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DUST MONITORING AND CONTROL EFFICIENCY MEASUREMENT IN LONGWALL MINING

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ABSTRACT: Occupational hygiene has been an integral part of the mining industry for centuries; however its importance has grown with developments in mechanisation. While the focus in the past has quite correctly been on improving the controls on dust exposure, the future lies in identifying the efficiency of installed controls on operating longwalls, evaluating them through robust and quantitative sampling methods to ensure the most effective controls are in place to prevent occupational disease from occurring.

The current statutory testing regime identifies the exposure levels of personnel on an operating face, which gives a snapshot of the dust that these persons will be exposed to over the duration of a mining shift. Although this testing process clearly determines exposure levels, it does not give mine operators any indication of where dust is produced, how much dust is produced nor how efficient the installed controls are at mitigating produced dust.

This paper proposes a new testing methodology to determine installed control efficiency for both respirable and inhalable dust and reports the initial dust measurement results based on this methodology. The main objective of this sampling method is to identify dust loads at independent sources of dust generation on longwall faces and quantify the efficiency of installed controls for the mitigation of produced dust. The use of this new methodology will provide mine operators with a complete dust production signature of their operating longwall and allow the implementation of more efficient controls at independent sources of dust generation.

INTRODUCTION

Production from longwall mining in Australia has increased remarkably over the last several years. This increased productivity has meant that more dust is being produced and controlling respirable and inhalable dust continues to present the greatest ongoing challenge for coal mine operators. A recent report by the Director of mine safety operations branch of Industry and Investment NSW has found that there is an increasing level of inhalable dust being ingested by coal miners in New South Wales, potentially leading to long-term health problems (ILN, 2010). This increased exposure level for underground workers can be directly attributed to the increase in coal production and the continued development of medium and thick seam mines in Australia, which allow the installation of bigger and more productive longwall equipment.

Fugitive dust on longwalls has always been an issue of concern for production, safety and the health of workers in the underground coal mining industry both in Australia and globally. Longwall personnel can be exposed to harmful dust from multiple dust generation sources including, but not limited to; intake entry, belt entry, stageloader /crusher, shearer, shield advance and dust ingress from falling goaf or over pressurisation of the goaf. With the increase in production created from the advancement in longwall equipment, dust loads have also increased and this has resulted in an increase in exposure levels to personnel. Control processes in place for the mitigation of dust vary from mine to mine, with each individual mine having a dust mitigation setup that is only effective for that particular mine operation.

The industry has been using statutory dust measurements in underground coal mines conducted by both 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

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entering the longwall from different sources, which presents difficulties in determining the relative effectiveness of the different control technologies in use.

It is the aim of the safety and health management system at a mine to provide ways of suppressing excessive airborne dust and provide ways of ensuring workers are not exposed to any air stream with an average respirable dust concentration calculated over an eight hour period (as measured in accord with AS 2985) exceeding either 2.5 mg/m^3 of air for coal dust or 0.1 mg/m^3 of air for free silica (Coal Mines (Underground) Regulation 1999).

In a notice issued by the Chief Inspector of Coal Mines, dated 7th December 2004, in the New South Wales Government Gazette Number 200 (File No: C99/0691), the specified limits for respirable dust were quoted as follows:

> *"For the purpose of Clause 161 of the Coal Mines (Underground) Regulation 1999 definition of 'specified limit'), the specified limit for quartz-containing dust is 0.12 mg of respirable quartz and the specified limit for respirable dust, other than quartz-containing dust, is 2.5 mg. These limits are with respect to the mass of respirable dust per cubic metre of air sampled and apply only to the underground parts if underground mines".*

The National Occupational Health and Safety Commission has adopted a limit of 0.1 mg/m^3 for quartz (Adopted National Exposure Standards For Atmospheric Contaminants in The Occupational Environment [NOHSC: 1003 (1995)]). This is with respect to an eight hour time weighted average (TWA) and has taken effect on 1st January 2005. There has also been a change to AS2985-2004 (AS2985-2004 Workplace atmospheres - Method for sampling and gravimetric determination of respirable dust), to bring it in line with the relevant ISO Standard and resulting in a higher flow rate during sampling. Studies undertaken through Coal Services Pty Ltd have confirmed that to cater for the change in flow rate the current limit of 0.15 mg is equivalent to a limit of 0.12 mg at the higher flow rate.

The long standing practice in underground coal mines has been to collect samples from crib room to crib room and for a minimum period of five hours. This is to avoid a number of practical difficulties in collecting samples during travel. Research undertaken indicates that crib room to crib room sampling of 0.12 mg, at the higher flow rate and with a travelling time conversion factor applied, corresponds to a limit of 0.1 mg for portal to portal sampling. The end result is that for underground mines the working limit for quartz is effectively unchanged and remains at a level where silicosis has not been observed in the coal mining workforce. The change in limit for respirable dust, other than quartz-containing dust, is to take into account the higher sampling flow rate now required by AS2985-2004.

SOURCES OF DUST GENERATION

Regardless of dust loads, which are directly proportional to tonnages produced, longwall dust generation at each independent source, produces relatively the same percentage of dust as a proportion of total face dust in each operating longwall.

Research from NIOSH (Organiscak, *et al.*, 1986) indicates that there are primarily six individual dust generating sources on an average longwall, not only in Australia, but by extension, all operating longwalls globally. Figure 1 shows the location of each of these independent sources of dust generation. Figure 2 shows a chart of total face dust as a percentage generated from independent sources.

- **Shearer cutting and cleaning** – is the largest dust source on a longwall face. A significant portion of dust occurs in the crushing zone around the tip of the pick. In general, 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 lower amount of coal being cut.
- **Roof support/chock movements** – As chocks lowered and advanced, crushed coal and/or rock falls from the top of the chock canopy directly into the face ventilation airflow. Most of this dust becomes airborne, and quickly disperses into the walkway.
- **Stage loader/crusher** – This is an area of high dust make, where the dust can severely contaminate intake ventilation and expose face operators to high dust exposures.

- **Face spalling/AFC dust** – Dust generated due to face spalling ahead of the shearer is a major problem in thick seam longwall faces. Dust can also be lifted up from the AFC by ventilation, particularly when the direction of coal transport is against the direction of the airflow.
- **Intake contaminations** – Dust can be generated at all the conveyor transfer points along the intake airways. The movement of any equipment outbye can also cause significant quantities of dust to be raised into the atmosphere.
- **Goaf falls** – Dust can be generated due to roof caving behind the chocks and sudden goaf falls. A significant proportion of this goaf dust can be pushed onto the face as the leaked airflow returns to the face along the face support line.

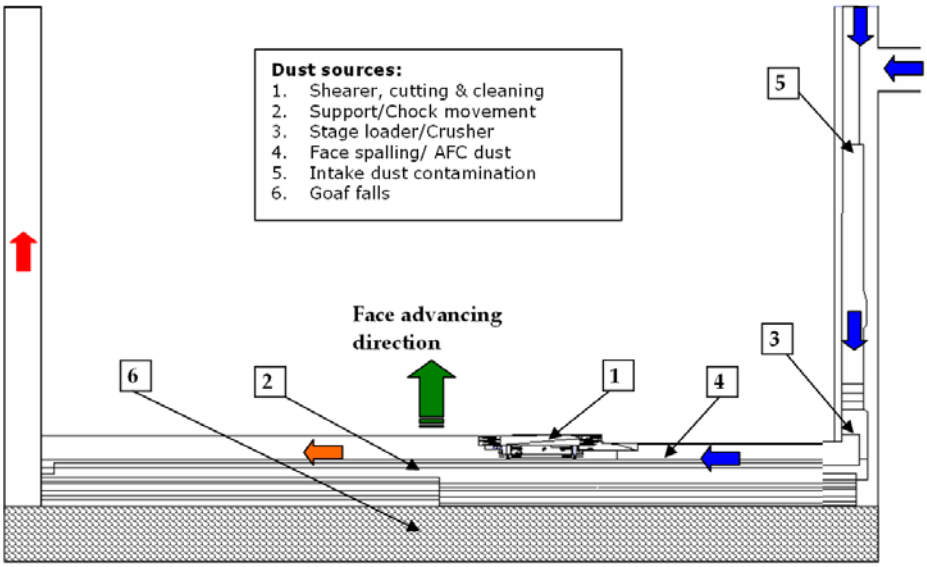

Figure 1 - Sources of dust generation on longwalls

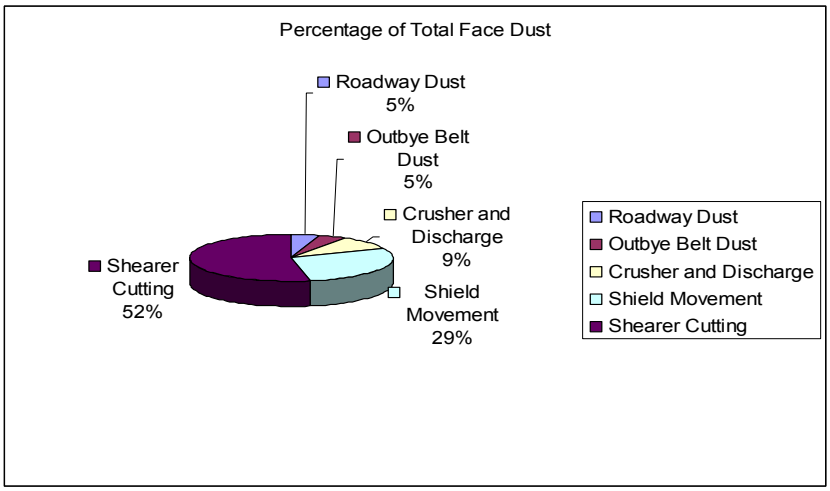

Figure 2 - Total face dust as a percentage generated from independent sources

EXISTING DUST MONITORING PRACTICES

AS2985 and AS3640 clearly define the process used to determine personal exposure levels in coal mines. The same equipment will be used to collect dust load at each individual source of dust generation on a longwall to ensure uniformity of collected data, reliability of data analysis and approved for use in underground coal mines.

Section 6.1 of AS2985 - Workplace atmospheres - method for sampling and gravimetric determination of respirable dust states the essential features of a sampling system consisting of a filter (on which the

sample is collected) and a pump for drawing the air through the filter. The filter shall be secured in a holder that prevents air from leaking around the edge of the filter. The filter shall be preceded by a size-selective sampler.

According to Section 6.1 of AS3640 - Workplace atmospheres - method for sampling and gravimetric determination of inhalable dust the essential features of a sampling system are an inhalable dust sampling device (containing a filter on which the sample is collected) and a pump for drawing the air through the device. The filter shall be secured in the device in such a manner that it prevents air from leaking around the edge of the filter.

Table 1 provides a summary of respirable dust samples results in NSW mines for the 20 year period 1984 – 2004.

Table 1 - Respirable dust results (including re- samples) 1984 - 2004

Mining Method	No. Personal Samples	Number > 3mg/m^3	% Exceeding Limit
Longwall Faces	16 686	1 131	6.8
Other Underground	32 583	531	1.6

From these sample results, it is clear that the current controls for mitigating longwall dust exposure levels is highly successful in the removal of respirable dust.

New South Wales government testing of inhalable coal dust conducted by Coal Services Pty Ltd in the state's longwall mines has found more than a third of the samples taken exceeded the 10 mg per cubic metre limit (Cram, 2006)

A 10 mg/m^3 limit on inhalable dust in coal operations was imposed in December 2007 by notice provided under the Coal Mine Health and Safety Act.

In an article dated Tuesday, 9 March 2010 in the International Longwall News (ILW, 2010), The Director of the Mine Safety Operations Branch under the Department of Industry and Investment, issued a safety alert to all mines who have been advised to identify and control risks in relation to excessive failures of inhalable dust exposure levels. According to the article, the results of coal dust testing in the Newcastle region revealed that 44 out of 104 samples taken in longwall operations exceeded 10 mg/m^3 – a failure rate of 42.3%. Fifty of the 95 longwall samples in the Hunter region – which is more than half at 52.6% – failed the government limit. None of the 29 longwall samples in the Western region failed while 25.3% of the samples in the Southern District exceeded the limit.

Examining the sampling reports, the following were found to be the likely causes of high coal dust levels:

- Inadequate ventilation;
- Inadequate water or dust control;
- Poor operator positioning;
- Damaged equipment;
- Poor work practices.

It further suggests the following strategies to combat the problem:

- Isolation or capture of dust at source via sealing of transfer points, BSL, crushers;
- Operating water sprays at appropriate locations and as near as possible to the point of breakage with sufficient water volumes, pressure and correct sizing of water jets/droplets;
- Ventilation of the correct quantities and at the right location;
- Advance ventilation ducting/brattice to mine ventilation standard;
- Regular maintenance of dust suppression equipment;
- Operator positioning, job rotation and automation;
- Control of dust levels along travelling roads;
- Respiratory protection by personal protective equipment.

In contrast to the success of the current longwall dust controls in mitigating respirable dust, the above analysed results of inhalable dust exposure levels clearly indicate that the current longwall controls for mitigating inhalable dust are less successful.

USING DUST LOAD MEASUREMENTS TO DETERMINE CONTROL EFFICIENCY

A new testing methodology has been developed between the University of Wollongong, Coal Services, The Department of Investment and Industry and the CFMEU, to determine installed control efficiency for both respirable and inhalable dust. This new methodology retains gravimetric sampling for dust load sampling to ensure uniformity of the collection process, validity of the collected data and quantification of the analysed results. Also, the sampling methodology has been designed to ensure the collected data is deemed quantifiable to satisfy the requirements of a scientific research project and for reference in potential future projects. The objective of this new sampling methodology is to identify dust loads at independent sources of dust generation on longwall faces and quantify the efficiency of installed controls for the mitigation of dust generation. This data will then be used to create a benchmark or signature for the longwall mine in relation to dust loads from different sources of generation. Once this signature is established, quantifiable testing can be undertaken on new or improved controls to ensure maximum efficiency in removing respirable and inhalable dusts.

NEW TESTING METHODOLOGY

The dust collection process on a longwall must be arranged so that there is a collection of respirable and inhalable dust at each independent source of dust generation.

The first stage in this methodology is to determine the placement of monitors on each of the independent sources of dust generation. In each location, separate monitors and heads will be used to sample both respirable and inhalable dust loads. Figure 3 below details monitor and head placement along a longwall face. Next the amount of dust produced at each individual source of dust generation is measured. This will require the mine to turn off the controls at these individual locations during sampling period, to allow produced dust to be measured accurately at each of these sources.

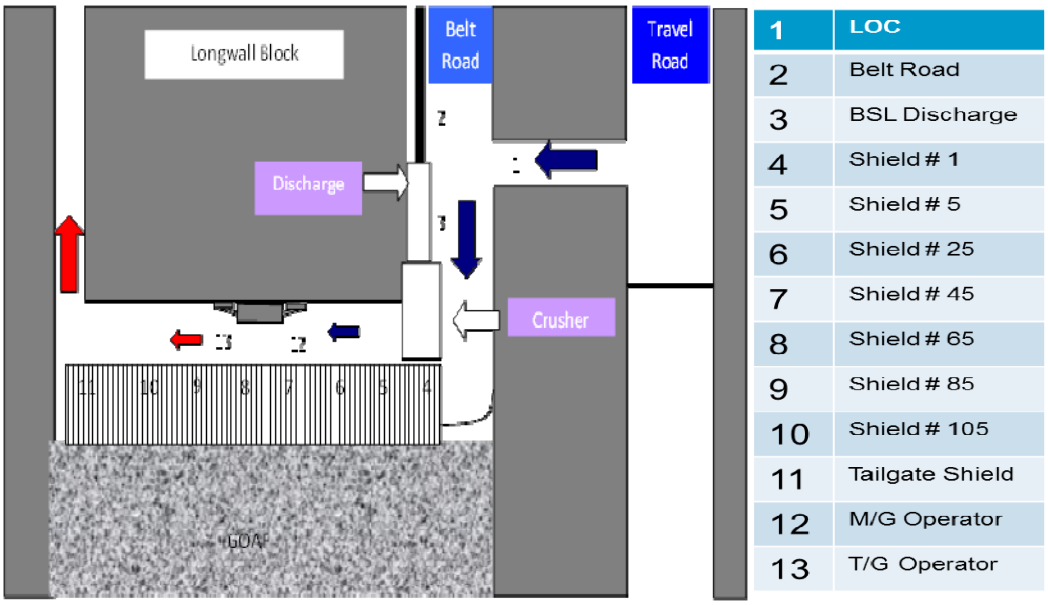

Figure 3 - Details of monitor and head placement in a longwall face

This will not be an issue for the controls on outbye conveyors, travel roads, BSL discharge, crusher and shield sprays; however, turning off all controls on shearers will produce resistance from mine operators. It will be necessary to leave the drum sprays on as in most applications; these are used more for frictional ignition suppression than dust mitigation. Additional sprays such as crescent sprays and shearer clearers could be turned off for the period of the testing; assuming gas levels are below ignition points.

Controls will be turned back on and sampling heads changed to remeasure dust loads with controls operating. The difference between these two tests will determine the efficiency of the installed controls. The sampling strategy can be tailored to each individual mine to have on or minimum impact on production interruption.

RESULTS OF THE NEW TESTING METHODOLOGY

A NSW Hunter Valley underground coal mine was the first mine to have the new testing methodology applied in October 2010. The intention of this research is to test every longwall mine in NSW to obtain a best practice dust control setup and prove the new testing methodology can be used as a valuable alternative tool to the current statutory testing.

The results of the testing found that the current installed controls reduce the amount of respirable dust by an average of 40% and the amount of inhalable dust by an average of 34%.

Other findings indicated that outbye roadway dust entering the longwall through the last open cut-through needs to be addressed along with the dust control on the maingate drum. Whilst the tailgate operator saw a reduction of 40% when the controls were turned on for respirable dust, the maingate operator only saw a 27% reduction in dust exposure levels.

Although this result may look solid on the surface, detailed analysis of each individual source of dust generation gives a true picture of how well installed controls mitigate the dust at each individual source of dust generation and highlights where improvements can be made to further enhance control efficiencies.

The results for the last open cut-through indicate that there was a dust load of 0.32 mg/m^3 of respirable dust and 1.18 mg/m^3 of inhalable dust during the first set of tests with no controls operating for 255 minutes. The second set of tests indicated, when the raw data was adjusted to 255 minutes, that there was a dust load of 0.23 mg/m^3 for respirable dust and 1.97 mg/m^3 for inhalable dust. This shows a reduction in respirable dust levels of 29% and an increase in inhalable dust levels of 67%.

The results in the belt road show a 37% decrease in respirable dust levels from 0.40 mg/m^3 with no controls on to 0.25 mg/m^3 with controls on. Inhalable test results indicate a 31% reduction in dust levels from 2.33 mg/m^3 with controls off to 1.61 mg/m^3 with controls on. This indicates that the installed controls which include sprays on the BSL discharge are effectively mitigating both the respirable and inhalable fractions from the airway.

At the maingate chock, or chock No 1, respirable levels were reduced by 38% from 0.71 mg/m^3 with controls off to 0.44 mg/m^3 with controls on. Inhalable levels were reduced by 89% from 96.29 mg/m^3 with controls off to 10.56 mg/m^3 with controls on.

Chock No 5 saw a respirable dust level of 0.88 mg/m^3 with controls off and 0.80 mg/m^3 with controls on giving a 9% reduction in dust levels. The corresponding inhalable reading has been discarded as the inhalable sample head for the second set of data had little or no dust on the filter as the pump was either not working or had been turned off and not turned back on when the heads where changed.

Chock No 5 respirable levels have remained high as this is the point on the face where crusher dust is flushed over due to the maingate corner sprays and maingate wing forcing the ventilation further along the face.

Chock No 25 saw a 56% reduction in respirable dust from 2.84 mg/m^3 with controls off to 1.25 mg/m^3 with controls on. Inhalable dust was marginally decreased by 1% from 19.37 mg/m^3 with controls off to 19.09 mg/m^3 with controls on.

At chock No 45, respirable levels were reduced by 45% from 3.37 mg/m^3 with control off to 1.86 mg/m^3 with controls on. Inhalable dust was reduced by 73% from 36.6 mg/m^3 with controls off to 9.98 mg/m^3 with controls on. This number seems exceptionally high when compared to the samples collected on chock No 65 which showed an increase in inhalable dust of 36% from 28.59 mg/m^3 with controls off to 38.77 mg/m^3 with controls on.

The corresponding respirable results at chock No 65 indicate a 47% reduction in dust loads from 3.63 mg/m^3 with controls off to 1.93 mg/m^3 with controls on.

Chock No 85 saw a reduction in respirable dust of 63% from 5.68 mg/m^3 with controls off to 2.12 mg/m^3 with controls on. Inhalable dust was reduced 36% from 22.28 mg/m^3 with controls off to 14.34 mg/m^3 with controls on.

Chock No 105 saw a reduction in respirable dust of 50% from 4.07 mg/m^3 with controls off to 2.05 mg/m^3 with controls on. The inhalable dust load again had a failure during the second set of tests, so no result is available for analysis.

Finally, the tailgate tests have shown to be the most interesting with an actual increase in both respirable and inhalable dust loads. The respirable fraction increased 44% from 2.21 mg/m^3 with controls off to 3.19 mg/m^3 with the controls on. Similarly, the inhalable fractions increased 25% from 49.43 mg/m^3 with controls off to 61.88 mg/m^3 with controls on.

The tailgate operators' position saw a 40% reduction in respirable dust from 1.65 mg/m^3 to 0.99 mg/m^3 whilst the maingate operator position saw a 27% reduction in respirable dust from 1.33 mg/m^3 to 0.99 mg/m^3.

The findings of this testing process clearly define an operating signature and benchmark performance of the currently installed controls to remove both respirable and inhalable dusts on the longwall face.

Figures 4 and 5 clearly show the effectiveness of the installed controls at each of the sampling points for respirable and inhalable dust respectively.

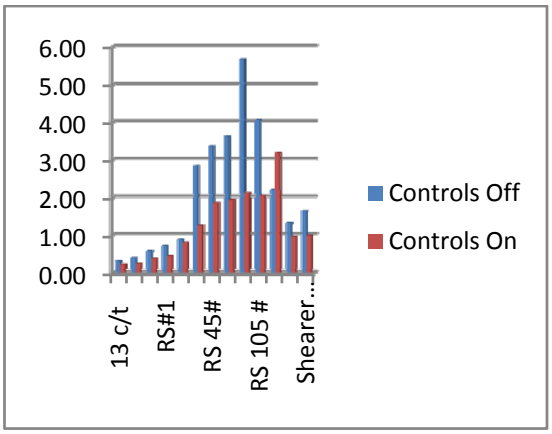

Figure 4 - Respirable dust

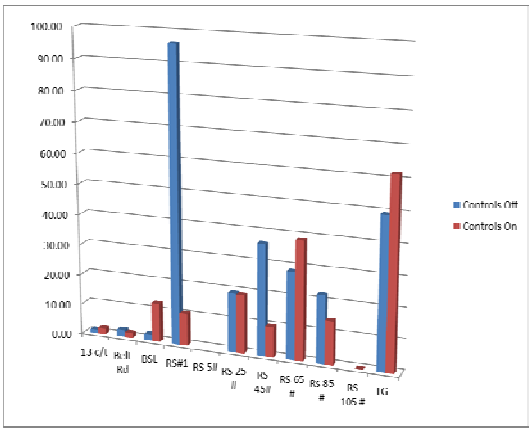

Figure 5 - Inhalable dust

CONCLUSIONS

It is very difficult and in many instances expensive to measure control efficiencies, with many mines relying on subjective opinion as to the effectiveness of the installed controls. Little or no scientific research has been undertaken to quantify how effective installed controls are in relation to removing the produced dust on operating longwalls.

The current longwall controls for mitigating dust highlight a serious dichotomy in the results obtained during statutory testing for respirable and inhalable dust exposure levels.

Respirable dust exposure levels are well controlled, with less than 6.5% of all samples taken being above the regulatory exposure limit, indicating that current installed dust mitigation controls are working.

In contrast to the success of longwall dust controls in mitigating respirable dust exposure levels, are the results of inhalable dust exposure levels testing, which shows that in excess of 30% of samples taken exceeded the statutory exposure levels.

This dichotomy of results indicates that a serious problem exists where the smaller respirable particles, usually less than 10 in size are removed from a contaminated airway, whereas the larger inhalable particles, usually greater than 10 , are not removed.

The current statutory testing regime for respirable and inhalable dust samples identifies the exposure levels of personnel on an operating face which gives a snapshot of the dust that these persons will be exposed to over the duration of a mining shift. Although this testing process clearly determines compliance to the Coal Mines Health and Safety Regulation 2006, it does not give mine operators any indication of where dust is produced, how much dust is produced nor how efficient installed controls are at mitigating produced dust.

The use of this new testing methodology will provide mine operators with a complete dust production signature of their operating longwall and allow the implementation of more efficient controls at independent sources of dust generation that will have a quantifiable efficiency number on dust knockdown.

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