evaluating sources of respirable quartz dust in underground coal mines

M.J. Schultz & R.A. Haney
Mine Safety and Health Administration, Pittsburgh Safety & Health Technology Center, Pittsburgh, Pennsylvania, USA

ABSTRACT: Identification of sources of quartz dust and their contribution to occupational exposure can be a significant aid to developing a dust control strategy for an underground coal mine. In many cases, mine operators are concerned more with the percentage of quartz and the resulting "reduced dust standard" than with the actual gravimetric concentration of quartz. The Mine Safety and Health Administration conducts studies to identify sources of respirable quartz dust in underground coal mines and assess the impact on dust control. Dust samples are collected on the mining occupations and upwind and downwind of the various mining operations, such as mining and bolting. The upwind and downwind samples are relocated as the equipment moves. During the study, quartz sources throughout the section and work practices of the miners are noted. This paper reviews the results of several of these studies and the impact that identifying quartz sources has on dust control.

1 INTRODUCTION

The Environmental Assessment and Contaminant Control Branch of the Dust Division, Pittsburgh Safety and Health Technology Center assists MSHA enforcement personnel in evaluating dust control plan approvals and compliance with dust standards throughout the mining community. The surveys normally consist of multiple shift respirable dust sampling on most of the crew members, along with area samples of the main intake entry, the belt entry, the immediate intake of the working face and the immediate return of the working face. Typically, a time study of mining activities is also conducted in conjunction with the dust sampling. Additionally, bulk samples may be collected of materials on the section for quartz analysis. The information obtained from these studies is used to identify and quantify both respirable dust sources and quartz sources for the sampled section and to make recommendations to reduce workers' exposure to both respirable coal dust and quartz dust. This paper discusses how the dust surveys are conducted on mining sections and how information obtained from these surveys is used to identify quartz dust sources. The use of quartz concentrations in micrograms per cubic meter ($\mu g/m^3$) provides a more reliable quartz indicator than percentage (%) quartz.

2 REGULATIONS REGARDING QUARTZ

The Code of Federal Regulations, Title 30, Part 70 regulates mandatory health standards for underground coal mines. Subpart B, Section 70.101 states that when quartz exceeds 5%, the average dust concentration shall be maintained to an equivalent concentration determined by dividing the percent quartz into the number 10. This mandatory health standard essentially limits exposure to quartz to a Mine Resource Establishment (MRE) equivalent concentration of 100 $\mu g/m^3$. Table 1 shows various quartz concentrations and the associated calculated standards. Multiplying this equivalent standard by the percent quartz shows that this standard limits equivalent concentrations of quartz concentrations to 100 $\mu g/m^3$. Table 1 shows the dust standard at various percentages of quartz and how these dust standards are equal to 100 $\mu g/m^3$ of quartz.

Table 1. Dust Standard equivalent to 100 μg/m^3.

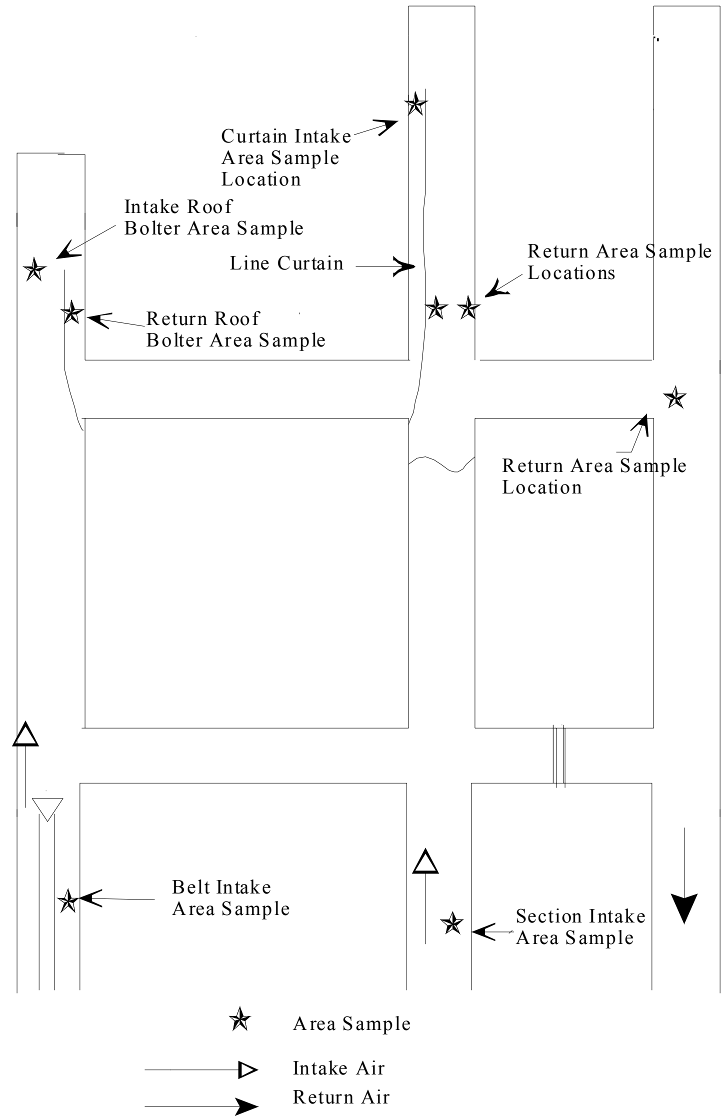
% Quartz	DUST Standard mg/m^3	Quartz Concentration μg/m3
5	2.0	100
10	1.0	100
20	0.5	100
50	0.2	100
100	0.1	100

When analyzing the data from the surveys, it is useful to look at both quartz concentrations and as percents. If data from a survey showed a dust source contributing a dust concentration of 0.1 mg/m^3 respirable dust, it may not be considered a significant dust source. However, if the sample contained a high percentage of quartz, it would be a major problem on this section. Respirable dust samples are not generally analyzed for quartz if they are less than 0.10 mg in total weight. If you saw this same data as 100 μg/m^3 of quartz, it would immediately alert you to a problem. As shown in Table1, 0.10 mg/m^3 of respirable dust can be equivalent to 100 μg/m^3 of pure quartz.

3 DESCRIPTION OF SURVEYS

Dust surveys are often conducted, at the request of a MSHA District Manager, to evaluate dust conditions for plan approval at a mine that has been experiencing repeated over-exposures to respirable dust. The over-exposures are often the result of a reduced respirable dust standard on the mining section. The reduced dust standard is due to a high percentage of quartz in previous dust samples. The surveys generally occur over period of multiple days and involve respirable dust sampling of most employees working on the section. Respirable dust area samples are also taken at specific locations on the section. The area samples are typically located in the immediate intake entry or entries, in the belt intake entry if belt air is being used to ventilate the face, in the immediate intake of the working place and in the immediate return out-by the continuous miner. Since roof-bolting machines may be a significant source of quartz, area samples are also taken on the intake side and the return side of the roof-bolting machine. Figure 1 shows typical placement of area samples during a survey. A time study is also conducted during the survey to monitor mining activities. All respirable dust pumps are checked periodically throughout the shift and any conditions that might affect dust concentrations are noted.

Figure 1. Typical Section Area Sample Locations.



After the study is completed, the dust samples are weighed at the Pittsburgh Safety and Health Technology Center for determination of final weight gain. Weight gains are adjusted by the use of a blank sample. Once final weight gains are determined, they are converted to MRE equivalent concentrations. The dust samples are also evaluated for quartz and the results are reported on a microgram (Φg) and percent quartz basis per sample. These results are then evaluated to locate specific quartz sources so that recommendations can be made to improve dust control and reduce quartz concentrations on the section.

4 QUARTZ SOURCES

Before the data from the survey is analyzed, it is helpful to identify potential sources of quartz on the section. Quartz is present in most of the strata in a coal mine. Generally, when a mine experiences a quartz problem, mine management immediately concentrates on the continuous miner of the working section. Table 2 is a list of common minerals found in a coal mine along with typical silica contents. As shown in the table, coal is generally one of the lower sources of silica on the section. Considering that any coal that is reaching the middle to upper limits of this coal silica range, is most likely not a viable product, generally the silica source on most sections is not the respirable dust generated from the cutting of coal.

If the respirable dust survey conducted on the section identifies the continuous miner as a silica generation source, the cutting of partings or middlemen, or the cutting of roof and floor material would be the most likely source of the silica. Bulk samples of the floor rock, roof rock, or of any middlemen can be collected and analyzed for quartz to identify the silica source. Once identified, procedures can be developed to reduce the dust generated from this source.

Table 2. Quartz Content of Common Minerals.

Quartz Content Of Common Minerals	
Mineral	Percent Silica
Limestone	1 - 20%
Granite	20 - 70%
Sandstone	50 - 100%
Shale	5 - 20%
Slate	15 - 40%
Coal	0 - 10%

5 RESULTS OF A DUST SURVEY

Table 3 gives the results of a two-day dust survey conducted at a coal mine in southern West Virginia. The section was a 5-entry development section using a blowing ventilation system. Coal was transported from the face to the section belt using a mobile bridge conveyor. The continuous miner was equipped with a flooded bed scrubber. Evaluation of the first day's results shows that all the occupational samples were under the 2.0 mg/m^3 dust standard. The highest concentration was on the miner operator helper who had a 1.235 mg/m^3 concentration. The designated occupation on this section was the miner operator. The roof bolter was established as a sampling designated area on this section. During normal sampling procedures, the miner helper would not have even been sampled, despite him having the highest dust concentration on this first day. Although all of the occupational dust concentrations were under 2.0 mg/m^3, all but one of the samples exceeded 100 µg/m^3 due to high percentages of quartz. This situation is not evident until you look at the micrograms per cubic meter of quartz.

Table 3. Respirable dust sample concentrations.

Day	Area/ Occupation	Min.	Conc. (mg/m3)	Quartz (%)	Quartz µg/m^3
1	Miner Op.	480	0.837	16.8	140
1	Miner Helper	480	1.235	20.3	251
1	#1 Bridge Op.	480	1.054	19.0	200
1	#2 Bridge Op.	480	0.474	13.0	61
1	R. S. Roof Bolt	480	0.687	18.4	126
1	L. S. Roof Bolt.	480	0.896	15.4	138
1	Main Intake	406	0.000	N/A	
1	Main Return	358	2.560	20.4	522
1	Miner Intake	355	0.072	11.7	8
1	Miner Return	317	3.254	19.3	628
1	Intake Bolter	107	2.070	18.4	381
1	Return Bolter	79	1.284	19.0	244
2	Miner Op.	480	0.690	11.0	76
2	Miner Helper	480	0.474	9.4	45
2	#1 Bridge Op.	480	0.430	7.4	32
2	#2 Bridge Op.	480	0.279	5.7	16
2	R. S. Roof Bolt	480	0.411	14.3	59
2	L. S. Roof Bolt.	480	0.712	13.3	95
2	Main Intake	393	0.042	N/A	
2	Main Return	330	3.329	21.7	722
2	Miner Intake	322	0.107	11.7	13
2	Miner Return	300	1.723	18.0	310
2	Intake Bolter	134	0.561	30.3	170
2	Return Bolter	130	0.525	22.2	117

Dust generation sources can also be identified by the area samples and the occupational dust measurements. The best method of doing this is to evaluate the outby dust sources and continue into the working section. Differences between successive dust measurements indicate the amount of dust and silica generated by an operation.

6 CONTROL OF INTAKE DUST CONCENTRATIONS

Section 70.100(b) of the Code of Federal Register (CFR) states that "Each operator shall continuously maintain the average concentration of respirable dust within 200 feet outby the working faces of each section in the intake airways at or below 1.0 milligrams of respirable dust per cubic meter of air (1.0 mg/m^3)." Intake dust sources can be below the 1.0 mg/m^3 respirable dusty limit but they can still be exceeding the 100 µg/m^3 quartz limit.

From Table 1, it can be seen that a 0.5 mg/m^3 intake dust concentration that exceeds 20% quartz also exceeds the 100 mg/m^3 of quartz Similarly, a 0.3 mg/m^3 respirable dust concentration at 40% quartz also would exceed the 100 µg/m^3 of quartz. Outby dust sources can have increased silica content. Lower level dust concentrations measured in the intake air for a working section are often discounted, but may contain a high enough percentage quartz to result in a reduced standard for the mining section. Controlling intake dust levels is important because they effect all workers on a mining section.

Once an outby dust source is identified, corrective action can be made to minimize dust generation. The use of water or surfactants in the water supply to minimize dust along belt lines has become much more common with the increased use of belt air at the working face. If the section intake area samples indicate outby dust source problems but an outby dust source can not be identified, an additional outby dust survey may need to be conducted to locate the dust source.

Evaluating the dust concentrations in Table 1, both intake dust samples concentrations were sufficiently low so that the intake was eliminated as a potential significant dust-generating source.

7 CONTROL OF SECTION DUST OUTBY THE WORKING FACE

Comparing the average intake area sample concentrations with the intake area sample before the continuous miner or before the roof bolter will indicate how much dust is being generated on the working section outby the working face. As with the intake samples, these intake samples must also be looked at for μg/m^3 of quartz. If this concentration is considered excessive, dust sources throughout the section must be identified. Typically, the major source of outby dust generation is the haulage equipment used to transport the coal away from the face to the section belt. This can be shuttle-cars, ram cars or a mobile bridge conveyor. Keeping roadways clean and watered down can significantly reduce section dust generation. Keeping a roadway clean limits the amount of material available to generate dust. Keeping the roadways wet by watering them down prevents the entrainment of the dust into the ventilating air current during movement of the equipment. Water sprays may be needed on continuous haulage equipment to lower dust generation.

With more mines using belt air as intake air for the section, dust generated from crushers/feeder has become a more significant dust source of working sections. Belt crushers/feeders are designed to break and size coal to be properly loaded onto the belt. The crushing of rocks or the grinding of large rocks create excessive amounts of dust and quartz. Compounding this situation is that these rocks generally have a higher percentage of quartz than coal. This high quartz containing dust contaminates the entire working crew. Maintaining the crusher bits and water sprays can significantly reduce section dust.

From Table 1, this area of the working section generated under 0.1 mg/m^3 of respirable dust to the working section. This dust contained an average of 11.7% quartz. This calculates into an average of 10 μg/m^3 of quartz gain from this area. Reductions can be made in this area, but it is not a major contributor to the dust problem.

8 DUST CONTROL ON THE CONTINUOUS MINER

Once the outby dust generation sources are evaluated, the continuous miner can be examined. The face intake quartz dust concentration should be compared to the exhaust quartz concentration on a μg/m^3 basis. If there is a significant increase in this concentration, then the cutting of the roof, floor or partings is the most likely source quartz and procedures need to be implemented focusing on this aspect of the mining activity. If the coal dust concentration has a significant increase on the mg/m^3 basis, then the overall face mining process needs to be evaluated.

Various factors influence the amount of dust generated and carried away from the continuous miner. Maintaining good bits, water sprays and proper cutting technique can reduce dust generation. The amount of dust carried away will be influenced by face ventilation, water sprays, scrubber capacity, and scrubber efficiency. The same factors need to be considered when reducing either respirable dust or quartz dust from the continuous miner.

Continuous miner machine operators can also reduce dust generated by modifying the cutting technique. Every system is different and most continuous miner operators are aware of the best technique to cut coal under their mining conditions. Miner operators must especially be aware of cutting partings and other variations in the coal seams. These variations tend to create more dust and more quartz.

Face ventilation is crucial to control dust generation at the working face. Blowing line curtain typically is the preferred face ventilation system when cutting a deep cut although some systems have used exhaust ventilation. Exhaust face ventilation systems are considered better for dust control. Blowing ventilation systems are considered superior for methane control in the working face. Whether a blowing or exhausting ventilation system is used, the amount of air ventilating the working face directly affects dust concentrations. Just like methane, ventilating air currents proportionally dilute dust concentrations.

Reviewing the results of day one of the survey shows that everyone who continuously worked downwind of the mining activities exceeded the 100 μg/m^3 of quartz. The #2 bridge operator was mostly in intake air had a quartz exposure less than the 100 μg/m^3 . The three miners closest to the face had quartz levels of 140 μg/m^3 , 251 μg/m^3 , and 200 μg/m^3 . The immediate continuous miner return had a quartz level of 628 μg/m^3. These results indicate that the face area was a major source of quartz. With information obtained from observations of this work area, recommendations were made to reduce dust generated at this location. Recommendations made included: increased air flow, undercutting middle man partings before cutting the partings, increased water spray pressure, maintaining sharp continuous miner bits, increasing the efficiency of the scrubber and proper work positioning of the miners.

Many of these recommendations were observed on the first day of the survey. These recommendations were provided to mine management after the first day of the survey. Mine management directed personnel to undercut the partings and changed work positions. They also increased the line curtain velocities, changed out worn bits and slightly increased water pressure. Sampling was again conducted on the second day of the survey. Results of the second day of sampling showed significant reductions in dust and quartz, despite increased mining tonnage on this second day.

9 ROOF BOLTERS

The drilling of roof rock for roof bolts generally produces the dust with the highest quartz percentage on a working section. The first step in controlling dust at this location is to control the dust at the dust source before it becomes air borne. The dust collection system on the roof bolter must be maintained in its proper working condition. Roof bolter operators must clean out their dust boxes before they become full. Over-filling the dust boxes can contaminate the entire system. Dust boxes must be cleaned so that dust generated while cleaning these boxes does not contaminate so that the dust generated while emptying the boxes does not contaminate the working section. The dust boxes should be cleaned at locations where haulage equipment will not be tramming through the discarded dust. Filters for the dust collection systems should also be cleaned in return air. Extra filters can be maintained on the roof-bolting machine so that the filters can be cleaned when at the appropriate location. When cleaning the dust boxes, employees should not only keep themselves in fresh air, but they should also keep from contaminating their clothing with the dust.

Recently, a roof bolter equipment manufacturer has designed a bagging system for the dust collection boxes. This system will eliminate a lot of the dust generated while emptying the dust boxes and also eliminate some of the clothing contamination.

Good airflow needs to be directed to the roof bolting area. When possible, air used to ventilate roof-bolting activities should be directed directly to the return so that dust generated from roof bolting does not contaminate workers downstream.

The roof-bolters averaged 134 μg/m^3 on the first day of the study and 77 μg/m^3 on the second day of the study. At this mine, the roof-bolters were both inby and outby the return air of the continuous miner. Due to this type of changing bolting locations, the area samples located at the roof bolter cannot identify the amount of quartz created by the roof bolter.

10 CONCLUSIONS

1. Quartz dust generated during roof bolting operation effects both the percent of quartz in the dust and the exposure to the roof bolter.
2. Because of dilution, the quartz generated during roof bolting operations generally does not have a significant impact on the continuous miner percent quartz or quartz concentration.
3. The primary source of quartz for the continuous miner is mining activities such as cutting top or mining in a high quartz coal seam.
4. The dust generated by the continuous miner has a significant impact on quartz percentage and concentration on roof bolter working downwind of the continuous miner.