and drill shroud locations. The drill shroud location was the ground-shroud seam, and the drill stem location was on top of the drill platform. Multiple samplers were used at each sampling location to obtain

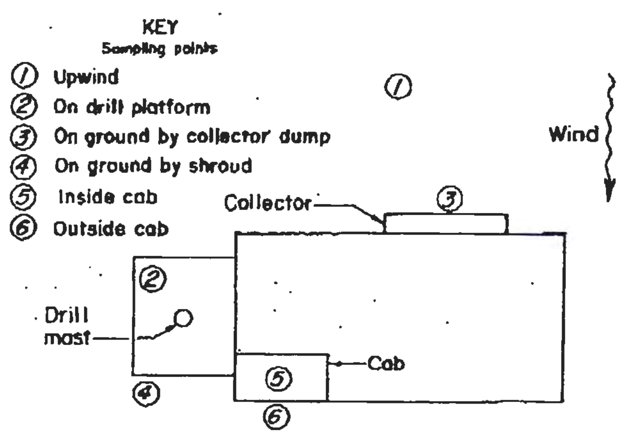

FIGURE 1. - Sampling arrangement for tests.

a more reliable estimate of the dust concentrations. In addition, the samplers were repositioned as necessary to minimize the effects of local wind shifts and eddy currents around the drill.

Respirable dust filters were preweighed and postweighed using standard procedures, and each package of three samplers was averaged to improve the measurements. For each package of three filters, any filter with a significantly higher mass was excluded from the calculation if Coulter counter analysis showed a significant amount of non-respirable-sized dust. One filter of sufficient mass (>0.2 mg) was chosen from each package for quartz analysis by the standard P-7 method.

Bulk samples of cutting material from around each drill hole and from the collector dump were collected and analyzed for quartz by X-ray diffraction. The drill-hole cuttings were sampled by taking a random scoop of material from each hole periphery. For each week of testing in December and February, the random scoops were combined into one gross sample. In April and June, the random scoops were combined daily to give one gross sample for each day of testing. Bulk samples from the collector dump were treated in the same manner. The sole purpose of collecting bulk samples was to obtain a rough estimate of the quartz content of the overburden. Therefore, specific techniques for obtaining representative bulk samples were not used.

Instantaneous dust concentrations were also continuously recorded using RAM-1[3] dust monitors and data loggers. These data, although not directly comparable with the gravimetric data, are valuable for analyzing specific occurrences that happen in too short a time period to be measured gravimetrically. The RAM-1 data were analyzed for time duration, maximum dust concentrations, and average dust concentrations during specific events of the drilling operation.

During sampling, a recording wind anemometer was used to measure wind direction and velocity, in order to maintain proper sampling locations during the tests.

GRAVIMETRIC RESULTS AND DISCUSSION

The collected gravimetric samples indicate that the drill rig used at the surface coal mine site has three major sources of dust during the dry drilling operations. Time-weighted averages (TWA's) of the analyses indicate that these are the collector dump (fig. 2), the drill shroud, and the drill stem. Combined, they contributed 90 pct of the total respirable dust and 89 pct of the respirable quartz dust measured during the 17-day sampling period.

Table 1 shows the gravimetric concentration of respirable dust for the various sources. Table 2 shows the respirable quartz concentrations. Although these tables show percentage contributions that total approximately 90 pct, the individual contributions may not be numerically correct. The reason for this is that during sampling under conditions with frequent wind direction shifts it is virtually impossible to prevent some "overlap" between sampling locations; i.e., each sampling location will measure some amount of dust from sources other than the one it is attempting to measure. Also, the amount of overlap cannot be reliably estimated. However, it is reasonable to state that the majority of dust sampled at any given location is due to the source that those samplers are attempting to measure. Therefore, the relative ranking of the collector dump, drill shroud, and drill stem dust sources is in order. Each source contribution was calculated from the ratio of the TWA for that source and the TWA sum.

Two other minor dust sources contributed only 10 pct of total respirable dust and 11 pct of total quartz dust. These were a dragline located between 200 and

[3]Reference to specific products does not imply endorsement by the Bureau of Mines.

FIGURE 2. - Typical dust emissions from drill collector dump cycle.

TABLE 1. - Gravimetric concentrations of respirable dust from dust sources

Source	Respirable dust,[1] mg/m³					Contribution to total, pct[2]
	Dec. 1983	Feb. 1984	Apr. 1984	June 1984	TWA	
Collector dumping.	ND	3.34	10.53	16.33	11.95	38
Drill shroud......	4.16	5.99	14.46	6.31	8.86	28
Drill stem........	8.01	26.82	2.64	8.10	7.55	24
Total........						90
Second drill rig..	7.49	.85	.31	1.02	2.94	9
Dragline..........	ND	.55	.05	.15	.35	1
Total........						10

ND Not determined.
[1]Concentrations are not Mining Research Establishment (MRE) equivalents.
[2]Corrected for background dust from dragline.

400 ft upwind and a second drill rig located within 15 to 100 ft of the first rig.

These dust concentrations do not necessarily reflect the actual exposure of the drill operator or helper to these sources. Since the measurements were made at the dust sources, they estimate only the relative magnitudes at the dust sources and, therefore, potential operator or helper exposures.

Gravimetric dust samples were also collected inside the drill cab and outside, near the cab door. The results are shown in table 3.

TABLE 2. - Respirable quartz concentrations from dust sources

Source	Respirable dust, mg/m³					Contribution to total, pct[1]
	Dec. 1983	Feb. 1984	Apr. 1984	June 1984	TWA	
Collector dumping..	0.25	0.22	0.81	1.10	0.72	41
Drill shroud.......	.28	.42	.75	.95	.57	32
Drill stem.........	.35	.11	.30	.40	.29	16
Total........	....	....	....	....	.....	89
Second drill rig...	.38	.06	.02	.16	.17	10
Dragline...........	ND	.02	ND	.01	.02	1
Total........	....	....	....	....	.....	11

ND Not determined.
[1]Corrected for background dust from dragline.

TABLE 3. - Gravimetric concentrations of respirable dust at drill operator

Location	Respirable dust,[1] mg/m³					Respirable quartz contribution to total dust, pct
	Dec. 1983	Feb. 1984	Apr. 1984	June 1984	TWA	
Inside the cab...	0.55	3.45	1.96	0.66	1.65	6
Near the cab....	.07	2.94	1.52	.48	1.43	6

[1]Concentrations are not MRE equivalents.

Since the cab door of the monitored drill rig was usually open during the sampling period, almost the same amount of respirable dust and quartz dust was measured inside and outside the cab. If the cab door were closed, there would be less dust inside the cab.

The average quartz content of all airborne respirable dust samples was 7 pct. In comparison, the average quartz content of the collector dump material was 21 pct, and the average quartz content of the drill-cutting material around the drill hole was 18 pct.

There were insufficient data to determine if weather or seasonal changes influenced the dust levels measured.

RAM-1 RESULTS

Table 4 summarizes the data obtained from sampling in the immediate vicinity of the collector dump point during four tests. The collector released dust during the sampling cycle, which occurred 21.6 pct of the time during sampling. The maximum values listed are the values measured during the collector dump cycle, which ranged from 16.0 to 68 mg/m³. The peak duration averages ranged from 4.4 to 25.1 mg/m³, and the cumulative test averages ranged from 2.2 to 4.2 mg/m³. However, data logger scaling limits in test 4 restricted the measurable concentration to 25.5 mg/m³. As a result of the significant number of truncated peaks, it is suspected that the data for test 4 may be significantly underestimated.

Results of RAM-1 sampling at the drill shroud and drill stem locations are presented in table 5 and show that maximum values ranged from 24.4 to 98 mg/m³. In addition, the number of peaks greater than 10, 20, and 40 mg/m³ are listed to show how severe the magnitudes and numbers of peaks are during short time periods. Cumulative test averages ranged from 3.2 mg/m³ to greater than 7.4 mg/m³. Both shroud and drill stem sampling locations represent leakage from the shroud. Analysis of the drill stem test in table 5 showed that changing or pulling drill rods accounted for 49 pct of the dust from that source; 40 pct of the dust was due to emissions during actual drilling; and the remaining 11 pct was due to dust

TABLE 4. - RAM-1 data for collector dump cycle sampling

Peak[1]	Peak duration: Time, min:s	Peak duration: pct of cumulative time	Peak concentration, mg/m³: Max value	Peak concentration, mg/m³: Duration av	Cumulative test av,[2] mg/m³
Test 1:					
1	1:24	1.7	18.6	7.9	NAp
2	2:48	3.4	19.2	4.6	
3	2:12	2.7	22.5	6.6	
4	4:24	5.3	20.2	5.5	
5	1:48	2.2	15.4	4.4	
6	1:48	2.2	21.9	6.5	
7	2:48	3.4	20.8	7.1	
8	5:24	6.6	16.0	5.3	
Total or average	22:36	27.5	19.3	6.0	2.2
Test 2:					
1	1:36	5.0	20.9	4.9	NAp
2	4:24	13.8	>25.5	>6.0	
3	1:24	4.4	18.0	6.0	
Total or average	7:24	23.2	21.5	5.6	3.6
Test 3:					
1	1:10	4.3	18.0	6.1	NAp
2	:40	2.5	37.0	17.4	
3	1:10	4.3	68.0	25.1	
4	2:10	8.0	28.0	9.9	
Total or average	5:10	19.1	37.7	14.6	4.2
Test 4:					
1	2:00	3.3	>25.5	>13.6	NAp
2	2:40	4.4	>25.5	>15.0	
3	1:50	3.0	>25.5	>10.7	
4	1:50	3.0	>25.5	>13.4	
5	1:00	1.6	23.9	11.0	
6	:50	1.4	>25.5	>15.9	
Total or average	10:10	16.7	>25.2	>13.3	>3.6

NAp Not applicable.

[1]A peak is defined as any interval in which the dust concentration increases significantly above the background concentration, beginning when the dust concentration starts to increase above the instantaneous background concentration and ending when the concentration decreases to the instantaneous background concentration.

[2]Average of peaks and background.

TABLE 5. - RAM-1 data for drill shroud and stem sampling

Sampling location	Test duration, min	Max value, mg/m³	Number of peaks: >10 mg/m³	Number of peaks: >20 mg/m³	Number of peaks: >40 mg/m³	Cumulative test av,[1] mg/m³
Drill shroud	32	>25.5	12	7	ND	>3.4
	32	>25.5	29	21	ND	>6.8
	18	>25.5	7	3	ND	>3.2
	32	>25.5	20	8	ND	>4.8
	27	[2]98.0	ND	9	5	7.0
	40	24.4	5	3	0	3.2
	22	>25.5	6	3	ND	>4.7
Drill stem	101	>25.5	36	28	ND	>7.4

ND Not determined. [1]Average of peaks and background.

[2]Data logger scale limit changed from 25.5 to 255 mg/m³.

TABLE 6. - RAM-1 data for event sampling

Event	Duration, min	Max value, mg/m^3	Event cumulative av, mg/m^3
Shroud bottom seal broken.....	NAp	21.3	9.7
Shroud bottom sealed..........	NAp	.6	.3
Shroud bottom seal broken.....	NAp	>25.5	>7.0
Shroud bottom sealed..........	NAp	8.2	3.6
Shovel cuttings...............	0.75	8.9	5.6
	.63	18.4	11.3
	3.00	24.0	15.7
	.40	>25.5	>9.3
	.50	15.7	4.7
	.70	19.0	12.1
	1.20	>25.5	>23.3
Work on collector.............	NAp	18.6	7.9

NAp Not applicable.

from the collector dump, shroud, and a second drill rig reaching the drill stem sampler.

Dust levels associated with specific events during the drilling operation are presented in table 6. Comparison of event cumulative averages for when the shroud bottom was sealed and not sealed (drill raised up) show dust reductions of 97 pct and greater than 49 pct when the shroud bottom was sealed. Shoveling drill cuttings by the drill helper resulted in an average dust concentration of greater than 11.7 mg/m^3, and maintenance work (changing filters) on the collector resulted in an average concentration of 7.9 mg/m^3.

CONCLUSIONS

1. The collector dump, drill shroud leakage, and drill stem seal leakage may account for up to 90 pct of the respirable dust and 89 pct of the respirable quartz generated during drilling.

2. The collector dump cycle is an intermittent dust source occurring only 21.6 pct of the time, but it can account for 38 pct of the dust, with peak dust concentrations reaching 68 mg/m^3.

3. Shroud leakage can account for 28 pct of the dust, with peak concentrations reaching 98 mg/m^3.

4. Short-term dust concentrations of greater than 11.7 and 7.9 mg/m^3 can be expected (on the average) from shoveling drill cuttings and from maintenance work on dust collectors, respectively.

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