# Review of Real-Time Respirable Dust Survey Findings in Australian Coal Mines

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**Abstract.** Over the last 12 years, more than 20 real-time respirable dust surveys have been undertaken at various longwall and development faces in eight Australian underground coal mines by the authors. A number of the surveys were done in a series to monitor the improvements of dust conditions from various dust control devices or strategies applied in these mines or to evaluate the effectiveness of these devices. These real-time respirable dust surveys were conducted using state of art real-time Personal Dust Monitors (PDMs), a prototype of a continuous personal dust monitor (CPDM) recently introduced in US coal mines by the 2014 US MSHA final dust rules. The PDM was introduced into the Australian coal mining industry through an ACARP funded research project to evaluate the real-time PDM for personal respirable dust evaluation use particularly in engineering studies. This paper attempts to review the findings from these surveys undertaken in Australian coal mines. They provide guidance for performing effective, efficient and practical way real-time respirable dust surveys in an engineering study in the future. This is especially important due to the recent progressing incidences of Coal Workers Pneumoconiosis (CWP) in the Australian coal mining industry.

**Keywords:** Real-time respirable dust survey · Personal dust monitor (PDM) Coal workers pneumoconiosis (CWP)

## 1 Introduction

Dust on longwall production faces has always been an issue of concern for production, safety and the health of workers in the underground coal mining industry in Australia and globally. Longwall personnel can be exposed to harmful dust from multiple dust sources including, but not necessary limited to, intake roadways, outbye conveyor belts, crusher/beam stage loaders (BSL), shearers, longwall face support shields (or chocks) advances and dust resulting from falling mined-out areas (such as gob or goaf) or over pressurization of the mined out areas.

Production from longwall mining in Australia has increased remarkably over the last two decades. The Table 1 shows some of the monthly and annual production records in various publication sources [1–6].

With the increase in coal production due to the advancement in longwall equipment technology and methodology, dust loads have also increased and this has resulted in an increase in personnel dust exposure levels. Increased production has also meant that


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**Table 1.** Australian longwall production records published over the years

| Monthly production records | | | Annual production records | | |
|---|---|---|---|---|---|
| Year | Mine | Tonnage | Year | Mine | Tonnage |
| 2000 | Oaky Creek | 772,029 | 2005 | Beltana | 7,627,644 |
| 2005 | Beltana | 955,049 | 2009 | Newlands North | 8,318,421 |
| 2009 | Newlands North | 961,891 | 2015 | Grasstree | 10,000,000 |
| 2009 | Oaky North | 1,146,721 | 2015 | Narrabri[a] | 10,000,000 |
| 2015 | Grasstree | 1,200,537 | | | |

[a]Was projected by ICN report, July 2015

more dust is being produced and controlling both respirable and inhalable dust continue to present the greatest ongoing challenge for the coal mining industry.

In Australia this increased dust exposure level for underground coal workers can be directly attributed to the increase in coal production and the continued development of medium and thick seam mines, which allow the installation of bigger and more productive longwall equipment. Dust control mitigation processes vary from mine to mine, with each individual mine having a dust mitigation setup that is effective for that particular mine operation.

Since May 2015 more than 20 new CWP cases have been reported in the Queensland coal mining industry, with most in underground operations and one case from a surface operation. A review of the respiratory component of the Coal Mine Workers' Health Scheme in Queensland is recently undertaken as the first step of a five-point action plan to tackle the issue.

CWP has been a major concern in the U.S. over the last few years despite recorded conformance to exposure level legislation. This has led to issues on the validity and suitability of dust control strategies and the dust sampling methodologies currently utilized in Australia and the U.S. The U.S. MSHA has recently reduced the shift averaged permissible exposure limit for respirable coal dust from 2.0 to 1.5 mg/m$^3$. Starting February 2016, MSHA requires the use of Continuous Personal Dust Monitors (CPDM) to measure real-time respirable dust exposure under certain circumstances.

Real-time respirable dust sampling techniques have particular application for determining high source locations, efficiency of engineering means of suppression and other approaches to handle the problem. This paper gives an overview of case studies where real-time respirable dust monitoring was utilized to optimize dust control strategies at various Australian and US mines. The use of real-time respirable dust monitoring is able to provide mine operators with a comprehensive dust production signature of their operations hence allowing the implementation of more efficient controls at individual dust sources.

Statutory dust measurements in underground Australian coal mines were conducted mainly by Safety in Mines Testing and Research Station (SIMTARS) and Coal Services that rely on Australian Standards AS 2985 for respirable size dust particles, and AS 3640 for inhalable size dust particles. The majority of dust sampling to date has been with cyclone separation and collection of the sized particles for weighing, generally over the period of a full shift.

Although the above statutory method provides an accurate measurement for the total dust exposure for the period sampled, it does not always accurately reflect the source, quantity and timing of respirable dust entering the longwall face from different sources. This presents difficulties in determining the relative effectiveness of the different control technologies in use.

## 2 Review of Dust Controls and Monitoring

National Institute for Occupational Safety and Health (NIOSH) research [7] indicates that there are at least six individual dust sources on an average longwall production face. NIOSH Studies indicated that longwall shearers and chocks are the main dust sources on longwall faces, representing up to 80% of the total dust make. As the longwall shearer travels along the face, a significant portion of dust occurs in the crushing zone around the pick tips of the cutting drum. Generally the leading drum cuts the full drum height and generates the majority of the dust, while the trailing drum produces less dust due to the less coal being cut, concurrently as longwall supports (shields or chocks) are lowered and advanced. Crushed coal and/or rock can fall from the top of the chock canopy directly into the face airflow. Most of this dust becomes airborne, and quickly disperses into the walkways.

Dust generated due to face spalling ahead of the shearer is a major problem particularly for thick seam longwall faces. Dust can also be lifted up from the Armored Face Conveyor (AFC) by ventilation air when the direction of coal transport is against the direction of the airflow. Dust can be generated at all the conveyor transfer points along the intake airways. The movement of any outbye equipment can also cause significant quantities of dust to be raised into the atmosphere. A portion of dust can also be produced following roof caving behind the chocks and/or sudden gob falls. A significant part of this gob dust can be pushed onto the face as the leaked airflow returns to the face along the face support line.

### 2.1 Longwall Dust Controls

The mining industry's pursuit to achieve statutory dust levels worldwide has produced a number of methods for longwall dust control over the decades. These dust control methods include ventilation controls, water sprays mounted on shearer drums, deep coal cutting, modified cutting sequences, shearer clearer, dust extraction drum, water infusion, use of scrubbers at stage loader/belt transfer points and other methods. The majority of the dust control techniques have been developed in the USA, UK and some other western countries and their application is more suited to low to medium coal seam heights up to 3.0 m. Longwall management has been partially successful in controlling operators dust exposure levels by adopting a combination of the above dust control techniques.

The two main dust control approaches generally adopted by the industry are administrative and engineering. Administrative controls or work practices are designed to minimize the exposure of individual workers by positioning them in the work area in such a way as to limit the time they are exposed to a particular dust source [8]. Work practices can be effective in protecting some individuals only if they are followed properly and consistently, and if the environmental exposure remains constant and predictable. Unfortunately, this is not the characteristic of longwall mining in general. Furthermore, the potential for frequent change of location can make it very difficult to identify sources of dust exposure. Engineering controls aim to lower the levels of respirable dust in the mine atmosphere by either reducing dust generation or by suppression, dilution, or capturing and containing the dust. These control measures are usually designed for application to particular conditions. Some are restricted to one operation while others are more general in nature.

A typical dust control design on a longwall includes the basic use of sprays as the first point of control. The sprays used vary considerably from mine to mine. However, a typical spray setup would include solid or hollow cone sprays for the BSL discharge and crusher with various water pressures and flow rates. The number and positioning of sprays will vary from mine to mine. The shearer will have a series of drum sprays dependent on the drum type, usually supplied by the manufacturer. Some mining operations utilize a "shearer clearer" which consists of a series of up to 10 sprays dependent on desired configuration. These sprays are usually in a solid cone configuration. For shield generated dust, solid cone sprays are positioned in the support canopy. In most cases the aim of dust mitigation has not been the total suppression of the coal dust, but to reduce the respirable dust from the vicinity of the mine workers.

Face ventilation has always been the primary means to dilute and remove airborne dust by increasing face air quantities. Some mines modify the behavior of the ventilation by employing ventilation curtains and brattice wings to reduce the amount of air going past the Main Gate (MG) chocks, over pressurizing the gob and returning somewhere further along the face with contamination. Longwall face ventilation quantities in Australian mines range typically from 40 $m^3/s$ up to over 100 $m^3/s$ depending upon the production and gas dilution requirements.

Examples of engineering dust controls currently utilized in Queensland coal mines as reported recently [9] are

- automation and remote equipment operation (offering the opportunity to remove the operator from the source of the dust)
- ventilation controls (providing clean air through the mine)
- enclosure of dust sources (for example, dust curtains around certain equipment)
- use of water sprays and other wetting agents to suppress dust (including at the cutting face and on conveyor belts)
- use of scrubbers and dust extraction drums
- modified cutting sequences
- enclosed air-conditioned (filtered) and positive pressure cabins on mobile equipment such as trucks, shovels and dozers, and
- maintenance of roadways through grading, watering and the application of salt granules to prevent the accumulation of dust.

While the development of longwall mining has led to high productivity records, the consequent production of high amounts of airborne dust has placed even more stringent demands on dust controls. Extensive studies have shown that high dust exposures on longwall mining operations are mainly due to:

- Inadequate air volume and velocity;
- Insufficient water quantity and pressure;
- Poorly designed external water spray systems;
- Lack of dust control at the stage loader and crusher;
- Dust generated during support movement; and
- Cutting sequences that position face workers downwind of the cutting machine.

## 2.2 Dust Monitoring

The current personal dust monitoring regime in Australia provides the mine tested result with a single figure for shift average respirable dust exposure levels for five samples taken over a minimum of 4 h during a production shift. The majority of dust sampling to date has been carried out with cyclone separation and collection of the sized particles for weighing, generally over the period of a full shift. Although this method provides an accurate measurement for the total dust exposure for the period sampled, it does not always accurately reflect the source, quantity and timing of respirable dust entering the longwall from different sources, hence presents difficulties in determining the relative effectiveness of the different control technologies in use. Tests based on this methodology also have a number of limitations including reduced information from the results and the large number of invalid samples due to over-exposure to dust levels.

Since 1st February 2016, US mine operators have been required to use the CPDM to sample for respirable coal mine dust on working sections of underground coal mines and other areas. In addition, the CPDM must be used to sample air for all Part 90 miners (miners who have evidence of Black Lung), and may be used for sampling at surface mines if approved. From on 1st August 2016 (24 months after the effective date) concentration limits for respirable coal mine dust will be reduced. The overall respirable dust standard in coal mines is reduced from 2.0 to 1.5 mg/m$^3$ of air. The standard for Part 90 miners and for air used to ventilate places where miners work is being reduced from 1.0 to 0.5 mg/m$^3$ of air.

The CPDM is a belt-wearable, computerized device that measures and displays the real-time, accumulated and full-shift exposure to respirable coal mine dust as shown in the Fig. 1. Reporting dust concentrations in real-time empowers miners and operators to take immediate action to avoid excessive airborne dust levels that can injure miners' lungs. Unlike the samples from existing dust sampling devices that require several days to collect, ship and process, the CPDM's measurement of respirable dust provides more immediate, full-shift exposure data. This device, which represents a major improvement in respirable dust sampling technology, was approved for use by both MSHA and NIOSH.

Real-time respirable dust sampling technique has particular application for determining high source locations, efficiency of engineering means of suppression and other approaches to handling the problem. The following sections give an overview of case studies where real-time respirable dust monitoring was utilized to optimize dust control strategies at various Australian mines. They also attempt to review and summarize the findings from these real-time respirable dust surveys undertaken in Australian coal mines. They provide consideration and guidance for performing future real-time


**Fig. 1.** MSHA respirable dust rule—phase II continuous personal dust monitor

respirable dust surveys for engineering studies in an effective, efficient and practical way. This is especially important due to the recent incidences of CWP in the Australian coal mining industry.

These real-time respirable dust surveys were conducted using state of art real-time PDMs which is the prototype of the CPDM as recently introduced to US coal mines by the 2014 US MSHA final dust rules. The PDM was originally developed to measure respirable coal mine dust mass to provide accurate exposure data at the end of a work shift. Additionally, the new monitor continuously displays near real-time dust exposure data during the shift. The PDM uses a tapered-element oscillating microbalance (TEOM) to measure the mass of dust deposited on a filter and continually displays the cumulative exposure concentration data.

The accuracy and precision of the PDM has been determined by comparison to gravimetric filter samplers in the laboratory and in four US coal mines. Laboratory results with different coal types and size distributions showed that there is a 95% confidence that the individual PDM measurements were within ±25% of the reference measurements. Mine test results indicate that data taken with adjacent PDM and reference samplers are indistinguishable.

The PDM was first introduced into the Australian coal mining industry through an ACARP funded research project to evaluate the real-time PDM for personal respirable dust evaluation use particularly in engineering studies.

## 3 Real Time Respirable Dust Surveys and Findings

Over the last 12 years, 24 real-time respirable dust surveys have been undertaken at eight Australian underground coal mines with about 135 series of PDM measurements in their production and development faces. A number of examples are given in the following sections to illustrate real-time dust monitoring in Australian coal mines to identify dust sources and to optimize duct controls. Results from dust monitoring using real-time PDM instruments are shown from two Australian coal mines with a particular emphasis given to the longwall dust sources and controls in place. Dust control strategies utilized are also described.

## 3.1 Sources of Dust Generation

Mine A is a gassy longwall mine with seam and extraction thickness of about 4.0 m, typical longwall panels were 200 m wide using 114 two-leg chock shields and 2.8–3.8 km panel lengths. Ventilation air quantities at longwall production faces were ranging from 70 to 90 $m^3/s$. The longwall panel has a number of potential dust sources. A detailed survey is able to assist in evaluating the contribution of each component dust source, show the contribution from a number of major sources and the cumulative dust level faced by a miner at different points throughout the panel. The particular longwall panel ran from Chock No 1 at the MG to Chock No 114 at the Tail Gate (TG) with four operators, namely MG operator, MG Shearer operator, TG Shearer operator and Chock operator. For conformity of approach a number of reading sequences were taken just inbye the MG at Chock No 8 or just outbye the TG at Chock No 110. Dust readings for a number of measurements sequences are set down and average values calculated.

Tests were also carried out to monitor the dust suppression efficiency of sprays in the BSL and at the belt transfer point where the longwall belt and the main trunk belt met. For the BSL test, one PDM was placed outbye of BSL, the second PDM was placed on top of the BSL inbye of the spray and the third PDM further inbye of the BSL at Chock No 8. During the test, BSL sprays were on initially and then disconnected for about 30 min and then reconnected again.

The results showed that with the water sprays off dust concentration levels downstream of the BSL were dramatically increased to more than 1.0 $mg/m^3$ while the dust concentration level upstream of BSL remained constant (0.2–0.3 $mg/m^3$) with little variations. It was found that the fluctuations in dust levels measured by the PDM upstream of the BSL correlated well with whether there is coal loaded on the moving conveyor belt or not. When there is no coal on the belt the dust levels upstream of the BSL were measured at around 0.2 $mg/m^3$. It is possible to draw a horizontal line as shown in Fig. 2 to indicate whether there is coal on the belt or not.

In undertaking longwall studies it is important to maintain consistency with measurement conditions along the face activities. Figure 3 examines studies undertaken over the majority of a shift. The shearer position data was downloaded from the mine monitoring system. A cutting sequence took on average slightly less than one hour. It can be seen in the figure that seven cutting cycles occurred across the 7-h study time period with good regularity. One early period of 45 min of cutting was lost to belt structure removal. Measurements were carried out at longwall face positions monitoring the dust levels experienced by shearer and chock operators in a unidirectional mining cutting sequence. Results of these tests for various operator position combinations are analyzed and summarized as shown Table 2.

Figure 3 also illustrates monitoring dust make across the length of a shearer when cutting from MG to TG and then back to MG between 15:30 and 16:17 as shown by the shearer position data downloaded from the mine monitoring system. One PDM unit

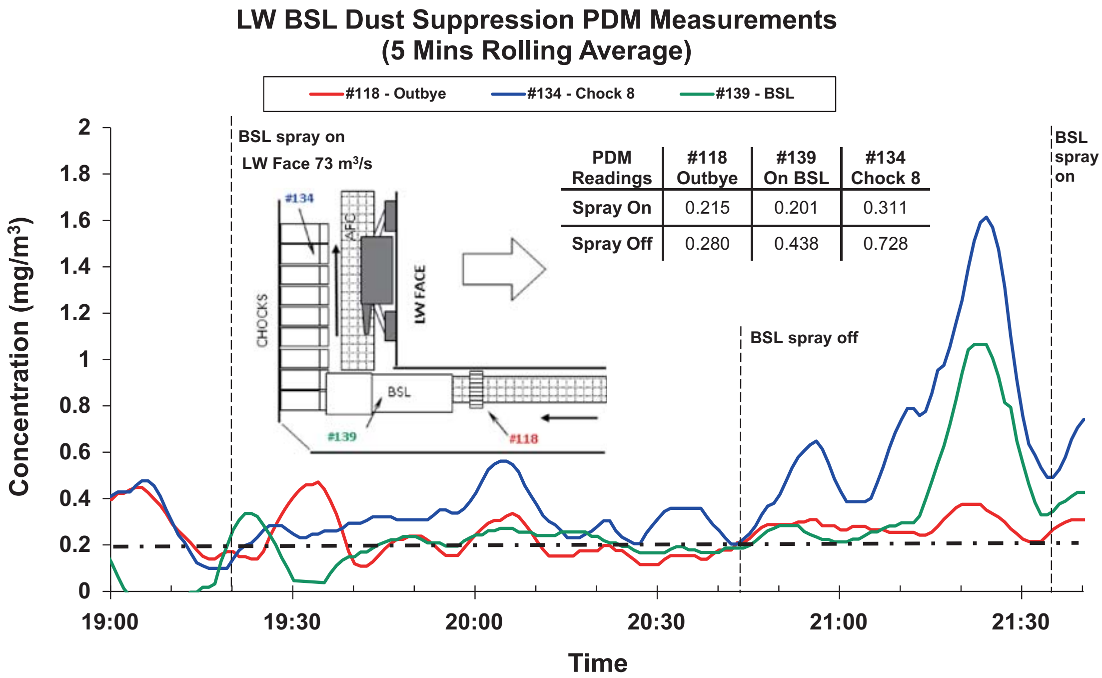


**Fig. 2.** Real-time PDM dust readings across a Longwall BSL with sprays on and off

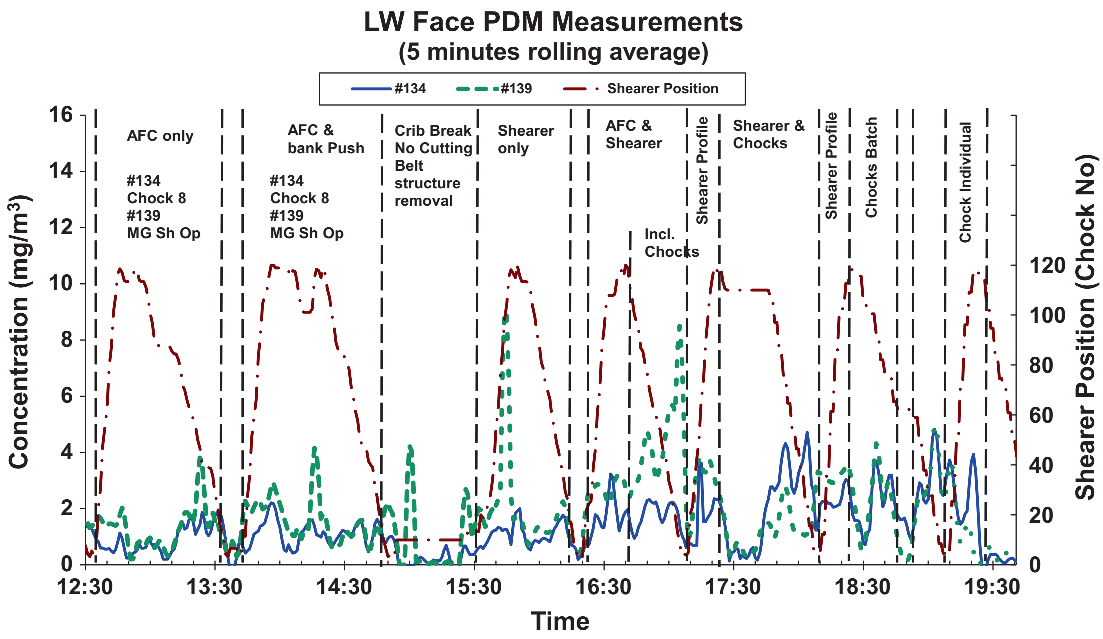


**Fig. 3.** Real-time dust surveys with shearer positions and dust levels

(#134) was worn by a person who shadowed the MG shearer operator for a cutting cycle during unidirectional cutting with average dust level of 1.05 mg/m$^3$ recorded. The other PDM unit (#139) was worn shadowing the TG operator with average dust level of 2.09 mg/m$^3$ over the same period. The results showed an increase (1.04 mg/m$^3$) in dust exposure faced by the TG operator over the MG operator. The

**Table 2.** Dust readings across different sources within a longwall panel

| Test no. | Check #8 | MG operator | TG operator | Check operator | Inbye chock operator | Chock #10 | Comments |
|---|---|---|---|---|---|---|---|
| 1 | | 1.00 | 1.12 | | | | Shadowing operators |
| 2 | | 1.11 | | 1.52 | | | Shadowing operators |
| 3 | | | | | | 3.90 | Fixed position test |
| 4 | | 1.53 | | | | 4.57 | Shearer clearer off |
| 5 | | 1.58 | | | | 4.65 | Shearer clearer off |
| 6 | 0.89 | 1.29 | | | | | AFC dust only |
| 7 | 1.12 | 1.62 | | | | | AFC and bank push dust |
| 8 | 1.64 | | | | 4.26 | | AFC, shearer & chock dust |
| 9 | | 1.51 | | | 3.18 | | Shearer & chock dust |
| 10 | | | 1.53 | | | | Outside air stream (5 min ave.) |
| 11 | | | 1.47 | | | | Outside air stream (30 min ave.) |
| Average | 1.22 | 1.38 | 1.37 | 1.52 | 3.72 | 4.37 | |

unusual anomalous "bump" in the PDM 139 result trace at about 15:45 is put down to a significant face-slabbing fall which was very obvious to those nearby.

## 3.2 Effectiveness of Dust Control Devices

Mine B is a gassy longwall mine as well with mining heights ranging 4.1–4.5 m. Typical longwall panels are 250 m wide using 151 two-leg large and heavy chock shields and about 2.5–4.0 km long with twin heading gate roads. Over a period of five years, eight series of real-time dust surveys at Mine B's longwall faces to assess the baseline dust situations and to optimize the effectiveness of various dust controls were implemented.

Performance audit of the BSL Dust Scrubber for respirable dust reduction has been undertaken. The first part of the surveys evaluated the scrubber operating normally for a period of extensive face cutting with the scrubber sprays alternatively off and on. A second part of the surveys was undertaken with the aim to monitor dust along the face with the scrubber on and compare with a similar situation with the scrubber off. Face coal cutting activity and shearer position on the face was recorded during both tests.

The BSL dust scrubber survey was undertaken in consecutive tests with the scrubber water sprays off and on. With an air quantity of 36.7 $m^3/s$ flowing through the BSL, it is possible to calculate the dust make from the BSL and crusher. Results were evaluated depending on whether face cutting was occurring or not. The results demonstrated that the overall average filtration efficiency of the BSL dust scrubber is about 47% with mining active or not active. However, when mining was active, the dust filtration efficiency of the scrubber is reduced to about 21%. When mining is not active, the filtration efficiency of the scrubber is increased to about 78%.

Higher level of efficiency occurred when the scrubber was not “working hard”. This indicates that with active mining the scrubber was overloaded and a lesser proportion of the dust is impacted or captured by water droplets. It is clear that the dust scrubber performs effectively at low dust loads but not as effectively at higher loads. It was recommended that consideration be given to using two independent scrubber units with one drawing air from the crusher and the other from under the hood at the outbye BSL end where coal passes onto the panel conveyor belt (Fig. 4).

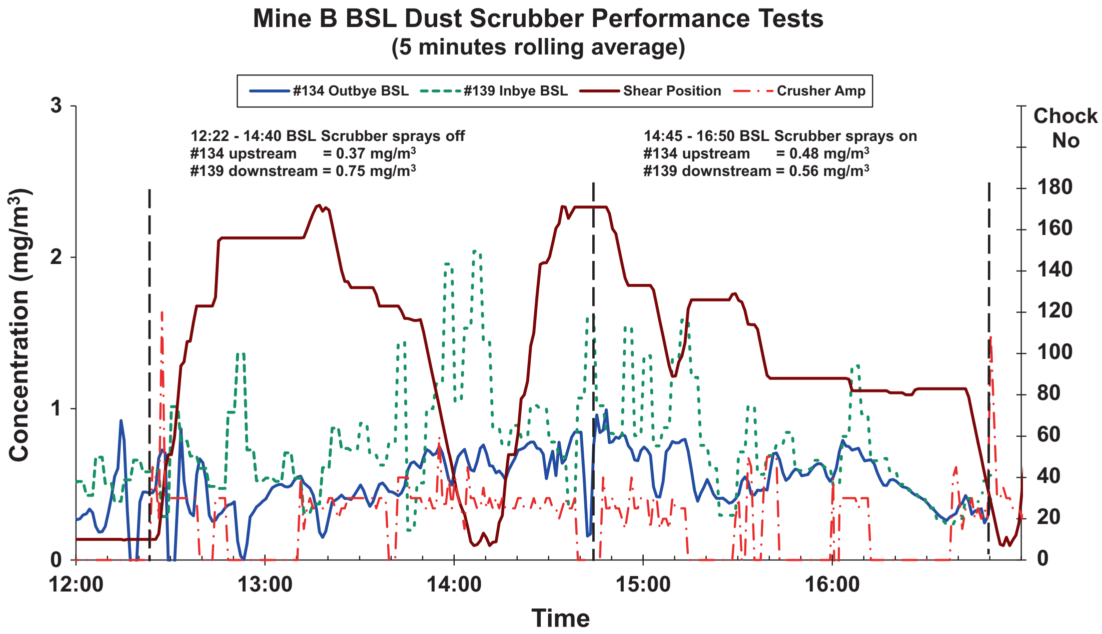


**Fig. 4.** BSL Dust Scrubber performance test PDM results

Several real-time longwall dust surveys were conducted at Mine B to evaluate the dust situations with various dust controls implemented over the years. The Table 3 gives dust levels at various manning positions in the longwall production area recorded. During the initial longwall dust survey (Baseline—Standard), standard dust controls and strategies were implemented. The results from the survey formed the baseline data.

In the next two series of dust surveys undertaken about four and 12 months after the initial surveys, improved dust controls and strategies were applied. Improved and additional dust controls and strategies which contributed lower dust levels at various longwall positions in the second series of the dust surveys were as follows:

1. Improved face air quantity,
2. New finer shearer sprays (50%) installed,
3. New sails installed on the top of MG Drive,
4. Good housekeeping—washing away loose coal on platoons in the face walkway.

**Table 3.** Summary of three survey series of dust results at various manning positions

| Average dust levels ($mg/m^3$) | Face Q ($m^3/s$) | Outbye Level | MG Chock #8 | MG shearer operator |
|---|---|---|---|---|
| Baseline—standard | 63.4 | 0.28 | 2.54[a] | 1.91 |
| Improved condition 1 | 71.2 | 0.30 | 1.16 | 1.33 |
| Improved condition 2 | 70.5 | 0.30 | 0.62 | 0.91 |

[a]Unusual local high dust level experienced was a direct result of additional dust created by strata stress loaded MG chocks (No 1 to 5) advancements

Further improved and additional dust controls and strategies resulting in lower dust levels at various longwall positions in the third series of surveys were as follows:

1. Full finer shearer sprays installation completed.
2. Water Mist Venturi system installed at Chock #6 with three sprays in the front at 45° and one at the back with 10° to the face line.

### 3.3 Summary of Findings from Real Time Dust Surveys

As mentioned earlier, over the last 12 years, 24 real-time respirable dust surveys have been undertaken at eight Australian underground coal mines with about 135 series of PDM measurements in their production and development faces. More than 80 series of real-time PDM measurements have been undertaken in seven Australian longwall mines in 12 separate longwall panels. Some longwall panels had up to three real-time PDM surveys done during their production periods for various purposes such as baseline dust surveys, evaluations of dust controls, strategies and new shearer cutting method on dust levels. The Tables 4 and 5 show summary of panel dimension, ventilation and production details of these longwall panels during the real-time PDM surveys. In brief,

1. Except for two panels were in Highwall longwall mines, the rest were in traditional longwall mines with multiple heading Mains and two or three gate roads.
2. Seven panels used Homotropal belt arrangement and five had Antitropal belt arrangements.
3. Eight panels had dedicated intakes from back panel shafts or bleeder roads.
4. Eight panels utilized the Uni-Directional (Uni-Di) shearer cutting method. However, one of these switched to the Bi-Directional (Bi-Di) shearer cutting during its second series of real-time PDM surveys. The rest of panels used the Bi-Di cutting. Cutting web depths of these panels were either 850 mm or 1000 mm.
5. Panel widths were ranging from 200 to 300 m and the mining heights were from 2.7 m to 4.3 m high with panel lengths ranging from 1890 to 3770 m.
6. Panel ventilation pressures varied from 300 to 1450 Pa. Total panel air quantities were in the range of 46–138 $m^3/s$ with face air quantities varied from 34 to 77 $m^3/s$.

Table 6 gives a summary of the real-time PDM survey results and purposes of these surveys in the 12 Australian longwall panels. PDM measurements were classified into

**Table 4.** Summary of ventilation arrangements and roadway dimensions

| Mine LW | Panel ventilation | | | Roadway | | Beltway | Comments |
|---|---|---|---|---|---|---|---|
| | Pressure (Pa) | Total Q ($m^3/s$) | Face Q ($m^3/s$) | Width (m) | Height (m) | | |
| A1 | 1350 | 75 | 37 | 5.2 | 3.2 | Antitropal | Bleeder road return |
| A2 | 1450 | 90 | 65 | 5.2 | 3.2 | | |
| B1 | 300 | 126 | 48 | 5.4 | 3.4 | Homotropal | Back shaft intake |
| B2A | 450 | 80 | 47 | 5.3 | 3.2 | Homotropal | Bleeder road intake |
| B2B | 500 | 81 | 58 | 5.3 | 3.2 | | |
| B3A | 1100 | 113 | 64 | 5.4 | 3.4 | Homotropal | Back shaft intake |
| B3B | 850 | 103 | 71 | 5.4 | 3.4 | | |
| B3C | 420 | 95 | 71 | 5.4 | 3.4 | | |
| B4 | 1200 | 110 | 77 | 5.4 | 3.4 | Antitropal | Back shaft intake |
| C1 | 1000 | 90 | 55 | 5.4 | 3.5 | Homotropal | Highwall LW panel |
| C2 | 1000 | 90 | 60 | 5.4 | 3.5 | | |
| D1A | 1210 | 85 | 50 | 5.3 | 2.7 | Homotropal | 3 Hdgs; back shaft intake |
| D1B | 1160 | 85 | 56 | 5.3 | 2.7 | | |
| D2 | 950 | 92 | 58 | 5.3 | 2.7 | Homotropal | 3 Hdgs; back shaft intake |
| D3A | 1260 | 138 | 34 | 5.3 | 2.7 | Homotropal | 3 Hdgs; back shaft intake |
| D3B | 1260 | 138 | 34 | 5.3 | 2.7 | | |
| E | 330 | 46 | 40 | 5.4 | 2.7 | Antitropal | Highwall LW panel |
| F | 1000 | 77 | 45 | 4.8 | 3.3 | Homotropal | Back boreholes intake |
| G | 600 | 87 | 75 | 5.4 | 2.9 | Antitropal | Bleeder road return |

various manning or positional categories along the LW face area namely, outbye or background, BSL/Crusher, MG Chock (support) or AFC, Shearer MG side (or operator's position), Shearer TG side (or operator's position), Cock operator and TG Chock positions.

As expected the average dust levels of manning or positional locations in these longwall panels are progressively increasing as locations move further inbye of the longwall face areas. The following gives a summary of findings from the Table 6. As limited date available at Chock operator and TG Chock positions, no further analysis is done in these two positions.

**Outbye, BSL/Crusher and MG Chock Positions**. Outbye or background of longwall panel dust levels were ranging from 0.10 to 0.37 mg/$m^3$ with an average of 0.24 mg/$m^3$. Some of the lower outbye dust levels were found in the longwall panels with separate or dedicated fresh air intakes such as back panel shafts. An average of 13% reduction in outbye dust levels can be found with such panel intake arrangements. Longwall panels with Homotropal belt arrangements for their belt roads also have

**Table 5.** Summary of LW production face details

| Mine LW | Face height (m) | Panel width (m) | Cutting method | Web depth (mm) | Panel length (m) | Face position (m) | Face Q ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| A1 | 4.0 | 205 | Uni-Di | 1000 | 2590 | 2190 | 37 |
| A2 | | | | | 2490 | 2090 | 65 |
| B1 | 4.3 | 300 | Uni-Di | 850 | 2550 | 850 | 48 |
| B2A | 3.4 | 300 | Uni-Di | 850 | 1890 | 1650 | 47 |
| B2B | | | | | 1890 | 1350 | 58 |
| B3A | 4.3 | 300 | Uni-Di | 850 | 3180 | 2950 | 64 |
| B3B | | | | | 3180 | 2650 | 71 |
| B3C | | | | | 3180 | 950 | 71 |
| B4 | 4.3 | 300 | Uni-Di | 850 | 3300 | 2550 | 77 |
| C1 | 4.2 | 205 | Uni-Di | 850 | 2450 | 1150 | 55 |
| C2 | | | | | 2450 | 950 | 60 |
| D1A | 2.7 | 300 | Uni-Di | 1000 | 2420 | 760 | 50 |
| D1B | | | | | 2420 | 560 | 56 |
| D2 | 2.7 | 300 | Uni-Di | 1000 | 3620 | 1150 | 58 |
| D3A | 2.7 | 300 | Uni-Di | 1000 | 3770 | 3350 | 34 |
| D3B | | | Bi-Di | | 3770 | 3350 | 34 |
| E | 2.9 | 264 | Bi-Di | 1000 | 3350 | 3100 | 40 |
| F | 3.2 | 275 | Bi-Di | 1000 | 3000 | 2600 | 45 |
| G | 2.9 | 200 | Bi-Di | 1000 | 3530 | 820 | 75 |

lower outbye dust levels with an average of 16% reduction of outbye dust levels could found with Homotropal belt when compared with Antitropal belt panels.

Dust levels at BSL/Crusher were between 0.24 and 0.66 mg/m$^3$ with an average dust level of 0.47 mg/m$^3$. Longwall panels with Homotropal belt arrangements also have lower dust levels at BSL/Crusher with the difference about 30% found between Homotropal and Antitropal belt panels.

Average dust level found in the MG Chock position (or AFC dust source) was about 0.91 mg/m$^3$ with a range from 0.36 to 1.91 mg/m$^3$ of dust levels measured. Interesting, longwall production panels more than halfway through their overall panel lengths have shown much lower dust levels (about 50–100% reductions) in all these positions when compared with panels still had more than 50% of the overall panel lengths. Panels with Uni-Di cutting also have lower dust levels in BSL/Crusher and MG Chock positions when compared with the panels with Bi-Di cutting.

**Shearer MG and TG Positions**. Average dust levels at shearer MG and TG positions are 1.40 and 2.06 mg/m$^3$ respectively. Further analyses of the effects of various panel geometry, production and ventilation parameters on shearer MG and TG positions reveal the following findings as shown in Table 7.

Based on Table 7, it was found that

**Table 6.** Summary of PDM survey results for the 14 Australian LW panels

| Mine LW | Outbye | BSL crusher | MG Chock/AFC | Shearer MG | Shearer TG | Chock operator | TG Chock | Comments |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.23 | 0.45 | 1.22 | 1.38 | 1.37 | 1.52 | 4.37 | Baseline |
| A2 | 0.19 | 0.55 | 1.07 | 1.77 | 2.52 | 3.43 | 6.68 | Baseline |
| B1 | 0.10 | 0.24 | 0.82 | 1.12 | 1.43 | | | Baseline |
| B2A | 0.37 | 0.54 | 0.85 | 1.41 | | | | BSL, Baseline |
| B2B | 0.28 | 0.45 | 1.33 | 1.61 | 1.70 | 1.47 | | Baseline, Bi-di Trial |
| B3A | 0.28 | 0.48 | 0.71 | 1.91 | 2.18 | | | Baseline |
| B3B | 0.23 | 0.38 | 0.74 | 1.33 | | | | Improvements I |
| B3C | 0.22 | 0.30 | 0.62 | 0.94 | | | | Improvements II |
| B4 | 0.33 | 0.54 | | 1.27 | | | | Baseline |
| C1 | 0.25 | 0.47 | 0.68 | 0.75 | 0.88 | | | Baseline |
| C2 | | | | 0.76 | 1.02 | 1.57 | 2.88 | Shearer scrubber |
| D1A | 0.18 | | 0.61 | 1.41 | | | | Baseline |
| D1B | 0.16 | | 0.36 | 1.04 | | | | Improvements |
| D2 | 0.26 | | 0.54 | 1.12 | | | | Radial drums |
| D3A | 0.19 | | 1.57 | 2.39 | | | | Baseline |
| D3B | 0.19 | | 1.91 | | 8.69* | | | Bi-di cutting trial |
| E | 0.29 | 0.52 | | 1.98 | 5.21 | 2.97 | | Baseline |
| F | 0.25 | 0.50 | 0.68 | 1.67 | 2.24 | 2.80 | 4.42 | Baseline |
| G | 0.28 | 0.66 | | | | | | Baseline |
| Average | 0.24 | 0.47 | 0.91 | 1.40 | 2.06 | 2.29 | 4.59 | |

**Table 7.**

| Panel parameters | Average dust level (mg/m$^3$) | |
|---|---|---|
| | Shearer MG | Shearer TG |
| Panels still had more than half of panel lengths | 1.70 | 2.83 |
| Panels still had less than half of panel lengths | 0.89 | 0.83 |
| *Dust level reduction percentage* (%) | 90 | 240 |
| Cutting web depth—1000 mm | 1.59 | 2.83 |
| Cutting web depth—850 mm | 1.23 | 1.44 |
| *Dust level reduction percentage* (%) | 29 | 97 |
| Face mining heights more than 4.0 m | 1.58 | 3.05 |
| Face mining heights less than 4.0 m | 1.25 | 1.57 |
| *Dust level reduction percentage* (%) | 26 | 95 |
| Panel width less than 250 m | 1.48 | 2.55 |
| Panel width more than 250 m | 1.17 | 1.45 |
| *Dust level reduction percentage* (%) | 27 | 76 |
| Panel with Bi-Di cutting method | 1.82 | 3.72 |
| Panels with Uni-Di cutting method | 1.35 | 1.59 |
| *Dust level reduction percentage* (%) | 35 | 135 |

- Newer longwall production panels with more than 50% of their overall panel lengths remaining have higher dust levels in shearer MG and TG positions which are almost two to three times higher than those panels with less than 50% of their overall panel lengths left.
- Panels with cutting web depth of 850 mm have dust levels of 29 and 97% reduction correspondingly at the shearer MG and TG positions as well when compared with the panels with 1000 mm web depth.
- A similar relationship in dust level reductions (26 and 95%) in these two shearer positions is observed in panels with lower than 4 m face mining heights when compared with the panels with more than 4 m face heights.
- Similarly, panels with less than 250 m panel width have dust levels of 27 and 76% reduction correspondingly at the shearer MG and TG positions as well when compared with the panels with more than 250 m wide.
- Panels with Uni-Di cutting also have lower dust levels (35 and 135% less) at shearer MG and TG positions when compared with the panels with Bi-Di cutting. In fact, average dust level of panels with Uni-Di cutting at shearer TG is less than half of panels using Bi-Di cutting.

It should be noted that these findings are only looking at the particular influence of one individual parameter have on the dust levels along some longwall face positions. Full comprehensive analysis of these parameters in various combinations should be undertaken in order to have better or broad understandings of their combined effects on the dust levels along some longwall face positions in these longwall panels.

## 4 Conclusions and Recommendations

Two case studies of real-time dust monitoring in Australian longwall mines were summarized and presented. This is with particular emphases on the real-time dust monitoring as an engineering tool that can effectively and efficiently assess impacts of dust controls and/or strategies implemented at mines. Statuary shift-averaged monitoring will still have its roles to identify whether there is a dust issue or not at this stage but it will not be able to assist the optimisation of dust mitigation controls and strategies in a practical way.

Some preliminary findings on the influences of panel geometry, production and ventilation parameters have on the dust levels along longwall face positions in 12 Australian longwall panels based on real-time dust survey results were discussed. It was found that separate or dedicated fresh air intakes and Homotropal belt arrangements could provide lower outbye or background dust levels for the longwall production faces. Longwall panels with production faces in their second half of overall panel lengths, shallower cutting web depth, lower face mining heights, narrower longwall panel widths and Uni-Di cutting method could all contribute to lower dust levels at some manning or positional locations along the longwall production faces. Further detailed analyses of these parameters and their combined influences on the dust levels along selected longwall face positions in these longwall panels are recommended.

Australian longwall mining experience has indicated that the efficiency of some of the existing dust control methods reduces significantly in thick coal seams and under high production environments. As the current trend in the industry is to substantially increase the face production levels and to extract more thick coal seams, there is an urgent need for detailed investigation of various dust control options and development of appropriate dust management strategies. Findings from this paper provide some basic consideration and guidance for performing any future real-time respirable dust surveys for engineering studies in an effective, efficient and practical way. This is especially important due to the recent emerging incidences of CWP in the Australian coal mining industry.

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