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A CRITICAL EVALUATION OF DUST SAMPLING METHODOLOGIES IN LONGWALL MINING IN AUSTRALIA AND THE USA

Brian Plush , Ting Ren and Naj Aziz

ABSTRACT: Questions relating to the validity and subsequent suitability of the current dust sampling methodologies utilised in Australia and the USA have recently come under scrutiny. The reason for this scrutiny is that there has been a significant increase in Coal Workers' Pneumoconiosis in the USA over the last few years despite recorded conformance to exposure level legislation. The opinion by many in the underground coal mining operators in Australia is that the current testing regime tells them very little about the actual operational production of dust on the longwall face in relation to where it is produced, how much is produced or how efficient installed controls are at preventing this dust from entering the atmosphere. Evaluation of the current testing regimes in Australia and the USA are proposed, which identify limitations that are raising questions relating to its suitability to ensure worker health in the underground coal mining operators.

INTRODUCTION

Evaluation of a workplace is primarily undertaken to establish if the workplace environment is safe for employees to perform their normal duties. Occupational hygiene has been an integral part of the mining operators for centuries; however its importance has grown with developments in mechanisation and rising community expectations of better occupational health.

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. The US EPA describes inhalable dust as that size fraction of dust, which enters the body, but is trapped in the nose, throat and upper respiratory tract. The medium aerodynamic diameter of this dust is about 10 μm.

A report by the director of mine safety operations branch of Operators and Investment NSW has found that there is an increasing level of dust being ingested by coal miners in New South Wales, potentially leading to long-term health problems (Chief Inspector Safety Bulletins, NSW, 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 operators 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, stage loader/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.

Studies by NIOSH in the USA have shown that prolonged exposure to excessive levels of airborne respirable coal dust can lead to coal workers' pneumoconiosis (CWP), progressive massive fibrosis (PMF), and chronic obstructive pulmonary disease (COPD). These diseases are irreversible and can be debilitating, progressive, and potentially fatal. The continued occurrence of CWP in underground coal mine workers and the magnitude of respirable and inhalable dust overexposures in longwall mining occupations illustrate the need for the mining operators to improve existing dust control technology on longwalls, not only in the USA, but in Australia as well, to prevent the incidence of lung diseases from occurring.

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Dust sampling of employees in Australian coal mines is carried out by cyclone separation and collection of the sized particles for weighing, generally over the period of a full shift to measure personal exposure levels to airborne contaminants. This testing methodology is described in AS2985 Workplace Atmospheres - Method for sampling and gravimetric determination of respirable dust and AS3640.

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 (NSW Govt. Gazette).

Questions relating to the validity and subsequent suitability of the current dust sampling methodologies utilised in Australia and the USA have recently come under significant scrutiny. The reason for this scrutiny is that there has been a significant increase in Coal Workers' Pneumoconiosis (CWP) in the USA over the last few years despite recorded conformance to exposure level legislation, and the opinion by the underground coal mining operators in Australia that the current testing regime tells them very little about the actual operational production of dust on the longwall face in relation to where it is produced or how to prevent this dust entering the atmosphere.

The current testing regime in Australia provides the mine tested with a single figure for respirable dust exposure levels for five samples taken over a minimum of four hours during a production shift. These figures only provide information relating to the exposure levels of the person sampled, relative to the 300 mm breathing zone described in AS2985, and does not provide any feedback on where the dust has come from or any other information that would allow the mine site to implement improvements in mitigation procedures should a non-compliance, or failure to statutory regulations occur.

For the testing regime in the USA the problem is more serious as a direct result of a known increase in CWP identifying 1000 new cases per year since 1984 and the recent findings of the Upper Big Branch disaster where autopsies revealed seventeen of the 24 victims' autopsies (or 71%) had CWP. This compares with the national prevalence rate for CWP among active underground miners in the USA which is 3.2%, and the rate in West Virginia which is 7.6%.

Further, of the 17 UBB victims with CWP, five of them had less than ten years of experience as coal miners, while nine had more than 30 years of mining experience. At least four of the 17 worked almost exclusively at UBB. All but one of the 17 victims with CWP began working in the mines after the 2.0 mg coal mine dust limit was put in to effect in 1973. This was an exposure limit that was believed at the time sufficient to prevent black lung disease. This exposure limit has since been determined ineffective for protecting miners' health (Davitt, *et al.,* 2010).

CURRENT AUSTRALIAN DUST MONITORING PRACTICES

AS2985 and AS3640 clearly define the process to be used to determine personal exposure levels in coal mines.

According to NSW Coal Services Pty Ltd respirable dust testing analysis, there have been 18 900 respirable dust samples, including re sampling, taken in the period 1984-2007 (Mace 2008). Of these samples, it has been reported that there have been 1200 samples above the exposure limit for respirable dust in NSW, which represents less than 6.5% of total samples taken (Mace, 2008).

Coal Services background, regulations and testing methodology for NSW respirable dust sampling

Dust monitoring service

As reported by the NSW Coal Services Health (formerly the Joint Coal Board and JCB Health) Dust Monitoring Service (Cram, 2003) is quality accredited and has been the sole organization involved with personal dust monitoring in the NSW coal operators since the current regulations were gazetted in

March 1984. The service has the total support and acceptance of both management and unions. The specified limit for respirable dust other than quartz-containing dust is 3 mg of respirable dust/m^3 of air sampled. The specified limit for quartz-containing dust is 0.15 mg of respirable quartz/m^3 of air sampled. In NSW sample collection commences at the time of leaving the crib room at the start of the shift and ceases on arrival at the crib room at the end of the shift. The sampling period, if practicable should be not less than five hours. While it is the responsibility of mine management to meet the frequency of sampling required by the CMRA the Coal Services Health monitoring programs are structured in such a manner that management's obligations are fulfilled were possible.

The integrity of results is guaranteed by a Coal Services Health employee present in the workplace during the sampling shift recording such information as ventilation quantities, blocked sprays, operator location, water pressures or anything which may affect results. Results are used solely to identify problem areas which may exist and are not used at any time for punitive measures. Where areas of high dust concentrations are found to exist, efforts are directed to these areas in order to rectify the problems. These efforts in many cases involve management, union and coal services health initiatives. Results of the sampling are forwarded to the Colliery Manager, Senior Inspector of Coal Mines, United Mineworkers District Check Inspector and included in the coal services health dust database.

If the result of any sample exceeds the specified limit a re-sample must be taken within seven working days in similar circumstances to those existing when the sample was collected. If the resample still exceeds the specified limit the District Inspector of Coal Mines may, in writing, direct the Colliery Manager to carry out additional procedures to reduce the concentration of airborne dust.

The following information is extracted from the document titled "Airborne Dust in Coal Mines Respirable Dust and Quartz Inhalable Dust Coal Services Pty Ltd, 2008":

Sampling: method used to determine the respirable dust concentration of air in working places

The approved sampling method adopted in the New South Wales coal operators is personal gravimetric sampling. In this method, respirable dust is collected from the breathing air very close to the nose and mouth of a mine worker and the amount of dust is then measured by weighing. The weight of fine dust drawn into the lungs gives the most accurate prediction of the likelihood of developing pneumoconiosis (being dusted). The samples are taken by means of a small battery powered pump worn by the mine worker as shown in Figure 1. The pump is connected with a piece of plastic hosing to a sampling unit (or cyclone) that is clipped to the individual's shirt. A steady stream of air is drawn through the sampling unit where the coarse dust is first removed and only the very fine respirable dust is collected on a filter and weighed.

Purpose of dust sampling

A comprehensive monitoring programme is continually being carried out to determine whether dust levels at every coal mine are kept below the approved limits and to protect the long term health of mine workers.

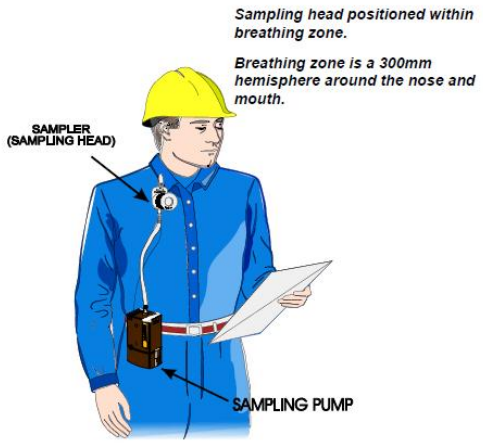

Figure 1 - personal dust sampler

Working places sampled

As per the NSW Coal Mine Health and Safety Regulation (NSW CMHST) 2006, mine workers are sampled regularly. For longwall faces, sampling is carried out at intervals not exceeding six months on each producing shift. For continuous miner panels, sampling is carried out at intervals not exceeding 12 months on each producing shift. Other underground working places, open cuts, coal preparation plants, crusher and loading stations are all sampled at intervals not exceeding 12 months on only one production shift.

Dust results

Copies of all results are sent to the mine operator, inspector of coal mines and operators check inspector. Following a failed result, the mine manager informs the person who was sampled and there is an obligation under the (NSW CMHST) 2006 to take action to correct the situation. Coal Services, through the Standing Dust Committee (SDC), also maintains an overview of the results of the dust sampling programme in mines and where necessary advises the mine management on how to improve the situation. This SDC recommends the display of all results on the mine notice boards.

Limits for extended shifts

The current exposure limits for dust and quartz are based on a 40 h week (8 h shifts 5 d a week) over a 40 year working life. For working weeks greater than 40 h therefore the exposure limit needs to be lower. As a general rule the exposure limit can be adjusted by a factor calculated from the ratio of weekly exposure in a normal work cycle to the average weekly exposure in the extended cycle. The NSW coal services health and safety trust normally provide information on the extended shift exposure limit adjustment factors for coal mine dusts.

Results if a person is exposed to variable dust levels

The method of dust sampling is designed to give the average result for the duration of the shift taking into account periods of high and low exposure dust. The dilution effect of a worker being exposed to a non-contaminated atmosphere following a short but high exposure would therefore be beneficial to the worker such as job rotation during the shift. One of the key factors involved in the onset of lung dust disease is the total amount of coal dust or quartz that a person has inhaled during their working life. It is not based on whether the person has been exposed to a high level of dust in a single event on one part of a shift or due to a particular mining method.

Method used to determine the inhalable dust concentration

The gravimetric method used for respirable dust sampling is also used for inhalable dust sampling. The main difference is the sampling head which collects dust particles below 100 microns rather than only the very small respirable dust particles.

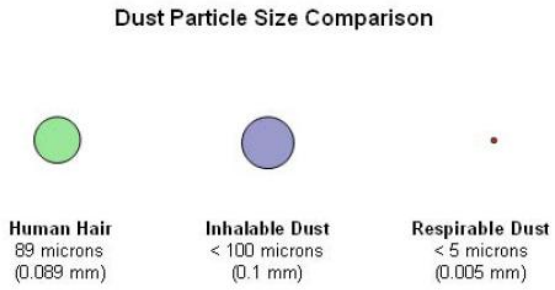

Figure 2 - Dust particle size comparison

Location and frequency of sampling inhalable dust

As per the NSW CMHST *2006* mine workers are sampled regularly. For longwall faces, sampling is carried out on each producing shift at intervals not exceeding 12 months. For continuous miner panels, any part of a mine where cement products are being applied, other underground places including

crusher stations, open cuts and coal preparation plants are all sampled on one shift only at intervals not exceeding 12 months.

Respirable dust exposure limit in NSW coal mine

The concentration of respirable dust should not exceed 2.5 mg/m^3 over the sampling period. The concentration of respirable quartz dust should not exceed 0.12 mg/m^3 in underground coal mines and not exceed 0.1 mg/m^3 in open cut coal mines and the surface parts of underground coal mines.

Determination of limits

The current coalmine exposure standard was determined after extensive research at a number of NSW coalmines in the early 1980's and these levels are constantly being reviewed in the light of new research. There has been a steady decrease in dust disease patterns in NSW coalmines over the last 30 y and consequently the SDC considers that compliance with current exposure standards will provide effective protection. The gravimetric measurement of respirable dust and quartz is the internationally recognised technique for monitoring the dust exposure of coal mineworkers.

Inhalable dust exposure limit in NSW coal mines

Inhalable dust is the visible dust particles below 100 μm size. It is the concentration in milligrams of inhalable dust per cubic metre (abbreviated to mg/m^3) of air, collected from the breathing zone (not inside respirators or airstream helmets) of mine workers during their working shift. The concentration of inhalable dust should not exceed 10 mg/m^3 in all coal mining operations.

Background, regulations and testing methodology for Queensland respirable dust sampling according to SIMTARS

Sampling Strategy

Respirable dust samplers are distributed amongst a selection of personnel performing a range of activities. Respirable dust monitoring involves workers wearing a personal sampling device consisting of a constant flow sampling pump connected to a cyclone elutriator positioned within the breathing zone (300 mm radius extending in front of the face and measured from the mid-point of a line joining the ears). Operators are requested to wear these devices for the entire shift, or a period representative of their normal duties.

Sampling Techniques

Techniques involved in the measurement of respirable dust followed those outlined in Australian Standard 2985 - 2004 - *Workplace Atmospheres - Method for sampling and gravimetric determination of respirable dust* and Simtars laboratory procedure LP00138. Respirable quartz (SiO2) concentrations were subsequently determined using methods described in the NH and MRC (1984) document 9 on quartz analysis and Simtars laboratory procedure LP001610. Constant flow sampling pumps connected to a Simpeds cyclone elutriator containing a 37 mm 5 μm GLA-5000 filter are used to collect respirable dust samples. A flow rate of 2.2 L/min is set prior to sampling and checked at the conclusion of the sampling period using a calibrated flow meter.

Results derived using these methods represent time weighted average concentrations of respirable dust encountered by operators during their normal working shift. With respect to respirable dust, a time-weighted average implies a mass of respirable dust collected over a known time period (preferably more than 4 h) from which an average mass/volume concentration is calculated. It is from time weighted average concentrations that assessments are made with respect to acceptable health levels and compliance with regulatory requirements.

LIMITATIONS ASSOCIATED WITH THE CURRENT TESTING IN AUSTRALIA

Calls from operators are advocating for a review of the current inhalable and respirable dust sampling methods used in Australia and to investigate alternative sampling methodologies applicable to major underground coal mining tasks, report on their validity within the codes, guidelines and standards and

propose a new testing methodology that better identifies atmospheric contamination caused by dust produced during the cutting cycle in longwall mining.

It has been suggested that with changes in the work routines of many Australian miners, the traditional way of sampling is no longer adequate. Further, operators believe that the current testing process is getting what are believed to be data errors arising from how sampling is being conducted not by over exposure to dust levels. Many samples are being contaminated leading to a failed result. The operators feel that rather than being recorded as a failure to the tested mines these should be deemed as invalid samples and quite rightly retested.

Mining operators have been investigating alternative ways of placing dust sampling units to eliminate contamination whilst still meeting the strict codes, guidance and standards applied to this area. Operators want to identify techniques that more accurately identify what specific work activities lead to specific results which will assist further in managing specific risks. Mining operators would like to include instantaneous or real time monitoring devices that may also assist with identification and eventual mitigation of airborne contaminant risks.

It has been suggested that there is a need to establish a database of best practice dust suppression techniques used by longwalls for the operators to peruse and use along with the management of sampling data. Currently the operators invest significant money in the sampling conducted by the regulatory regime but receive very little useful information on how to mitigate airborne contaminants. With the volume of data collected the operators should have a fairly accurate picture and understanding of the underground longwall work environment to help refine installed controls and measure their dust knockdown efficiency, but currently only receive single sample information with details recorded for a five sample batch not individual samples. The operators feel it would be better to have information on individual pieces of plant and equipment, tasks and activities and on the practices of crews or individuals. The operators would also like to see a review which will document standards of approach in the areas of dust control efficiencies to capture a definitive benchmark which will allow for a more scientific approach to the management of airborne contaminants.

Operators are suggesting a review of competency requirements for persons undertaking dust sampling, along with a review of the occupational exposure limits and identification of possible legislative shift adjustment criteria specifically designed to better reflect the continual changes in the mining environment.

CURRENT USA DUST MONITORING PRACTICES

According to the federal register, October 19 2010, Section 202(b) (2) of the federal mine safety and health act of 1977 requires each underground coal mine operator to continuously maintain the average concentration of respirable dust in the mine atmosphere during each shift to which each miner in the active workings is exposed at or below 2.0 μmof respirable dust per cubic meter of air. Section 205 required that when coal mine dust contains more than five percent quartz, the respirable coal mine dust standard must be reduced according to a formula prescribed by NIOSH.

The federal register further states that under United states of America Mines Safety and health Administration's' (MSHA's) existing standards, mine operators are required to collect bimonthly respirable dust samples and submit them to MSHA for analysis to determine compliance with applicable respirable dust standards (compliance samples). If compliance samples do not meet the requirements of the applicable dust standard, MSHA issues a citation for a violation of the standard and the operator is required to take corrective action to lower the respirable dust concentration to meet the standard.

Additionally, according to the federal register, the operator must collect additional respirable dust samples during the time established in the citation for abatement of the hazard or violation (abatement sampling). Underground coal mine operators must collect and submit two types of samples during bimonthly sampling periods: (1) Designated Occupation (DO) samples taken for the occupations exposed to the greatest concentrations of respirable dust in each mechanised mining unit (DOs are specified in s.70.207); and (2) Designated Area (DA) samples collected at locations appropriate to best measure concentrations of respirable dust associated with dust generation sources in the active working of the mine (s.70.208). The operator's approved ventilation system and methane and dust control plan, required in existing 30 CFR part 75, must show the specific locations in the mine designated for taking the DA samples. In addition, mine operators take respirable dust samples for part 90 miners (s.90.207

and s.90.208). Compliance determinations are based on the average concentration of respirable dust measured by five valid respirable dust samples taken by the operator during five consecutive normal production shifts or five normal production shifts worked on consecutive days (multiple-shift samples). Compliance determinations are also based on the average of multiple measurements taken by the MSHA inspector over a single shift (multiple, single-shift samples) or on the average of multiple measurements obtained for the same occupation on successive days (multiple-shift samples).

LIMITATIONS ASSOCIATED WITH THE CURRENT TESTING IN THE USA

According to the federal register, October 19 2010, exposure to respirable coal mine dust can cause lung diseases including coal workers' pneumoconiosis (CWP), emphysema, silicosis, and chronic bronchitis, known collectively as black lung. These diseases are debilitating, incurable, and can result in disability, and premature death. While considerable progress has been made in reducing the respirable coal mine dust levels, miners continue to develop black lung.

Based on a recent draft report from the USA National Institute for Occupational and Health (NIOSH, 2010), the prevalence rate of black lung is increasing in the nation's coal miners; even younger miners are showing evidence of advanced and seriously debilitating lung disease, as shown in Figure 3.

The report continues further details that in the last decade, death certificates list coal workers' pneumoconiosis, commonly called black lung disease, as a cause in more than 10 000 deaths. Black lung disease is caused by inhaling coal mine dust. It results in scarring of the lungs, emphysema, shortness of breath, disability, and premature death. The prevalence of black lung disease decreased by about 90% from 1969 to 1995 after the enactment of the coal mine health and safety act. Unfortunately, since 1995, the prevalence of black lung among those who have participated in the coal workers' health surveillance program and who have been coal miners for more than 20 years has more than doubled. Severe and advanced cases of lung disease occur currently in young underground miners as young as 39. Identification of advanced cases among miners under age 50 is of particular concern, as they were exposed to coal-mine dust in the years after the 1969 federal legislation had mandated disease-prevention measures. An increased risk of pneumoconiosis has been associated with work in certain mining jobs, in smaller mines, in several geographic areas, and among contract miners (CDC).

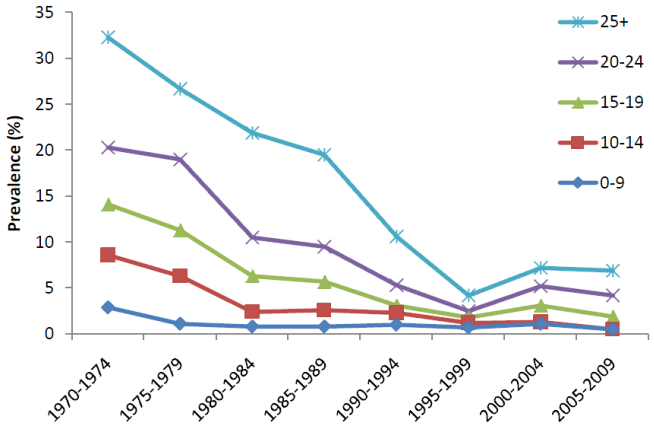

Figure 3 - Percentage of miners examined in the NIOSH coal workers' X-ray surveillance programme with Coal workers' pneumoconiosis by tenure in mining (NIOSH, 2010)

CONCLUSIONS

Both Australia and the USA have identified that the currently installed controls for the mitigation and removal of harmful coal dust from the underground mining environment have proven, in the first instance, to be hard to measure in terms of the success in mitigating airborne contaminants, and secondly, in the case of the USA, have failed to remove the risk of underground workers contracting CWP from their working environment.

In the case of the USA, The federal register, October 19, 2010 suggests that a reduction in the current exposure levels from 2 mg/m^3 to 1 mg/m^3 be implemented as the only practical solution to reducing the alarming increase in CWP amongst younger underground workers.

Along with the proposed reduction in exposure levels, several provisions in the proposed rule change, that is, basing noncompliance determinations on single shift sampling, sampling of extended work shifts to account for occupational exposures greater than 8 h per shift, and changing the definition of normal production shift, would singularly lower coal miners' exposure to respirable dust. For example, MSHA's Quantitative Risk Assessment (QRA) estimates the reduction in health risks when two provisions of the proposed rule are implemented-the proposed respirable dust limit and single shift sampling. The QRA shows that these two proposed provisions would significantly reduce the risks of CWP, severe emphysema, and death from non-malignant respiratory disease (NMRD). The proposed rule change would potentially create 50 fewer cases of severe emphysema and 15 fewer deaths due to NMRD per thousand exposed cutting machine operators. The other provisions in the proposed rule would further reduce health risks to miners. Cumulatively, the proposed provisions would reduce the continued risks that coal miners face from exposure to respirable coal mine dust and would further protect them from the debilitating effects of occupational respiratory disease.

In Australia, it has been suggested that the traditional way of sampling is no longer adequate. Operators members believe that the current testing process is getting sample failures due to reasons other than high exposure levels, for example, uneven distribution of dust on the filter paper and pumps not running a full shift, and rather than being recorded as a failure to the tested mines these should be deemed as invalid samples and quite rightly retested.

Mining operators also want to identify techniques that more accurately identify what specific work activities lead to specific results which will assist further in managing specific risks. Mining operators members would also like to look at instantaneous measuring devices that may also assist with identification and eventual mitigation of airborne contaminant risks.

There is a need to establish a database of best practice dust suppression techniques used by longwalls for the operators to peruse and use along with the management of sampling data. With the volume of data collected the operators should have a fairly accurate picture and understanding of the underground longwall work environment to help refine installed controls and measure their dust knockdown efficiency, but currently only receive single sample information with details recorded for a five sample batch not individual samples. The operators feel it would be better to have information on individual pieces of plant and equipment, tasks and activities and on the practises of crews or individuals. The operators would also like to see a review which will document standards of approach in the areas of dust control efficiencies to capture a definitive benchmark which will allow for a more scientific approach to the management of airborne contaminants.

Finally, it has been suggested that a review of competency requirements for persons undertaking dust sampling be undertaken and that a review of the occupational exposure limit is covered and suggested legislative shift adjustment criteria is recommended to better reflect the continual changes in the mining environment.

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