SILICA DUST SOURCES IN UNDERGROUND LIMESTONE MINES

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ABSTRACT

NIOSH's Pittsburgh Research Laboratory is currently involved in research to identify silica dust sources and generation in underground metal/nonmetal mines. The ultimate goal of this research is to develop control technologies to reduce worker exposure to respirable silica dust. Baseline dust surveys were conducted in underground limestone mines in Pennsylvania to investigate primary silica dust sources, generation levels, and controls being used. Three primary sources currently under investigation include dust generated by crushing facilities, face shots, and haul trucks. A summary of sampling procedures, resulting data, and methods being investigated to reduce silica dust will be discussed.

INTRODUCTION

Chronic overexposure to respirable crystalline silica may lead to silicosis, which creates irreversible and progressive deterioration once the dust has been deposited in the lung tissue. Historically, mining has been a one of the highest risk industries for worker exposure to crystalline silica dust. Through the 1980's and into the 1990's, United States Bureau of Mines (USBM) research program addressing silica dust sources and worker exposure had mainly focused on surface and underground coal mining and surface processing operations for the nonmetal mining industry. Numerous studies were conducted which have lead to the development of improved control technologies for reducing silica exposure in high-risk occupations in these operations. However, studies addressing silica dust occurrence and exposure in underground metal/nonmetal mines had not been a high priority in the USBM dust control research program. When the health and safety research functions of the USBM were transferred into the National Institute for Occupational Safety and Health (NIOSH), a strategic planning effort was conducted to identify areas of need that warranted new or continued research efforts. To identify high risk occupations in underground metal/nonmetal mines, the MSHA compliance sampling results were evaluated for contaminant code 523, which is defined as a full shift sample with a total mass gain on the filter equal to or greater than 0.1 mg and a crystalline quartz respirable fraction greater than or equal to 1% determined by X-ray diffraction (XRD) following the NIOSH 7500 Analytical Method (NIOSH, 1994b). For the period from 1993 to 1998, the data shows that the average percent of these samples exceeding the Threshold Limit Value ® (TLV) ® was 15%, with considerably higher overexposures for high-risk occupations (MSHA, 1999). Consequently, a research project was initiated to address worker exposure and silica dust control for the more than 10,000 miners currently employed in over 300 underground metal/nonmetal mines (MSHA, 2000).

MSHA classifies the metal/nonmetal division in four main categories; sand and gravel, metallic minerals, nonmetallic minerals, and stone. A major component of the underground metal/nonmetal research program is the investigation of silica dust in the underground crushed and broken limestone industry, which is one of the main commodities in the stone category. Figure 1 is the frequency of MSHA dust sampling (MSHA, 2001), as a percent of total samples taken, for the major commodities in the underground stone industry for the years 1996 to 2000. The sampling data shows that 43% of the sampling occurs in the crushed and broken limestone commodity.

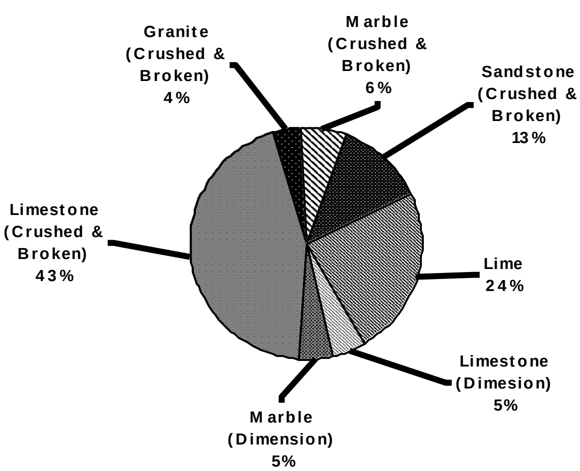

Figure 1. MSHA dust sampling as percentage of total samples taken.

Currently, there are approximately 110 underground crushed and broken limestone mines in the US, representing the largest segment of the underground stone industry. Depending on the geology, some limestones may have a higher sand component, while others have a higher calcite component. Studies on the sources of silica dust (Ramani, et. al., 1987) have shown a strong correlation between the airborne concentration and percent silica in the host rock. Historically, higher levels of silica have been observed in mines located in the Northeastern and South Central MSHA districts. The Northeastern and South Central Districts have 19 and 18 mines respectively, and account for 35% and 25% of the total samples taken (MSHA, 2001).

Due to demand, the number of underground crushed and broken limestone mines are increasing on a yearly basis as quarry operators exhaust their surface reserves and begin underground operations. Room-and-pillar mining methods are utilized, typically using pillars with square dimensions ranging between 10.6 to18.3 m (35 to 60 ft). The entries are considered large mine openings with entries widths ranging from 9.1 to 18.3 (30 to 60 ft) and entry heights on development ranging from 4.9 to 12.1 m (16 to 40 ft). After benching, entries can be over 18.3 m (60 ft) high. Many of the dust sources, which are not problematic in a surface operation, have now become a issue in the underground environment. Many of these sources may increase the level of respirable silica dust at generation points as well as in the overall mine atmosphere since these large openings can be difficult to ventilate. Occupations with the highest risk of overexposure include truck drivers, crusher operators, front-end loader operators, and rotary drill operators. On average, 20 to 25% of the samples from these occupations exceed the TLV ®(MSHA, 2001).

The NIOSH research program is addressing these silica issues by quantifying dust levels at major sources in the underground crushed and broken limestone industry. Baseline sampling surveys were conducted for three different sources, 1) dust generated by an underground dump/crusher facility; 2) dust generated by face shots; and 3) dust within a truck drivers cab generated by loading, dumping and tramming activities. The objective of these studies was to determine silica dust levels generated by these operations and assess the controls in use. The ultimate goal of this research is to develop or modify dust control technologies to reduce worker exposure to respirable silica dust.

SAMPLING INSTRUMENTS USED IN SURVEY

Two types of dust sampling instruments were used in these studies. The first type and primary dust measuring instrument was the gravimetric sampler operated at 1.7 L/min with the 10 mm Dorr-Oliver cyclone and a 37 mm PVC filter. The pumps featured automatic compensation for changes in temperature and altitude, but calibration was adjusted at the mine site using a primary standard to within plus or minus 2.5%. The filters were weighed before and after sampling to calculate overall respirable dust concentrations (which includes all dust types and particulate) based on the sampling rate and time. The filters were then analyzed using XRD following the NIOSH Analytical Method 7500 (NIOSH, 1994b), to determine the silica weight, so that the silica concentrations could be calculated.

The second type of sampling instrument was the MIE, Inc. personal DataRAM (pDR). The pDR is a real-time aerosol monitor. The instrument was operated in the active mode to monitor respirable dust. Before entering the unit, dust is classified using a 10 mm Dorr-Oliver cyclone and a pump operated at flow rate of 1.7 L/min. The pDR measures and records the concentration of respirable airborne dust (which again includes all dust types and particulate) using a light scattering technique. Light-scattering instruments offer only a relative measure of concentrations but provide a continuous record of dust levels so that concentrations can be evaluated over any time interval during the sampling period.

SAMPLING AT A DUMP/CRUSHER FACILITY

Sampling Strategy

Approximately 50% of all underground limestone mines have their crushers located underground **(**NIOSH, 1999**)** which can be a major source of silica as well as nuisance dust. In this particular case study, the mine is considering different methods of controlling dust at their underground crusher using either a push-pull ventilation system or a fan-powered dust collector. NIOSH and mine personnel agreed to complete a dust study to quantify dust levels being generated by the current operation. This would be accomplished by area sampling at key locations around the crusher to determine the dust levels generated from the dumping and crushing operations and to identify potential zones of high dust concentration.

Current dust controls for this study consisted of a 37.1 kw (50 hp) axial vane fan positioned inby the crusher as shown in figure 2. The fan was positioned in this area in an effort to prevent dust-laden air from rolling back into the intake air as the trucks dumped. The fans function was to blow dust away from the dump/crusher location and down the belt entry into the return airway. The crusher is a 222.6 kw (300 hp) jaw type rated at 907 t/h (1000 stph). The belt entry is isolated from the main developments using both permanent and curtain stoppings in crosscuts along its entire length of approximately 152 m (500 ft). The crusher operator was located in an enclosed booth that was equipped with a pressurization and filtration system. A spray bar system was used at the dump location to control dust during the truck dumping operation. Any personnel entering or working in the vicinity of the crusher were required to wear personal protective equipment.

Table 1 identifies the types of dust samplers that were positioned at each sampling location, while figure 2 illustrates the relative location of these sampling stations around the crusher.

Table 1. Dust sampler location and description for crusher survey.

Site	Location	Sampling Instruments		Description
		Gravimetric	pDR	
1	Intake	4	1	2 grav samplers on each rib, pDR on one rib
2	Dump	3	1	all samplers on rib upwind of dump site
3	Crusher	3	1	samplers at control booth above crusher
4	Belt	3	1	inby open mandoor in stopping at return
5	Return	4	1	2 grav samplers on each rib, pDR on one rib
6	Entry A	2	0	on rib in entry parallel to belt entry

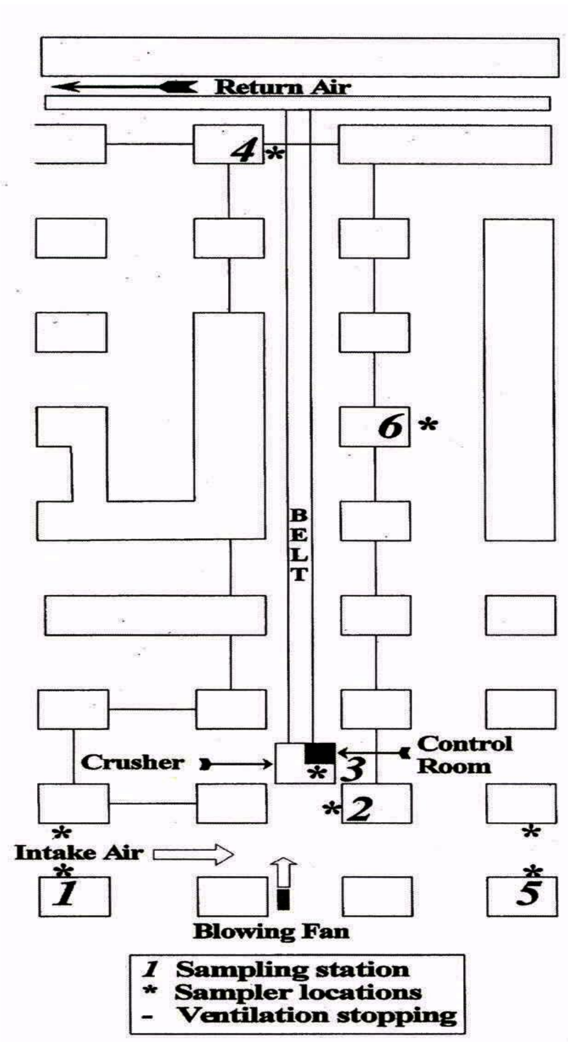

Figure 2. Location of sampling stations, blowing fan, and stoppings.

Samples were collected for three consecutive days with an average sampling time of about five hours per shift. During this time, the number of trucks that dumped and the tonnage processed through the crusher were recorded. In addition, anemometer readings were taken at a 1.2m by 2.1 m (4ft by 7 ft) doorway at the end of the belt entry leading to the return to monitor airflow from the crusher to the return airway. This information is given in table 2 and shows consistent values for all three sampling days.

Table 2. Production and air velocity measured during sampling.

Shift Number	1	2	3
Number of trucks	129	128	107
Measured tonnage, metric tons (short tons)	4624 (5098)	4711 (5194)	4214 (4647)
Average air velocity at doorway, m/s (fpm)	2.8 (565)	2.6 (506)	2.3 (460)

Results

Figure 3 summarizes the average concentrations for the 3 sampling days for the respirable dust and silica dust. The following is

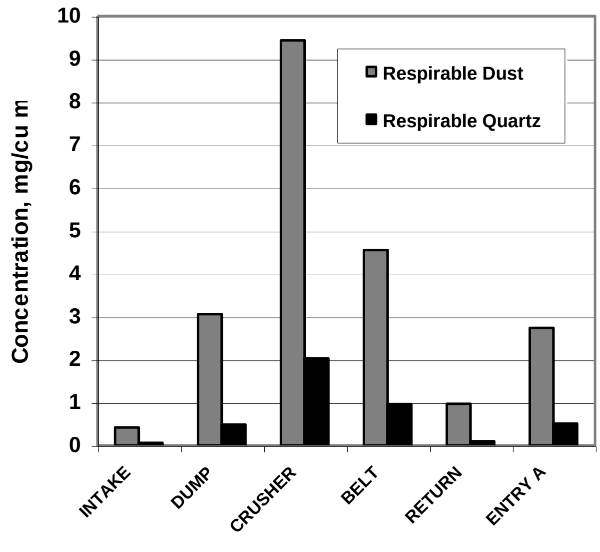

Figure 3. Average dust concentrations for 3 shifts of sampling.

notable for each of the six locations:

Site 1- Intake: This station had respirable and silica concentrations of 0.42 and 0.06 mg/m^3, respectively. These dust levels were the lowest observed from all locations and indicates that very little if any dust is migrating from the crusher back into the main developments on the intake side.

Site 2 - Dump: When compared to the crusher and belt, this station has lower respirable and silica concentrations. This suggests that the 37.1 kw (50 hp) fan is preventing dust rollback from the crusher as the trucks dump.

Site 3 - Crusher: This location had the highest concentrations of both respirable and silica dust. Of interest, is the fact that respirable concentrations increase threefold from the dump to the crusher location, a distance of roughly 18.2 m (60 ft). This indicates that the current fan is preventing dust migration back from the crusher, but lacks the ability to effectively move it away from the crusher. Observation from inside the operator's booth showed that during the dumping cycle a large plume of dust was created but the low air movement allowed the dust to remain around the crusher for an extended period of time. Stratification or layering of the air may be causing this effect as the fan is suspending the dust above the crusher, but is ineffectual in removing it.

Site 4 - Belt: Both the respirable and silica dust concentrations at the belt location are half of the levels at the crusher, at a distance of approximately 152 m (500 ft) from the crusher. The pDR concentration graphs from the belt were characterized by very consistent levels of dust throughout the sampling period when compared to the pDR graphs from other locations, which usually showed spiked traces of high and low concentrations. The pDR graphs in figure 4 illustrate the difference in dust patterns between the belt (site 4) and crusher (site 3) sampling stations for a typical day of sampling. Since the dust is well diluted and uniform when it reaches the end of the belt this indicates that the fan air is slowly moving the air down the entry, but not very efficiently.

Site 5 - Return: This location behaved much the same as the intake location with low respirable and silica concentrations showing that very little dust is migrating from the dump/crusher back into the main developments on the return side of the crusher. Once again, these samples suggest that the fan is preventing dust rollback from the crusher toward the intake entry.

Site 6 - Entry A: Dust levels were nearly three times higher than at the return sampling location. This indicates that dust leakage is occurring through the line curtains along the belt entry and this dust has the potential to be carried toward the working faces.

Conclusions

This baseline survey was conducted to evaluate dust generation and migration around an underground crusher during normal production activities. Dust concentrations around the crusher and down the belt entry were higher than desired and could be reduced with improved dust capture. The current fan location is performing a function by clearing dust at the

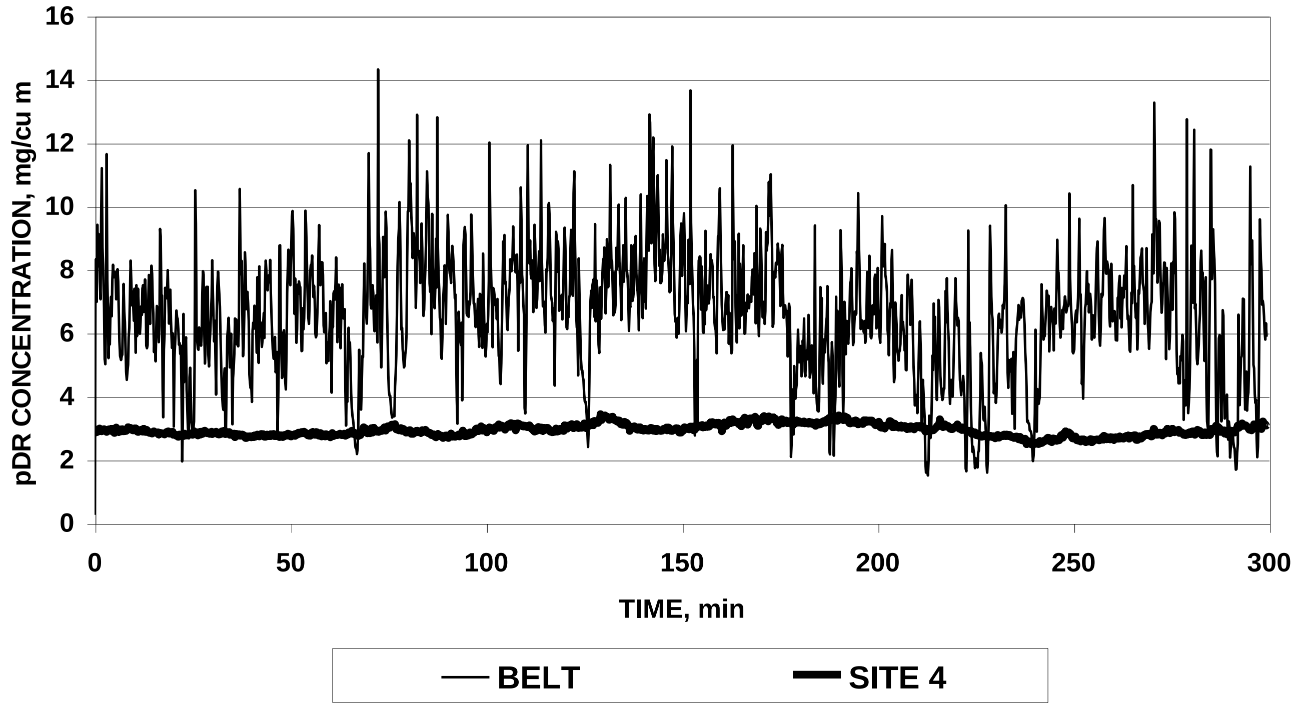

Figure 4. pDR dust levels at site 3 (crusher) and site 4 (belt) during a typical sampling day.

dump and keeping it from recirculating back to the main developments. Either a push-pull system with two auxiliary fans or a fan-powered dust collector is being considered and should provide an effective approach for reducing dust levels. The push-pull system would require a second fan to be placed outby the crusher in the belt entry with exhaust tubing placed as close to the crusher as possible to maximize dust capture. Tubing will then be attached to the blowing side of the fan to transport captured dust directly to the return airway. The second alternative would involve the installation of a fan powered dust collector with filtration system to remove airborne dust and discharge clean air. Either system would increase dust capture at the crusher, thus lowering dust levels at the crusher and in the belt entry. Additionally, less dust would leak through the stoppings into Entry A.

SAMPLING DURING FACE SHOTS

Sampling Strategy

Dust generated from face shots can increase the respirable dust levels in the general mine atmosphere as the dust may not be well diluted or may have a high retention time depending on the ventilation patterns in the mine. After the blast, the dust tends to move in a cloud following the general mine ventilation course until it leaves the mine. In this study, the mine is planning ventilation changes by constructing approximately 30 curtain stoppings and installing two low pressure propeller fans to better ventilate the working faces in the mine. These stoppings and fans will increase the volume of air to the faces and establish a directional flow of air from the eastern to the western side of the mine.

The objective of the study is twofold: 1) to document respirable dust and silica generated from face shots; and 2) to determine the retention time of the dust cloud as a means to evaluate the mine’s air velocity. This baseline study was initiated to assess the current ventilation, particularly on the east side of the mine. The sampling strategy was to set up sampling stations in key locations in the mine’s air course and begin sampling before the faces were shot. Gravimetric samplers would be used

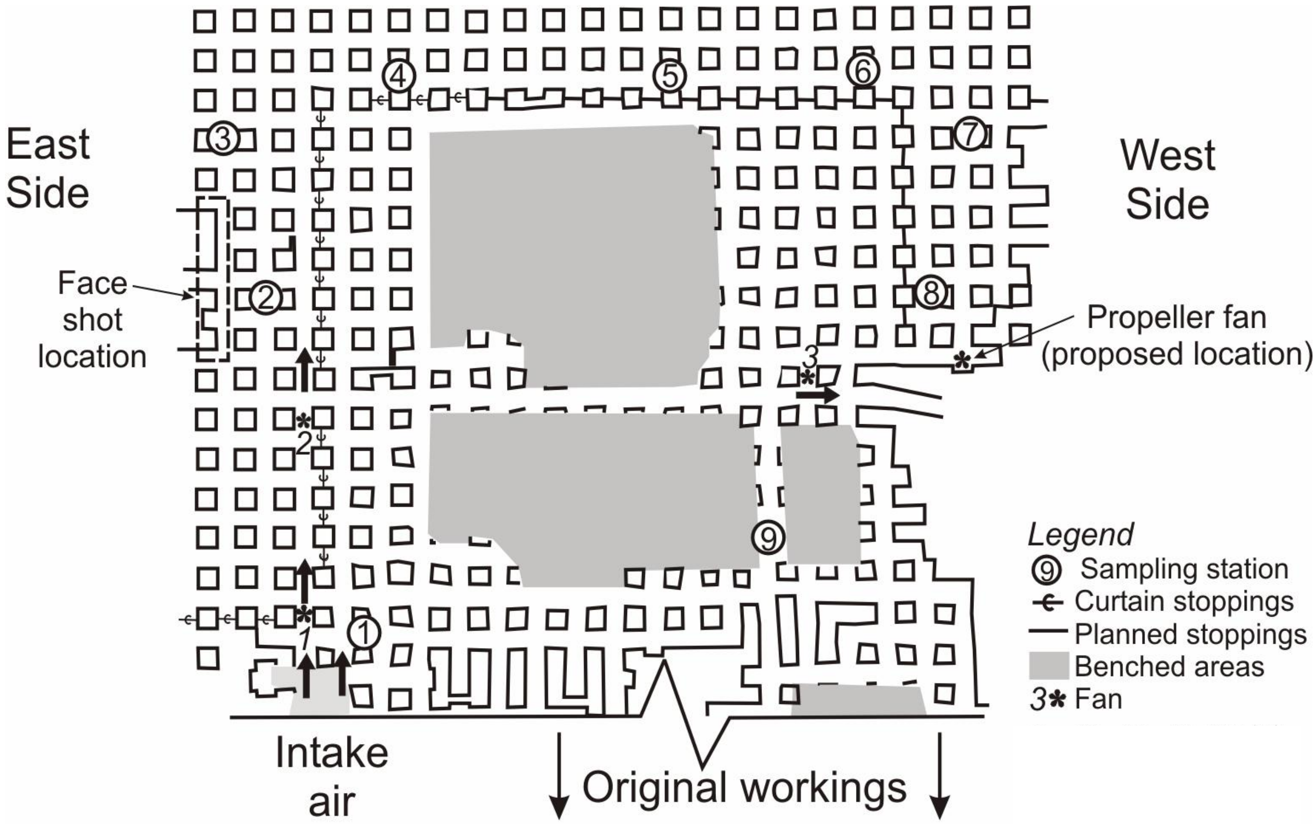

Figure 5. Mine workings showing location of sampling stations, stoppings, and fans.

to determine respirable dust and silica generated by face shots. Personal DataRams (pDRs) would provide a timed record of the dust cloud arrival at these selected areas which could then be used to verify air movement patterns and quantify the mine's overall air velocity.

Location of Samplers

Nine sampling locations in the mine were selected as shown in Figure 5. Site locations were based on suspected air flow patterns in the mine and the potential of dust from the face shots in the working developments to pass that particular location and record the arrival of the dust cloud. All instrument packages were positioned on the rib approximately 1.52 m (5 ft) above the floor. Dust samples from shots were collected on two separate days. Three face shots took place on the first day of sampling and one shot on the second day. All face shots were on the east side of the mine as shown in figure 5. Also shown in figure 5 are: 1) the location of three axial vane booster fans and their blowing direction. These fans are mobile and can be moved depending on ventilation patterns required for mining; 2) the proposed location of the low pressure propeller fan at the west side of the mine; 3) curtain stoppings which were built on the east side of the mine; and 4) curtain stoppings at the back and west side of the mine that still need to be constructed. Table 3 identifies the types of dust samplers that were positioned at each sampling location.

Results – Dust Sampling

Gravimetric samplers were located at Sites 1, 2 , 3, 4, and 8. Figures 6 and 7 show the gravimetric data collected during the two days of sampling. It should be noted that the gravimetric samplers reflect an average concentration for the entire sampling period. For this survey, this would include the dust generated by the shot as well as an extended period of sampling with little or no dust being generated. Consequently, the concentration values are lower than the dust concentrations

Table 3. Dust sampler location and description for face shot survey.

Site	Sampling Instruments		Description
	Gravimetric	pDR	
1	2	1	Intake side – Monitor dust that may rollback into fresh air circuit from face shots on east side of mine
2	2	1	General air circuit - 4 sites located on inby side of the curtain stoppings to monitor dust migration from face shots on east side of mine
3	2	1	
4	2	1	
5	0	1	
6	0	1	General air circuit – 3 sites were located on the on the western side of the mine on the inby side of the curtain stoppings. They monitored dust migration from face shots on the eastern side of the mine and were used to assess the effectiveness of the air circuit being planned
7	0	1	
8	2	1	
9	0	1	Return side - Monitor dust that may migrate past the location of the main exhaust fan and into fresh air circuit

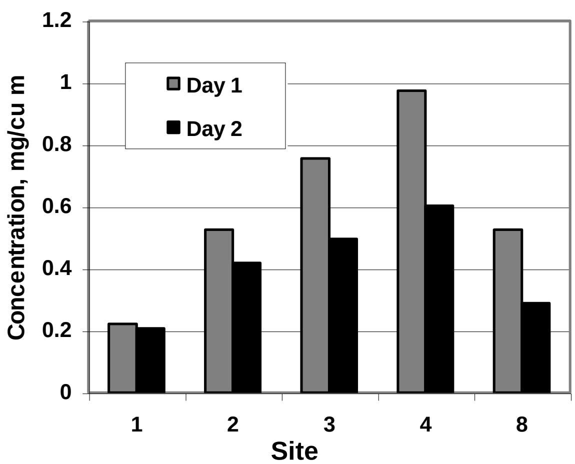

Figure 6. Respirable dust concentrations.

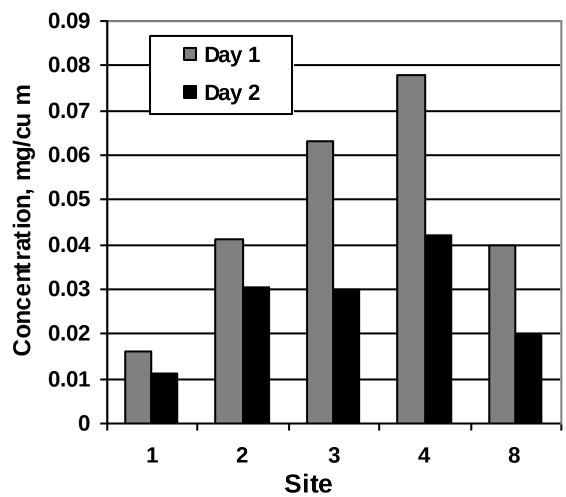

Figure 7. Respirable quartz dust concentrations.

being generated by the face shots. If samples were taken for a shorter length of time (1-2 hrs) as the dust cloud passed a particular location the concentrations would most likely be higher (as reflected by the pDR sampling data which will be discussed later).

When examining graphs in figures 6 and 7, several points need to be noted. First, site 1, the control intake location, had the lowest concentration with little variation in the concentration values for the two days of sampling. This indicates that booster fan 1 in the present location (see figure 5) together with the curtain stoppings on the east side of the mine are operating effectively to prevent dust generated by face shots from rolling back to site 1, the intake. Second, on the first day of sampling, three shots took place on the east side of the mine as compared to the second day which had only one face shot. This is evident in the concentration values for both respirable dust

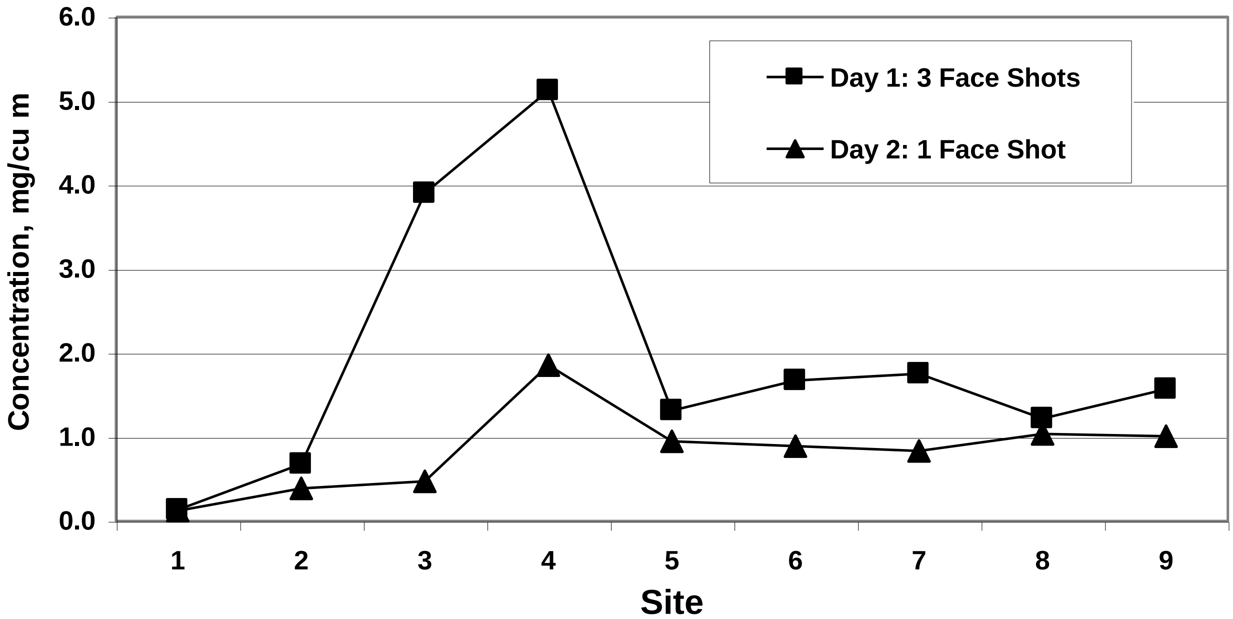

Figure 8. Average concentrations from pDRs for a 1 hour period during the peak arrival of dust from face shots.

and quartz dust which are higher on the first day at all locations. This should be expected since more shots would generate more dust. Third, the graph shows the increasing concentration from site 2 to site 4 indicating that the ventilation on the east side of the mine is moving the dust as planned. However, once the dust cloud was beyond the last curtain stopping (located two entries past station 4 as shown in figure 5) it began to break-up and disperse through the benched area on the west side of the mine as shown by the lower concentration at site 8.

Figure 8 shows the pDR concentrations at each location for a particular time interval, that being a 1 hr period during the peak arrival of the dust cloud produced by the face shots. This time interval was selected because pDR data showed that most of the dust from the shots had past the sampling locations within this time frame. Therefore, figure 8 represent a snapshot of the dust concentrations at each location as well as the movement of the dust. The general trend of this graph is similar to the concentration graph from the gravimetric samples in figure 6 and 7. Concentrations are low at site 1, the intake sampling location, then progressively increase from sites 2 through 4 on the mine's eastern side, then decrease at sites 5 through 9 where the last curtain stopping was installed. Again, this decrease in concentration is due to the dust cloud breaking-up and dispersing through the benched area. Once the curtain stoppings are complete on the west side of the mine and the benched area is isolated this should result in less dust dispersion and better movement of the dust from the faces.

Results - Estimate of Air Velocities

Limestone mines are classified as large opening mines where entries can exceed 12 m (40 ft) in width and 7.6 m (25 ft) in height. Commonly used air measurement techniques, such as anemometers and smoke tubes, are unable to measure extremely low air velocities associated with large openings. Tracer gases have been used successfully to assess ventilation patterns in large opening mines, but are very time consuming and costly. As a means to assess air velocities, dust clouds generated by face shots were monitored using the pDRs to time the movement of the dust through the mine.

Table 4. Estimated air velocities after face shots

pDR Location, Site #	Distance from Face Shot, m (ft)	Peak Concentration on pDR, mg/m^3	Time to Peak Concentration, min	Estimated Air Velocity, m/s (fpm)
3	36.5 (120)	12.5	5	0.12 (24)
4	122 (400)	11.5	20	0.10 (20)
5	228 (750)	1.8	35	0.11 (21)
6	288 (950)	1.7	65	0.08 (15)
7	320 (1050)	1.9	70	0.08 (15)
8	335 (1100)	1.4	100	0.06 (11)
9	350 (1150)	1.9	110	0.05 (10)
			Average Velocity	0.09 (17)

Stations 3 through 9 were located downwind of the blast area as shown in figure 5. The pDR=s were all set to record concentrations at 10 second intervals. The concentrations from the pDRs were graphed versus time and the arrival of the dust cloud was observable as a peak concentration on the graph. Table 4 summarizes this information.

As shown in table 4, estimated velocity show a decreasing trend with distance from the face shots. Peak concentration falls dramatically after the dust passes station 4 where the last stopping is located, but peak concentrations from the dust cloud were still apparent as the cloud broke-up and became diluted. An average of all the velocities gives a value of 0.09 m/s (17 ft/min), which would be an overall average air velocity for the entire mine. Using this value to estimate a retention time of the dust from face shot locations in the eastern section of the mine to the proposed location of the fan 3 (see figure 5) near site 8 gives a value of 1.2 hrs. From face locations closer to fan 3, on the west side of the mine, the retention time would be approximately 15 minutes.

Conclusions

Respirable dust concentrations from both the pDR's and gravimetrics are low at site 1, the intake sampling location, then progressively increase from sites 2 through 4 on the mine's eastern side, then decrease at sites 5 through 9. This decrease in concentration, beginning at site 5, is due to the dust cloud breaking-up and dispersing through the benched area. This is the approximate position of the last curtain stopping and the air began to short circuit into the benched area at this location. Second, the current location of fans 1 and 2 (see figure 5) together with the completed stopping have improved air flow on the east side of the mine. Part B of the study will be initiated once the curtain stoppings are complete on the west side of the mine and the low pressure propeller fans are installed as shown in figure 5. This should result in less dispersion of the dust into the bench area and better movement of the dust cloud from the faces and out of the mine. Third, the air velocities as calculated from the pDR data is very consistent with an average velocity for the entire mine of approximately 0.09 m/s

(17 ft/min). As a result, this value gives dust retention times from face shots located in the eastern section of the mine to the proposed location of the fan near site 8 of 1.2 hrs. From closer face locations in the west side of the mine, the retention time is approximately 15 minutes. Air velocities should increase and retention times be reduced once the project is completed.

REDUCING DUST LEVELS IN AN ENCLOSED TRUCK CAB

Background

Underground limestone mining operations use various types of heavy equipment to prepare the faces for blasting and to load and haul the limestone product from the mine. Equipment commonly used at these operations include face drills, front end loaders, and haul trucks. The original cab designs on this equipment degrades through normal operation in the harsh mine environment and the protection initially afforded to the operators is compromised. Therefore, many equipment operators can be exposed to elevated levels of respirable silica dust. In an effort to improve the protection of workers exposed to harmful dusts in enclosed cabs, NIOSH has entered into a number of cooperative research efforts with mining companies and cab filtration and pressurization companies. Several studies regarding the effectiveness of these systems have been published for surface coal operations (Cecala, et al., 2002 and Organiscak, et al., 2000). These units were installed on front-end loaders and overburden drills to reduce both respirable coal and silica dust in the operator's cab. In this study, NIOSH and Sigma Air Conditioning Inc. entered into a cooperative cost-sharing agreement to evaluate the impact of retrofitting a haul truck at an underground limestone mine with a new system to reduce the operator's exposure to silica dust.

The truck selected for retrofit with the new unit was a Euclid R-50 manufactured in 1975. This truck had multiple duties. For the most part, it was used to haul fines from the processing plant to one of two different locations. On most trips, the operator would dump the fines at an outside stockpile. Occasionally, this truck would also haul the fines into the mine and dump them for backfill. When needed, the truck would also be used to haul stone from the faces in the mine and dump them at the outside crushing facility. The truck was originally fitted with a heating and air conditioning unit that did not filter the intake air or pressurize the cab. The unit was functional, but outdated and required replacement.

The Euclid R-50 was retrofitted with a Sigma Model EC5- 0500 rooftop mounted unit. The new system had heating, air conditioning, air filtration, and cab pressurization features. The pressurizer is a 2-stage cyclonic and 1-stage particulate filter. It has a separate blower and motor to positively supply air to the return air chamber of the air conditioner. The first stage filter, has a 95% efficiency rating for particles 0.5 μm. This filter is designed to remove the larger particles and reduce the loading of the second and final stage filter, a pleated spun polyester washable medium, which is 99% efficient on particles > 0.5 μm. Installation of the unit took two 8-hr shifts and another shift of resealing the cab with foam weather stripping around the doors and service panels and caulking to seal smaller cracks. A positive static pressure of 0.01 inches of water gauge was achieved after resealing.

Sampling

The main objective of this study was to determine the impact on silica dust within the truck cab after the new system was installed. To make this assessment, gravimetric samplers were used to measure dust concentrations both outside and inside the truck cab. Baseline dust sampling was conducted before the unit was installed and sampling repeated after the installation of the new system. The position of the gravimetric samplers was the same for both the pre- and post-installation parts of the study. Their location was selected as not to interfere

Table 5. Pre and post installation dust concentrations

	Outside Cab		Inside Cab	
	Respirable Dust mg/m^3	Respirable Quartz Dust mg/m^3	Respirable Dust mg/m^3	Respirable Quartz Dust mg/m^3
Day	**Pre-Installation: Original AC and Heating System**			
1	0.401	0.033	0.271	0.020
2	0.662	0.056	0.369	0.042
3	0.213	0.015	0.197	0.008
Average	0.425	0.035	0.279	0.023
Day	**Post-Installation: Sigma Model EC5-0500**			
1	1.037	0.083	0.430	0.026
2	1.069	0.068	0.288	0.016
3	0.924	0.061	0.234	0.010
Average	1.010	0.071	0.317	0.017

with operator's vision or operation of the truck. Two gravimetric samplers were positioned outside the cab below the front window, and two were positioned in the cab to the right of the operator, at the same height as the breathing zone. Sampling was conducted for three shifts before installation and then three shifts after installation. Sampling time was approximately 6 hrs per shift. During sampling, a time study was conducted on the truck and dust conditions noted for each day.

Results

Table 5 summarizes the dust concentrations values from the gravimetric samplers for the six days of sampling. The concentration values for each day are the average of the two gravimetric samplers for that day of sampling. The "Average" row is the survey average. Figure 9 graphs the reduction in respirable dust and respirable quartz dust for the outside versus the inside of cab based on pre- and post-installation 3-day averages in table 5. The reduction of respirable dust and respirable quartz dust was 34% (0.425 mg/m^3 to 0.279 mg/m^3) and 33% (0.035 mg/m^3 to 0.023 mg/m^3) respectively, before the new system was installed. After installation of the new system, the reduction improved to 69% (1.010 mg/m^3 to 0.317 mg/m^3) and 75% (0.071 mg/m^3 to 0.017mg/m^3), respectively. Figure 9 illustrates that the new unit afforded a greater protection to the operator from outside dust levels.

Figure 9 represent the comparison of outside to inside levels of dust for the pre- and post-installation of the unit. However, to obtain a

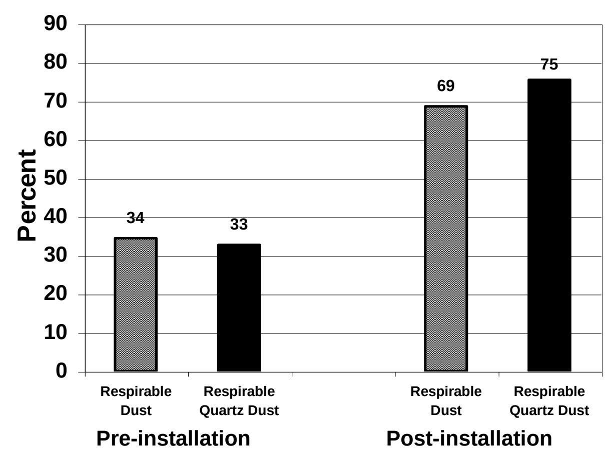

Figure 9. Percent reduction of dust in cab (outside versus inside of cab).

actual reduction in dust inside the cab, measured dust levels in the cab must be compared. It should be noted that the conditions for all three days, during post-installation sampling, were much dustier than during pre-installation. This was visually noted during sampling and supported by the measured dust concentration in table 5. The respirable dust and the quartz dust concentrations outside the cab during post-installation sampling are double the values during pre-installation. These higher concentrations influence the amount of dust actually penetrating the cab. This needs to be taken into account to determine the actual reduction in cab dust before and after installation of the unit. Figure 10 takes these

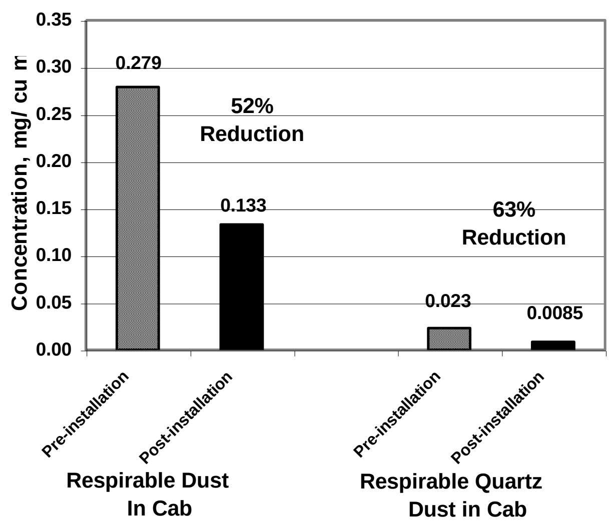

Figure 10. Reduction in dust concentrations in cab when normalizing values to baseline.

higher outside concentrations into account by normalizing the average concentration values during post-installation to the baseline values during pre-installation inside the cab. Using this analysis, a 52% reduction in respirable dust and a 63% reduction in respirable quartz dust is achieved in the cab after the new system was installed. This is a measure of the actual improvement in the cab working environment.

Another way to illustrate the effectiveness of the new system is by determining the increase in the cab protection factor (Heitbrink, et. al., 1998). This factor is calculated by dividing the average outside concentration by the inside concentration given in table 5. The protection factor for the respirable dust before and after installation is 1.5 and 3.2, respectively. For the respirable quartz dust the protection factor before and after installation is 1.5 and 4.1, respectively.

At this mine, several newer Komatsu trucks were operating as mine trucks hauling stone from the faces to the outside crusher. As a final measure to evaluate the new system, a 5-yr old Komatsu 100 ton truck was sampled for one day to determine the effectiveness of the pressurization and filtration system originally supplied on this truck. The number of samplers and their positioning outside and inside the cab were the same as that of the Euclid R-50. The average outside and inside respirable concentrations were 0.71 and 0.22 mg/m^3, respectively. This gives a reduction of 70% from outside to inside the cab and a protection factor of 3.3. These values are very similar to the Euclid R-50 after retrofit with the new system (69% and 3.2) indicating that the retrofitted system was equivalent to the performance of the newer trucks.

Conclusions

This field study on a haul truck at a limestone mine retrofitted with a new filtration and pressurization unit demonstrates that older model trucks can be successfully upgraded to protect the operator from silica dust. Studies have shown (Cecala, et.al., 2002 and Organiscak, et.al.,2000) that two key components for successful installation and operation are effective filtration and cab integrity. Outside air, as well as inside recirculated air, should be filtered through a high quality and high efficiency filter and the cab should be sealed to attain a positive pressure. In this study, a 63% reduction in respirable quartz dust within the cab was achieved after the new unit was installed and the protection factor for respirable quartz was increased from 1.5 to 4.1. The new filtration and pressurization system compared favorably to a newer Komatsu truck as the reduction in respirable dust and protection factor were very similar.

SUMMARY

NIOSH is conducting research in an effort to lower the silica dust exposure of workers at underground limestone mines. Dust surveys were conducted to quantify respirable dust generated by an underground crusher, face blasts, and the load-haul-dump cycle of a haul truck. These surveys evaluated current dust controls and for the haul truck, evaluated a new filtration system for the enclosed cab. A summary of each survey follows:

Underground crusher - Sampling results indicated that dumping and crushing activities at the underground crusher are liberating high levels of respirable dust. The axial vane fan currently located inby the crusher was shown to prevent liberated dust from rolling back toward the intake air entry. However, sampling results also indicate that the liberated dust is not effectively moved to the return entry and dust is leaking through stoppings designed to isolate the crusher entry. Additional controls (another auxiliary fan or dust collector) and improved stoppings are being planned by mine management. NIOSH will conduct a follow-up survey to evaluate the effectiveness of added controls.

Face shots - Mine-wide sampling was conducted to quantify dust levels generated during face shots and monitor airflow movement/dust migration throughout the mine after the shots. The mine was in the process of installing a series of stoppings to provide directed movement of the air and dust out of the mine. Baseline survey results indicated that the stoppings constructed on the east of the mine are effectively moving shot-generated dust to sampling station 4. When the dust cloud reached the west area of the mine where additional stoppings need constructed, air velocities and dust levels dropped suggesting that the dust is dispersing throughout the benched entries of the mine. The mine is continuing to install stoppings and plans to install new fans to assist air movement and dust removal. NIOSH will conduct a dust survey in the near future to evaluate the impact of the new ventilation system on dust retention in the mine.

Haul trucks - Dust sampling was conducted to quantify the respirable dust levels present inside an enclosed cab on an older haul truck. A filtration/pressurization system was then retrofitted on this truck and the seals on the enclosed cab were improved. The cab was sampled again to document any changes in cab dust levels. Results show that quartz dust levels in the enclosed cab were reduced by over 60% with the new filtration unit installed.

NIOSH will continue to investigate control technologies that can be implemented to effectively reduce worker exposure to silica dust in underground limestone mining operations.

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