2017

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Publication Details

David Cliff, Jill Harris, Carmel Bofinger and Danellie Lynas, Managing occupational health in the mining industry, in Naj Aziz and Bob Kininmonth (eds.), Proceedings of the 17th Coal Operators' Conference, Mining Engineering, University of Wollongong, 8-10 February 2017, 296-305.

MANAGING OCCUPATIONAL HEALTH IN THE MINING INDUSTRY

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ABSTRACT: With the recent resurgence of "black lung" detection in the Australian Coal Mining Industry, the spotlight has fallen onto the management of the health aspects of health and safety. Too often health is seen as being hard to manage because it may relate to chronic and/or extended exposure to harm. However proper application of risk management techniques including focussing on critical controls and the continued effectiveness of these controls works as well on occupational health issues as it does on safety issues. This paper will demonstrate that risk management can be successfully applied to health issues including respirable dust, fatigue and psychological impairment. The resurgence of 'black lung" will be used as a case study to underline the need to identify critical controls and institute processes to measure and maintain their effectiveness and not allow them to be eroded.

INTRODUCTION

This paper addresses the management of occupational health in the coal mining industry using exposure to respirable coal dust in underground mining operations as an example. The key to implementation of modern OHS legislation is the requirement to reduce health and safety risks to workers to as low as reasonably practicable and to an acceptable level. The legislation does not specify what an acceptable level of risk is. In some cases it does provide guidance through stipulating such things as the maximum acceptable exposure to a hazardous substance, such as respirable coal dust, to which a worker can be exposed. There is an emphasis on “Duty of Care” where the onus is on the mine operator to establish risk levels and provide a work environment in which employees are not exposed to unacceptable levels of risk. Information, instruction, training and supervision are provided. The duty of care is shared between employer and employee however the primary responsibility rests with the employer, who has the largest control over working conditions.

Safety management is more mature than health management (Figure 1), often due to the perception of risk (or lack thereof) surrounding health issues. Safety risks are generally more visible, and therefore more salient, whereas health risks are often not immediately visible. Safety consequences usually have an immediate impact whereas health consequences often have a latency period of many years. Adding to the complexity of the situation are confounding risk factors such as the multi-factorial nature of most occupational diseases, individual inherent health differences (e.g. predisposing medical conditions) and transiency within the workforce making it difficult to identify exposure and understand causal relationships.

In terms of respirable dust exposure, there have been significant numbers of exceedances of the occupational exposure standard since at least 1991. Bofinger, Cliff and Tiernan (1995) reported on personal and static respirable dust monitoring over the preceding three years at four longwall mines in Queensland. Static measurements indicated a trend for increasing dust concentrations as the distance from the maingate increased. Cliff and Kiz (2002) analysed personal respirable coal dust measurements recorded by each mine and the Department of Natural Resource and Mines up to mid-2001 for the 11 longwall mines in Queensland. Measurements exceeded the statutory eight-hour equivalent exposure standard in 15.6% of cases (see Figure 2). Most recently, in a presentation at the 2016 Queensland Mining Health and Safety Conference, Djukic and Gill (2016) indicated respirable dust exposure levels regularly exceeded acceptable levels across a number of mine sites measured

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between 2000 and 2016 (see Figure 3). The black tracer line represents the total production across all sites with operating longwalls.

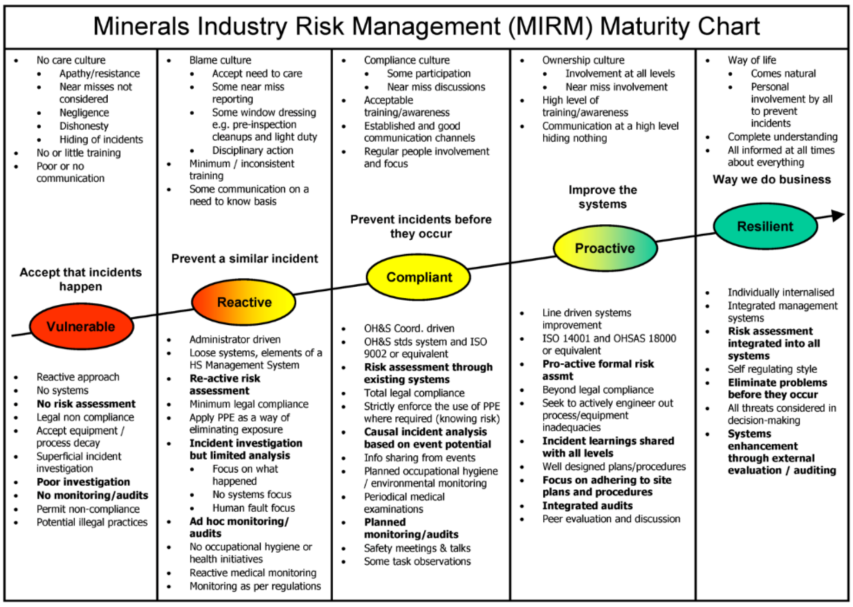

Figure 1: MIRM Safety Maturity Chart (Foster and Hoult, 2013)

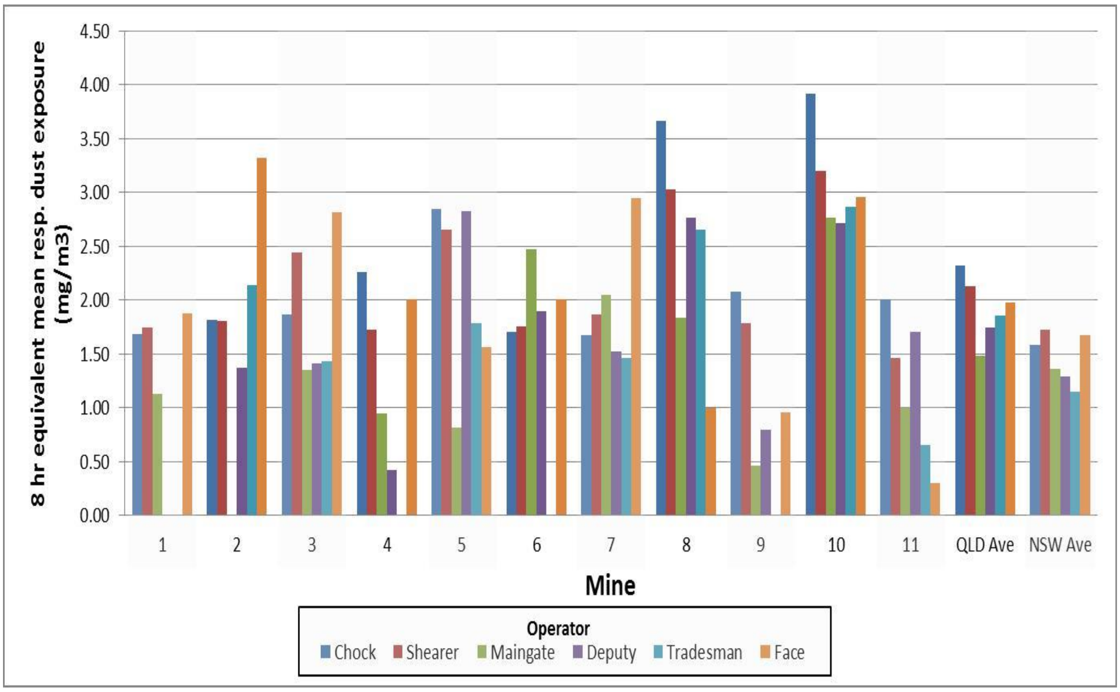

Figure 2: Operator category eight-hour equivalent mean respirable dust exposure (Cliff and Kizil 2002)

The health effects of long term exposure to coal dust can be significant. The inhalable dust fraction has been defined by ISO 7708 (AS3640-2004) and is the dust fraction of the airborne particles which are taken through the nose or mouth during breathing into the body. Inhalable dust is made up of all the dust sizes that can deposit throughout the respiratory tract, and includes dust which will deposit in the upper and lower airways of the respiratory tract and through mucocilary clearance mechanisms in the gastrointestinal tract. The larger particles deposit in the upper airways (nose and throat).

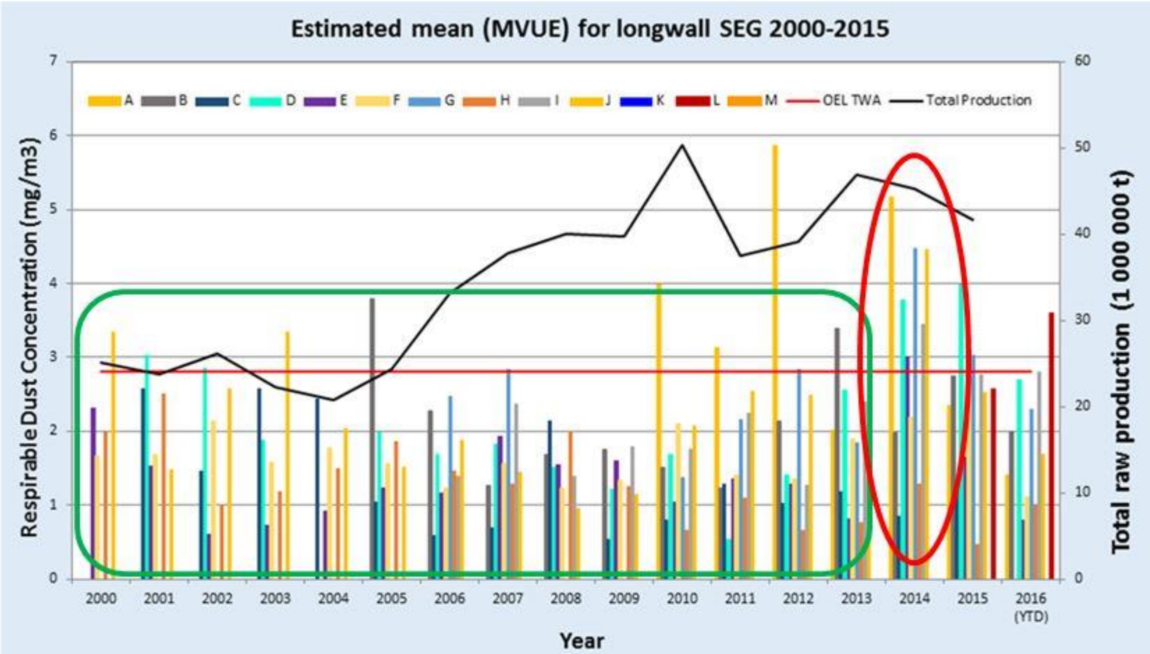

Figure 3: Estimate mean (MVUE) for longwall SEG 2000-2015 (Djukic and Gill, 2016)

The smaller particles can penetrate the upper airways and deposit in the lungs (thoracic fraction) and respirable finer particles can penetrate to the alveolar region or gas exchange region (respirable fraction). The Queensland Coal Mining Health and Safety Regulations 2001 limit respirable dust exposure to levels not exceeding 3.00 milligrams per cubic metre (mg/m^3) of air during any shift. The potential of coal dust to cause pneumoconiosis has long been recognised, and is essentially linked to exposure to respirable dust.

WHY IS OCCUPATIONAL HEALTH DIFFICULT TO MANAGE?

It is generally well-recognised that occupational health is more difficult to manage than safety and is sometimes described as the "poor cousin of safety" in terms of the time and resources spent on health management and the cost associated with illness and disease resulting from occupational exposures (Hopkinson and Lunt 2014).

The most recently reported total costs of injury and illness in the mining industry in Australia are $1280 million and $1160 million respectively (Safe Work Australia 2015), indicating that injury is a slightly more significant cost, however it is also recognised that cases of work-related disease are under-reported in both workers compensation data and through ABS surveys of the workforce. (NOHSC 2000; Safe Work Australia 2015). Because some diseases have long latency periods (e.g. cancers and pneumoconioses) and others are difficult to link to occupational exposures (e.g. cardiovascular and respiratory diseases), workers' compensation data significantly under-represent the actual incidence of occupational diseases (Safe Work Australia 2014). There is no comprehensive system of surveillance for occupational disease or illnesses in the mining industry in Australia.

Further complexities for the management of occupational disease are the interaction between occupational exposures and lifestyle factors and the complication of individual issues that might make a person more vulnerable to dosage and exposure (e.g. effect of smoking or asthma on the results of exposure to dust). Unlike injury where there is usually a clear relationship between an incident and the workplace, most occupational diseases are multi-factorial in nature, with workplace exposures constituting one important part of the risk matrix.

Symptoms of occupational disease often do not manifest until after an employee has left the workplace or retired from work. Tracking a person once they have left the work place is difficult and costly – however, it can be done.

A good example is Health Watch from the Australian Institute of Petroleum (Monash Centre for Occupational and Environmental Health 2013). Follow-up of individuals is further complicated by changes in occupation over a work life and the lack of records of work history including that no occupation is recorded on the Australian National Death Index.

In safety there is a strong recognition of the advantages of leading indicators such as high potential incidents, in addition to lagging indicators, to demonstrate management of an issue. In occupational health, there remains a nearly total reliance on lagging indicators, such as the incidence of disease, to determine the effectiveness of the management of occupational health issues. The faulty logic of this is demonstrated by the current Queensland situation. The lag indicators used include x-rays which have been shown to be faulty in terms of the implementation, quality and diagnosis (Monash Centre for Occupational and Environmental Health 2016).

The health related data systems that could provide information on leading indicators are ineffective. They do not capture data on prevailing work environments which could be used as a lead indicator and would assist in establishing relationships with health outcomes. The time lag from exposure to manifestation of dust related disease, the limited avenues to address the disease once it has been diagnosed, the difficulties with diagnosis and trouble tracking individuals show that we need to be pro-active in the management of occupational health issues.

USING THE BOW-TIE APPROACH TO MANAGE OCCUPATIONAL HEALTH ISSUES

The bow-tie approach is a method commonly used to assist in the selection of controls for managing risks. While the focus needs to be on preventive controls, for health related issues it is often placed on mitigating controls. Monitoring is often wrongly considered as a control measure rather than a tool to assess the adequacy of the control measures in place.

The bow-tie approach provides a visual representation of the barriers used to prevent an unwanted event and mitigate its consequences. The knot in the bow-tie is the unwanted event - the point at which control is lost (see Figure 4). To the left of the knot are the causes and preventive and controls (i.e. a fault tree) and to the right are the mitigating controls and consequences (i.e. an event tree). The inclusion of both types of controls, plus the visual nature of the outputs allows gaps in the application of controls to be more easily identified. A problematic situation whereby there is a reliance on mitigating controls to reduce the severity of harm is quickly detected. A more proactive approach would be characterised by robust levels of preventive and controls (on the left side of the bow-tie) that minimise the exposure of workers to a hazardous event. The inclusion of mitigating controls is important to reduce the severity of harm, but the ideal scenario is preventing the event from occurring in the first place. Seatbelts are a mitigating control that reduces harm for example, but they do not prevent the vehicle losing control; controls that address driver behaviour, road surfaces and fit-for-purpose vehicles, help to achieve this. Successive layers of barriers are required to safeguard workers from adverse events – as described by Reason (2000) in his 'Swiss Cheese' metaphor.

The bow-tie method is widely used by mining companies in Australia to assist them in the implementation of safer operations – generally within a risk management framework. The controls shown represent those currently recommended in literature, provided by government mining and non-mining agencies (including mining regulations, codes of practice, guidelines and safety bulletins) and those known to be used by the industry. Information was also accessed from RISKGATE, an Australian Coal Association Research Program (ACARP) funded website, which has bow-ties for 18 mining-related hazards (see www.RISKGATE.org, Kirsch *et al.* 2013). RISKGATE was developed between 2010 and 2015 from information provided by industry experts. The 'dust in atmosphere' bow-tie is within the RISKGATE Occupational Hygiene Topic.

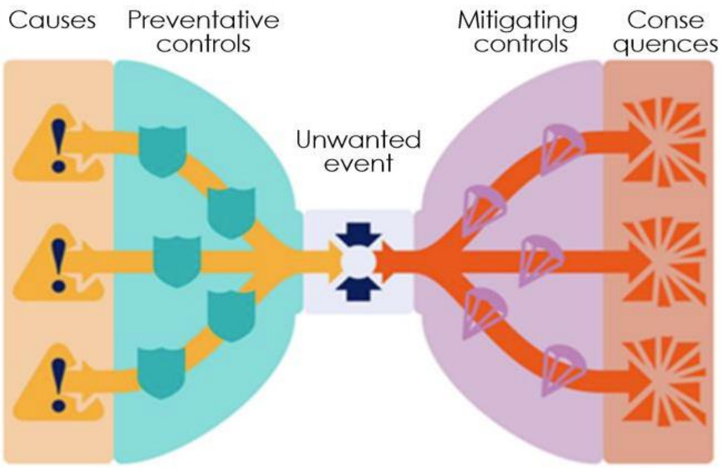

Figure 4: A schematic of the bow-tie approach (Kirsch *et al,* 2013)

A bow-tie for managing risks associated with hazardous levels of dust in the underground coal environment was developed – and is shown in Figures 5 and 6. The bow-tie includes controls that are indicative of those being used by the industry. It is a framework to consider the current focus of controls – to better determine whether there has been an over-reliance on mitigating controls, such as medical surveillance rather than preventive controls. Another aim of this discussion was to evaluate the application of bow-tie analysis to health-related mining hazards. For a more definitive list of controls used to manage respirable dust see, for example, Aziz, Cram and Hewitt (2009).

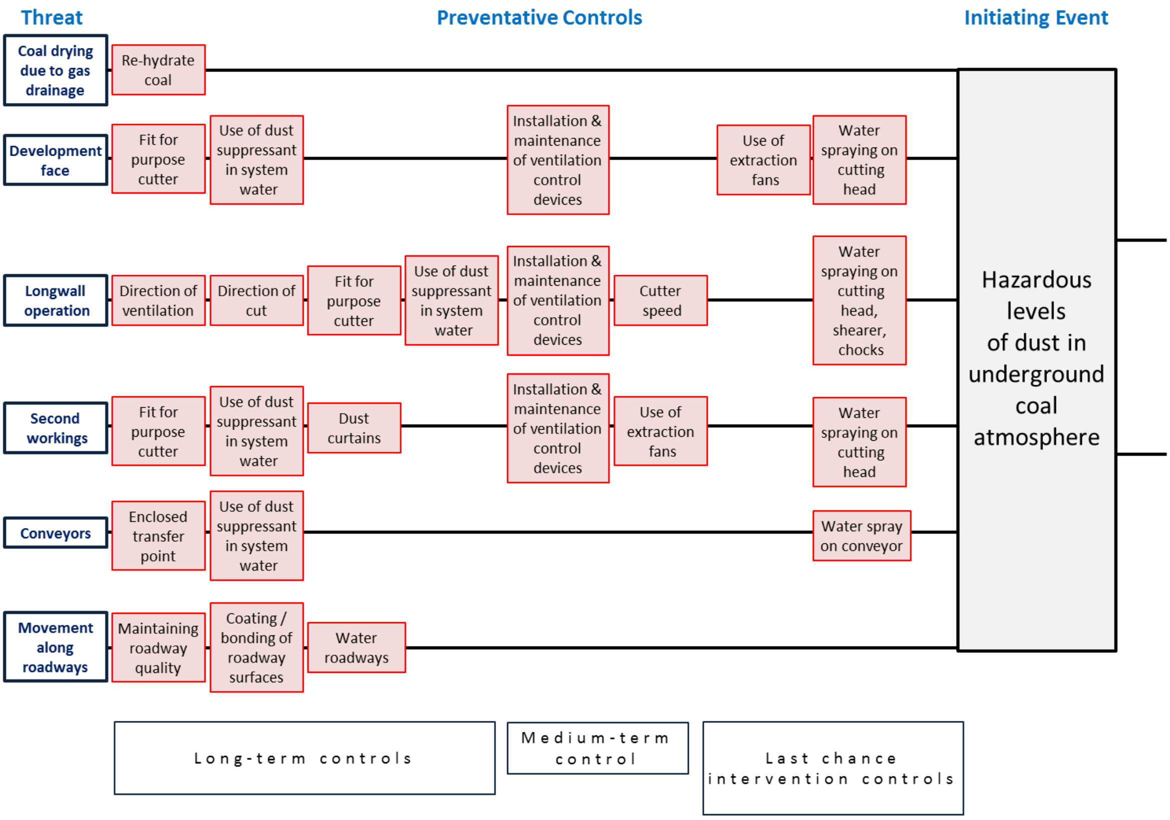

Figure 5: Threats and preventive controls (left-side) of the hazardous levels of dust in underground coal atmosphere bow-tie

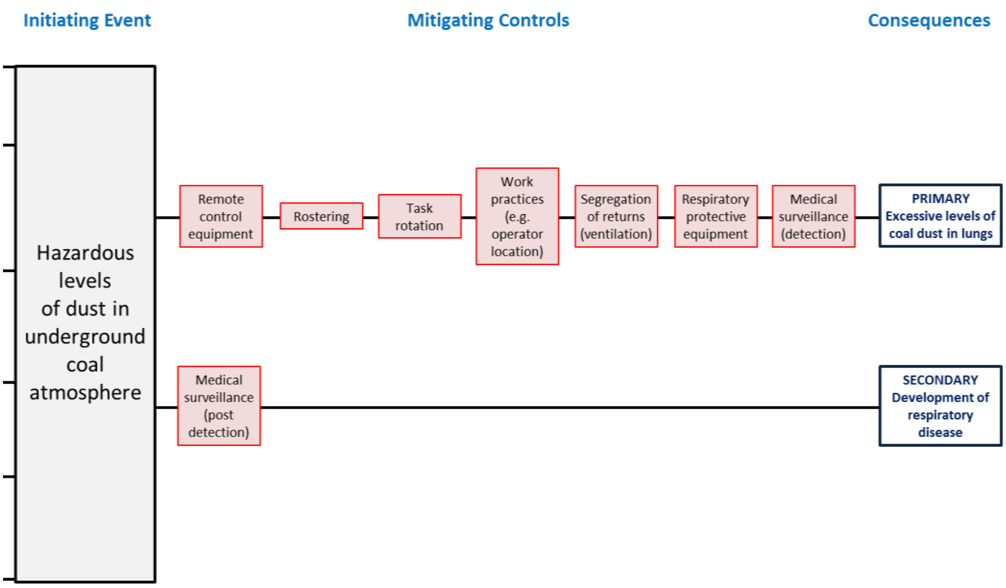

Figure 6: Mitigating controls and consequences (right-side) of the hazardous levels of dust in underground coal atmosphere bow-tie

The initiating or unwanted event (i.e. knot of the bow-tie) is hazardous levels of dust in the underground coal environment. It refers to atmospheric concentrations of dust that have the potential to cause harm. The potential for harm results from a combination of the concentration and the duration of exposure. Sources of dust include coal and silica and other respirable minerals. In this paper controls that seek to eliminate or minimise the amount of dust generated have been designed as preventive controls, while those that reduce excessive exposure to harmful atmosphere as mitigating controls. Mitigating controls are methods that do not prevent the amount of atmospheric dust generated instead they focus on minimising hazardous dust exposure. One such control is respiratory protective equipment. A caution given by Aziz, Cram and Hewitt (2009) regarding personal protection, which could more broadly be applied to other mitigating controls is – "[they] should only be used as a last line of defence and must not take the place of prevention or dust suppression techniques" (p. 568). In other words, coal mine workers' exposure to respirable dust must be kept to an acceptable level and below the regulated limit.

Mining plans and procedures, such as ventilation plans and traffic management plans are not considered to be controls – but rather activities that support controls. It is considered to be better to identify controls according to the International Council on Mining and Mineral's new definition of a control, which is an act, object (engineered) or system (combination of act and object) intended to *directly* prevent or mitigate an unwanted event (ICMM, 2015; see also Hassall, *et al* 2015). Accordingly, dust monitoring is not considered to be a control, because in itself it does not prevent the generation of dust or mitigate the exposure to dust. Rather, timely and efficient monitoring is a means of verifying the performance of these controls.

Six threats were identified involving underground mining events/tasks where workers are present and dust suppression controls are required. These are:

1. Coal drying due to gas drainage
2. Dust generated during *development face operations*
3. Dust generated during *longwall operations*
4. Dust generated during *second working operations*
5. Dust generated on *conveyors*
6. Dust generated as a result of *movement along roadways*

The first threat relates to the drainage of gas (and moisture) from the coal seam that occurs prior to mining to remove methane and CO_2. Rehydration moistens the dried coal, reducing the potential for dust emissions.

The other five threats refer to operating environments and activities – including cutting operations at the face (i.e. development, and for second workings and longwall mining methods), conveyors for coal transport and roadways for vehicle transport; that disperse high concentrations of respirable dust into the underground atmosphere. Most Queensland underground coal mines use longwall mining methods. Longwall mining is thought to give rise to four times as much dust as continuous mining, particularly when production rates (machine speeds) are high (Monash Centre for Occupational and Environmental Health 2016). In addition, bi-directional cutting can result in increased coal mine dust exposure for miners.

The preventive and controls used in the bow-tie can be generally grouped into five categories: proper use of water sprays, ventilation (including use of extraction fans), fit for purpose cutters, cutting practice (e.g. speed, direction), and dust suppressant in the water system. The exception is for those controls related to movement along roadways, which involve quality, type and watering of roadways.

Two consequences are identified: (1) excessive levels of coal dust in the lungs and (2) development of respiratory disease. These are considered separately as they represent different stages in the trajectory of respirable illness – the first consequence may not necessarily lead to the second, but where it does, prognosis often occurs many years after exposure. Methods to reduce the amount of time that workers are exposed to harmful levels of dust include remote control mining; rostering, task rotation and work practices (including the positioning of workers near/on equipment); the segregation of returns and respiratory protective equipment. Although medical surveillance (e.g. X-rays, spirometry) is shown as a control for both consequences, when used as a control for the first, it is primarily used for the detection of early stages of respiratory abnormalities consistent with coal mine dust lung disease, that in-turn is used to prompt follow-up, referral and intervention. In the second consequence medical surveillance transitions from detecting pre-clinical changes in respiratory health to detecting confirmed cases of Coal Worker's Pneumoconiosis (CWP), involving tertiary intervention to track and manage disease progression.

This bow-tie does not address the impact of important individual factors (e.g. smoking, pre-existing lung capacity) that may confound the trajectory of illness and or cause one worker compared to another to be more vulnerable to adverse outcomes. Workers with multiple risk factors may be more vulnerable. This is difficult to capture in a bow-tie format. However, highlighting the role of individual factors can hinder the implementation of effective controls. For example, focussing on the individual, can lead to screening and recruiting of employees rather than a focus on preventing safety risks in the first place (see a more thorough discussion of a similar scenario in the Education and Health Standing Committee, Parliament of Western Australia (2015) report into the impact of FIFO work practices on mental health). Also, a recent finding of the Monash Review of Respiratory Component of the Coal Mine Workers' Health (2016) for the Queensland Department of Natural Resources and Mines found that there was a tendency for companies to attribute abnormal respiratory results on smoking rather than exposure to harmful levels of dust.

The bow-tie shown suggests that controls are available to address both prevention and mitigation of harmful levels of respirable dust in the underground coal mine environment. Recent confirmed cases of CWP in Queensland indicate that preventive controls have not been performing efficiently. An overconfidence in the current dust management system can perhaps be attributed to a reliance on the medical surveillance records of underground coal mining workers, which have until recently suggested the elimination of CWP. We now know that these health screening procedures have failed to effectively monitor the detection of respiratory abnormalities and CWP in workers (Monash report, 2016). A reliance on these measures to confirm the effectiveness of controls is also questioned, considering the potential long latency of disease. As highlighted in the previous section, the long-term nature of health outcomes is problematic in terms of tracking workers over time, the follow-up of workers once they have left the industry, and the keeping of effective health data systems. Measuring control effectiveness has more recently become a focus in the management of risk in mining (Hassall, Joy, Doran and Punch, 2015; ICMM, 2015).

DISCUSSION

As the bow tie above illustrates, if workers are exposed to excessive respirable dust levels then either there are insufficient controls in place or they are ineffective. Given the plethora of research and advice on the subject there can be no reason for having insufficient controls. Controls fail to be effective because they are inherently inadequate or their effectiveness is eroded. Examples of control erosion include turning off or reducing the frequency of dust suppression water sprays because they impede the ability of the shearer driver to see where he is cutting. Lack of water pressure, poor maintenance of sprays and failing to change cutter picks often enough are all examples of factors that will erode the effectiveness of controls. A key factor in establishing control effectiveness is monitoring the implementation to not only ensure the controls are installed and operating as designed, but they actually achieve the desired level of control. Indeed monitoring must go beyond installation but extend to operation and maintenance. In these current days of cost control and production pressures it is easy to see where the continued operation of some dust suppression controls might be seen as negatively impacting on production. For example: production downtime whilst sprays are maintained. The current standard practice of monitoring exposure over a whole shift is not designed to detect sources of dust nor locations where a worker has been exposed to excessive dust levels. Real time dust monitoring is required if control effectiveness is to be monitored. Unfortunately there are currently very few real time monitoring devices approved for unrestricted use in Australian underground coal mines, though they have approval in the USA.

Because disease associated with excessive dust levels, like many occupational health issues, has a long term, cumulative impact, the immediate effect of ineffective controls is not obvious and can lead to a false sense of security, and a questioning of whether or not the control was really required in the first place. The apparent CWP free period of over twenty years may have led to a complacency and a questioning of the need to for dust controls other than Personal Protection equipment (PPE) and resulted in inadequate the exposure monitoring of the workforce. This complacency would be compounded by pressure from other areas of health and safety that have received attention in modern times, such as fatigue management, mental well-being, drug abuse and alcohol consumption – putting pressure on limited OHS budgets.

The bow-tie model demonstrates the need to manage respirable dust in a holistic manner. The NSW Work Health and Safety (Mines and Petroleum Sites) Regulation 2014 defines dust as an element of the principal hazard airborne contaminants and thus mandates the creation of a principal hazard management plan to control exposure to it. This is not a requirement in Queensland, though following the recent detection of CWP in Queensland coal miners, most Queensland underground coal mines have formed dust management committees and developed dust management plans.

Bow-ties can be applied to other occupational health issues, indeed using bow-ties to visualise the control process for occupational health issues illustrates just how complex managing these issues can be. RISKGATE (Kirsch *et al*, 2013) developed by coal industry working groups, contains within it bow ties for a wide range of health issues. The occupational hygiene topic contains bow- ties for respirable dust, diesel exhaust, hazardous substances, noise, heat and cold, vibration, asbestos and synthetic mineral fibres, waterborne contaminants and various kinds of radiation. The fitness for duty topic contains bow ties for alcohol consumption, misuse of drugs, physical fitness, fatigue, and mental ill-health. These bow-ties contain threats, preventive controls, consequences and mitigating controls. In some cases such as the mental ill-health topic, it is difficult to define controls in the traditional sense. It is also difficult to measure the effectiveness of these controls other than through the frequency of the unwanted event or its consequences. Many of the controls will involve interaction with factors off the mine site and beyond the control of the mining company. The company can however influence the worker and the community behaviour through education and awareness and the provision of professional support and a positive work environment.

CONCLUSION

This paper has demonstrated, through the example of respirable dust exposure, that occupational health issues in Queensland underground coal mines have generally not been managed in the same way as other safety based hazards. The over reliance on mitigating controls, the lack of monitoring of the effectiveness of the controls and the mistaken reliance on medical examinations to indicate any adverse outcome has meant that CWP is still an issue in our coal mines.

By adopting a systematic risk management approach, incorporating techniques such as the bow tie methodology outlined above and paying proper attention to monitoring the effectiveness of controls, occupational health risks can be managed. Management needs to be approached in a holistic manner not piecemeal and not relying on PPE to protect the worker.

REFERENCES

Aziz, N, Cram, K and Hewitt, A, 2009. Mine dust and dust suppression, in RJ Kininmonth and EY. Baafi (eds.) *Australian coal mining practice – Monograph 12*, 3rd edn, pp: 553-579 (Australian Institute of Mining and Metallurgy, Carlton, Victoria)

Bofinger, C, Cliff, D and Tiernan, G, 1995. Dust and noise exposures of longwall workers in the Bowen Basin in Queensland, Australia in *Proceedings of the 26th International Conference of Safety in Mines Research Institutes, Central Mining Institute,* Katowice, Poland, 7 September 1995

Cliff, D and Kizil, G, 2002. An estimation of the exposure of Queensland underground coal longwall workers to respirable dust in *Proceedings of the Queensland Mining Industry Health and Safety Conference,* Townsville, Queensland, pp: 13-16.

Djukic, F and Gill, E, 2016. Risk based exposures and legislation in Queensland longwalls– does it work? Paper presented to the Queensland Mining Safety and Health Conference, Gold Coast, Queensland, pp: 14-17 August 2016.

Education and Health Standing Committee, Parliament of Western Australia 2015, The impact of FIFO work practices on mental health: final report, viewed 26 October 2016, http://www.parliament.wa.gov.au/Parliament/commit.nsf/(Report+Lookup+by+Com+ID)/2E970A7A4934026448257E67002BF9D1/$file/20150617%20-%20Final%20Report%20w%20signature%20for%20website.pdf

Foster, P and Hoult, S, 2013. *The Safety Journey: using a safety maturity model for safety planning and assurance in the UK coal mining industry minerals* 2013, 3, pp: 59-72

Hassall, M, Joy, J, Doran, C and Punch, M 2015, ACARP report C23007: Selection and optimisation of risk controls, ACARP, viewed 20 October 2016, http://www.acarp.com.au/yourorder.aspx?id=C23007

Hopkinson, J and Lunt, J, 2014. In the same breath. *The Safety and Health Practitioner*, vol. 32, p:4.

International Council on Mining and Metals 2015, *Health and safety critical control management: good practice guide*, viewed 25 October 2016, https://www.icmm.com/publications/pdfs/8570.pdf

ISO 7708 (AS3640-2004) Workplace atmospheres - Method for sampling and gravimetric determination of inhalable dust, Standards Australia, Sydney, Australia.

ISO 7708 (AS3640-2004) Kirsch, P A, Harris, J, Cliff, D and Sprott, D, 2013. Industry scale knowledge management – RISKGATE and Australian coal operations, in *Proceedings of the World Mining Congress*, Montreal, Canada, pp: 11-15 August 2013.

Monash Centre for Occupational and Environmental Health 2013. *2013 Health watch, The Australian Institute of Petroleum Health Surveillance Program:* Fourteenth Report, November 2013, Monash University, Melbourne, Australia.

Monash Centre for Occupational and Environmental Health 2016. *Review of respiratory component of the coal mine workers' health scheme for the Queensland Department of Natural Resources and Mines: final report*, Monash University, Melbourne, Australia.

National Occupational Health and Safety Commission 2000. *Data on OHS in Australia: the Overall Scene*, NOHSC, Canberra, Australia.

Reason, J, 2000. Human error: models and management, *British Medical Journal*, vol. 320, pp: 768-770.

Safe Work Australia 2014. Occupational Disease Indicators 2014, viewed 23 October 2016, http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/occupational-disease-indicators-2014

Safe Work Australia 2015. The cost of work-related injury and illness for Australian employers, workers and the community: 2012-2013, viewed 23 October 2016, http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/cost-injury-illness-2012-13.