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# Reducing Dust and Respirable Crystalline Silica Near Conveyors Using a Hybrid Dust Control System

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**Abstract**

Occupational exposures to respirable dusts and respirable crystalline silica (RCS) is well established as a health hazard in many industries including mining, construction, and oil and gas extraction. The U.S. National Institute for Occupational Safety and Health (NIOSH) is researching methods of controlling fugitive dust emissions at outdoor mining operations. In this study, a prototype engineering control system to control fugitive dust emissions was developed combining passive subsystems for dust settling with active dust filtration and spray-surfactant dust suppression comprising a hybrid system. The hybrid system was installed at an aggregate production facility to evaluate the effectiveness of controlling fugitive dust emissions generated from two cone crushers and belt conveyors that transport crushed materials. To evaluate effectiveness of the system, area air measurements ($n = 14$ on each day for a total of 42 samples) for respirable dust were collected by NIOSH before, during, and after the installation of the dust control system in the immediate vicinity of the crushers and the nearby conveyor transfer point. Compared to pre-intervention samples, over short periods of time, geometric mean concentrations of airborne respirable dust were reduced by 37% using passive controls ($p = 0.34$) but significantly reduced by 93% ($p < 0.0001$) when the full hybrid system was installed. This proof-of-concept project demonstrated that the combined use of active and passive dust controls along with a spray surfactant can be highly effective in controlling fugitive dust emissions even with minimal use of water, which is desirable for many remote mining applications.

**Keywords** Respirable dust · Respirable crystalline silica · Dust control

## 1 Introduction

Depending on dose and duration of exposures, there is ample data documenting that occupational exposures to respirable dusts and respirable crystalline silica (RCS) can lead to adverse acute and chronic health outcomes including silicosis [1], lung cancer [2, 3], and other respiratory diseases [4, 5]. Although the causes and effects of such diseases have been known for many centuries, overexposure to RCS remains a significant occupational hazard in mining [6–9] as well as for workers in the construction, engineered stone fabrication and oil and gas extraction industries [10]. The International Agency for Research on Cancer (IARC) classifies RCS (both respirable quartz and cristobalite) as carcinogenic to humans, based on epidemiologic and animal studies [11]. Respirable-sized particles (< 10-µm aerodynamic diameter), including RCS, reach the deepest parts of the lung: in the alveoli where gases are exchanged.

In 2016, the Occupational Safety and Health Administration (OSHA) promulgated a new standard to help reduce occupational exposures to RCS [12]. The revised OSHA Permissible Exposure Limit (PEL) is 0.05 mg [50 µg] of respirable crystalline silica per cubic meter of air ($m^3$), averaged over an 8-h day. In addition to the lower PEL, the regulation also required operators at hydraulic-fracturing sites to implement engineering controls to mitigate RCS exposures by June 23, 2021. The Mine Safety and Health Administration (MSHA) is also concerned about RCS exposures

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and implemented a new rule for the mining industry [13] which would lower the existing PEL to 50 μg/m$^3$ as a time-weighted average per day. It is worth noting that lowering the PEL to 50 μg/m$^3$ would match the current NIOSH recommended exposure limit.

Since many industrial processes require cutting, grinding, crushing, or screening of silica-containing materials, complying with environmental and workplace regulatory exposure limits is often a challenge for mining and quarrying operators, highlighting the need for research into determining the effectiveness of engineering controls for respirable particulates. Notable point sources for fugitive emissions that, if uncontrolled, may cause high concentrations of airborne dusts (including RCS) include rock crushers and transport belt conveyors [14]. Currently, many mining operators do not utilize engineering controls for mitigating fugitive dusts emitted by crushing or conveyance systems. NIOSH and its industry partners are conducting research studies to devise solutions that can reduce concentrations of fugitive dust emissions resulting in elevated airborne dust concentrations during crushing, grinding, and transport of rock/aggregates at surface mining sites.

As part of their research effort, NIOSH partnered with Benetech® to develop new approaches for reducing fugitive dust emissions associated with belt conveyors at mining properties. The collaboration is intended not only to develop systems that reduce dust emissions, but also ensure ease of service. This focus on ease of service will to help avoid entanglements in belts and conveyance equipment that are often associated with the cleanup of fugitive material.

The joint effort involves a Research Collaboration Agreement (RCA) with primary goals to create a new hybrid dust control system for retrofitting onto conveyors and transfer points, by combining Benetech®'s current technologies for dust settling ("MaxZone®" and "Mini-Pak") with a compact dust filtration system that was designed by NIOSH. To this end, a tailored system for dust containment and suppression was designed and fabricated at Benetech® facilities in Chicago, IL. while a prototype dust filtration system was assembled and tested at the NIOSH Spokane Mining Research Division (SMRD). Once individually validated, these subsystems were combined into a hybrid dust control system and deployed at an aggregate production site near Spokane, WA, USA, in partnership with Central Pre-Mix (CPM).

## 2 Methods

The work plan for the RCA included collaborative development of a hybrid dust reduction system consisting of three subsystems working together to achieve: (1) passive dust control, (2) active dust control/filtering, and (3) material wetting with a surfactant. The subsystems were vetted by way of laboratory testing followed by field deployment.

### 2.1 Passive Dust Control

The first subsystem was designed to provide passive dust control based on the existing Benetech® "MaxZone®" product line, comprising an enclosure system for settling dust and containment of fugitive dust emissions. The system includes baffles, shrouding, and a unique interface that seals onto the moving belt. Ease of maintenance and elimination of confined space entry requirements are integral to the system.

At their facilities in Chicago, IL, USA, Benetech® designed and fabricated a dust containment system tailored to the cone crushers and conveyor system at the CPM field site. The system is based on their existing technology in which dust containment is achieved by modular sections of shrouding mounted onto the conveyor frame, with internal baffles that contain the dust inside the enclosed space, and external access panels for ease of inspection. The design incorporates an interface between the shrouds and the belt to prevent escape of dust, which includes an internal liner that can be externally adjusted and serviced. This thereby eliminates confined space entry requirements and enables the ability to achieve fine clearance adjustments and alignment. The interface also includes a dual rubber seal that is adjustable with quick-adjust clamps, ensuring that it rides smoothly on the belt, to prevent spillage and escape of fugitive dust (Fig. 1).

**Fig. 1** Passive dust reduction system tailored to the #15 conveyor at CPM, based on Benetech®'s MaxZone® technology. The system comprises shrouds in sections with baffles at each junction, and a patented belt sealing interface with "XN liners" and dual-rubber adjustable seal

## 2.2 Active Dust Control

The second subsystem was designed to augment the passive dust settling by active collection and filtration of any residual airborne dust inside the shroud enclosure before the conveyed material exits the enclosed system.

At their facilities in Spokane, NIOSH designed and tested various portable dust filtration prototypes that would be appropriate for inclusion in the hybrid system [15]. The work included laboratory evaluation of pleated filter media, combined with a pulse-jet cleaning akin to a system described previously [16]. The design of the active dust control system includes a compressed air tank and air delivery system located within the filter housing that allows air-jet blast cleaning of the clogged filters (Fig. 2). The system was designed to incorporate off-the-shelf parts whenever possible to make the end product more commercially viable. The prototype has been dubbed the "Dustinator."

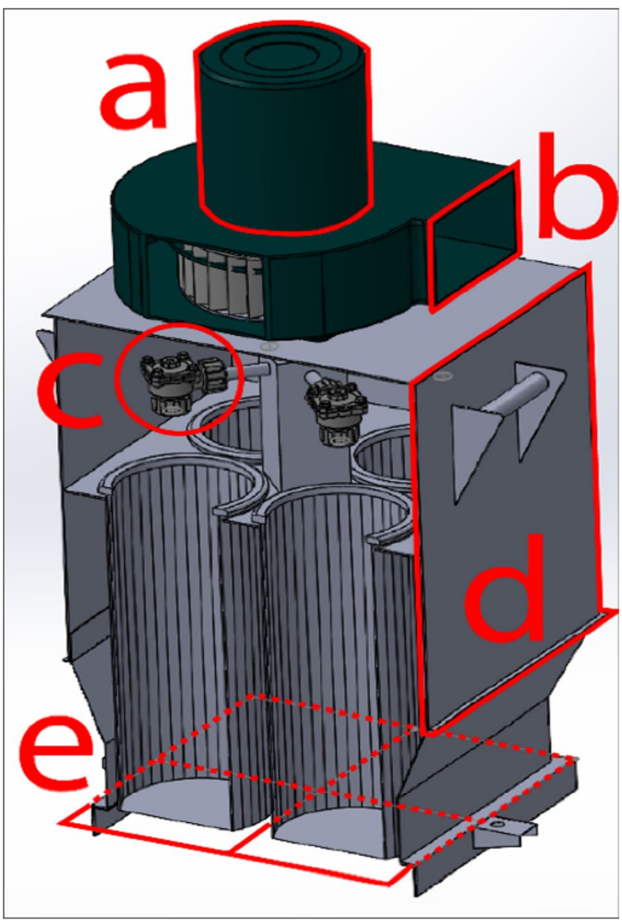


**Fig. 2** Prototype filtration system ("Dustinator") tested by NIOSH: (**a**) powered blower (220v-3HP), (**b**) clean air exit, (**c**) jet pulse nozzles (4 each), (**d**) filter housing, and (**e**) mounting flange and dust/air inlet

Design trade-offs included minimizing size and weight while maximizing flow rate and thus filtering capacity. The final prototype was therefore limited to a three-horsepower blower mounted atop the unit (Model Compact GI-4V-126, NY Blower Co., Willowbrook, IL, USA). The blower has a maximum flow rate of 1200 ft$^3$/min and can maintain 1000 ft3/min when drawing air through four seasoned filters. To provide an adequate filter surface area to maintain low face velocity, the system was designed with four 8-inch diameter filters that are 21-inches long.

The protype is approximately $2' \times 2' \times 3'$ in size and consists of an upper and lower section. The blower evacuates the upper section which in turn draws air up from the lower section through the four MERV-rated pleated filter cartridges. Filter cleaning is achieved by pneumatic jet-pulse valves mounted directly above the filters, actuated by a Pentair/Goyen ECS controller (Goyen Controls LTD, NSW, Australia) that monitors differential pressure between the upper and lower sections and activates jet pulses when the differential reaches a preset threshold. In a previous study, tests were conducted to optimize the size and outlet geometry of the valves to maximize the potential for complete filter cleaning while minimizing compressed air usage [15]. Through testing, it was determined that optimum parameters for this system were a source pressure of at least 60 psi, pulse time of 150 ms, and valves with a 1″ exit port.

## 2.3 Spray System

The third subsystem includes a surfactant spray bar placed at the exit that was designed to quell any residual dust that might exit the enclosed system. This was achieved by synchronizing the spray of surfactant to the pulse-jet cleaning of subsystem 2. Synchronizing the spray with the pulse-jet cleaning ensures that the surfactant and associated water are only consumed when needed due to the dust generated by the pulse-jet cleaning which would otherwise be contained by subsystem 2.

To achieve this, Benetech® engineers devised a modified version of their current portable dust suppression system, called the "Mini-Pak," that mixes a proprietary surfactant with water to feed a spray-bar suppression system (Fig. 3). The Mini-Pak contains a surfactant-metering pump that is driven by the flow in the water supply line. For this application, the Mini-Pak was modified by adding a solenoid valve downstream from the metering pump to affect the previously mentioned synchronization. Additionally, due to the cold climate at the CPM field site, the system was insulated and fitted with a heater to prevent freezing of the pump and surfactant tank.

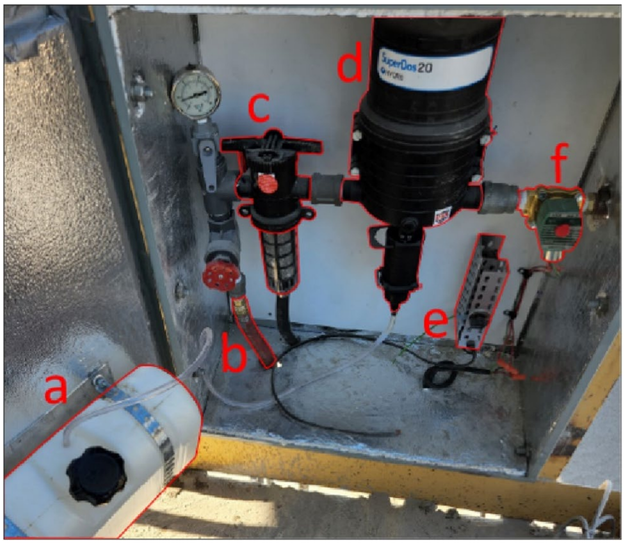


**Fig. 3** Benetech®'s prototype dust suppression system, enclosed in an insulated cabinet for installation at the CPM site: (**a**) surfactant tank, (**b**) 80-psi water inlet, (**c**) back-flushable filter, (**d**) surfactant pump, (**e**) heater, and (**f**) solenoid valve

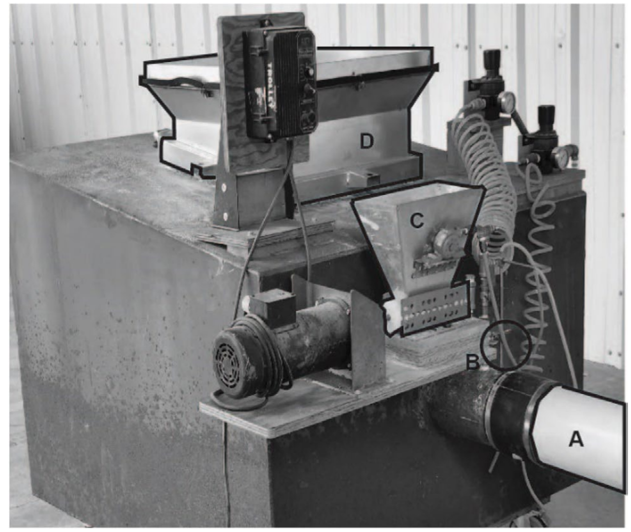


**Fig. 4** Experimental setup for dust collector tests: (**A**) air inlet, (**B**) ports for flow measurement and dust injection, (**C**) dust generator, and (**D**) flange for mounting the Dustinator

# 3 Results

## 3.1 Testing

Before installation of the combined subsystems into a hybrid system at the field site, the prototype active filtering system and the spray suppression system were tested using a NIOSH-conceived test setup described previously [15]. For the current work, the prototype "Dustinator" (Fig. 2) was mounted onto the test bed, and the dust generator was adjusted to emulate the conditions expected inside an enclosed transfer point by mixing rock dust into a large chamber (Fig. 4) at concentrations of approximately 300 mg/m$^3$. The modified Mini-Pak was mounted on a rack nearby, and the activation of the spray surfactant system was integrated into the jet-pulse controller. The Mini-Pak system was designed to deliver spray surfactant during each jet-pulse sequence to settle the potential dust cloud created by the pulsing.

Testing of the active filtration system focused on two things: verifying that the filter surface area was adequate for the flow rates expected from the chosen blower, and effectiveness of filter cleaning. To evaluate the match between the flow rate and filter surface area, the differential pressure across the filters was measured continually using a Dwyer Magnehelic gage while dust was injected into the test chamber during operation. Hubercarb Q100 Mine Safety Dust (JM Huber Corporation) was used for this purpose and the concentration monitored using a calibrated nephelometer (pDR-1500, Thermo Fisher Scientific, Waltham, MA, USA) to ensure that the dust generation remained approximately constant. As dust built up on the filters, the differential pressure increased until it reached a preset threshold, at which time a series of jet pulses cleaned the filters. During testing, the flow rate was monitored to ensure adequate flow as the dust cake built up on the filters. The initial flow rate for this system was approximately 1000 ft$^3$/min, and the desired lowest flow rate (when filters require cleaning) was targeted as 600 ft$^3$/min. Results showed that for dust concentrations of approximately 300 mg/m$^3$, this resulted in differential pressures in the range of approximately 2″ to 4″ (inches of water column, IWC) and cycle times on the order of 35 min (Fig. 5). The cycle time indicates how long it takes for enough dust to build up on filters that the

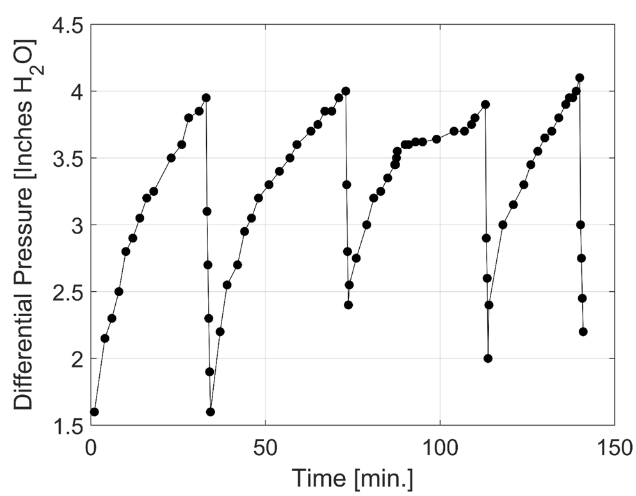


**Fig. 5** Typical changes in differential pressure during testing

pressure differential reaches the upper threshold, and the jet pulses are triggered.

The effectiveness of the jet-pulse cleaning system was evaluated by observing the sudden drop in differential pressure across the filters when the pulses were initiated. This can be seen in Fig. 5. At the run time of 33 min, the differential pressure reached the pre-set upper threshold, and pulsing was initiated at each filter in turn, until the lower threshold was reached, which typically took 3–5 pulses. Optimization of the system was achieved by monitoring the air flow and differential pressure and adjusting the controller to provide air pulses to clean the filters at appropriate set points. During testing, particulate concentrations were measured before and after the filters, and (mass based) filtration efficiencies of approximately 99% were calculated from nephelometer data for all tests. The validity of this approach is supported by the fact that the mineral content and small size range (mainly respirable sized particles) are similar to the "Arizona road dust" that was used to calibrate the nephelometer [17].

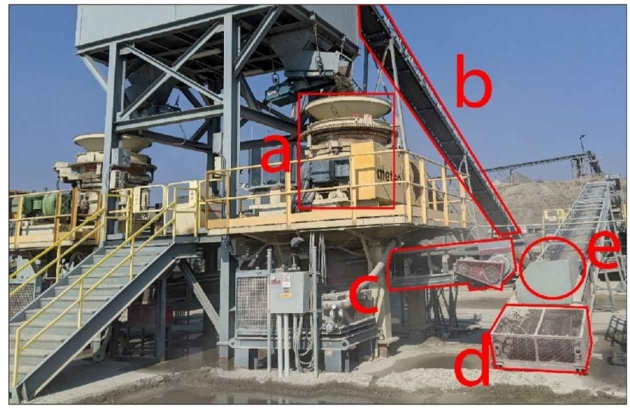


**Fig. 6** Crusher/conveyor system at the CPM site, before installation of the dust control system: (**a**) crusher #2, (**b**) feed conveyor #2, (**c**) head end of horizontal conveyor #15, (**d**) tail end of return conveyor #13, and (**e**) transfer point

## 3.2 Field Installation

Once the subsystems were individually tested, they were installed at the CPM field site. The aim of the field deployment was to demonstrate and evaluate the effectiveness of the hybrid system in real on-site conditions. Installation of the hybrid system was customized to fit the geometry of and reduce dust generated by two cone crushers and a horizontal conveyor.

At the site, the #15 horizontal conveyor carries material from #1 and #2 cone crushers (Nordberg HP300 crushers) and dumps the material onto the #13 conveyor to return material to the shaker deck (Fig. 6). The purpose of the installation was to enclose the #15 conveyor, the crusher chutes feeding it, and the transfer point between the #15 and #13 conveyors.

The installation included retrofitting the crusher and conveyor system in four steps:

1) Retrofitting the #15 conveyor with a passive dust control system based on the MaxZone® technology (shown in Fig. 1)
2) Designing and installing a shrouding system around the transfer point
3) Installing the active dust collection system (Dustinator)
4) Installing a spray bar at the system exit, triggered by the Dustinator controller module.

Installing the passive dust control system entailed retrofitting shrouding onto the #15 conveyor (as in Fig. 1). The shrouding was mounted to the conveyor frame in short sections with baffling placed strategically between the sections. The baffles are made of wear-resistant rubber and hang downward to the expected level of the material on the belt. The sealing system includes an internal liner that can be adjusted and serviced externally (eliminating confined space entry requirements) and enables the ability to accomplish fine clearance adjustments and alignment. To prevent dust from escaping between the shrouding and the moving belt, a dual-rubber seal runs the length of the shrouding. The seal is adjustable with quick-adjust clamps, so that it rides smoothly on the belt, preventing both spillage and escape of fugitive dust.

While adjustment of the sealing interface against the belt proved to be extremely effective, special attention was required to seal the areas between the crusher chutes and the newly installed shrouding. To seal those areas, a soft low-durometer rubber was used and attached to the conveyor framing to prevent vibration of the chutes from being transmitted to the shrouding and conveyor frame.

To prevent dust leakage around the transfer point, a system of shrouding was custom built to enclose the entire transfer point, with removable access panels for inspection and maintenance (Fig. 7). The enclosure was attached to the frame of the #13 conveyor and rubber flaps were positioned to cover gaps as needed. Prevention of leakage around the transfer point was improved by the nearby dust collector, which created a slight vacuum inside the transfer point, reducing the escape of fugitive dust. To prevent the escape of dust from the exit, where conveyor #13 carries material to the shaker deck, a 3-nozzle spray bar was installed inside the shrouding near the exit, with a standoff of approximately 16″ from the belt, and a rubber flap was hung to cover the exit and ride on top of the conveyed material. The spray nozzles were fan-type nozzles with an angular pattern that provided slight overlap of the applied spray. The individual nozzle flow rate was chosen


**Fig. 7** Crusher/conveyor system at the CPM site, after installation of the dust control system: (**a**) MiniPak cabinet, (**b**) Dustinator, (**c**) shrouding/belt sealing system, (**d**) transfer point enclosure, (**e**) spray bar (at exit)

as 0.5 gal/min which proved adequate to wet the material while minimizing water and surfactant usage.

Once the passive system was installed, the Dustinator was mounted downstream of the second crusher, using a customized flange-mount built into the MaxZone® conveyor shrouding. The location of the dust collector (Fig. 7) was strategically chosen to remove unsettled dust from within the shrouding downstream of the crushers, and to draw air and dust from within the transfer point enclosure to reduce leakage from the transfer point.

Power for the blower, air compressor, and Goyen controller were pulled from a nearby junction box. The system was wired so that when the conveyor is running, the blower, air compressor, and controller are also activated. The compressor tank stores enough air for multiple pulses and refills the internal Dustinator tank to 80 psi within 15 s after each pulse. The controller monitors the differential pressure across the filters, and when it reaches the upper threshold, it initiates a pulsing sequence until the pressure drops to a lower threshold.

During normal operation, the passive and active systems work together to control dust in the system, but when the jets pulse to clean the filters a burst of pressure and dust is created, challenging the system. To quell that burst, during each pulsing sequence the controller sends power to the water solenoid to activate the spray suppression system.

The final step of the field installation was to incorporate the spray suppression system. The modified Mini-Pak (Fig. 3) was placed inside a steel cabinet mounted on the crusher frame near the Dustinator. The inlet was supplied with 80-psi water pressure, and the outlet was connected by hose to the spray bar system. The water solenoid was wired to the Goyen controller, and a separate power line was provided for the cabinet heater.

## 3.3 Evaluation

To evaluate for reduction of fugitive emissions and RCS achieved by the hybrid system, NIOSH researchers conducted air sampling around the crushers before, during, and after the installation of the hybrid dust control systems. Air sampling was conducted one day before the installation, one day when the "passive portion" of the system had been installed, and a third day after the complete hybrid dust control system was installed and functioning.

Three days of air sampling were conducted using 14 samplers each day for a total of 42 area air samples. The air sampling was designed to investigate differences in concentrations of area airborne respirable dust concentrations in all directions around the conveyor transfer point. Samplers were positioned approximately 5–10 ft from the primary point sources of dust generation (i.e., rock crushers and conveyors) and 5–10 ft apart and at a height of approximately 5 ft above the ground, as shown in Fig. 8. The precision of placing the air samplers in the exact location was ensured by referring to a sampler map drawn over an aerial satellite view.

Area air samples were collected according to NIOSH Method 600 [18]. Additionally, the airborne respirable quartz concentrations were analyzed according to NIOSH 7500 by an American Industrial Hygiene Association accredited laboratory. Specifically, personal air sampling pumps (SKC AirChek TOUCH, SKC In) calibrated to 1.7 L per minute flow rate were used with 10-mm (mm) Dorr Oliver size selective nylon cyclones to collect the respirable fraction of the area airborne dust samples. The Dorr Oliver cyclones used 3-piece cassettes containing 37-mm diameter 5-µm pore size GLA-5000 PVC filters. Sample filters were pre- and post-weighed following the NIOSH Method 600 to yield the mass of dust on each filter sample. The dust mass, pump flow rate, and collection time determined each sample's time-weighted average (TWA) respirable dust concentration. While the particle concentration and deposition rate varied, the TWA approach captures the average deposition over the time span of sampling period and is considered a standard approach when taking dust samples. The sampling times varied slightly for each day, depending on the duty cycle of the crusher, but all samples were collected for at


**Fig. 8** Sampler placement map showing location of 14 pumps. Note the image is oriented north up

least 2 h while the crushers were run without interruption, specifically the sampling duration ranged between 120 and 406 min. The sampling duration was dictated by the period of time for which the crusher was operated on a given sampling day.

All area respirable dust samples were above the limit of detection (LOD) of the NIOSH Method 600, except for one collected on the final post-install sampling day. This sample was thus estimated using a method of estimation commonly used for nondetectable values. Specifically, since the data possessed a moderate skewness, with a geometric standard deviation of 2 or less for each sampling day, the analytical LOD divided by $\sqrt{2}$ was used to estimate this below detect value [19]. The minimum detectable concentration for the one nondetectable sample was 49 μg/m$^3$.

Due to the impact of wind variations and weather on air samples, measurements were taken on days with similar prevailing wind direction and meteorological conditions (Table 1).

### 3.3.1 Statistical Analysis

This study compared the paired, by sampling location, differences between the three sampling days utilizing survey data to determine the paired differences' expected mean and standard deviation. The sample size requirements of the data to achieve a statistical power of 80% ($\beta = 0.2$) and

**Table 1** Prevailing wind direction and meteorological conditions on dust sampling days

| | Sustained wind direction | Sustained wind speed | Average temperature | Humidity |
|---|---|---|---|---|
| Pre | 210 | 18 | 41 | 81.4 |
| Passive | 230 | 14 | 57 | 76.6 |
| Active | 210 | 22 | 57 | 86 |

a significance level of 5% ($\alpha = 0.05$) for detecting a mean difference between paired groups have been met.

The Kolmogorov–Smirnov and Anderson–Darling tests for normality yielded significant *p*-values ($p < 0.0002$), indicating sufficient evidence to confirm that the data does not come from a normal distribution. A log probability plot also confirms that the data distribution follows an approximately lognormal distribution. To account for the non-independent nor random sampling methodology, a nonparametric test for comparing multiple groups of paired continuous data from the same distribution required the Friedman's test. In this test, the response variable is the respirable dust, the sampling day is the grouping variable, and the sample location is the blocking variable. In this way, the between and within variance is accounted for properly. The Friedman chi-squared test statistic is 21, with 2 degrees of freedom and a *p*-value $< 0.0001$, indicating enough evidence to reject the null hypothesis that the mean respirable dust is the same for each sampling day. In conclusion, there is a significant difference in respirable dust concentrations between sampling days.

Additional post hoc testing for pairwise data utilized the Wilcoxon signed-rank test with a Bonferroni correction. Comparing the geometric mean of the measured dust concentrations for the three sampling days shows a reduction with each new implementation (Fig. 9 and Table 2). The installation of the passive system resulted in a 37% reduction in geometric mean respirable dust concentration compared to pre-installation sampling, although the reduction was not statistically significant ($p = 0.34$). Observations were made in the field during this second survey, where it was visually apparent that the transfer point, yet to be controlled, was still emitting considerable dust.

Area samples of respirable dust and RCS were determined to be statistically significantly lower following installation of the active fugitive dust control system compared to both the pre-installation and the passive-installation dust concentrations. There was a 93.5% reduction in geometric mean respirable dust concentration after the active system was installed compared to pre-installation levels ($p < 0.0001$). Dust levels were also significantly lower when the active system was installed compared to the passive-installation concentrations ($p < 0.0001$).

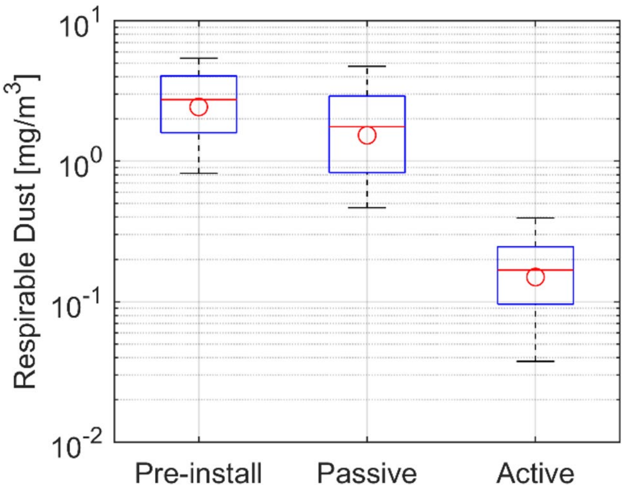


**Fig. 9** Respirable dust concentrations. On each box, the central mark indicates the median, and the bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. The whiskers extend to the most extreme data points

These data indicate that the aggregate transfer point of the conveyance system was responsible for a significant amount of the dust generated in the "passive only" scenario (second survey) and illuminates the effectiveness of combining the technologies for passive dust settling, active dust collection, and spray suppression into a hybridized dust control system.

During the third survey, additional measurements were taken to further ascertain the performance of the dust control system. While the system was running, the respirable dust inside the dust collector inlet (the region above the moving material) was measured in real time with a pDR 1500 (Thermo Fisher Scientific, Franklin, MA, USA) and found to be in the range of 40–60 mg/m$^3$. Simultaneous to that measurement, a second pDR 1500 measured the respirable dust levels just outside the dust collector and was found to range between 0.1 and 0.2 mg/m$^3$. Similar measurements were taken on the shroud surrounding the transfer point. The respirable dust concentrations inside the shroud ranged between 1 and 3 mg/m$^3$, while just outside the shroud, the levels ranged between 0.05 and 0.1 mg/m$^3$. Both of these sets of measurements confirmed the high efficiency of the dust collection system and that the active dust collector was maintaining a negative pressure inside the shrouding which did not allow the escape of dust into the surroundings.

These results suggest that reductions in area concentrations of respirable dusts and RCS are achievable using a hybridized dust control system. The RCS percentage by weight ranged from 22 to 32% in the air samples in this study. Taken together, these data highlight the importance of reducing dust levels at mine sites using engineering control techniques such as this hybrid dust control system.

This study admittedly would benefit by having more sampling surveys spanning a wider range of weather conditions. Over the course of the three surveys, 14 samples were taken on each day for a total of 42. The number of samples was insufficient to measure a significant change in dust concentration due to the installation of the passive controls. However, the reduction in dust due to both the passive and active systems combined was large enough that the relatively small sample size was sufficient.

## 4 Conclusion

This collaborative project between NIOSH and Benetech® demonstrated a reduction in area airborne respirable dust and RCS that appears achievable by implementing an innovative dust control system to control release of fugitive dust emissions by rock crushers and transport belt conveyors. In this demonstration, a significant reduction in area concentrations of airborne respirable dusts by 93% was achieved. This level of reduction has the potential to reduce workers' exposure to RCS, thereby reducing their risk of development of silicosis, lung cancer, and other diseases.

The results of this study provide insights into the importance of engineering controls to reduce point source generation and fugitive dust emissions as one way to control exposure risks for worker and communities surrounding aggregate production sites Preventing exposures to RCS is a high priority for NIOSH researchers and controlling occupational exposures to fugitive dusts containing RCS is a responsibility of companies producing mineral aggregates. These results are likely to be of interest to mine operators who desire to reduce levels of respirable dusts and RCS in their operations, as well as to researchers, industrial hygienists, and environmental engineers who work in the field of environmental and public health and control for respirable particulates, especially those containing silica.

## 5 Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of NIOSH, Centers for Disease Control and Prevention

**Table 2** Area air respirable dust concentrations at each stage of intervention implementation

| | Pre-install ($n=14$) | Passive-install ( $n=14$) | Active-install ( $n=14$) |
|---|---|---|---|
| Geometric mean (GSD) (µg/m$^3$) | 2432 (1.79) | 1529 (2.14) | 159.1 (2.15) |

(CDC). Mention of any company or product does not constitute endorsement by NIOSH, CDC.

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**Data Availability** The data presented in this study are available on request from the corresponding author.

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