Chapter 56

DUST CONTAMINATION OF PANEL/FACE INTAKE AIR

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ABSTRACT

The contribution of the various outby sources to the contamination of the panel intake air has been the subject of a relatively small number of studies. In this paper, after a brief review of past studies, results from recent experiments on rates of contamination of intake air by outby dust sources are presented. Present study indicates that each outby source by itself may not be a major contributor. The loading point in the continuous miner section did not appear to be of major concern from contamination point of view. Belt entry including transfer point contributes significantly to the intake air dust level, though reentrainment was not a major source of dust. In longwall panels, the stageloader-crusher was the most dominant source. The panel-to-main belt transfer point was not a major source. Taken collectively, the contribution of all outby sources can be significant. In one longwall section, at the beginning of the longwall face, the contribution of all the outby sources and the headgate cut-out operation was observed to be about 80% of the permissible exposure limit (2 mg/m^3). In modern high production longwalls, the application of effective dust control measures to reduce the dust generated from the outby sources is essential to achieve compliance with the dust standards.

INTRODUCTION

The concern over the high incidence of fires in the belt and trolley haulage entries led to the regulation of the air quantity and velocities in these entries under the Federal Coal Mine Health & Safety Act of 1969 (MSHA, 1989). With regard to the belt entry ventilation, the regulation further specified the isolation of the belt entry from intake and return aircourses, and the dumping of air in the belt entry directly into the return. In addition to the immediate impact on the air distribution system, this provision affected mine ventilation planning as well. The use of belt entry as an intake airway for ventilating the working faces has been a matter of discussion between MSHA, mine operators and mine workers since the early days of the legislation. Several petitions were filed by the operators requesting permission to use the belt entry to ventilate the active workings; several were approved contingent upon increased monitoring of the ambient air quality in the belt entry.

An MSHA committee, appointed by the Assistant Secretary of Labor to review the major aspects of the belt entry ventilation issues, concluded the following among others (MSHA, 1989).

- Safety improvements can be made in the belt conveyor entries of the underground coal mines, particularly in the area of fire protection.
- Directing belt entry air to the working face can at least be as safe as other ventilation methods provided carbon monoxide monitors or smoke detectors are installed in the belt entry.
- Proper design of ventilation system can protect escapeways from rapid smoke contamination in the event of belt fire.
- There is no reason to relax the requirement of separating belt haulage entries from return air courses.

The review committee identified other issues those are relevant to the use of belt entry for ventilation including the impact on airborne respirable dust concentration, and fighting fires in the belt entry, but found that the contribution of belt air to the respirable dust concentration in the face is not significant even though the belt air is more dusty than the primary intake air. An Advisory Committee appointed by the Secretary of Labor on the use of air in belt entry to ventilate production areas concluded that velocity limits (minima and maxima) in belt entry should be based on methane layering and dust entrainment such that methane and dust levels are at or below the levels specified in the standards (MSHA, 1992).

BACKGROUND

According to MSHA, longwalls in continuous compliance of federal dust standards decreased from 40% in 1990 to 28% in 1995. Although dust levels have remained relatively unchanged over this period, averaging 1.7 mg/m^3, approximately 25% of the operating longwalls were in noncompliance during any given bimonthly sampling cycle. Among the reasons attributed to the emergence of these compliance problems are higher production rates and productivity, higher gas and dust emission rates, and the increased face widths and panel lengths. To meet the increased air quantity requirement at the face, mines are seeking permission to use the belt entry air for face ventilation. Using belt air in the face can lead to the contamination of intake air from several outby sources including loading points, belt and transfer points.

Organiscak, Jankowski and Kelly (1986) identified the stageloader-crusher as the dominant outby dust source in a longwall panel contributing to more than 50% of dust exposure of the shearer operators. The contribution of the panel belt was also significant representing 25% of the permissible exposure limit of 2 mg/m^3. According to a recent report (Organiscak and Jankowski, 1996), the combined contribution of all outby dust sources to longwall face dust level has decreased from 51% in early 1980's to 41% in early 1990's indicating improvements in controlling contamination from outby sources.

While not strictly an outby source, the headgate cut-out operation in a longwall face is a major source of contamination of the face intake air at the beginning of the face. The duration of headgate cut-out operation is small in comparison to that of the cutting cycle; however, the potential for the contamination of intake air is significant. In a number of field evaluations (Cecala, Organiscak and Jankowski, 1987), respirable dust levels of 20 to 30 mg/m^3 have been observed at the shearer operator's location during the headgate cut-out. In high production longwalls, as the number of passes per shift increases, this source becomes even more relevant for control.

According to Potts and Jankowski (1992), the average respirable dust level in the belt entry upwind of the feeder-breaker in a continuous miner section was 0.26 mg/m^3. Feeder-breaker generated upto 0.2 mg/m^3 of dust. On a longwall mining section, the average respirable dust level in the belt entry upwind of stageloader-crusher was 0.59 mg/m^3. Stageloader-crusher generated between 0.5 to 0.9 mg/m^3 of respirable dust. The difference in the dust levels measured between the continuous miner section and longwall mining section was attributed to the differences in the production rates. With regard to belt entry dust levels, they found that belt entry length and production rate of the section affected the dust levels. The entry length effect equated to roughly 0.1 mg/m^3 increase in dust for 305 m (1000 ft) increase in length and the production effect equated to roughly 0.1 mg/m^3 increase in dust for 181 to 454 tonnes (200 to 500 tons) per shift increase in production. In this study, the belt speed was 2.03 m/s (400 fpm) and the air velocity varied between 0.53 m/s and 0.91 m/s (105 fpm and 180 fpm). The dust level in the belt entry was unaffected. The benefits of increased dust dilution appeared to outweigh the effects of additional dust sources in the continuous miner section. Due to the increased air quantity, the respirable dust level in this section reduced by 0.1 to 0.3 mg/m^3 during cutting.

On the basis of a study in six longwall sections, Haney (1996) indicated that the contribution of the stageloader-crusher to face dust levels ranged from 0.5 to 1.3 mg/m^3. The concentration of dust in the belt entry approached or exceeded 1.0 mg/m^3. However, when this air was used in the face, the actual contribution to face exposure was relatively low, in the range of 0.1 to 0.3 mg/m^3 because the belt air flow was a small percentage of total intake going to the face. He concluded that the use of belt air will generally increase the intake dust level; however, depending on the specific section, dust control and ventilation configuration, the dust exposure of face occupation could either go up, go down, or remain unchanged.

DESCRIPTION OF EXPERIMENTS

In the present study, two sets of experiments were conducted to study the intake air contamination. In the first set, dust surveys were conducted in three mines which were not using belt air for face ventilation but employed longwalls. In these mines (Mines A1, B1 and C1), dust surveys were limited to the longwall face area including the intake and stageloader-crusher. In the second set, dust surveys were conducted in four mines which were using

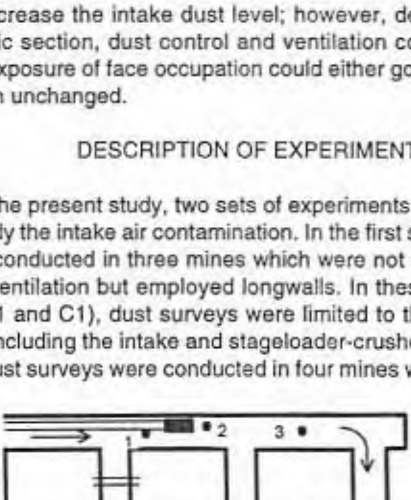

Figure 1. Layout of sampling stations in continuous miner section in Mine A2.

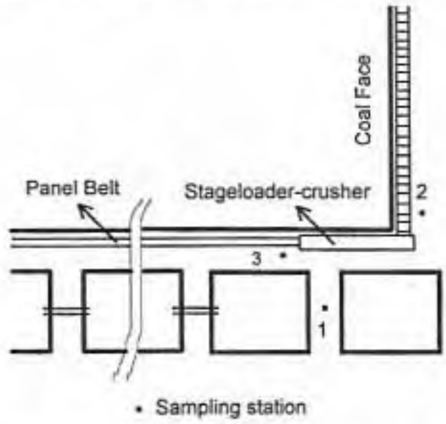

Figure 2. Layout of sampling stations in the longwall sections.

belt entry air for face ventilation. In these mines (Mines A2, B2, C2 and D2), the survey was extended to estimate the contribution of outby dust sources viz. stageloader-crusher in the longwall section, feeder-breaker in the continuous miner section (Mine A2), panel belt entry, and panel-to-main belt transfer point.

Sampling Plans

The sampling plans were specifically developed to isolate and quantify the dust contamination arising from the following outby dust sources :

Loading point in the continuous miner section : For determining the contribution of the loading point in the continuous miner section, two experiments were conducted in mine A2. The layout of the sampling stations is shown in Figure 1. At each station, a gravimetric personal dust sampler was used to determine the average respirable dust concentration at that station for the sampling period. In addition, at stations 1 and 2, a RAM was also installed to provide a continuous record of dust concentration profile during the experiment.

Stageloader-crusher : In mines A1, B1 and C1, during the first set of experiments, one sampling station was located in the intake cross-cut and the other between shield-5 and shield-10 close to the head gate. These are indicated as stations 1 and 2 in Figure 2. Gravimetric personal dust samplers were used to determine the airborne respirable dust concentration in the intake and the headgate station. The increase in concentration from station 1 to station 2 is attributed to the contamination from the stageloader-crusher and the headgate cut-out.

In mines B2, C2 and D2, a third sampling station upwind of the stageloader-crusher was added to the earlier experimental design (station 3 in Figure 2). Gravimetric personal samplers were used to determine the average respirable dust concentration during the sampling period. Additionally RAM units were also set at station 2 and 3 in order to determine the dust generation rate of the stageloader-crusher during the time the shearer is cutting coal. This experimental setup is used to determine the contributions of the stageloader-crusher, the belt entry and the primary intake to the dust level in the intake air to the face.

Panel Belt : The panel in mine A2 was a continuous miner panel whereas the panels in mines B2, C2 and D2 were longwall production panels. The length of the belt entry in the continuous miner panel was about 2440 m (8000 ft) and in the longwall panels, it was between 915 to 1065 m (3000 to 3500 ft). A number of sampling stations (5 to 8) was established along the panel belt from the head to the tail. The stations were 90 to 270 m (300 to 900 ft) apart in longwall belt entry and 395 to 670 m (1300 to 2200 ft) in the continuous miner belt entry. Gravimetric personal dust sampler was used to determine the average respirable dust concentration at the stations.

Panel-to-main belt transfer point : To estimate the contamination of air in belt entry by the panel-to-main belt transfer point, two sampling stations were established in mines B2, C2 and D2 - one outby the transfer point in the main belt entry and the other inby of the transfer point in the panel belt entry. Gravimetric personal dust samplers were used for respirable dust sampling.

RESULTS

Loading point in continuous miner section : The airborne respirable dust concentration at the three sampling stations for the two experiments in mine A2 are shown in Table 1. In both the experiments, airborne respirable dust concentration at the sampling station 2 was below 1.0 mg/m^3. The increases in concentration from station 1 to station 2 were 0.38 mg/m^3 and 0.20 mg/m^3 in experiments 1 and 2, respectively. These can be viewed as the amount of contamination by the loading point. In experiment 1, 70% of the section air was flowing through the belt entry. The respirable dust concentration at station 3 was 0.5 mg/m^3. Therefore, the contribution of the loading point to the section intake was 0.26 mg/m^3. In other words, 52% of the overall respirable dust level of the combined section intake is the result of contamination from the loading point.

Table 1. ARD concentration at the three sampling stations in Mine A2*

Mine	Experiment No.	Average ARD Concentration (mg/m^3)		
		Station 1	Station 2	Station 3
A2	1	0.29	0.67	0.50
	2	0.28	0.48	0.47

*See Figure 1

The respirable dust concentration profiles recorded by the RAMs at station 1 and station 2 for experiments 1 and 2 are shown in Figure 3. Using the production, air quantity and the RAM data calibrated to the gravimetric respirable units (mg/m^3), the average airborne respirable dust generation rates at the loading point can be calculated for a given time interval. For example, for two different time intervals during experiment 1, the average airborne respirable dust generation rates were found to be 579 mg/tonne and 237 mg/tonne. In experiment 2, the results for two time intervals were 58 mg/tonne and 32 mg/tonne. The high dust generation rates in experiment 1 are indicative of the occasional dust control problems experienced at the loading point. The variability in the dust generation rates in experiment 2 is attributed to the normal changes in production rate and air quantity.

Stageloader-crusher : The airborne respirable dust concentration and air quantity measured at station 1 and station 2 in mines A1, B1 and C1 are shown in the Table 2. The increase in the concentration from station 1 to station 2 is due to the dust generated from the stageloader-crusher and headgate cut-out operations.

The mean contribution of the stageloader-crusher and headgate cut-out in mines A1, B1 and C1 were 0.37 mg/m^3, 1.31 mg/m^3 and 1.34 mg/m^3, respectively. Clearly, the stageloader-crusher and headgate cut-out operation in combination continues to be a major source of contamination at the beginning of the longwall face.

Data from the second set of experiments (mines B2, C2 and D2) were analyzed to determine the concentrations at stations 1, 2 and 3. These concentration data along with the air quantity data at these stations are shown in Table 3. These data are used to calculate the contributions of the belt entry, the primary intake and the stageloader-crusher/cut-out operations to the dust level at the headgate station (Figure 2, station 2). The concentration at station 3 (upwind of stageloader-crusher) is due to the contamination from the belt entry. The concentration at station 1 (intake crosscut) is due to the contamination by sources upwind in the primary intake. The concentration at station 2 (headgate station) is due to the concentrations at station 3, station 1 and the addition of dust by the stageloader-crusher and headgate cut-out operations. The belt entry contribution to the concentration at station 2 in experiment 1 of mine B2 is shown in Table 4 as 56% and is calculated from Table 3 data as follows : [{(1.12)(7.438)/(0.87)(7.438+9.713)} x 100 = 56%]. The contribution from the belt entry to the concentration of 0.87 mg/m^3 at station 2 is 0.49 mg/m^3 (0.87x0.56). Similar calculations are made for the primary intake where the contribution is 0.12 mg/m^3, i.e. 14% of the concentration at station 2. Finally, the contribution of the stageloader/headgate cut-out operations (0.26 mg/m^3 or 30%) is calculated as the difference between the concentration at station 2 and the sum of the contributions from the belt and the primary intake, i.e. [0.87-(0.49+0.12) = 0.26 mg/m^3].

As shown in Table 4, the contribution of the stageloader-crusher/headgate cut-out operations to the face intake dust level ranged from 0.26 to 0.97 mg/m^3 and as a percent of the dust level at station 2, it is between 20% to 66%, and between 13% to 48% of the permissible exposure limit of 2 mg/m^3. In mine B2, data was also collected on the face concentrations. It was observed that the contribution of the stageloader-crusher/headgate cut-out operations ranged from 13% to 56% of the average face concentration.

During the experiments in mine B2, data was collected on the production from the longwall face and a time study was also conducted on the shearer operation. Using the RAM data collected at station 3 and station 2 (when the shearer is downwind of station 2) and assuming that the primary intake concentration does not change during these periods, it was possible to determine the contribution of the stageloader-crusher alone to the concentration at station 2. Knowing the production during these periods, total air quantity (sum of air quantity at station 1 and station 3) and the contribution of the stageloader-crusher alone, the dust generation rate of the stageloader-crusher was calculated in terms of mg/tonne. The dust generation rates of the stageloader-crusher during experiments 1, 2 and 3 were 14, 60 and 47 mg/tonne, respectively. Difference in the cutting rates of the shearer and changes in the air quantity (primary intake and belt air) are some of the reasons for the variation in the dust generation rates.

Panel Belt Entry : In mines A2, B2, C2, and D2, for all the sampling stations along the panel belt entries, the respirable dust concentrations and the air quantities flowing in the entry at these locations were obtained. In all the panels, the belt speed was approximately 3.25 m/s; the air velocities ranged from 0.81 m/s to 2.50 m/s. Air quantity flowing through belt entry ranged between 34% to 69% of the total quantity delivered at the face. The respirable dust mass flow rates at the stations (the product of the air quantity at the station (m^3/s) times the average airborne respirable dust concentration (mg/m^3) at the station) is used to determine the rate of contamination of the air flow along the belt entry. Shown in Figures 4 and 5 the airborne respirable dust (ARD) concentration, air quantity and ARD mass flow rate for stations in the continuous miner section (Mine A2), and the longwall production pan-

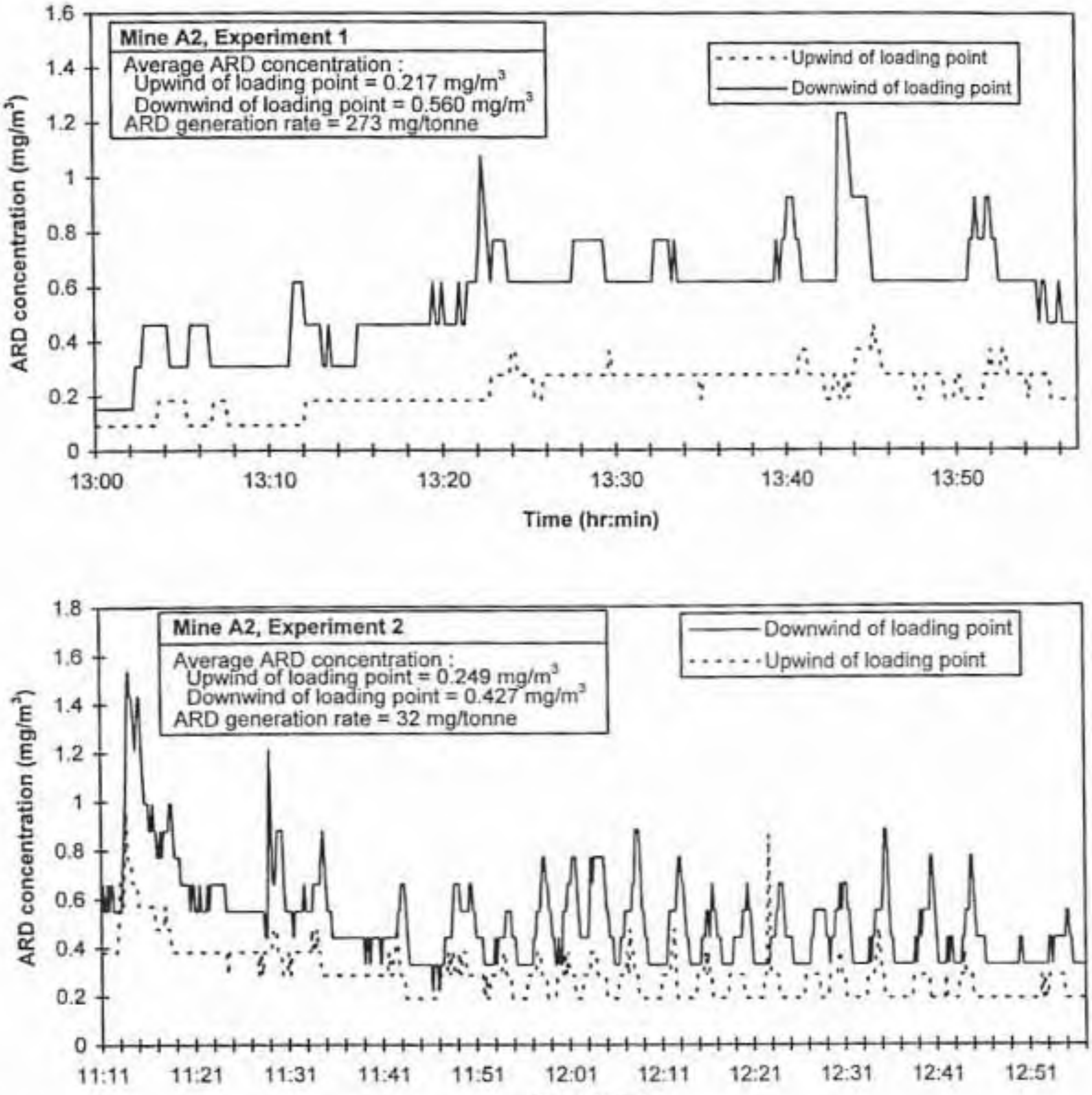

Figure 3. ARD concentrations upwind and downwind of the loading poin in Mine A2.

el in mine C2, respectively. In the continuous miner section (Figure 4), the airborne respirable dust concentration remained almost unchanged and the air quantity decreased as the air moved towards the face due to leakage into the return. This resulted in a decrease in the airborne respirable dust mass flow rate. Insignificant change in the dust concentration coupled with a decrease in the air quantity indicates that there was no significant net addition of dust to the air in the belt entry. In all the longwall panels, the air quantity increased as the air moved towards the face due to leakage from the primary intake. The respirable dust concentration either remained unchanged or increased from the head of the belt towards the face. As a result, the average respirable dust mass flow rate increased towards the face as shown in Figure 5. The incremental mass flow rate of respirable dust in the belt entry air for every 305 m (1000 ft) length is calculated for all the experiments (Table 5). Increasing mass flow rate of respirable dust in the belt entry air flowing towards the face can be due to dust entrained from the belt, walking or other movements in the belt entry. As the floor was generally wet, contribution of walking and other movements can be considered negligible.

In the continuous miner section, the contribution of the belt entry was 0.2 mg/m³. This is 40% of the combined intake dust level, and 10% of the permissible exposure limit of 2.0 mg/m³. As discussed earlier, the contribution of the belt entry in contaminating the face intake ranged from 0.24 to 0.49 mg/m³ (Table 4) in the longwall production panels. This contribution ranged from 15% to 56% of face intake dust level, i.e. 12% to 24% of the permissible exposure limit of 2 mg/m³.

Panel-to-main Belt Transfer Point : The respirable dust concentrations at the sampling stations established to quantify the dust generated by the panel-to-main belt transfer point in mines B2, C2 and D2 are shown in Table 6. Dust generated at this outby source ranged from 0.017 mg/m³ to 0.1 mg/m³. In mine B2, the air in belt entries travel all the way from the surface through the main belts to panel belts. This may be the reason for the comparatively higher rate of contamination in mine B2.

Cumulative Effects : In longwall production panels, the cumulative effect of all the outby sources can be quite substantial. The

Table 2. ARD concentration and air quantity at station 1 and station 2*

Mine	Experi-ment No.	ARD Concentration mg/m³		Air Quantity m³/s		C_2-C_1 mg/m³
		Station 1 (C_1)	Station 2 (C_2)	Station 1	Station 2	
A1	1	0.38	0.42	25.485	11.706	0.04
	2	0.07	0.32	N.A.	14.358	0.25
	3	0.13	0.75	21.252	14.231	0.62
	4	0.25	0.45	25.018	11.291	0.20
	5	0.11	0.80	16.914	9.836	0.69
	6	0.09	0.62	14.619	11.964	0.53
	7	0.11	0.34	26.775	6.584	0.23
	8	0.09	0.47	19.326	14.111	0.38
	Mean	0.15	0.52			0.37
B1	1	0.56	1.75	N.A.	11.235	1.19
	2	1.34	3.44	18.972	12.833	2.10
	3	0.45	1.08	15.004	13.148	0.63
	Mean	0.78	2.09			1.31
C1	1	0.21	1.51	3.874	4.165	1.30
	2	1.00	3.13	6.387	3.276	2.13
	3	0.45	2.91	8.187	7.148	2.46
	4	0.83	1.32	5.124	N.A.	0.49
	5	1.51	1.82	10.660	5.697	0.31
	Mean	0.80	2.14			1.34
Grand mean		0.47	1.32			0.85

RAM dust profile from one of the experiments in mine B2 is shown in Figure 6. The RAM was mounted on shield 8. There were 162 shields at the face and, therefore, the shearer was upwind of the RAM for less than 5% of the operating time. Yet, the RAM profile indicates significant peaks in the concentration profile when the shearer is downwind of RAM, presumably from all sources outby the face.

The contribution of the loading point and the belt air to the intake air dust level in the continuous miner section did not appear to be a matter of concern.

DISCUSSION

This study has quantified the contributions of the outby sources such as stageloader-crusher/feeder-breaker, panel belt, and panel-to-main belt transfer point to the contamination of the intake air. The results of the study indicate that outby dust sources have significant potential to contaminate the intake air.

Table 3. ARD concentration and air quantity at the three sampling stations in longwall production panels*

Mine	Experi-ment No.	ARD Concentration (mg/m³)			Air Quantity (m³/s)		
		Station 3	Station 1	Station 2	Station 3	Station 1	Station 2
B2	1	1.120	0.220	0.870	7.438	9.713	14.161
	2	0.700	1.600	1.620	7.810	15.038	19.040
	3	0.916	0.280	1.460	8.814	17.481	14.704
C2	1	0.437	0.302	0.481	15.223	N.A.	14.498
D2	1	0.527	0.242	1.021	15.223	N.A.	26.051
	2	0.541	0.348	0.960	16.915	7.646	22.895

*See Figure 2

Table 4. Contibution of stageloader-crusher and panel belt in contaminating intake air

Mine	Experi-ment No.	Contribution (%)			Contribution (mg/m³)			Contribution (% of PEL*)		
		Belt Entry	Primary Intake	Stage-loader	Belt Entry	Primary Intake	Stage-loader	Belt Entry	Primary Intake	Stage-loader
B2	1	56%	14%	30%	0.49	0.12	0.26	24%	6%	13%
	2	15%	65%	20%	0.24	1.05	0.33	12%	53%	16%
	3	21%	13%	66%	0.31	0.19	0.97	15%	9%	48%
D2	2	39%	11%	50%	0.37	0.11	0.48	19%	5%	24%
	Mean	33%	26%	42%	0.35	0.37	0.51	18%	18%	25%

*Permissible Exposure Limit of 2 mg/m³

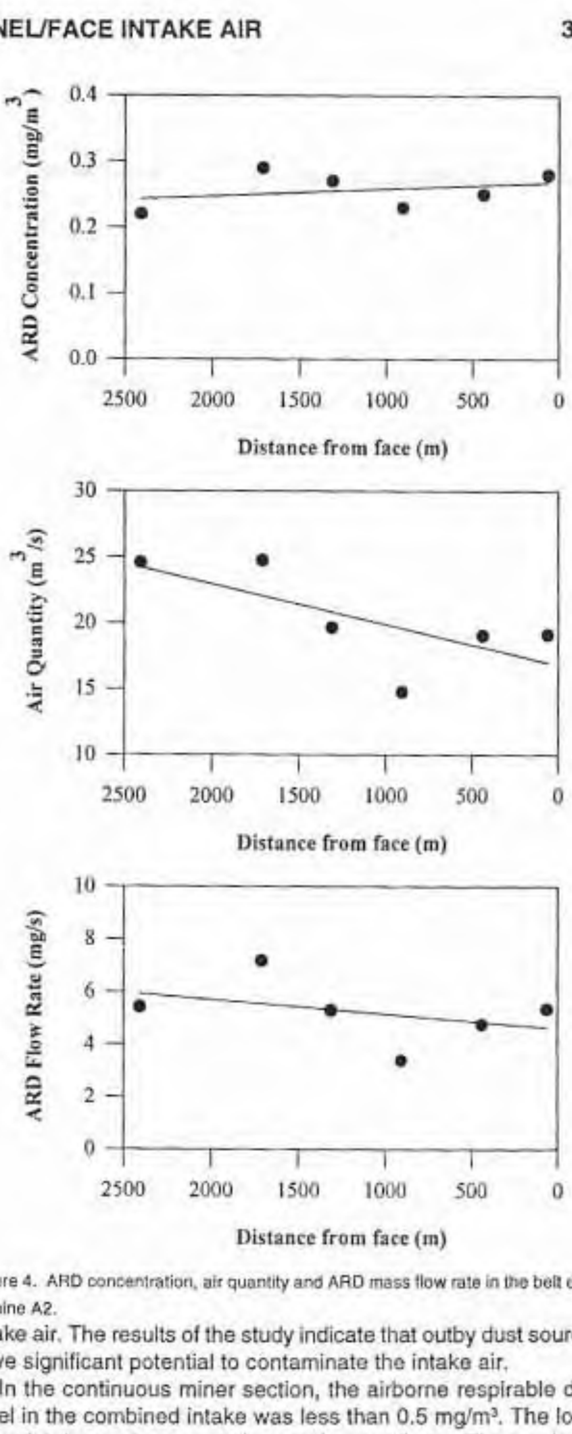

Figure 4. ARD concentration, air quantity and ARD mass flow rate in the belt entry of mine A2.

In the continuous miner section, the airborne respirable dust level in the combined intake was less than 0.5 mg/m³. The loading point does not appear to be a major contributor. The respirable dust level in the belt entry remained almost unchanged indicating very little contamination. This may be due to low production rate from the section resulting in low rate of coal transport through the section belt.

In the longwall production panels, the stageloader-crusher was found to be the most significant source. The control of dust from this source needs considerable attention irrespective of whether the belt air is used for face ventilation or not. Experiments in mines B2, C2 and D2 indicated that the contribution of the stageloader-crusher and headgate cut-out varied from 20% to 66% of the face intake dust level, and between 13 to 48% of the permissible exposure limit for face workers. The control of dust

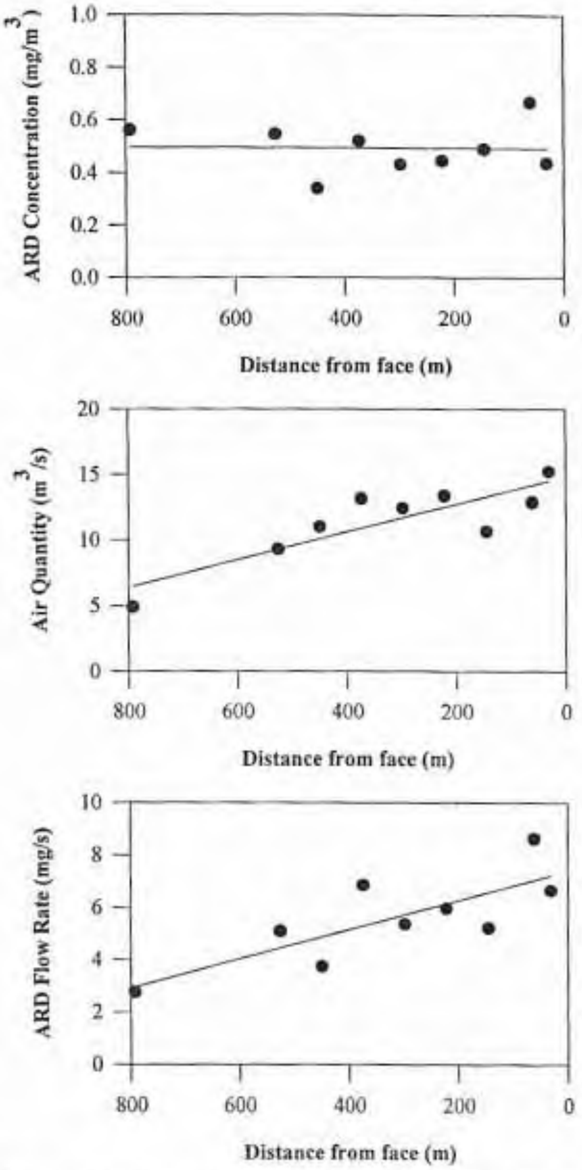

Figure 5. ARD concentration, air quantity and ARD mass flow rate in the belt entry of mine C2.

generated and entrained from this source, which occurs at the beginning of the face, will have considerable beneficial impact on longwall face concentrations. The high variability in the dust generation rates of the loading point (32 mg/tonne to 579 mg/tonne) and the stageloader-crusher (14 mg/tonne to 60 mg/tonne) reveals the need for monitoring the conditions that cause these variabilities, and ensuring all dust control measures are effectively deployed.

Although entrainment of respirable dust was noticed in the panel belt entry, the contamination was not significant. The absolute respirable dust level upwind of the stageloader-crusher in longwall panels in all experiments, excepting one, was less than 1 mg/m³. The contribution of the belt entry varied from 12 to 24% of the permissible exposure limit of 2 mg/m³. The contamination of belt air depends on several factors viz. production rate, belt speed, air velocity, wetness of coal, belt maintenance and cleaning practices. In the present study, experiments were conducted

Table 5. Increase in ARD mass flow rate every 305 m (100 ft) in the belt entry

Mine	Experiment No.	Increase in ARD mass flow rate (mg/s)
B2	1	1.638
	2	0.875
	3	1.445
C2	1	1.713
D2	1	1.003
	2	0.612

Table 6. ARD concentration near the panel-to-main belt transfer point

Mine	Experiment No.	Upwind of transfer point (mg/m³)	Downwind of transfer point (mg/m³)	Increase in concentration (mg/m³)
B2	1	0.430	0.470	0.040
	2	0.280	0.380	0.100
	3	0.410	0.430	0.020
C2	1	0.545	0.562	0.017
D2	1	0.461	0.488	0.027

at a maximum relative air velocity of 5.75 m/s with respect to coal over belt. At higher relative velocities (either higher belt speed or higher air velocity or both), the situation can be different.

The contribution of the panel-to-main belt transfer point was found to be the lowest among all the outby dust sources. In all the experiments, respirable dust generated at the transfer point ranged from less than 1% to 5% of the permissible exposure limit of 2 mg/m³.

Fortunately, the impact of most of outby sources of intake air contamination is small. However, in longwall faces, sources like stageloader-crusher and headgate cut-out seem to have a disproportionately large impact. Since high production longwalls are experiencing severe problems of staying under the mandated dust levels, the adoption of appropriate engineering control for reducing the intake air contamination is particularly important for these longwall faces.

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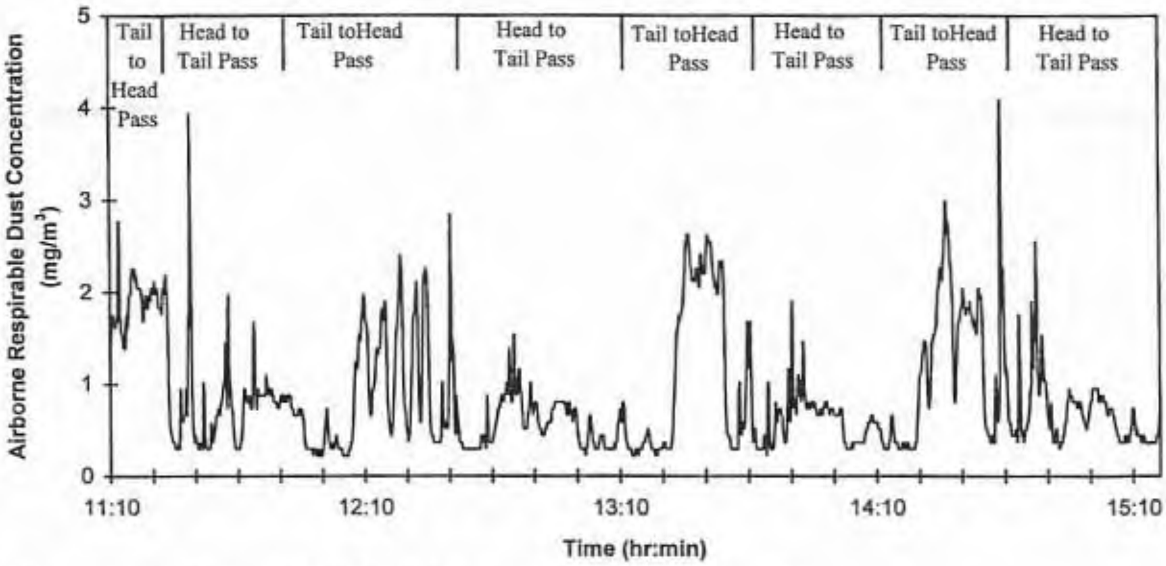

Figure 6. ARD concentration profile recorded by RAM at shield 8 in the longwall face in Mine B2, Experiment 1.

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