Assessment of respirable quartz dust exposures at roof bolters in underground coal mining

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Abstract

Roof bolter occupations in underground coal mines have long been susceptible to overexposures to respirable quartz. Data gathered from a series of underground studies showed that high exposures to respirable quartz dust arose from infrequent maintenance of the vacuum dust collection system and operation of the roof bolter downwind of the continuous mining machine.

Dust boxes and filters were not routinely cleaned, thus allowing dust to accumulate and to eventually bypass the final filters. This not only increased dust levels around the roof bolter but contaminated the intake airway of the continuous mining machine working downwind. High quartz dust levels in the intake airway of the roof bolter were measured when working downwind of the mining machine. Dust from the mining process flowed downwind and increased respirable quartz dust levels in the intake of the roof bolter.

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 quartz by weight, the dust standard is reduced according to the formula 10 / (% quartz). Compliance with either the 2.0 mg/m^3 standard or a reduced standard maintains quartz dust levels at or below 100 µg/m^3. In comparison, the NIOSH- recommended exposure limit for occupational exposure to respirable quartz is 50 µg/m^3[2].

Roof bolter occupations in underground coal mines have long been susceptible to overexposures to respirable quartz dust. Prior research showed that several operational factors contributed to this increased risk. Higher levels of quartz dust were measured at the roof bolter when this machine operated in the return air of the continuous mining machine. In addition, downwind exposures often increased when the mining machine cut rock[3,4]. Exposures also increased when dumping the dust collector box, although this source was controllable with proper care and attention.

Respirable quartz levels generated during bolting could vary considerably depending upon the condition of the dry vacuum collection system. Both studies showed, however, that these collection systems were very effective when properly maintained.

A review of 1999 compliance sampling data collected by the Mine Safety and Health Administration (MSHA) showed that roughly 70 percent of the 3400 roof bolter occupational samples exceeded 5 percent quartz. One-third of these samples had quartz concentrations exceeding 100 µg/m^3 [5]. These high levels of non-compliance could have resulted from improper maintenance of the vacuum dust collection system or from operation of the roof bolter downwind of the continuous mining machine.

Little information has been added to update the impact of new mining practices on roof bolter quartz exposures. Current mining systems now show increased use of flooded-bed dust scrubbers and deep cutting that can change downwind dust levels experienced by the bolter. This study evaluates the impacts of roof bolter positioning on quartz dust exposures measured at various locations around the mining unit.

Sampling procedures

Most sampling for respirable dust was conducted using gravimetric sampling. Permissible personal sampling pumps were calibrated at 2 litres/minute before each study. These pumps drew air through .10mm cyclones to deposit the respirable dust fraction onto pre-weighed 37mm filters. All filters were later weighed and respirable dust concentrations calculated. Two samplers were positioned at each sampling location. The average dust level at each sampling location was the numerical average of the two gravimetric dust concentrations. Samples with sufficient weight gain (0.40 mg) were analysed for quartz content using the infrared P-7 method[6].

This study also used a Miniram continuous dust monitor (GCA Corp., Bedford, Massachusetts, USA) sampling passively; that is without the aid of a pump. With normal air currents, dust-laden air flowed through a chamber housing a light source where the amount of light scatter was representative of a respirable dust concentration.

Dust samplers were placed around the continuous miner and roof bolter machines and were run only when these machines operated. Samplers were hung in the intake and return airways of the continuous miner. Gravimetric samplers were placed on the frame of the roof-bolting machine approximately 1-1.2 meters (3-4 feet) out-by the controls of the return side bolter operator. This site represented the bolter operator area samples. Gravimetric samplers also were hung in the intake and return airways of the roof bolter. Two different sets of samplers were used at the roof bolter machine, intake, and return sites. One set of samplers was used when the bolter operated upwind of the continuous miner and another set used when the bolter operated downwind. A comparison of these readings showed the change in dust levels around the roof bolter when this machine operated downwind of the continuous miner. The Miniram dust monitor was placed at the rear of the roof bolter frame above the cable reel to record dust levels for every bolted heading. Finally, two samplers were placed in the section intake to monitor dust levels at this location.

During this study, detailed time-study records were maintained to note the movement of machinery throughout the shift. This allowed correlation of measured dust levels with various machine activities.

Mining operations

Four underground continuous mining operations in the Appalachian coalfield were investigated. Each operation was sampled for three shifts except operation B which was sampled for two shifts. Operational and dust control parameters for the surveyed operations are given in Table 1. All continuous mining machines were equipped with flooded-bed type dust scrubbers. All face ventilation was single split with two operations using exhausting curtain face ventilation with one using blowing face curtain ventilation. The remaining operation used a combination curtain system with an exhausting curtain on one side of the panel and a blowing curtain on the other side. This face ventilation scheme is favoured as a means to reduce the number of drive-thru check curtains on a production section.

All surveyed mines operated twin boom roof bolters using permissible dry vacuum dust collectors equipped with canister-type filters. Dust boxes and filters were cleaned manually during the shift using a rake or roof bolt to scrape the drill cuttings on the mine floor. Each drill boom of the roof bolter at mine A had a three-compartment vacuum dust collector to classify the drill cuttings with the finest-sized particles collected by three canister-type filters. The bolter dust collectors at mine B also used a similar three-compartment arrangement. However, these dust boxes used only one filter to collect the finest-sized drill cuttings. The filters were cleaned by gently tapping them against a tire of the roof bolter. The bolter operators did not try to control or limit the amount of dust created while cleaning the boxes and/or filters.

The roof bolter at Mine C used a pre-cleaner mechanism to dump the coarsest drill cuttings on the mine floor. Due to the limited number of bolting places, this box and the filters were cleaned on an off-shift. At mine D, the roof bolter had an auto dump feature that deposited the drill cuttings in front of the rear bolter tire when the TRS was dropped. This dust box was not serviced during the study. Consequently, no information on dust box and/or filter cleaning was obtained at these two mines.

The data gathered and the observations made during these surveys suggested that significant respirable quartz dust exposures at the roof-bolting machine arose from infrequent maintenance on the vacuum dust collection system and/or positioning of this machine downwind of the continuous miner. Poor maintenance of the vacuum dust collection system may also have allowed roof bolter dust of high quartz content to travel downwind and contaminate the intake airway of the mining machine.

Maintenance of the roof bolter dust collection system

At some operations, the dust boxes

Operation	Range of seam heights (m)	Range of production (tons)	Average intake flow to continuous mining machine (m^3/s)	Scrubber quantity (m^3/s)	Continuous mining machine water spray system	
					Water spray pressure (kPa)	Water flow rate (lpm)
A	1.5 – 1.8	972 – 1387	2.4 – blowing[1] 3.9 exhausting	1.9	621	92.6
B	1.5 – 1.7	352 – 910	2.1[2]	1.6	483	61.0
C	1.1 – 1.2	343 – 502	2.1[3]	1.6	413	61.0
D	3.0 – 3.3	700 - 1800	2.7[3]	4.1	448	NC

Notes:

1. Entries 1 to 3 use exhausting line curtain, entries 5 to 7 use blowing line curtain and entry 4 uses either exhausting or blowing line curtain.
2. Blowing line curtain
3. Exhausting line curtain

NC = Not collected

Table 1: Operational and dust control parameters for surveyed operations

and filters were not frequently cleaned during the shift. This caused dust to build up in the boxes and to eventually bypass the filters. Dust flowed from the mufflers of the bolter and eventually formed a white haze around the bolting machines. The haze suggested that corrective actions (cleaning dust box, changing filters) should have been taken immediately.

At mines A and B, eventual cleaning of the dust boxes and filters reduced Miniram dust levels from 10 to nearly 80 percent as shown in Figures 1 and 2. At mine A, this data was gathered every shift. At mine B, this information was gathered on the first and third shift. However, the dust boxes and filters were initially cleaned before bolting on the first shift, so no dust reading was obtained before this cleaning. Mines C and D cleaned their dust collectors on other shifts.

The values shown in Figures 1 and 2 are Miniram averages for bolting an entire cut before and then after cleaning the dust boxes or filters. At mines A and B, cleaning the dust boxes and/or filters reduced these dust levels. There appeared to be little differences between cleaning the dust boxes or cleaning just the dust filters. Although cleaning of the boxes and/or filters led to reductions in Miniram dust readings, some dust continued to flow from the mufflers at both mines suggesting that fine dust particles were present throughout much of the vacuum system downstream of the filters. Only a thorough cleaning and purging of the dust collection system could clear this dust.

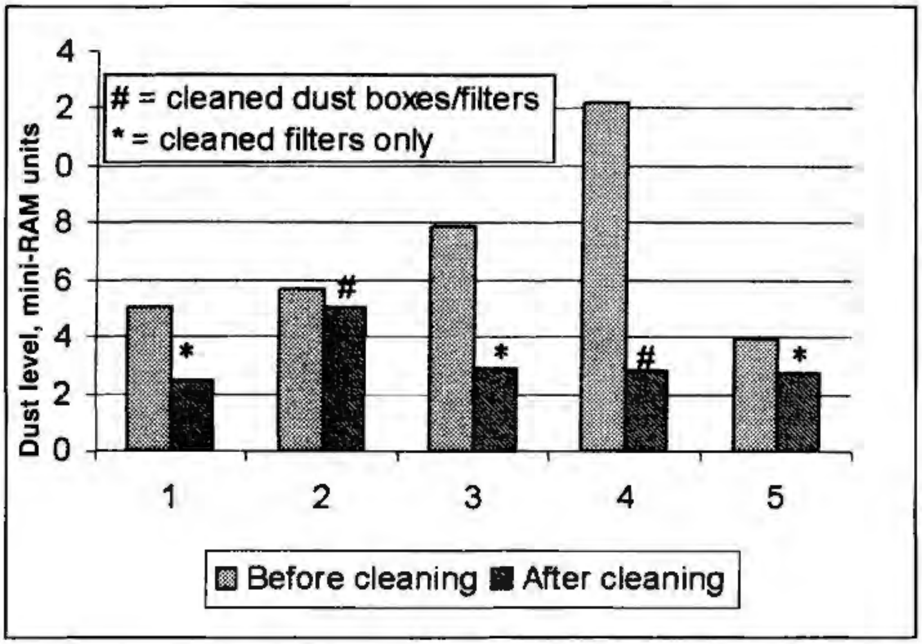

Figure 1: Effects of cleaning dust boxes and/or filters on Miniram dust levels around roof bolter (Mine A)

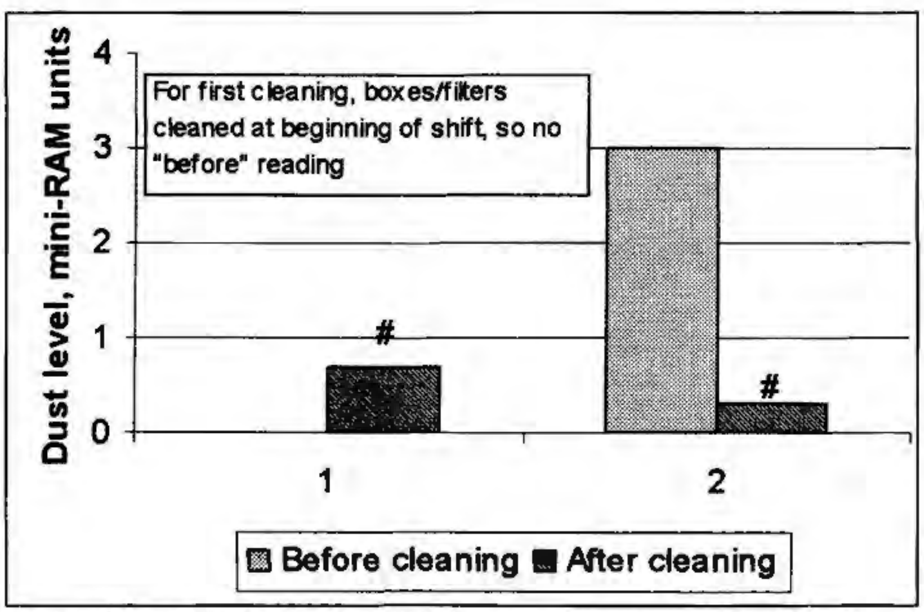

Figure 2: Effects of cleaning dust boxes on Miniram dust levels around roof bolter (Mine B)

Infrequent cleaning and subsequent contamination of the vacuum dust collection system at mines A and B led to high quartz dust levels measured at the roof bolter operator's sampling location. At mine A, quartz dust concentrations and percentages ranged from 103 $\mu g/m^3$ to 327 $\mu g/m^3$ and 12.3 to 13.7% quartz for three shifts surveyed. These values were measured when operating upwind of the continuous mining machine and in clean intake air. Hence, quartz exposures arose from dust generated by the bolter and not from any dust generated by the continuous miner. At mine B, the bolter operated upwind of the mining machine for only one shift during which time the quartz dust concentration and percentage at the roof bolter operator sampling location averaged 113 $\mu g/m^3$ and 9.1%, respectively.

Dust flow from roof bolter and mining machine

Past work has shown that the continuous mining machine is often the biggest dust source on the production unit and, as such, may increase dust levels for the roof bolter operators working downwind[3-4,7-8]. To limit quartz exposures, many MSHA dust control plans limit the time that the roof bolter works downwind of the mining machine[7]. The effect of roof bolter location was quantified by comparing quartz dust levels measured in the roof bolter intake when working upwind of the mining machine to those levels measured when working downwind (Figure 3).

Operating downwind of the mining machine at mine A increased quartz dust levels in roof bolter intake from 95 $\mu g/m^3$ to 204 $\mu g/m^3$ for shift 1. The high quartz dust levels measured when operating upwind of the continuous miner were attributed to dry haul road conditions. For shifts 2 and 3, quartz dust levels upwind of the mining machine were negligible, while downwind quartz levels increased from 44 $\mu g/m^3$ to 49 $\mu g/m^3$.

The data for mine B was not analysed for quartz due to insignificant weight gain on the roof bolter intake filters. The data for mine C shows that, on shift 2, the roof bolter only worked upwind of the mining machine. Filters collected from the first shift also had insufficient weight gain for quartz analyses.

Shift 1 data at mine D showed insufficient weight gain for quartz analysis. For shifts 2 and 3, quartz dust levels upwind of the mining machine were very low (<10 μg/m³). These increased to 55 μg/m³ and 23 μg/m³ downwind of the mining machine for shifts 2 and 3, respectively.

Figure 3 shows that quartz percentages varied between sampling locations upwind and downwind of the mining machine. At mine A, the quartz percentage in the bolter intake decreased from 13% to 11% on the first shift when downwind of the mining machine. This was attributed to the dilution of bolter dust by additional dust flowing from the mining machine. Downwind quartz dust percentages decreased to 5% for shifts 2 and 3 suggesting improved control of quartz dust during mining. Only slight increases in quartz percentage were apparent for shifts 2 and 3 at mine D.

These results showed that quartz dust generated by the continuous mining machine increased quartz dust levels at the roof bolter operating downwind. However, other work showed that quartz dust flowing from the roof bolter could increase quartz levels in the intake of the continuous mining machine working downwind[3,7-8]. This could occur in many ways, including inadequate maintenance of the vacuum dust collection system that caused leakage around the dust filters, improper cleaning of the dust box and/or filters that stirred up drill dust, or plugging of the drill steel that caused puffing of dust from the drill hole[7]. Any quartz dust liberated could flow downwind and contaminate the intake airway of the mining machine.

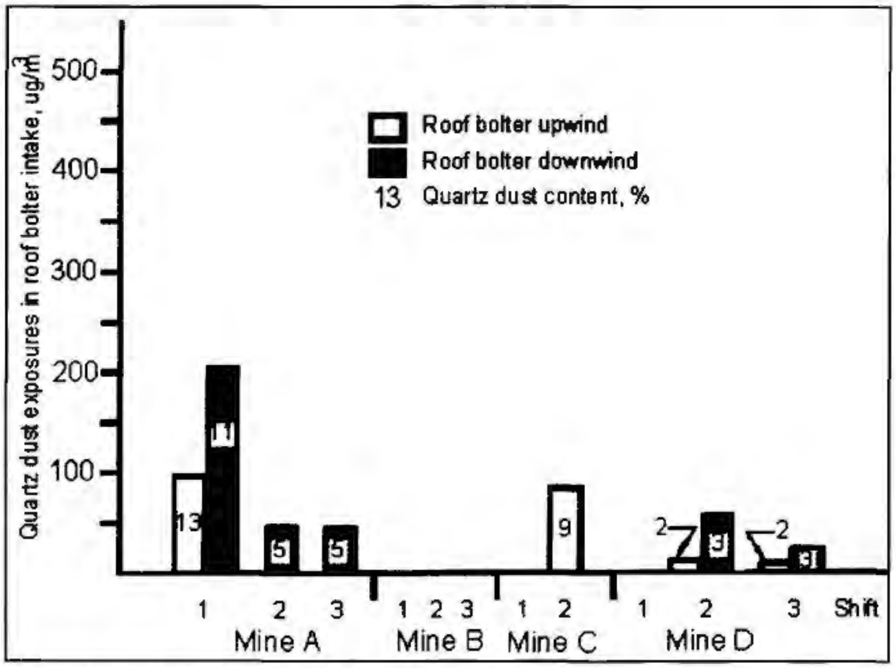

Figure 3: Roof bolter working upwind and downwind of mining machine. Comparison of respirable quartz dust levels in bolter intake

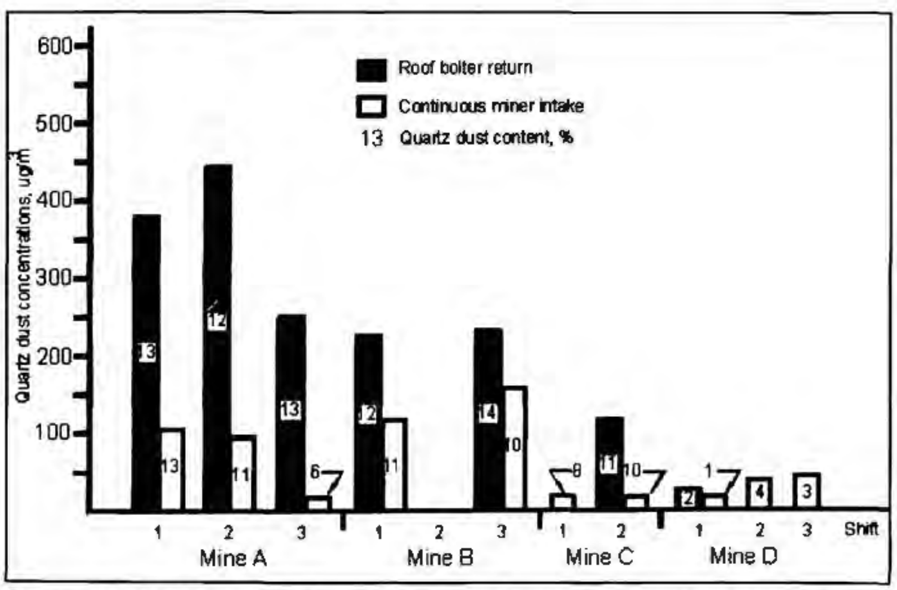

Figure 4: Roof bolter upwind of mining machine. Comparison of respirable quartz dust concentrations in roof bolter and mining machine intake

The impact of the roof bolter on the mining machine operating downwind was assessed by comparing quartz dust levels in the bolter return to those in the miner intake. However, these comparisons were not straightforward, because one set of bolter return samplers operated only with the bolter upwind of the mining machine while the miner intake samplers operated for both upwind and downwind positions of the bolter. However, the collected data showed that section intake quartz dust levels were very low for many of the studies. Thus, we believe that much of the quartz dust measured in the intake of the continuous miner arose, not from its operation upwind of the roof bolter but from its operation downwind.

Quartz dust levels in the section intake were generally low at mine A. The exception was the first shift where, due to very dry conditions on the haul roads, intake quartz dust levels averaged 95 μg/m³. Quartz levels in the bolter return averaged 380 μg/m³ while levels in the continuous miner intake averaged 103 μg/m³ (Figure 4). Thus, quartz dust present in the continuous miner intake arose from a combination of the upwind roof bolter and haul road dust.

Poor maintenance of the vacuum dust collection system during the second shift resulted in quartz dust concentrations exceeding 400 μg/m³ in the bolter return. Quartz dust levels averaged 94 μg/m³ in the continuous miner intake. Because section intake quartz dust levels were very low on this shift, most of the quartz dust in the intake of the mining machine is attributed to its operation downwind of the roof bolter. Improved maintenance of the vacuum dust collector on the third shift reduced quartz dust concentrations in the bolter return to 251 μg/m³ while quartz levels in the miner intake dropped to 14 μg/m³.

For shift 1, the impact of the roof bolter on continuous miner intake dust levels was confounded due to the presence of haul-road dust. However, the bolter likely added less than 103 μg/m³ of quartz dust to the intake air of the mining machine. For shifts 2 and 3, quartz dust levels of 14 to 94 μg/m³ in the continuous miner were attributed to the roof bolter working upwind.

Because section quartz dust levels at mine B were negligible, any quartz dust in the intake of the mining machine arose from its operation downwind of the roof bolter. For shifts and 3, the roof bolter added between 115 μg/m³ and 153 μg/m³ of quartz dust to the intake air of the mining machine. The continuous miner did not work downwind of the roof bolter for the second shift and, not surprisingly, quartz dust levels measured in the mining machine intake were negligible.

Negligible levels of quartz dust were measured in the section intake of mine C. In addition, quartz dust levels in the roof bolter return were negligible on the first shift because the vacuum dust collector was working very well. On the second shift, higher quartz dust concentrations were found in the bolter return likely a result of repeated instances of drill steel clogging that caused dust to flow from the drill hole. However, airflow between the bolter and continuous miner diluted this dust to lower levels in the intake of the continuous miner (15 μg/m³).

Quartz dust levels ranging from 2 μg/m³ to 15 μg/m³ were measured in the section intake of mine D. These levels were likely due to haulage activity near the intake samplers and very dry conditions that allowed dust to flow off the shuttle cars as they trammed through this area. The roof bolter added roughly 16 μg/m³ to the intake air of the continuous miner on shift 1. Quartz dust levels in the bolter return were not calculated for shifts 2 and 3 due to low weight gains on the gravimetric filters.

Quartz dust percentages in the bolter returns of mines A and B show that these operations had considerable difficulty controlling quartz dust from the roof bolters. This was due almost entirely to dust leakage through the vacuum dust collector. This condition could not only affect the occupational health of the bolter operators but also that of the continuous miner operator. Mines C and D had lower quartz dust percentages in the roof bolter return and, consequently, in the intake of the downwind mining machine. Reductions in respirable quartz dust levels and contents from the return of the roof bolter to the intake of the mining machine likely arose from dilution of the dust flow.

Summary

Recent MSHA data suggest that overexposures to respirable quartz dust continue for roof bolter operator occupations in underground coal mines. A series of studies conducted at four underground operations suggested that quartz overexposures could result from poorly maintained dust collection systems on the roof bolting machines or from the roof bolters working downwind of the mining machine.

Infrequent cleaning of the dust boxes and/or filters led to contamination of the vacuum dust collectors. The white dust observed flowing from the bolter mufflers suggested the need for corrective action to improve the efficiency of the collection unit. Cleaning the boxes and/or filters often produced dramatic decreases in dust levels flowing from these mufflers.

Elevated respirable quartz dust levels in the bolter intake were measured when working downwind of the mining machine. Increases in quartz dust levels from 50 μg/m³ to nearly 100 μg/m³ were measured when working downwind of the mining machine. Only slight changes in quartz dust percentages were measured. High dust levels around the roof bolter also contaminated the intake airway of the continuous miner working downwind. In several instances, data showed quartz dust levels exceeding 200 μg/m³ to 300 μg/m³ in the bolter return and approaching 100 μg/m³ in the intake of the mining machine.

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