Evaluation of the Approach to Respirable Quartz Exposure Control in U.S. Coal Mines

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Occupational exposure to high levels of respirable quartz can result in respiratory and other diseases in humans. The Mine Safety and Health Adminstration (MSHA) regulates exposure to respirable quartz in coal mines indirectly through reductions in the respirable coal mine dust exposure limit based on the content of quartz in the airborne respirable dust. This reduction is implemented when the quartz content of airborne respirable dust exceeds 5% by weight. The intent of this dust standard reduction is to restrict miners' exposure to respirable quartz to a time-weighted average concentration of 100 $\mu g/m^3$. The effectiveness of this indirect approach to control quartz exposure was evaluated by analyzing respirable dust samples collected by MSHA inspectors from 1995 through 2008. The performance of the current regulatory approach was found to be lacking due to the use of a variable property—quartz content in airborne dust—to establish a standard for subsequent exposures. In one situation, 11.7% (4370/37,346) of samples that were below the applicable respirable coal mine dust exposure limit exceeded 100 $\mu g/m^3$ quartz. In a second situation, 4.4% (895/20,560) of samples with 5% or less quartz content in the airborne respirable dust exceeded 100 $\mu g/m^3$ quartz. In these two situations, the samples exceeding 100 $\mu g/m^3$ quartz were not subject to any potential compliance action. Therefore, the current respirable quartz exposure control approach does not reliably maintain miner exposure below 100 $\mu g/m^3$ quartz. A separate and specific respirable quartz exposure standard may improve control of coal miners' occupational exposure to respirable quartz.

Keywords coal mining, exposure, resipirable quartz

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INTRODUCTION

Inhalation of respirable quartz can cause disease in humans. Silicosis, a pulmonary fibrotic condition, is the most commonly recognized result of overexposure to respirable quartz.[1,2] Chronic obstructive pulmonary disease (COPD) and lung cancer are also elevated among quartz-exposed workers.[2–4] Non-respiratory disease has also been associated with respirable quartz exposure, including scleroderma, rheumatoid arthritis, and renal disease.[5–7]

Miners, including coal miners, are occupationally exposed to respirable quartz during the extraction and processing of ore.[8–10] In coal miners, exposure to respirable quartz occurs when rock above, below, or within the coal seam is disturbed as the coal is extracted. Exposure can also occur when ground control methods are implemented in underground coal mines (e.g., installation of roof bolts) and when drill holes for exploration or placement of blasting agents are installed.

Coal miners' occupational exposure to respirable coal mine dust (RCMD) with or without respirable quartz is regulated by the Mine Safety and Health Administration (MSHA). MSHA inspectors collect air samples to evaluate exposure in relation to the respirable dust standard (RDS), to assess the adequacy of the operator's dust control practices, and for other purposes.

The RDS for RCMD is an 8-hr time-weighted average (TWA) concentration of 2.0 mg/m^3. Although not explicitly stated, the exposure limit for respirable quartz is essentially a TWA concentration of 100 $\mu g/m^3$. MSHA controls quartz exposure indirectly by reducing the 2.0 mg/m^3 RCMD RDS when the content of quartz in airborne RCMD exceeds 5% by weight. The reduction of the RDS is made by the following formula: applicable RCMD RDS (mg/m^3) = 10/percent quartz.[11] This relationship results in RCMD respirable dust standards that range from 2.0 mg/m^3 when 5% or less quartz is present, to 0.1 mg/m^3 at 100% quartz concentration.

When RCMD samples collected by MSHA inspectors exceed the minimum weight gain of 100 μg specified in the MSHA quartz analytical procedure, the sample is analyzed for quartz content using a Fourier-transform infrared method (MSHA Method P7).[12]

The reduced RCMD RDS becomes the respirable dust exposure limit for the section(s) of the mine represented by the sample data. Different sections within a single mine may have differing RCMD RDSs at a given time, based on the samples collected within those sections.

Mine operators may optionally submit their own samples for evaluation of quartz content if they believe the inspector's samples are not representative. Further details of the coal mine dust inspection process are available from MSHA.(13)

MSHA's respirable dust sampling convention is based on methods established by the British Medical Research Council (BMRC) using a horizontal elutriator.(14) To match the sampling characteristics of the elutriator, MSHA uses a Dorr-Oliver 10-mm nylon cyclone (Zefon International, Ocala, Fla.) at a flow rate of 2.0 L/min; the resulting dust concentration is multiplied by a constant factor of 1.38.(15) Results from this method differ from International Organization for Standardization (ISO)-based approaches, and conversion factors must be applied if data from the differing sampling methods are to be compared.(16) This article uses MSHA sampling data within MSHA's regulatory framework; therefore, no conversion of the MSHA dust concentration to the ISO basis is necessary.

For the current RCMD RDS reduction approach to control quartz to a 100 μg/m^3 level, two conditions must be assumed: (1) the quartz content of the airborne respirable dust will not increase as mining progresses, and (2) the RCMD concentration will not exceed the applicable RDS. This article examines the validity of the two stated assumptions using data collected by MSHA inspectors.

METHODS

MSHA inspector-collected respirable dust samples of underground coal occupations from 1995 through 2008 were retrieved from the MSHA Standardized Information System (MSIS) Samples database.(17) Mine operators also collect RCMD samples, although very few of these samples are evaluated by MSHA for quartz content except when in association with establishment of a reduced RCMD RDS as described above. Consequently, these operator samples are not actually used to evaluate miner exposure and are not included in this analysis. Samples that had been voided for any reason or that lacked a value for dust concentration, dust standard, quartz content, sample type, sample date, or occupation code were excluded from the data set.

Samples in the data set were classified by type of MSHA-assigned entity classification into two groups. The first group includes samples of designated occupations (DO) and non-designated occupations (NDO); this subset, labeled the Occupations group, included 38,038 samples. The second group comprises roof bolter-designated area (RBDA) samples; this group included 8220 samples.

A DO is the occupation on a mechanized mining unit (MMU) that is expected to have the highest respirable dust exposure.(18) An MMU is the organizational work group that extracts coal. NDOs are any occupations on an MMU except the DO. A designated area is an area identified by the mine operator where RCMD exposure samples must be collected bimonthly. The RBDA is known to have an elevated potential for exposure to respirable quartz and is included in this analysis for that reason.(19)

Samples were further classified by whether the mine section was on a 2.0 mg/m^3 RDS or a reduced standard and by the quartz content of the sample.

The grouped samples were examined to identify how many exceeded 100 μg/m^3 respirable quartz concentration.

RESULTS

Analysis of the MSHA inspector-collected RCMD sample data demonstrates that the existing indirect approach of controlling coal miners' exposure to airborne respirable quartz through regulation of respirable coal mine dust may be less protective than intended.

Table I presents data on samples with a dust concentration less than or equal to the applicable RCMD RDS. If the current quartz exposure control approach was effective, few or no samples in Table I would be expected to exceed 100 μg/m^3 quartz. However, it can be seen that 21.6% of the samples with a quartz content of >5% exceeded 100 μg/m^3 quartz

TABLE I. Samples with RCMD Concentration ≤ Applicable Respirable Dust Standard

		≤5% Quartz Content			>5% Quartz Content		
	RCMD RDS	Total N	N > 100 μg/m^3	% >100 μg/m^3	Total N	N > 100 μg/m^3	% >100 μg/m^3
Occupations	2 mg/m^3	13,956	0	0%	10,135	2,751	27.1%
Group	<2 mg/m^3	1336	0	0%	5211	942	18.1%
	All	15,292	0	0%	15,346	3693	24.1%
Roof Bolter DA^A	2 mg/m^3	1344	0	0%	1376	243	17.7%
Group	<2 mg/m^3	517	0	0%	3471	434	12.5%
	All	1861	0	0%	4847	677	14.0%
Total		17,153	0	0%	20,193	4370	21.6%

^{A}DA = designated area.

TABLE II. Samples with RCMD Concentration > Applicable Respirable Dust Standard

	RCMD RDS	≤5% Quartz Content Total N	≤5% Quartz Content N > 100 μg/m^3	≤5% Quartz Content % >100 μg/m^3 (%)	>5% Quartz Content Total N	>5% Quartz Content N > 100 μg/m^3	>5% Quartz Content % >100 μg/m^3 (%)
Occupations	2 mg/m^3	2350	691	29.4	1654	1654	100.0
Group	<2 mg/m^3	705	134	19.0	2691	2154	80.0
	All	3055	825	27.0	4345	3808	87.6
Roof Bolter DA	2 mg/m^3	152	41	27.0	105	105	100.0
Group	<2 mg/m^3	200	29	14.5	1055	767	72.7
	All	352	70	19.9	1160	872	75.2
Total		3407	895	26.3	5505	4680	85.0

concentration. For these samples, the RCMD RDS is not low enough to control respirable quartz exposure to 100 μg/m^3 or less. The basis of this problem is that the applicable RCMD RDS, which if not the default unreduced RCMD standard of 2.0 mg/m^3, was established based on earlier sampling results that do not reflect the quartz concentration encountered during subsequent mining. This can occur, for example, because the geology changed as mining progressed and more (or higher content) quartz-bearing rock is being extracted.

Samples exceeding 100 μg/m^3 are mathematically prohibited when the RCMD concentration is less than or equal to the RDS (a maximum of 2.0 mg/m^3) and the quartz content does not exceed 5%.

All samples in Table II exceed the applicable RCMD RDS and are subject to potential compliance actions on that basis. However, Table II samples that contain 5% or less quartz are excluded from the regulatory framework intended to control respirable quartz exposure due to their low quartz content, but 26.3% of these samples exceed 100 μg/m^3.

Of the Table II samples that contain more than 5% quartz, 85% exceed the 100 μg/m^3 respirable quartz level. For the 15% of samples that do not exceed 100 μg/m^3, the reduced RDS was low enough to control the quartz exposure, possibly due to the quartz content of the extracted material falling after the reduced RDS was established.

DISCUSSION

The data presented show that the current MSHA approach to regulating miner exposure to respirable quartz does not protect miners from excessive exposure to respirable quartz in all cases. Specific situations where this occurs include when the quartz content of the airborne dust increases due to changes in geologic conditions, i.e., more rock, or rock with higher quartz content must be extracted, and when the RCMD concentration exceeds the applicable RDS. In addition, if the mine operator submits optional samples for quartz analysis, the process for reducing the RDS may be extended by several weeks. During this period, RCMD exposure is regulated at the pre-existing dust standard, which may not be protective.

To assess the effectiveness of an occupational health exposure standard, the most appropriate metric is the extent of reduction of the adverse effect that it guards against. With occupational illnesses in general and pneumoconioses in particular, the long disease latency makes it difficult to make this assessment. However, if compliance with an occupational exposure limit (OEL) is expected to be protective against a specified health outcome, then evaluating the degree of compliance with the OEL may be a reasonable surrogate for effectiveness in the short term. When, as in this case, the exposure standard is only partially protective under conditions that can feasibly be encountered, the effectiveness of the OEL becomes very difficult to evaluate until enough time has passed to observe cases of disease.

Adoption of an independent and specific standard for airborne respirable quartz exposure in coal mining has been recommended by NIOSH, and by the Secretary of Labor's Advisory Committee on the Elimination of Pneumoconiosis among Coal Mine Workers.[20,21] A separate respirable quartz standard, as described by NIOSH,[20] could reduce miners' risk of overexposure to respirable quartz and, by extension, their risk of developing silicosis. Such a standard may include the collection of personal, full-shift samples as frequently as necessary to ensure that miners' exposure is maintained below the exposure limit. Also, assessment of each sample against a defined, fixed criterion would encompass more exposure conditions without reliance on prior sample results and would permit MSHA to focus additional resources on a currently unregulated exposure condition.

This analysis has not addressed the adequacy of the 100 μg/m^3 quartz exposure standard but only whether the exposure assessment component of the existing respirable quartz control strategy was competent to consistently define quartz exposure in relation to the permissible exposure level. The protection afforded by the current 100 μg/m^3 respirable quartz exposure standard is a fundamental consideration of any program to control pneumoconiosis and other adverse health effects in coal miners but is beyond the scope of this report.

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