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RESPIRABLE DUST MEASURED DOWNWIND DURING ROCK DUST APPLICATION

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ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) Pittsburgh Mining Research Division (PMRD) conducted underground evaluations in an attempt to quantify respirable rock dust generation when using an untreated rock dust and a rock dust treated with an anti-caking additive. Using PDM 3600s and 3700s, these evaluations measured respirable rock dust levels arising from a flinger-type application of rock dust on rib and roof surfaces. Rock dust with a majority of the respirable component removed was also applied in NIOSH's Bruceton Experimental Mine (BEM) using a bantam duster. The respirable dust measurements obtained downwind from both of these tests are presented and discussed. This testing did not measure miners' exposure to respirable coal mine dust under acceptable mining practices, but indicates the need for effective continuous administrative controls to be exercised when rock dusting to minimize the measured amount of rock dust in the sampling device.

INTRODUCTION

Two factors have combined to renew concern regarding respirable dust measurements and compliance. This renewed recognition is due to two regulations that have modified operators' rock dust schedules. First, the 80% incombustible requirement in intake entries has increased both on-section and outby-the-section rock dusting. Secondly, the recent respirable dust regulation change that has increased the number of respirable dust samples taken per sampling cycle. Previously, when only 5 samples were needed bi-monthly, rock dusting could be scheduled to not interfere with the respirable dust sampling schedule.

The significant number of samples now required under new regulations combined with the need to maintain 80% total incombustible content in active mining areas require the schedules for respirable dust sampling and rock dusting to intermix. This raises concerns about the amount of rock dust that potentially is included in the sampler weight gain. Additionally, the respirable dust maximum was lowered from 2.0 mg/m^3 to 1.5 mg/m^3 (effective August 1, 2016) increasing concern that rock dust contamination may be an issue. Currently, the acceptable practice is to apply administrative controls such as keeping the miners upwind during rock dust application or to schedule rock dusting during a maintenance shift when the number of miners present is lower.

NIOSH's research examining the quality of rock dust has led to the development of hydrophobic rock dusts.

In September 2011, NIOSH analyzed several rock dust samples being used in underground coal mines and determined that many of the samples did not meet the rock dust size requirements set forth in 30 CFR 75.2 (2). Almost half of the samples did not contain the minimum of 70% passing through a 200-mesh (75-µm) sieve. Upon investigation of other requirements included in 30 CFR 75.2, it was also found that all of the samples caked after being wetted and then dried. Since then, several rock dust manufacturers have developed anti-caking rock dusts. The anti-caking additives used are typically fatty acids that make the rock dust hydrophobic and are added in very low quantities (< 1%) (3). One function of the anti-caking additives developed is the usage as a fluidizing agent (4, 5, 6). While this development will add to the rock dust fluidity, another potential problem may be the increased airborne re-entrainment of rock dust as a result of vehicles running over the non-caked rock dust.

Respirable dust measurements downwind of rock dusting applications had not previously been collected. PMRD researchers collected sample measurements to identify the extent to which rock dusting activities may contribute to respirable dust sample measurements. Limited tests were conducted by dispersing treated and untreated rock dusts at a mine. Additionally, more controlled tests were conducted within NIOSH's Bruceton Experimental Mine to determine if removal of < 10-µm material can adequately reduce the respirable dust measurements downwind.

TEST METHOD

NIOSH conducted a series of controlled experiments at a participating mine site to assess the levels of respirable rock dust generated by applications of treated and untreated rock dusts to mine surfaces. Due to results obtained from the mine site testing, a supply of rock dust was classified so that a majority of the respirable dust was removed. The result was 6% < 10-µm material remaining in the final rock dust. This rock dust was then applied in the BEM to assess the reduction in respirable dust measurements downwind.

Mine Site Tests

The mine site testing evaluated the generation of respirable-sized rock dust during dry applications of untreated rock dust (33% < 10 µm) and treated rock dust (38% < 10 µm)[1]. Four tons of both the untreated and treated material were shipped to the mine site. The shipment of eight pallets was received two weeks prior to testing. Each 1-ton bag of rock dust was stored outside on the pallet on which it was delivered. The eight bags were covered with brattice cloth to protect them from moisture. The rock dust bags were not lined with a plastic water-resistant liner nor were they plastic-wrapped on the pallet. Otherwise, the rock dust was shipped and stored in the same manner that the manufacturer and mine normally ships and stores 1-ton bags of rock dust, respectively.

The section of the mine where the testing occurred was 10 breaks inby from the mine portal. Figure 1 displays the layout of the tests in two adjacent entries. The evening prior to each day of testing, the mine roof and ribs were washed with water by mine personnel to remove the existing rock dust. Curtains were hung in the crosscuts as close to the rib as possible so that the entry would be a continuous single entry in the dusted zone to the end of the sampling zone. A scoop was used to remove excess rock dust from the floor before rock dust application. Due to the available entry length, the dusted zone was 270 ft and the sampling zone was 100 ft. The test entries were 20 ft wide by 9 ft high. A mobile dry rock duster was used to apply dry treated and dry untreated rock dusts to the entries as shown in Figure 1 in a manner consistent with the practice at that operation. The rock dusts were applied at similar rates and at similar coverages to the mine surfaces.

[1] These particular rock dusts, with similar numbers of particles less than 10 microns, have been used extensively during NIOSH research and are used here as a means of comparison to past data.

Rock dust failing to adhere to the roof and ribs was allowed to fall and settle on the mine floor. Dust levels measured during this activity are considered to be indicative of dust generation due to rock dust application. For testing, instrumentation was placed approximately 100 ft downwind or outby the end of the rock dust zone (downwind set of sampling instruments in Figure 1).

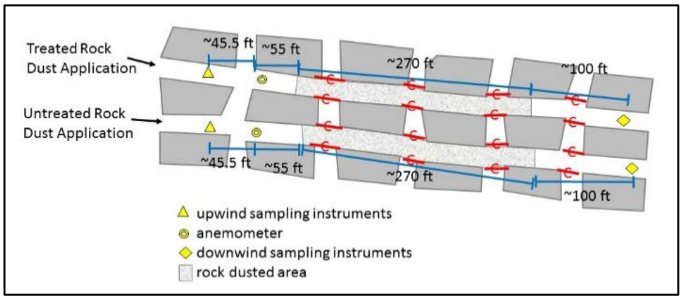

Figure 1. Layout of mine site tests.

The instruments used were PDM 3600s and provided continuous dust mass concentrations for 1-min sampling periods (7, 8). Two PDM 3600s were located approximately 100 ft downwind from the end of each application[2]. These instruments were positioned at mid-entry height with one set located on the right side of the entry (right return) and the other located on the left side of the entry (left return). Another PDM 3600 was located approximately 100 ft upwind from the start of each application, positioned at the same height and in the middle of the entry (intake), as a check on upwind dust levels.

About 55 ft inby the dusted zone, a permissible continuous-recording anemometer was centerline-placed. Hand-held anemometer traverses were conducted periodically during testing to verify ventilation consistency. During application of the untreated and treated rock dusts, ventilation airflow averaged from 78 to 113 fpm. The atmospheric pressure was 776 mm Hg with a consistent temperature of 56°F during testing.

BEM Tests

Two tests were conducted using a classified rock dust containing <~ 6% of material < 10 µm. The first test's ventilation rate was a low airflow (~100 fpm) and the second test was a high airflow (~220 fpm). The entry dimensions are 6.5 ft high by 11 ft wide. A continuous monitoring anemometer was placed approximately 50 ft inby the rock duster. The latest updated PDM 3700 was used to measure the respirable dust in the BEM tests. As with the mine site, the PDM 3700s were used for respirable dust measurements. PDM 3700s were placed approximately 50 ft inby the rock duster (upwind) and 100 and 500 ft outby (downwind) of the rock duster (see Figure 2).

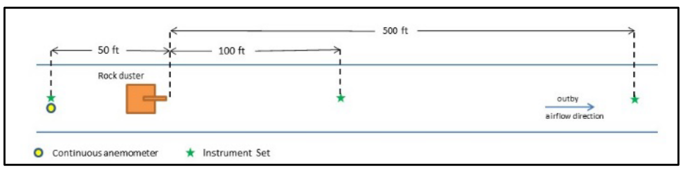

Figure 2. General layout of BEM tests.

A third test at a high airflow was conducted using a reference rock dust, which has historically been used in Lake Lynn Experimental Mine (LLEM) testing to determine the recommended minimum requirement of 80% total incombustible content (9).

[2] Based upon past dust dispersion studies, particles > 75 µm tend to settle and fall out of the air stream at 50-60 ft. At 100 ft, the dust that is still airborne would be respirable in size. Also, the instrumentation is located at least 100 ft downwind to allow any airborne dust within the entry to be more uniformly distributed across the entire entry to minimize uneven concentrations of dust that may be present closer to the applicator. This should also provide dust concentrations that are reproducible for similar test conditions.

RESULTS

Mine Site Tests

Instead of just one application of rock dust to the 270-ft section, two passes were made to apply the four total tons of rock dust.

Untreated Rock Dust Application. When two tons of the untreated rock dust were opened and emptied into the scoop of the flinger duster, the rock dust was observed as being extremely moist and wet. A sample was collected from a newly opened bag. When analyzed at the PMRD laboratory in Bruceton, the untreated rock dust contained an average of 12% moisture, while the treated rock dust contained an average of 0.13%[3]. When the rock dust was emptied into the scoop, it was observed that the rock dust was damp throughout the bag – no dry pockets of dust existed even at the center of the bag (Figure 3). Particle size analysis using the PMRD Beckman-Coulter analyzer indicated the untreated rock dust had a mean particle diameter of 17.8 µm and a median diameter of 15.4 µm. The specific surface area was measured at 8,885 cm^2/mL or 3,290 cm^2/g. This product was 99.99% < 75 µm, 91.4% < 38 µm, and 36.2% < 10 µm (Table 1).

Table 1. Description of rock dust particle size distributions.

Test Location	Mine Site	Mine Site	Mine Site	BEM	BEM
Rock Dust	Untreated	Mine's Untreated	Treated	Classified	Reference
Mean Diameter, µm	17.8	70.1	23.4	27.3	66.8
Median Diameter, µm	15.4	38.8	15.1	25.7	34
Specific Surface Area, cm^2/g	3290	1943	4365	1214	2810
% < 75 µm	99.99	68	95	99.7	63.9
% < 38 µm	91.4	49.5	77.7	82.8	51.3
% < 10 µm	36.2	20.5	43.1	5.9	32.5

Figure 3 - Untreated rock dust in the scoop. The rock dust is moist throughout.

Mine surfaces were still damp from being washed down the previous evening. Some water puddles were present on the mine floor. When the rock dust was applied, the rock dust was flung in clumps and did not "dust" the ribs (Figure 4). Visually, not much dust was generated during dusting, resulting in inadequate application afterwards (Figure 5). There was about ¼ in to ½ in of dust residing on the floor.

Figure 4. Flinger rock dusting machine applying the moist untreated rock dust.

[3] The moisture content was determined by measuring the mass difference before and after drying the sample in an oven at 105°C for 1 hr.

Figure 5. Moist rock dust applied to the mine entry by a flinger rock dusting machine.

In Table 2, the application of the rock dust is listed as "Rock Dusted Untreated" (application of first two tons of material) and "Re-Rock Dusted Untreated" (application of the final two tons of material) and provides a summary of the sampling data from the PDM 3600s.

PDM 3600 measurements in the intake air were 0.04 mg/m^3. When applying the moisture-laden rock dust with the flinger duster, PDM 3600-measured dust concentrations ranged from 0.11 to 1.28 mg/m^3 on the right and left sides downwind of the dusted zone, respectively.

Due to the inadequate distribution of the moisture-laden rock dust by the flinger (Figure 5), mine personnel applied more rock dust to the entry to maintain explosion hazard safety and remain in compliance with 30 CFR 75.403. Therefore, the mine applied rock dust from its own supply. The mine's 1-ton bags of rock dust are normally shipped on a pallet that is shrink wrapped with plastic.

The mine's rock dust was much drier. Particle size analysis indicates that the mine's rock dust had a mean particle diameter of 70.1 µm and a median diameter of 38.8 µm. The specific surface area is measured at 5,248 cm^2/mL or 1,943 cm^2/g. It was 68.0% < 75 µm, 49.5% < 38 µm, and 20.5% < 10 µm (Table 1). The flinger application was more consistent with the dry rock dust as opposed to the moist rock dust (Figure 6). During the application of the mine's rock dust overtop of the moisture-laden rock dust, the PDM 3600s downwind of the application measured 504.23 mg/m^3 and 489.38 mg/m^3 for the left and right returns, respectively. Both PDM 3600 instruments had a "PDM Mass Offset Error" message afterwards, indicating gains of > 0.2 mg in a 2-min sampling period.

Table 2. Dust sampling data.

Rock Dust Applied	Average Air Velocity ft/min	Activity Time min
Rock Dusted Untreated	84	12.7
Re-Rock Dusted Untreated	74	12.0
Rock Dusted Mine's Untreated	78	7.0
Rock Dusted Treated	89	4.8
Re-Rock Dusted Treated	80	3.5

Rock Dust Applied	Average PDM Dust Concentrations: Intake mg/m^3	Left Return mg/m^3	Right Return mg/m^3
Rock Dusted Untreated	0.04	0.52	0.11
Re-Rock Dusted Untreated	0.00	1.28	1.18
Rock Dusted Mine's Untreated	0.04	504.23 [1]	489.38 [1]
Rock Dusted Treated	0.26	1135.68 [1, 2, 3]	635.11 [1, 3]
Re-Rock Dusted Treated	0.03	1111.39 [1, 2, 3]	598.67 [1, 3]

[1] PDM Mass Offset Status Code - gains > 0.2 mg in 2 min period
[2] PDM TE Frequency Status Code - tapered element - should be vibrating at frequency range - would invalidate sample due to the frequency outside of
[3] PDM Flow out Range Status Code - sampling flow rate varies from 2.2 L/min by > 0.2 L/min

Figure 6. Flinger rock dusting machine applying the mine's dry rock dust.

Treated Rock Dust Application. Four tons of treated material were applied in the adjacent entry. Particle size analysis of the treated rock dust measured a mean particle diameter of 23.4 µm and a median diameter of 15.1 µm. The specific surface area was 11,787 cm^2/mL or 4,365 cm^2/g. This product was 95.0% < 75 µm, 77.7% < 38 µm, and 43.1% < 10 µm (Table 1).

The testing area was washed down the previous evening, and instrumentation placed in a manner similar to the first day. When the four tons of the treated rock dust were opened and emptied into the scoop of the flinger duster, the rock dust was dry and fluffy (Figure 7). When the treated rock dust was applied with the flinger, the scoop operator had to maintain a constant pace so that he would not be overcome by the dust cloud (Figure 8). To apply the entire four tons of treated rock dust, the scoop operator re-rock dusted the same 270-ft dust zone. Upwind (intake) PDM 3600 concentrations ranged from 0.03 to 0.26 mg/m^3. During application of the treated rock dust, downwind PDM 3600 measurements were roughly 1,100 mg/m^3 for the left side and roughly 600 mg/m^3 on the right side. The differences in the PDM 3600 measurements may be due, again, to variations in entry ventilation and the position of the scoop during the application process (operator located on the right side). Nevertheless, the dust concentrations measured are far above what the instrumentation is intended to sample (5 mg/m^3 and below).

Figure 7. Treated rock dust was dry and fluffy when loaded into the scoop.

Figure 8. Scoop operator applying treated rock dust using a flinger rock dusting machine.

BEM Tests - Classified Rock Dust Application

For testing within the BEM, a rock dust was classified to remove a large portion of the < 10-µm material. Particle size analysis indicates that the classified rock dust had a mean particle diameter of 27.3 µm and a median diameter of 25.7 µm. The specific surface area is measured at 3,279 cm^2/mL or 1,214 cm^2/g. It was 99.7% < 75 µm, 82.8% < 38 µm, and 5.9% < 10 µm (Table 1). A reference rock dust was also applied at high airflow for comparison. The reference rock dust particle size analysis indicates a mean particle diameter of 66.8 µm and a median diameter of 34.0 µm. The specific surface area is measured at 7,589 cm^2/mL or 2,810 cm^2/g. It was 63.9% < 75 µm, 51.3% < 38 µm, and 32.5% < 10 µm (Table 1). Neither of the rock dusts applied within the BEM were treated.

The respirable dust measurements for the classified rock dust applications are much less than those obtained from the mine site testing. However, the measurements, ranging from 17.3 to 43.2 mg/m^3, are still above and beyond the limit at which the instrumentation is designed to sample (5 mg/m^3). For the lower airflow, 43.2 and 28.8 mg/m^3 were measured 100 and 500 ft downwind, respectively (Table 3). As expected, at approximately double the flowrate, the measured values are roughly half of those previously measured, resulting in measurement of 20.8 and 17.3 mg/m^3 at 100 and 500 ft downwind, respectively. When compared to the reference rock dust used previously in LLEM testing, since the respirable content was approximately 5 times more than that of the classified dust, it is not surprising to see that the resulting measurements of respirable dust downwind were nearly 5 times that of the classified. Removing material < 10 µm in size did lower the measurements obtained on the PDM 3700s, but not lower than the permissible allowable limits.

Table 3. PDM Dust Concentrations for Rock Dust Testing.

	Air Velocity ft/min	Average PDM Dust Concentrations Intake mg/m^3	100 ft mg/m^3	500 ft mg/m^3
Pilot Scale Classified Rock Dust	95	0.03	43.24 [1, 2, 3]	28.84 [1, 2, 3]
Pilot Scale Classified Rock Dust	232	0.04	20.84 [1, 2, 3]	17.33 [1, 2, 3]
Reference Rock Dust	221	NA	131.61 [1, 2]	94.80 [1]

[1] PDM Mass Offset Status Code - gains > 0.2 mg in 2 min period
[2] PDM High Filter Load Status Code
[3] PDM Flow out Range Status Code - sampling flow rate varies from 2.2 L/min by > 0.2 L/min

SUMMARY

This study clearly demonstrates that the PDM 3600s and 3700s can be overloaded when positioned in the rock dust cloud. Surface applications of rock dusts having radically different particle size distributions (the classified untreated rock dust – 5.9% < 10 µm; treated rock dust – 43.1% < 10 µm) generated excessive dust levels downwind of application that consequently led to PDM 3600 and 3700 status codes during testing.

Untreated rock dust readily cakes when exposed to moisture, whereas the treated version remained readily dispersible. The only application that generated low measurements of respirable dust utilized an untreated rock dust that was exposed to moisture. This rock dust had clumped before application and did not adequately cover the entry surfaces during application.

This testing did not measure miners' exposure but rather area dust levels at fixed locations. It is recognized that coordinating of the dusting and sampling practices involved to comply with 30 CFR 75.403 (80% total incombustible content) and 75.100 (revised respirable dust rule) is difficult. However, due to elevated levels of respirable dust, acceptable mining practices would dictate that miners not be positioned immediately downwind of rock dust applications.

Another concern is the generation of respirable dust due to movement of workers/equipment through accumulations of rock dust on the floor. This concern may be further exacerbated by the addition of anti-caking agents. Therefore, additional underground testing should focus on the respirable dust generation due to re-entrainment of the rock dust rather than the application of the rock dust.

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DISCLAIMER

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health. The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of NIOSH.

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