Improving Silica Dust Control Through Targeted Research

Jay F. Colinet and Edward D. Thimons
National Institute for Occupational Safety and Health
Pittsburgh, PA

AB36-Comm-52-5

ABSTRACT

NIOSH conducted a strategic planning effort to identify those areas in mining with the greatest research needs. Data analysis and stakeholder input identified the need to reduce worker exposure to respirable crystalline silica dust as a high priority area. MSHA dust sampling data were analyzed to target the mining commodities and occupations with the greatest percentage of samples containing silica above compliance levels. In response, the Pittsburgh Research Laboratory (PRL) has implemented a multi-faceted research program to improve silica dust control for these problematic commodities and occupations. A review of silica compliance trends, PRL silica research programs, and recent control technology developments are provided here.

BACKGROUND

The Federal Coal Mine Health and Safety Act of 1969 and the Federal Mine Safety and Health Act of 1977 established exposure limits and sampling requirements to assess compliance with the respirable dust standards in mining. The Mine Safety and Health Administration (MSHA) is responsible for the collection of personal respirable dust samples, which are measured gravimetrically as an 8-hour time-weighted-average concentration. For coal mining, a permissible exposure limit (PEL) of 2 mg/m^3 for respirable coal mine dust has been established. The PEL is reduced if the respirable crystalline silica content of the samples exceeds 5%. Crystalline silica analysis (quartz) for coal mine dust samples is conducted using infrared spectrometry (Parobeck and Tomb 2000). The reduced PEL is calculated by dividing the percent silica into 10 (e.g., 10/10% silica, would reduce the PEL to 1.0 mg/m^3). Noncompliance occurs when the measured dust concentration exceeds 2 mg/m^3 or the reduced PEL, when applicable.

For metal/nonmetal mining, personal respirable dust samples are collected by MSHA inspectors and analyzed for crystalline silica dust (quartz, cristobalite, tridymite) using x-ray diffraction (Parobeck and Tomb 2000). All samples with a mass of at least 0.1 mg are analyzed for silica content. Samples with a silica content greater than or equal to 1% silica are considered respirable quartz (RQ) samples and are used to calculate a PEL. The PEL is determined by dividing 10 by the (% respirable quartz + 2). Therefore, a sample containing 10% silica in a metal/nonmetal mine would result in a PEL of 0.833 mg/m^3 (e.g., 10/12 = 0.833). Noncompliance occurs when the measured dust concentration is greater than 1.2 times the PEL.

When the health and safety functions of the U.S. Bureau of Mines were transferred into NIOSH, a strategic planning effort was initiated to utilize available data and stakeholder input to identify the areas with the greatest research needs. Part of this effort involved analyzing available data to assess the severity and likelihood of overexposure to respirable dust in the mining industry.

STRATEGIC PLANNING EFFORTS

In 1998, NIOSH personnel were charged with the task of analyzing available data to identify the greatest threats to the health and safety of miners. A risk analysis was completed, where the severity and likelihood of individual risks to miners were determined and ranked on a scale from low to high. For these purposes, severity was defined as the effect of an event when it occurs (e.g., death, disability, injury), while likelihood indicates the frequency at which an event occurs. High severity was assigned for those illnesses resulting in death, total disability, or significant decrease in the quality of life, while low severity represented illnesses causing little to no permanent disability or impairment. However, the development of this risk analysis for health-related threats to mine workers was complicated by the disease itself and the type of data available for analysis.

The development of health-related illnesses typically does not occur until extended exposure to the health hazard has been realized. The onset of the illness may not manifest itself until after the mine worker has left the mining industry or even retired. Consequently, the direct causal relationship associated with accident-injury reporting often is not available with health-related illnesses.

In underground coal mining, the Coal Workers' X-ray Surveillance Program was created in the Federal Coal Mine Health and Safety Act of 1969. Under this program, underground coal mine workers can volunteer to periodically have a chest radiograph taken to evaluate for the development of Coal Workers' Pneumoconiosis (CWP). However, surface coal miners and miners working in the metal/nonmetal mines did not have a similar federally-sponsored, x-ray program available. Consequently, the prevalence rate of CWP for active underground coal miners has been documented, but the prevalence of silicosis in the mining workforce has not routinely been monitored. Another confounding factor in determining contraction of these diseases is that radiographs can be used to identify lung disease, but an associated work history or autopsy is needed to distinguish between silicosis and CWP. Consequently, reported cases of CWP may actually be cases of silicosis.

The best available determination of silicosis within mine workers is obtained through the review of death certificates where silicosis is listed as the cause of death. Unfortunately, only 24 states identify the industry of work for the deceased on their death certificate and report this information to the National Center for Health Statistics

[NIOSH 1999]. Therefore, insufficient data is available to determine the actual number of cases of silicosis within the mining industry.

Severity of Risk to Miners

Extended exposure to airborne respirable dust can lead to the development of debilitating and potentially deadly lung diseases for mine workers. The principal threats to coal mine workers are the development of CWP and silicosis, with silicosis being the primary lung disease contracted by workers in the other mining commodities. In its early stages, CWP is classified as simple pneumoconiosis and the disease usually does not prevent the worker from working or carrying on with most normal activities. As the disease progresses to complicated pneumoconiosis or progressive massive fibrosis (PMF), more severe lung impairment results and the worker is considered permanently disabled. Likewise, varying types of silicosis exist and range from the most severe (acute silicosis) to the most common (chronic silicosis). In acute silicosis, the worker is exposed to extremely high silica concentrations over a relatively short period of 6 months to 2 years [NIOSH 1995]. The disease demonstrates a rapid progression to death from respiratory failure or tuberculosis, typically within one year of contracting the disease. Chronic silicosis develops over an extended exposure period (10+ years) at relatively low silica concentrations. Chronic silicosis is similar to CWP in that the disease initiates as simple silicosis but can progress to PMF and death. The toxicity of silica dust within the lungs results in silicosis continuing to progress as a disease even after the afflicted worker is removed from further dust exposure.

As indicated, limited data is available to accurately determine the extent of silicosis among mine workers. From data available for 1987 to 1996, a total of 232 deaths were attributed to silicosis in the coal, metal, and nonmetal mining industries [NIOSH 1999]. Despite the lack of data available for "sand and gravel" and stone operations, these mining-related silicosis deaths accounted for approximately 22% of the silicosis deaths reported by the 24 states that identified worker industry on the death certificates during this period. Several significant mining states, including Pennsylvania (490 silicosis deaths), Illinois (92 silicosis deaths), and California (144 silicosis deaths), were among the states that did not provide industry-specific data for the deceased workers.

A special x-ray program was offered to surface mine workers in Pennsylvania in 1994. Over 5% of the 150 miners examined were diagnosed as having silicosis [MSHA 1995]. The level of silicosis found in this initial survey prompted two additional rounds of radiographs being offered on a voluntary basis to surface miners in Pennsylvania. Over 1200 additional miners were examined and results indicate that nearly 7% of these miners had contracted silicosis [Anon. 2000].

The potential for silicosis to cause permanent disability and death, mining deaths continuing to occur from silicosis, and the continued prevalence of these diseases being identified in miners indicate that exposure to silica dust in underground and surface mining operations remains a very real and serious threat to miners' health. Consequently, a severity rating of "high" was assigned to silica dust exposure in NIOSH's strategic planning efforts.

Likelihood of Risk to Miners

For NIOSH's strategic planning, the lack of information on silica-dust-induced illness made it necessary to utilize exposure data as a proxy to determine the likelihood of contracting silicosis. This reasoning suggests that if overexposure to respirable silica dust continues to occur, then the future development of silicosis will occur in the mining workforce. For purposes of establishing a ranking of the likelihood of overexposure to dust, NIOSH adopted an arbitrary scale of overexposure that was similar to the ranking scale developed for the safety data in the strategic planning effort. If the percentage of samples exceeding the PEL was less that 5%, between 5 and 10%, or greater than 10%, risk ratings of low (L), medium (M), or high (H) were assigned, respectively.

As previously discussed, personal exposure data were used as an indicator for determining the likelihood of developing silicosis. MSHA dust sampling data were utilized as the measure of the likelihood of overexposure to silica dust for mine workers. Sampling data for the five-year period from 1988 to 1992 were available for the strategic planning effort for all mining commodities of interest and are provided in Table I. These data represent a summary of all samples collected by MSHA and include a vast array of both underground and surface mining occupations that were sampled. It should be noted that the sampling data for coal mining were obtained from the NIOSH document, "Criteria for a Recommended Standard: Occupational Exposure to Respirable Coal Mine Dust" [NIOSH 1995]. Sampling data for all other mining industries were obtained from the Mine Inspection Data Analysis System (MIDAS) database [Watts and Parker 1995]. These sampling results show that a substantial percentage of silica dust samples were exceeding the PEL in all of the mining industries.

Further analysis of the sampling data from 1988 to 1992 was completed to provide a more specific determination of overexposure to silica dust by underground and surface mining location for coal mining. For all other mining industries, overexposure data for underground, surface, and mill/plant locations were available. Table II provides the over-exposure rates that were observed and the corresponding likelihood rankings.

Table I. Silica dust sampling results by mining industry

Mining Industry	1988 - 1992 Samples	
	Number of samples	% > PEL
All mining	69,345	15
Coal	19,783	24
Metal	4,686	21
Nonmetal	4,796	13
Stone	22,428	12
Sand & Gravel	17,652	9

Table II. Likelihood ranking by mining location

Mining Industry	Location	Number of Samples	% of Samples > PEL	Rank
Coal	Under ground	16,240	24	H
	Surface	3,543	24	H
Metal	Under ground	1,178	27	H
	Surface	1,700	15	H
	Mill or Plant	1,808	23	H
Non metal	Under ground	424	16	H
	Surface	1,767	5	M
	Mill or Plant	2,605	18	H
Stone	Under ground	736	15	H
	Surface	12,486	9	M
	Mill or Plant	9,206	15	H
Sand & Gravel	Under ground	45	7	M
	Surface	10,027	7	M
	Mill or Plant	7,580	12	H

High Exposure Occupations

In addition to the above assessments, sampling data from the MIDAS database for the period from 1986 to 1995 were also examined and contained information on dust exposures for individual occupations in the various mining industries. Figure 1 illustrates a number of occupations that were frequently sampled and had high over-exposures for each mining industry. This information identifies problematic occupations that warrant future research in order to lower silica exposures.

Stakeholder Input

Qualitative data from 22 stakeholder sources (data gathered from letters, questionnaires, and meetings) were examined to assess the magnitude of concern expressed by the stakeholders for the many health and safety issues facing the mining industry. A ranking scale was developed that resulted in a high, medium, or low interest ranking based upon the number of stakeholders that expressed interest in each issue. Silica dust control received a "high interest" ranking from the stakeholder input examined.

As a result of this strategic planning effort, recent dust control research at PRL has focused upon surface drills and roof bolters in coal mining, plant operations at noncoal mines, and underground operations at metal and stone mines. An overview of the research addressing each of these areas will be provided.

ONGOING RESEARCH PROGRAMS

The Pittsburgh Research Laboratory is currently conducting dust control research for coal and metal/nonmetal mining for both surface and underground mining occupations at high risk for overexposure to respirable silica dust. The focus, methodology, and recent outcomes for each research program will be discussed.

Dust Control in Surface Coal Mining: As indicated by the compliance sampling results, the surface drill operator experiences the highest frequency of overexposures. Therefore, a multi-faceted research effort is being conducted to: reduce the amount of dust generated during drilling, improve the capture of dust liberated from the drill hole, and improve the protection offered by enclosed cabs on surface equipment.

A number of drilling parameters (e.g., drill rpm, thrust, bit type) along with the physical parameters of the rock being drilled (e.g., type, thickness, silica content) have the potential to impact the amount of silica dust liberated during drilling. Research has been initiated to document the impact of these parameters on dust generation. In order to evaluate differences resulting from changes in these parameters, a unique sampling system has been

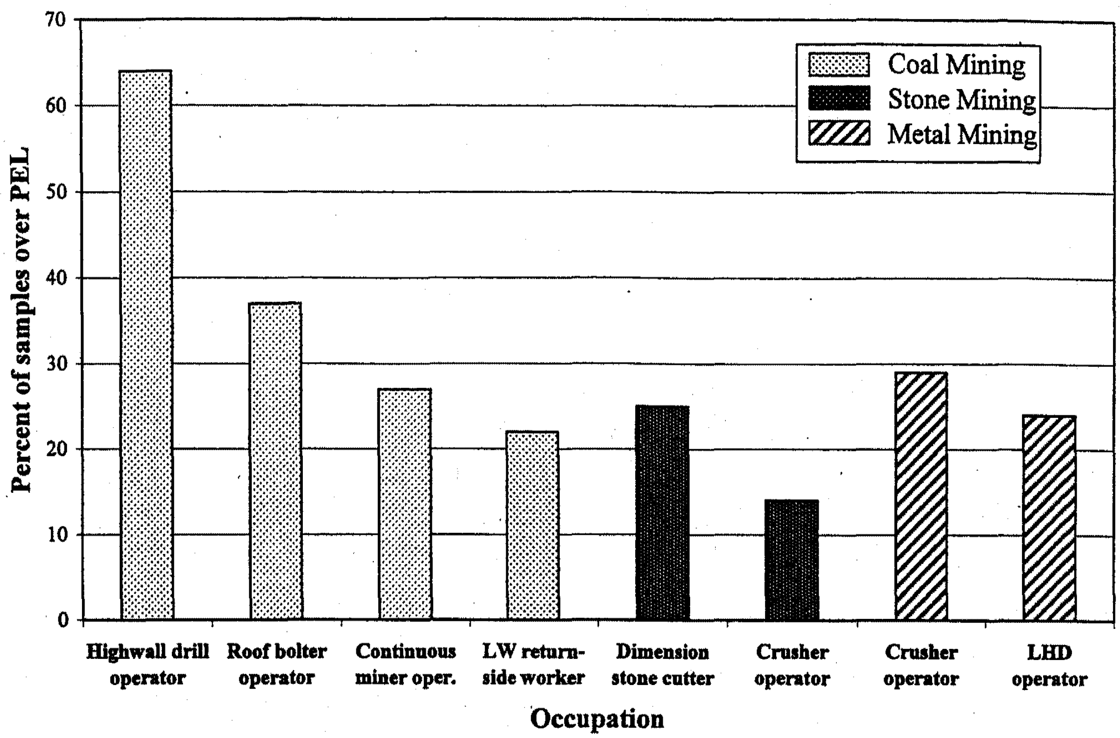

Figure 1. Silica exposures for select occupations from different mining industries.

developed. A multi-stage sampler will be used to sample dust levels in the hose leading from the collector to the drill table. This sampling will quantify dust generation from the major strata segments and examine the impact on dust when drilling parameters are changed. Preliminary evaluation of this sampling technique has been completed in the lab and at a cooperative mine site.

Dry dust collection systems on surface drills, which attempt to collect dust through a capture duct installed near the corner of the drill table, can be very effective. However, the distance separating the capture duct of the dry collector from the drill hole allows dust to escape the collector, particularly if the confinement of the drill shroud is compromised. Thus, research is being conducted at a full-scale test stand to position the collection point directly above the drill hole. A special hood had to be designed that would allow for dust capture without large drill cuttings causing the collector hood to plug. Full-scale laboratory tests indicate that the shroud can operate without clogging and improvements in capture efficiency are being evaluated.

Enclosed cabs on surface mining equipment can provide protection from respirable dust generated on the mining site. However, as the equipment ages, the integrity of the enclosed cabs and air supply systems to these cabs degrade and thus reduces the protection offered by the cab. PRL has conducted several research efforts to improve cab protection through the installation of new filtration/pressurization units and by restoring the integrity of the seals around the cab. Significant dust reductions were measured when the cabs were able to obtain some degree of pressurization. At a coal mine site, a positive pressure of 0.1 inches of water gage was achieved on a front end loader and resulted in a 90% dust reduction inside the cab [Organiscak et al. 2000]. However, at this same site, a surface drill could not achieve positive pressure in the cab and no improvements in dust reductions were observed. During the course of the research, it was found that mud brought into the cab on the operator's boots can be entrained into the cab environment, particularly if a floor-mounted heater is used, and add to the operator's dust exposure [Cecala et al. 2001]. A sweeping compound was tested that was shown to reduce dust from this source [Organiscak et al. 2001].

Control of Silica Dust Exposures in Underground Coal Mining

Roof bolter operators were identified as the highest exposure occupations in underground coal mines. Research was initiated to determine the source of these high exposures and then develop controls to address these sources. MSHA compliance sampling data were analyzed to identify a number of mining sections that were operating on reduced dust standards as a result of elevated silica levels. Two groups of mining sections were examined. The first group consisted of sections that were on reduced dust standards and were relatively consistent in meeting the reduced standard, while the second group was having difficulty maintaining compliance with the reduced standard. MSHA inspector data from these sections were evaluated to determine if differences in dust control technologies existed between the two groups. The factor that appeared to have the greatest impact was having the the roof bolter work downwind of the continuous miner. In this position, silica dust generated by the miner could be carried to the roof bolter operators. Therefore, research was initiated to develop air curtain technology for installation on roof bolters working downwind of the miner.

A canopy air curtain was developed that would filter a small quantity of dust-laden air and then discharge cleaned air through a plenum installed over the breathing zone of a bolter operator. Laboratory tests were conducted and indicated that the air curtain did reduce dust levels in the operator's breathing zone. However, the height added by installation of the air curtain may preclude its use in mines with lower seam heights. Subsequent research was conducted in an effort to achieve the same type of dust reduction while using an air tube, which would be less restrictive than the air plenum.

The longwall mining method is highly productive but also has the potential to create dust control problems on the longwall face. One likely source of silica dust exposure for longwall workers is dust liberated during the advancement of shield supports. With higher quantities of air being supplied to longwall faces, the impact of higher air velocities on this dust source has not been quantified. In response, a wind tunnel was fabricated to simulate dust dropping from the shield canopies to quantify the dust entrainment that occurs in high velocity airstreams. To date, tests have been conducted with coal dust that indicate the entrainment of respirable dust is greater than dilution effects when higher air velocities are introduced into the wind tunnel [Listak et al. 2001]. Future tests are planned to evaluate the entrainment characteristics of rock in these high velocity airstreams.

Silica Dust Control in Metal/Nonmetal Mining

As indicated by the MSHA compliance sampling data, occupations at both surface and underground metal/nonmetal mines are being exposed to unacceptable levels of respirable quartz. Research for this project is addressing both areas of concern. For surface occupations, studies are being conducted in a silica sand plant, a silica sand surface mine, and a dimension stone shop. Underground dust surveys have been conducted in limestone and gold mining operations.

At the silica sand plant, the clothing of workers can get contaminated with silica dust and should be cleaned to avoid secondary exposure to the worker. Currently, MSHA requires that this dust be vacuumed from the clothing and does not permit the use of compressed air to blow the dust off. Compressed air disperses the dust into the air, creating the opportunity to be inhaled by the worker. NIOSH, in cooperation with plant personnel, has been investigating the use of a clothes cleaning booth that utilizes compressed air but provides respiratory protection for the worker during the clothes cleaning process. Initial testing has utilized a manifold of air sprays to clean the workers clothes while the worker is wearing an air-purifying helmet in an enclosed booth. Preliminary results indicate that the air manifold removed a larger quantity of dust from worker coveralls in a shorter time than the normal vacuuming procedure. It appears that slight modifications to the manifold sprays will offer additional improvements in cleaning and additional testing is planned.

A rotary drill rig at the silica sand mine is being retrofitted with an air filtration/pressurization system to improve the protection offered by the enclosed cab. A baseline dust survey has been completed and the filtration/pressurization unit installed. Post-installation sampling is currently being conducted to evaluate the impact of the new system on dust levels inside the enclosed cab.

The dimension stone shop receives large slabs of stone which are then cut into smaller pieces using several different saws. Company officials were concerned about an accumulation of dust in the building, particularly during winter months when shop doors are closed. In an effort to reduce ambient dust levels, fan-powered air cleaners were installed near the roof and dust sampling was completed. Results indicate that the filters in the air cleaners became loaded in a relatively short time and caused a reduction in air flow through the cleaners. Additional research is being conducted to utilize the expertise of a filter manufacturer to improve the performance characteristics of the cleaners. In addition, the potential to use wetted filters near specific saws is also being investigated.

The number of underground limestone mines in the US is increasing and a common problem in many of these operations is the lack of well-defined ventilation systems. A limestone mine in Pennsylvania was utilizing an auxiliary fan to supply blowing ventilation to transport dust away from an underground crusher and down a belt entry to the main mine return. Dust sampling was conducted to evaluate the effectiveness of this installation and showed that the fan did prevent dust rollback into the intake entries but did not efficiently move dust from the crusher to the return. Two alternatives, a second auxiliary fan or a dust collector, are being considered for installation by mine personnel in order to reduce levels around the crusher.

In metal/nonmetal mines, haul truck drivers that are operating without enclosed cabs or cabs that have deteriorated with use have the potential for high dust exposure. A survey was conducted at an underground gold mine to evaluate the dust exposure of haul truck drivers working in trucks with open cabs. Instantaneous samplers were utilized in conjunction with time-study information to quantify the dust exposure occurring during the loading, hauling, and dumping cycle. At this mine, it was found that even though the dumping operation had the shortest duration, dumping accounted for the highest percentage of dust exposure. This information could then be used to implement additional controls at the dumping station to reduce dust levels.

SUMMARY

NIOSH conducted a strategic planning effort to identify areas where limited research funds should be directed to be of greatest benefit to the mining industry. Overexposure to silica dust and development of silicosis continue to occur at surface and underground mining operations. The need for development of improved control technologies was identified as an area of high priority by the NIOSH strategic planning effort. MSHA sampling data were utilized to identify mining commodities and occupations that have high percentages of samples exceeding the PEL. In response, research is being conducted to address dust controls for these occupations at both surface and underground mining operations in the coal and metal/nonmetal industries.

REFERENCES

Anonymous, 2000, Silicosis Screening in Surface Coal Mines — Pennsylvania, 1996-1997, Centers for Disease Control and Prevention, MMWR Weekly, July 14, 2000 / 49(27);612-5.

Cecala, A.B., Organiscak, J.A., and Heitbrink, W.A., 2001, "Floor Heaters Can Increase Operator's Dust Exposures in Enclosed Cabs," NIOSH Technology New No.486, March, 2001.

Listak, J.M., Chekan, G.J., and Colinet, J.F., 2001, "Laboratory Evaluation of Shield Dust Entrainment in High Velocity Airstreams," SME Preprint 01-144, SME Annual Meeting, Denver, Colorado, February 26-28.

MSHA, 1995, MSHA News Release No. 95-014, Mine Safety and Health Administration, April, 1995.

NIOSH, 1995, Criteria for a Recommended Standard: Occupational Exposure to Respirable Coal Mine Dust, National Institute for Occupational Safety and Health, DHHS (NIOSH) No. 95-106, 336 pp.

NIOSH, 1999, Work-Related Lung Disease Surveillance Report - 1999, National Institute for Occupational Safety and Health, DHHS (NIOSH) No. 2000-105, 202 pp.

Organiscak, J.A., Page, S.J., and Cecala, A.B., 2001, "Sweeping Compound Application Reduces Dust From Soiled Floors Within Enclosed Operator Cabs," NIOSH Technology News No. 487, March, 2001.

Organiscak, J.A., Cecala, A.B., Heitbrink, W.A., Thimons, E.D., Schmitz, M., and Ahrenholtz, E., 2000, "Field Assessment of Retrofitting Surface Coal Mine Equipment Cabs with Air Filtration Systems," Proceedings of the Thirty-first Annual Institute on Mining Health, Safety, and Research, Roanoke, Virginia, August 27-30, pp. 57-68.

Parobeck, P.S., and Tomb, T.F., 2000, "MSHA's Programs to Quantify the Crystalline Silica Content of Respirable Dust Samples," SME Preprint 00-159, SME Annual Meeting, Salt Lake City, Utah, February 28 - March 1.

Watts, Jr., W.F. and D.R. Parker, 1995, The Mine Inspection Data Analysis System (MIDAS), Appl. Occup. Environ. Hyg. 10(4), pp. 323-330.