Current Dust Control Practices on U.S. Longwalls

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ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) has conducted benchmarking surveys at longwall operations across the country to identify current operating practices and the types of controls being used. Gravimetric and instantaneous dust sampling was completed to quantify dust generation from major sources and determine the relative effectiveness of the different control technologies. Results from the underground dust surveys will be presented as an update on longwall dust control technology and operating practices.

INTRODUCTION

Longwall mining equipment and operational practices have improved dramatically from the early 1980s through the 1990s and this improvement continues today. By the late 1990s, longwall mine output accounted for 40% of all underground output in the U.S., and in 2004, longwall mines accounted for 51% of coal produced underground in the United States. Factors specific to longwall mines that supported productivity improvement include: higher capacity shearers, improved shield hydraulics and control, higher horsepower for equipment, wider face conveyors, and larger faces. Longwall panels averaged 940 ft wide and nearly 10,000 ft long in 2002, compared to an average of 750 ft wide and 7,000 ft long in 1994. New longwall panels, currently in the planning stage, may be as wide as 1,500 ft wide and as long as 15,000 ft. Overall production from U.S. longwall mines in 2004 was over 189.5 million tons. The average output from U.S. longwall mines has increased approximately 115% over the last 15 years, from 1.9 to 4.12 million tons (Fiscor, 2003).

Although significant gains in longwall dust control have been made, they have been challenged by substantial increases in coal extraction rates, which result in the potential to generate more dust (Webster et al., 1990). Average production during compliance sampling by mine operators has increased from an average of 2,800 tons per shift in 1990 to an average 5,600 tons per shift in 2004. Consequently, longwall operations continue to have difficulty in maintaining consistent compliance with the federal dust standard of 2.0 mg/m^3. During a five-year span from 2000 through 2004, mine operators and Mine Safety and Health Administration (MSHA) inspectors collected 7,421, and 1,587 compliance dust samples, respectively. Analysis of these samples show that 14% of the mine operator samples and 15% of the MSHA samples were equal to or exceeded 2.1 mg/m^3, the level at which a citation is issued (Niewiadomski, 2004).

The control of respirable coal dust provides an ongoing challenge for coal mine operators. Ventilation and water sprays remain the primary methods utilized to control dust generated during longwall mining. To compensate for ever-increasing production, mine operators have increased face air velocities and water quantities in an attempt to protect mine workers from excessive dust exposures. This paper describes the on-going research effort to identify the current status of longwall mining and dust control technology being applied in the industry.

LONGWALL SURVEYS

Sampling Methodology

Gravimetric dust samplers, identical to those used in compliance sampling, were operated at 2L/min in conjunction with 10-mm Dorr-Oliver nylon cyclones. Samplers were utilized at stationary and mobile sampling locations to quantify the levels of respirable dust generated at prominent sources along the longwall face. Gravimetric sampling was conducted on-section for 4 to 6 hours, and mine personnel did not wear any of the samplers. Calculated concentrations were not converted to Mining Research Establishment (MRE) equivalent dust levels and should not be compared to compliance sampling concentrations.

Personal DataRAMS (PDRs) were used adjacent to the gravimetric samplers at select sampling locations to obtain a time-related profile of dust levels generated during each sampling period. The PDR is an MSHA-approved, instantaneous dust measuring device where dust-laden air passes through a sampling chamber and a light source. The amount of light deflection in the chamber is measured and provides a relative measure of the dust concentration. Instantaneous dust levels were stored at 10-second intervals in an internal data logger and then downloaded onto a computer for analysis. Dust levels measured with the PDR can be calculated for any time period of interest (e.g., head-to-tail or tail-to-head passes).

Mobile dust sampling to determine the amount of dust generated by the shearer and by movement of advancing shields was conducted by a three-member NIOSH sampling team. Ideally, the UPWIND sampling location was approximately 7.6-15.2 m (25-50 ft) upwind of the headgate cutting drum and measured intake dust levels reaching the shearer. The SHEARER sampling location was located between mid-shearer and the tailgate end of the shearer. The sampling crew member was usually positioned within a shield or two of the tailgate shearer operator. This data provided an indication of the amount of dust that has migrated from the face between the cutting drums. When possible, the DOWNWIND sampling location was approximately 7.6-15.2 m (25-50 ft) downwind of the tailgate drum. Due to shield movement patterns, this sampling location had to be adjusted at certain mines. Each team member maintained their relative position with the shearer as it moved across the face. The difference in dust levels between the UPWIND and DOWNWIND locations was dust generation attributed to the shearer. In addition, similar mobile sampling was conducted upwind and downwind of shield movement on selected head-to-tail passes to isolate dust liberated during shield advance.

At each of these mobile sampling positions, each sampling crew member wore a sampling vest that contained two gravimetric pumps and four cyclones with appropriate filter cassettes (figure 1). Two of the four cyclones [attached to the sampling vest on the left and right sides of the chest area] were connected to the gravimetric pumps and used to sample dust levels during head-to-tail passes. The other two cyclones, also attached to the sampling vest on the left and right sides of the chest area, were used for sampling tail-to-head passes. If the shearer was stopped for an extended period (> 3 minutes), the gravimetric pumps were paused so that mobile sampling along the face was representative of dust levels during active mining. Along with the gravimetric sampling package, members of the sampling crew carried a PDR sampler.

Mobile sampling was augmented with stationary sampling packages. At each stationary sampling location, two gravimetric samplers were located adjacent to one another and operated over the same sampling period. Stationary sampling locations included the intake, belt entry, shield 10, and approximately 10 shields from the tailgate. Intake samplers were typically located in the last open crosscut and used to isolate the dust contamination from sources outby the longwall face. If the mine was utilizing the belt entry as an additional intake, gravimetric samplers were located outby the last open crosscut and the stageloader to monitor dust levels liberated in the belt entry. The shield 10 samplers were used to monitor the dust concentrations of air coming onto the face. The difference between dust levels measured at shield 10 and the intake and belt sources represent an estimate of dust liberated by the stageloader/crusher dust source. The tailgate sampling package provided an indication of the total dust generated along the face. The samplers were typically started after arrival upon the longwall face and operated continuously until sampling was completed. PDR samplers were also placed at the shield 10 and tailgate sampling locations.

In addition to dust measurements, sampling personnel monitored airflow and water quantities on the longwall section. During each shift of sampling, spot air velocity readings were taken with hand-held anemometers at 10-shield intervals down the face. These measurements were one-minute readings taken approximately one foot above the spill plate of the face conveyor. Also, a rough estimate of the area at each velocity sampling location was calculated to estimate the air quantity present. If possible, water flow meters were installed in the water line supplying the shearer and the line supplying the stageloader/crusher sprays. Periodic readings were taken from each of these meters to monitor the quantity of water being used to suppress dust.

Survey Results

Daily spot velocity readings were recorded approximately every 10 shields along the longwall face and were used to calculate the average face velocity. An increase in excess of 0.8 m/sec (157 ft/min) was seen when compared to average air velocities reported in the mid 1990s longwall study(Colinet et al., 1997). The average velocity of the surveyed longwalls was 3.4 m/sec (665 ft/min). Seven of eight longwalls had average air velocities greater then 3.0 m/sec (600 ft/min), with two mines averaging over 4.1 m/sec (800 ft/min). Along with air velocity calculation, a rough estimate of the area under the shields at each velocity sampling location was used to calculate average air quantity for each face. Average air quantities increased approximately 65% when compared to the mid-1990 longwall study. The average volume of air moving down the face was approximately 31.6 m^3/sec (67,000 ft^3/min), with a range between 24.3 to 39.1 m^3/sec (51,000 to 83,000 ft^3/min). Air quantity observed for six of the eight longwalls was greater than 30.2 m^3/sec (64,000 ft^3/min).

Substantial variations in operating conditions were encountered during the surveys. Comparing panel widths observed in these latest surveys with panel widths reported in a mid 1990s longwall study (Colinet et al., 1997) showed an increase of approximately 25%. Face panel widths ranged between 237.7 and 304.8 m (780 and 1,000 ft), and the average face width was 272.2 m (893 ft). Also, the average cutting height was 2.7 m (9 ft) with a range between 2.1 and 3.4 m (7 and 11 ft). Six of the eight mines surveyed to date utilized a bidirectional cutting sequence, with two mines employing unidirectional cutting.

Along with an escalation of air down the face, the use of water to the shearer has increased in an effort to control dust liberating from the face. An average of 492.0 L/min (130 gpm) was observed at the shearer for these longwall operations. The number of shearer drum sprays ranged between 35 and 62, and the average drum spray pressure was approximately 1034.2 kPa (150 psi). In the 1995 study, the average water usage at the shearer was 378.5 L/min (100 gpm) with an average drum spray pressure of 965.3 kPa (140 psi). Half of the mines surveyed utilized crescent sprays on the ranging arms.

Air-moving directional sprays systems were observed on the headgate side of the shearer at seven of the eight longwalls. Splitter arms used to keep fugitive dust away from the shearer operators were unique to each mining operation. The length and number of directional sprays varied greatly. The minimum length of the splitter arm was 2.7 m (9 ft), and the maximum length was 4.6 m (15 ft). The number of sprays ranged between 6 to 19. The type of spray, spacing between the sprays, and the directional angle of the sprays were mine specific. Sprays were directed downwind, toward the face, and in the direction of the roof and panline. Extension arms attached to the end of splitter arms were observed at three longwalls. The length of the extension arms ranged between 45.7 to 61.0 cm (18 to 24 inches) and were angled between 30 and 45 degrees toward the face. Two mines used venturi sprays which were mounted on top of the splitter arm. Average spray pressures were approximately 689.5 kPa (100 psi) when hollow cone sprays were utilized and in excess of 1551.3 kPa (225 psi) when venturi sprays were operated.

Deflector or sloughing plates were observed at three western longwalls. At one operation, a single plate spanned the length of the shearer and 6 venturi sprays were evenly spaced across the top of the plate. At the other two operations, deflector plates were split into three independent sections. Each section had five hollow cone sprays evenly spaced across the top of the plate. Various types of spray manifolds were observed at the eastern longwalls. Three or four manifolds consisting of four or five sprays were evenly spaced across the length of the shearer. The manifolds were either located on the face side of the shearer or on the top of the shearer close to the face. One operation, located spray manifolds toward the middle of the shearer and elevated the manifolds 15.2 to 30.5 cm (6 to 12 inches) off the shearer body.

Manifolds located above the lump breaker or on the shearer body to control dust in the tailgate drum area were observed on all but one longwall. A minimum of 4 and maximum of 16 sprays were directed toward the cutting drum or down onto the conveyor. One operation utilized a series of higher pressure sprays and directed them downwind just inside the spill plate. The sprays formed a water curtain that was effective at keeping fugitive dust out of the walkway. A tailgate splitter arm was observed on one longwall.

The minimum, average, and maximum dust levels for stationary and mobile gravimetric sampling locations are shown in figures 2 and 3. Intake dust levels were consistently low indicating very little dust contamination was occurring from outby sources. The maximum dust level measured was 0.34 mg/m^3 with the majority of the operations below 0.20 mg/m^3. Average dust levels at the intake sampling location were reduced by 53% when compared to the average intake samples measured during the previous (1995) longwall surveys. Half of the longwalls surveyed used belt air as a supplementary air source. For these longwalls, the average dust level in the belt entry was 0.41 mg/m^3, while the average intake concentration was 0.18 mg/m^3, approximately 2.3 times less than the belt entry dust concentrations.

The dust level monitored at shield 10 is a good indication of the dust entering the face from the stageloader/crusher along with intake and belt outby sources. Average dust concentration found at shield 10 was 0.67 mg/m^3. Dust levels associated with the stageloader/crusher operation can be determined by looking at the difference between intake/belt and shield 10 dust concentrations. On average, the amount of dust that can be attributed to the stageloader/crusher was 0.48 mg/m^3. A good indication of the amount of total dust generated along the face was monitored at the tailgate sampling location. Dust levels ranged between

1.04 mg/m^3 to 3.88 mg/m^3 and averaged 2.56 mg/m^3. Reductions in dust levels monitored at the stationary sampling locations in the belt entry, at shield 10, and at the tailgate ranged between 27% and 39% when compared to the 1995 study.

Average dust concentrations at the upwind and shearer mobile sampling locations were higher for the head-to-tail passes (figure 3). Dust levels at these two sampling locations reflect dust liberated from shields being advanced when mining head-to-tail. At the shearer sampling location dust generated by the shearer, primarily the headgate drum is also included. Isolating dust generated by the shearer is accomplished by subtracting the upwind sampling concentrations from the downwind concentrations. Average shearer-generated dust was found to be 2.06 mg/m^3 when mining head-to-tail and 2.82 mg/m^3 while cutting tail-to-head. Higher dust levels produced by the shearer were evident while mining tail-to-head when the headgate drum is the primary cutting drum. Shearer operators downwind of the headgate drum may be exposed to fugitive dust caused by the cutting action of the drum. This is not the case when mining head-to-tail when the dust generated by the primary cutting drum (tailgate drum) is downwind of the headgate shearer operator and possibly the tailgate shearer operator.

A comparison of levels at shield 10 with upwind samples for tail-to-head passes showed an increase of 0.49 mg/m^3. Dust liberated by face spalls, from the face conveyor, and dust migrating from the gob may be causing the increase in dust levels.

When comparing average dust levels from the UPWIND and SHEARER sampling locations, dust levels increased 0.51 mg/m^3 for tail-to-head cuts and 0.31 mg/m^3 for head-to-tail cuts. In the 1995 study, the increase in dust levels was 1.85 mg/m^3 and 1.29 mg/m^3 for tail-to-head and head-to-tail cuts when comparing the two sampling locations. This suggests that the increased air velocity down the face in conjunction with the directional spray systems have had a positive effect of confining fugitive dust close to the face and away from the walkway.

Instantaneous dust samples measured with the PDR were used to calculate relative dust concentrations at each sampling location along the face. These relative dust measurements calculated from PDR data were based upon time study data obtained on a per-pass basis. Extended downtimes and wedge cut dust concentrations were excluded from the average PDR dust concentration. The PDR dust levels were adjusted based upon the ratio between the average dust concentrations obtained from the two gravimetric samplers divided by the dust concentration obtained from the PDR.

Figures 4 and 5 illustrate adjusted PDR mobile sampling results from a typical head-to-tail and tail-to-head pass. Figure 4 shows that OUTBY dust levels are relatively low [averaging approximately 0.50 mg/m^3]. Significant increases in dust levels are found at the UPWIND sampling location. This supports the hypothesis that much of the dust liberated during head-to-tail passes is generated by advancing shields. Examining data at the SHEARER sampling location shows that the directional spray system in conjunction with the high velocity/volume of air moving down the face has a positive effect on diluting high dust levels generated by shield movement. Dust levels at the DOWNWIND sampling location [approximately 1 shield inby the tailgate shearer operator] are approximately equivalent to the dust levels recorded by the SHEARER samplers.

Figure 5 shows dust levels to be relatively low at the three shearer sampling locations when mining tail-to head. These dust levels are very similar to the outby dust levels measured at Shield 10 and the OUTBY sampling location. The spike in dust levels at the SHEARER and DOWNWIND sampling locations as the shearer approached the headgate is explained by shield advances. Because of unstable roof conditions, shields were pulled in advance of the shearer. The SHEARER and DOWNWIND samplers were inby the advancing shields and significant increases in dust levels were evident. These dust levels closely correspond to dust levels at the UPWIND sampling location when mining head-to-tail.

CONCLUSIONS

In the past decade, longwall operations have seen a significant increase in production and productivity and consequently, the potential to liberate more respirable dust is much greater. In an effort to control the exposure of respirable dust to longwall workers, mine operators have made substantial increases in the application of dust control technology.

Sampling data obtained from surveys conducted by NIOSH researchers show that a wide variety of control technology applications exists across the industry. These differences may be explained by differing operating conditions and equipment. Although the type of control technology used to regulate the amount of dust exposure seems to be mine specific, a number of similarities also exist and are viewed as keys for successful dust control:

- All operations are using a version of directional water sprays (shearer clearer) in an effort to confine dust near the face and away from workers.
- Increased air velocity down the face in conjunction with the directional spray systems had a positive effect of confining fugitive dust close to the face.
- The vast majority of operations are using some form of splitter arms on the headgate side of the shearer to contain dust liberation from the headgate drum.
- Spray manifolds located on the shearer seem to be effective at keeping the dust close to the face.
- Splitter arms and/or directional sprays are being used successfully at the tailgate end of the shearer to provide protection for the tailgate shearer operator.
- Increased air quantity (approximately 65%) provides greater dilution.
- Water quantity has increase by approximately 30%.

Also, sampling data has shown that dust liberation and worker exposure from shield advances is significant. Given that the majority of sampled longwalls are utilizing bidirectional cutting sequences, the shearer operators are being exposed to this dust during the head-to-tail cutting pass. Additional research is needed to identify effective control technologies for limiting dust exposure to shield dust.

REFERENCES

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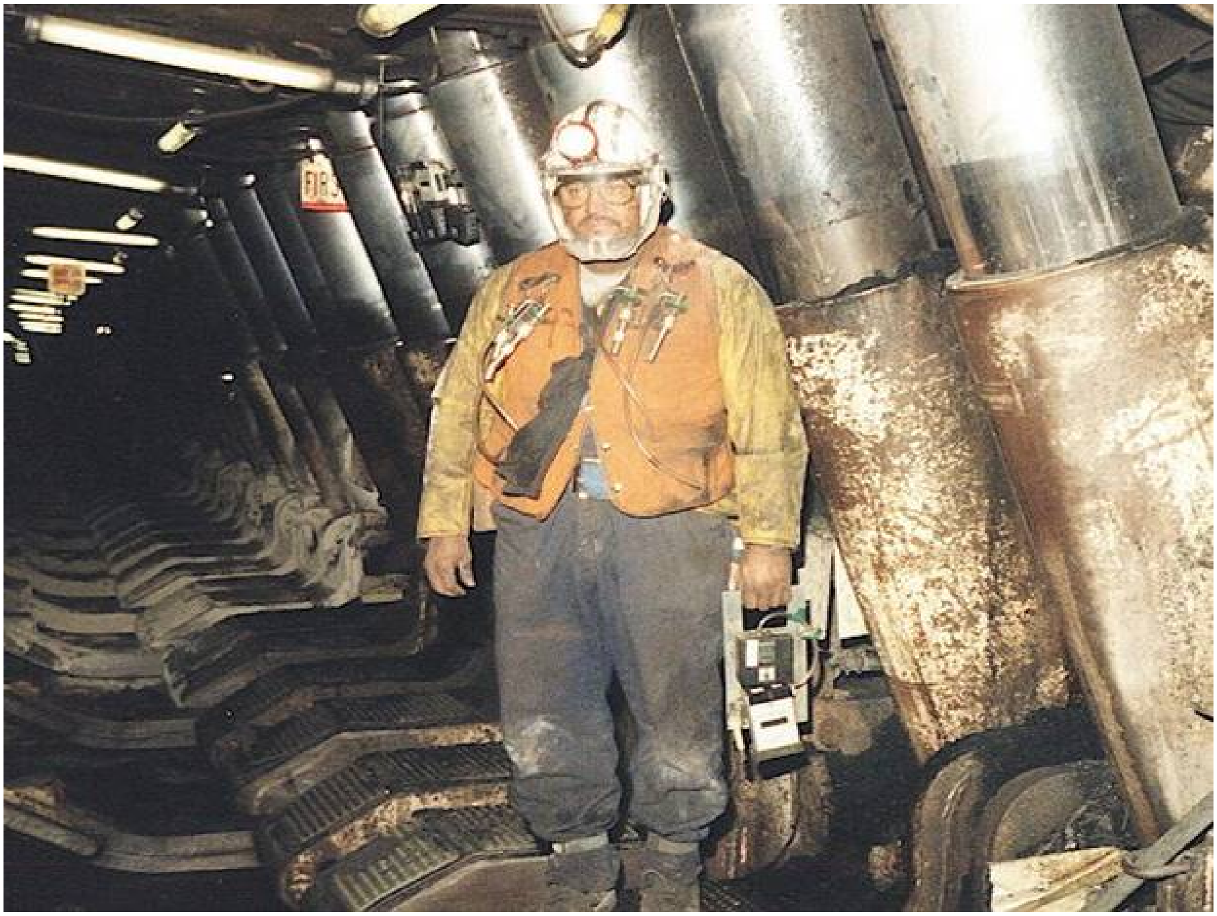

Figure 1 – Sampling crew member wearing sampling vest containing gravimetric pumps, cyclones with appropriate filter cassettes, and carrying a PDR sampler.

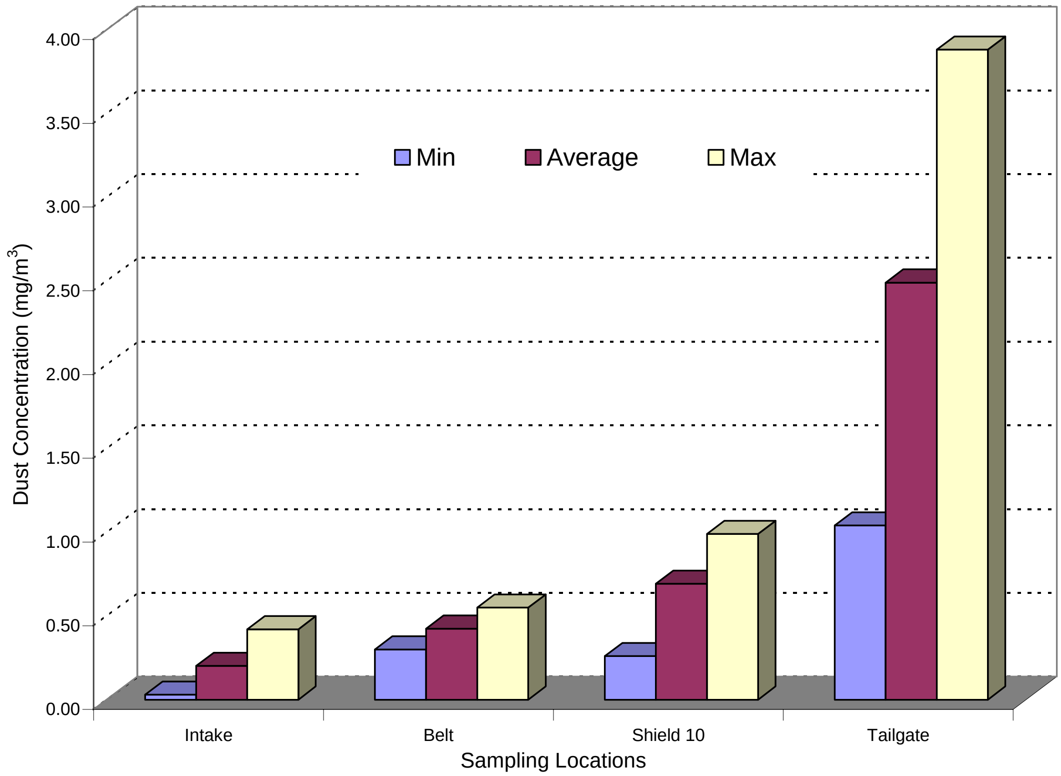

Figure 2 – Dust levels measured at the stationary sampling locations.

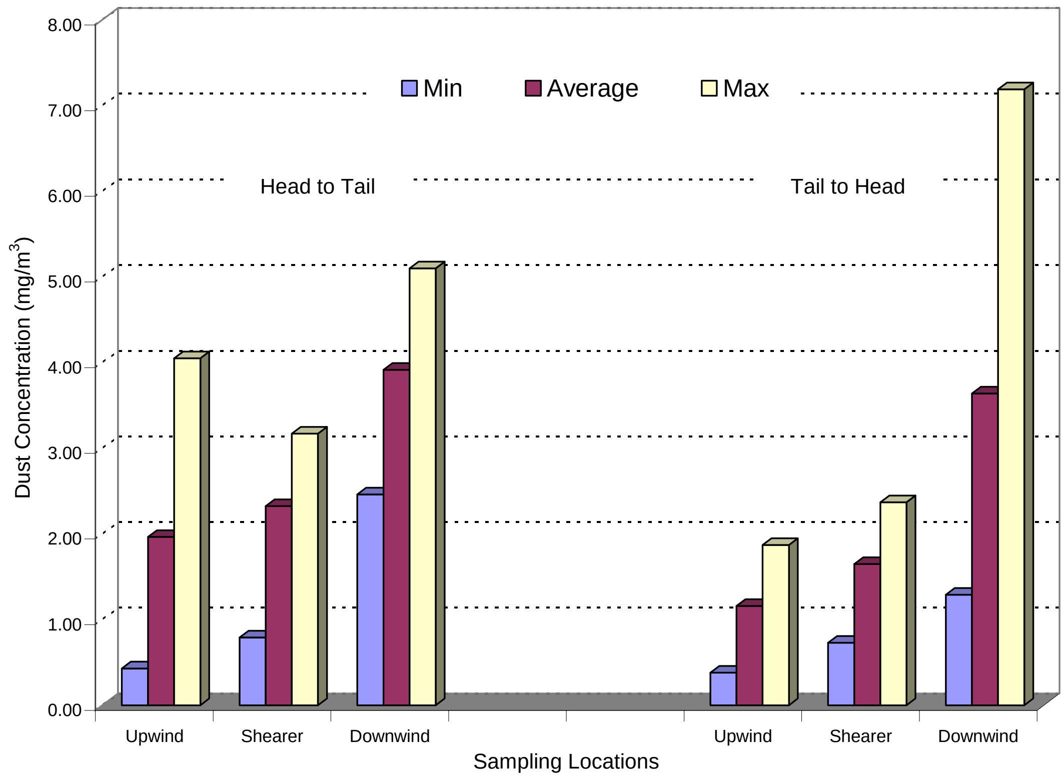

Figure 3 – Dust levels measured at the mobile sampling locations for head-to-tail and tail-to-head passes.

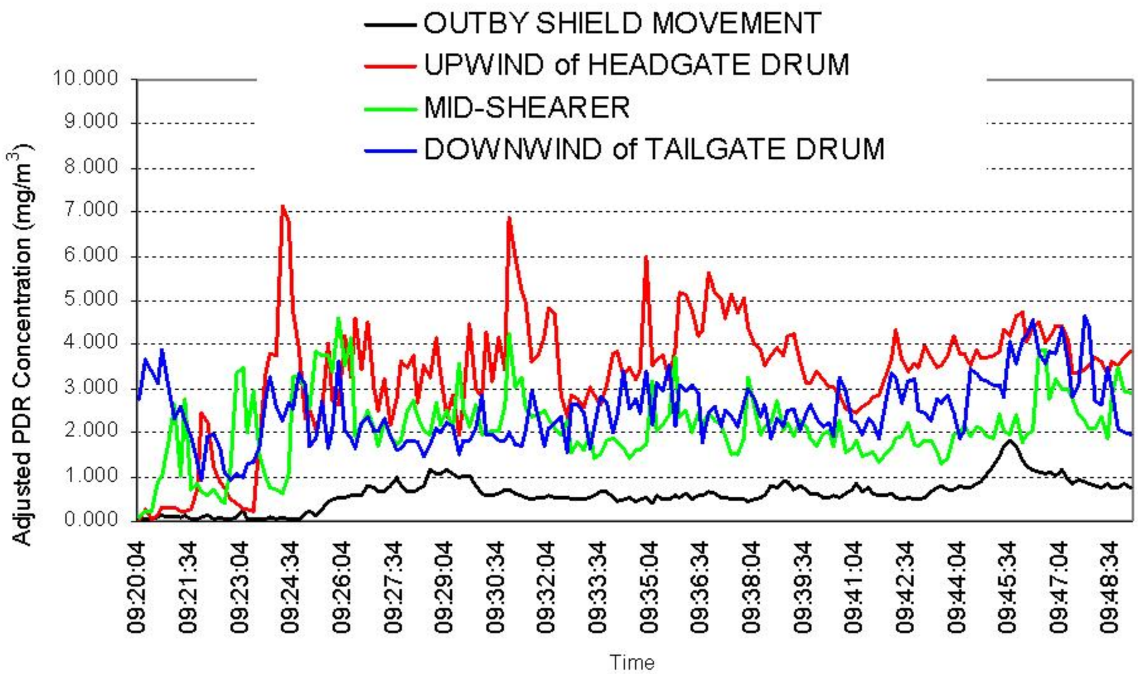

Figure 4 – Adjusted PDR dust levels for a head-to-tail pass.

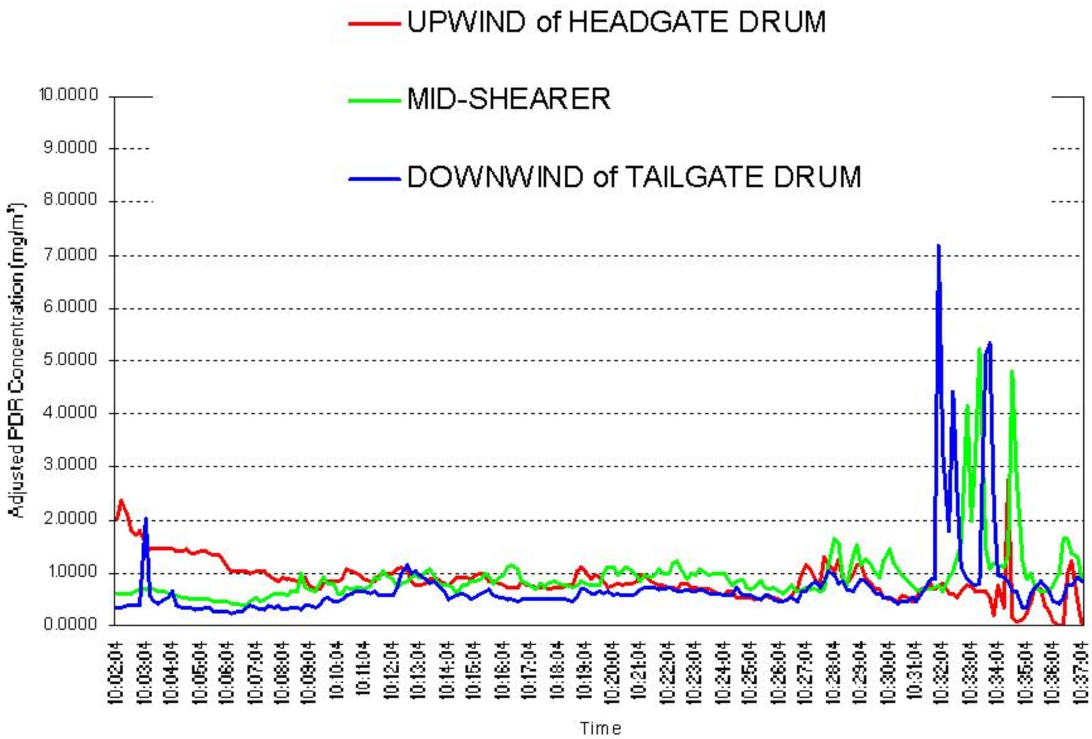

Figure 5 - Adjusted PDR dust levels for a tail-to-head pass.