CWP Inquiry
Sub No: 004

Underground Miners Lungs and related Occupational Health Issues in Australia.

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Introduction.

In writing this paper it became apparent to the author how slowly the Australian mining industry reacts to developments in the field of occupational health and safety and the subsequent implementation of more stringent occupational health standards adopted elsewhere and in particular North America.

If, for example, we address the situation prevailing in the field of dust control in mines we know that long-term exposure to respirable dusts, including coal and/or rock dust can cause debilitating lung diseases. Consequently health authorities and industry regulators have defined various exposure limits in an attempt to safeguard the health of workers.

Whilst the mining industry is particularly prone to dusty environments, underground coal mines have in particular been facing increasing challenges due to increasing volumes of coal production from power loading longwall faces and continuous mining panels. Increased coal production results in more inhalable (< 100 microns) and respirable (<10 microns) dust. It is therefore not surprising to see increasing incidence of Coal Workers Pneumoconiosis (CWP) or Black Lung disease occurring in both in the US and Australia.

The American Conference of Governmental Hygienists (ACGIH), for example, advocates a Threshold Limit Value of 0.9 mg/m3 respirable dust for bituminous or lignite mines and 0.4 mg/m3 respirable fraction for anthracite mines (U.S. Dep. of Labour 2016) whereas the 8-hour Threshold Limit Value (TLV) adopted by the coal industry in the USA has very recently been reduced from 2 mg/m3 to 1.5 mg/m3 at underground and surface coal mines. In Queensland and New South Wales, however, the current limits remain at 3 mg/m3 and 2.5 mg/m3 respectively.

As far as diesel fumes in underground mines is concerned its potential health hazard to miners has been known for more than fifty years as evidenced by a fairly comprehensive U. S. Bureau of Mines Report (Holtz, J. C, 1950). Indeed, the American Society of Mining Engineers' Second International Mine Ventilation Congress Proceedings published in 1980, included a whole section on the "Control of Diesel Contaminants" consisting of five technical papers. These papers were particularly informative and included reference to the diesel exhaust particulates being very small in size and difficult to control and could be a more severe problem than noxious gases in coal mining (Brezlin, J, et. al., 1976).

Reference was made in a couple of these papers to the initiative undertaken by the Canadian Department of Energy , Mines and Resources in awarding a contract to Ian W. French and Associates for a study of over 1500 relevant literature citations. This led them to define a new "Air Quality Index" as a means of assessing the health hazard to miners working with diesel-powered equipment in underground mines (French, I. W. and Associates, 1978). As stated in the contract specifications "a primary goal of this contract was the development of a criterion which could take account of the combined effects of the mixture of diesel pollutants (including soot) as they occur in the underground atmosphere." The result was the following Air Quality Index (AQI):

$$AQI = \frac{(CO)}{50} + \frac{(NO)}{25} + \frac{(RCD)}{2} + 1.5\left[\frac{(SO_2)}{3} + \frac{(RCD)}{2}\right]^{*} + 1.2\left[\frac{(NO_2)}{3} + \frac{(RCD)}{2}\right]^{**} \leq 4$$

if $(SO_2) = 0$ this term is omitted

if $(NO_2) = 0$ this term is omitted

(CO) = concentration of carbon monoxide in ppm

(NO)=concentration of nitric oxide in ppm

(RCD) = concentration of respirable combustible dust in mg/m^3 (assumed to include soot plus SO_4)

(SO_2) = concentration of sulphur dioxide in ppm

(NO_2) = concentration of nitrogen dioxide in ppm

The contractor recommended that an index value of 3.0 to 4.0 should be considered a sufficient heath threat to require the use of protective equipment such as Airstream helmets, while a value in excess of 4.0 would require corrective action to reduce the emission levels at the source or by additional dilution etc."

The respirable combustible dust in the above index is defined as particulates of diesel origin.

Bearing in mind such longstanding evidence it is disappointing to see so little evidence of these issues being taken seriously enough in Australia.

We Breathe to Live.

The prime focus of this paper is the need to ensure the long-term health of underground mineworkers' lungs. Let us therefore start by considering the workings of the respiratory systems and its in-built mechanisms for coping with unwanted pollutants (see Fig 1).

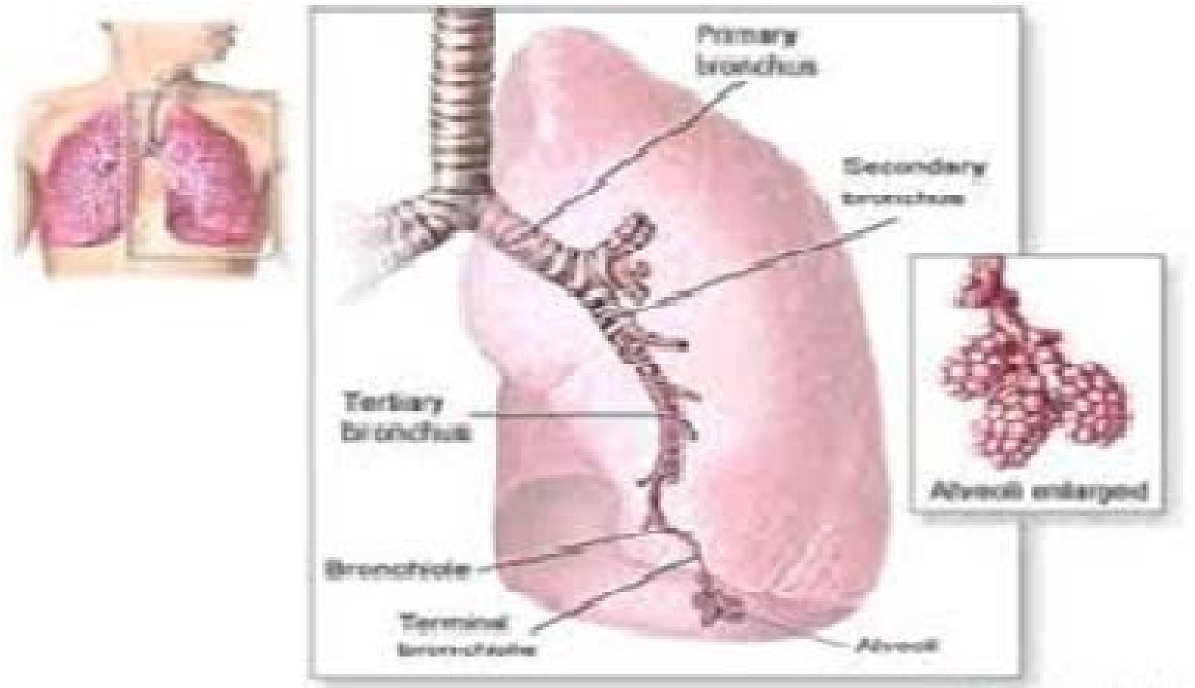

Fig 1. Diagrammatic representation of the human respiratory system

Air is inhaled through our nose and mouth into our windpipe (trachea), which subdivides into air passages known as bronchial tubes, which in turn subdivide further into smaller air passages know as bronchioles. These eventually terminate in some 300 million very small air sacs, referred to as alveoli, which are surrounded by tiny blood vessels, known as capillaries. This is where the returning blood stream gets rid of its unwanted carbon dioxide whilst at the same time recharging itself with oxygen from the inhaled fresh air.

Thankfully the respiratory system has its own in-built cleansing mechanism starting with the removal of the larger dust particles by the hairs in our nose. Beyond that we have the small microscopic hairs, known as cilia, in the bronchial system moistened with mucus, which continually transport the smaller particles upward by their wavelike motion to the throat from which they are spat out or swallowed.

However, the very fine coal dust particles remain in the inhaled air until they reach the alveoli sacs where there are no ciliated epithelial cells. There, the particles are attacked by cleansing cells known as macrophages and having engulfed them, they travel upwards to the bronchioles where the cilia take over to transmit the macrophages containing the fine dust to the throat.

When the system becomes overwhelmed with the quantity of fine respirable dust over long periods the macrophage cleansing system breaks down, with fine dust particles and dust containing macrophages building up in the lung tissue causing scarring and permanent injury; a condition known as coal workers' pneumoconiosis or black lung.

Fine silica in the inhaled air gives rise to a further problem since the macrophages release a toxic substance as it engulfs the silica, causing fibrous or scar tissue to form. Whilst this is part of the body's repairing mechanism, if the volume of crystalline silica is excessive the lung function becomes permanently damaged; giving rise to the progressive disease known as silicosis.

It is also worthwhile noting that the chemical composition of cigarette smoke adversely affects the wavelike motion of the cilia thereby weakening the body's cleansing system even further.

Coal Workers Pneumoconiosis.

The inhalation of dust has long been recognised as a health hazard leading to pulmonary diseases. Indeed, coal miners' pneumoconiosis or black lung is one of the most severe health and safety problems facing the coal industry today, with its prevalence increasing in both the USA and Australia. As stated in the Federal Register (the Daily Journal of the US Government) when reporting on Lowering Miners' Exposure to Respirable Coal Mine Dust "the prevalence rate of lung disease among our nation's coal mines continues despite the fact that incurable black lung is preventable.

Additionally, young miners are showing evidence of advanced and seriously debilitating lung disease from excessive dust exposure".

Consequently as from August 1st 2016 the operators of underground coal mines in the U.S. are required to continuously maintain the average concentration of respirable dust (less than 7 microns in size), to which each miner is exposed, at or below 1.5 mg/m3 of air.

However, going back to 2009 a timely warning was issued by a team of Australian researchers (Aziz N. et. al, 2009) when they stated that "although power loading longwall mining offers a safe method of extraction, it poses a severe problem in the control of airborne dust." (See Fig. 2)

Fig. 2. View of Shearer Power Loader operating on a longwall coal face.

The dust concentration across the traversable area of a power loading longwall face can vary considerably and following are concentration contours across a longwall face equipped with four-legged chocks some 50 metres downwind of the shearer (Balusi, 1993). It shows respirable dust concentrations in the miners breathing zone of between 3.39 and 7.38 mg/m3 (See Fig. 3)

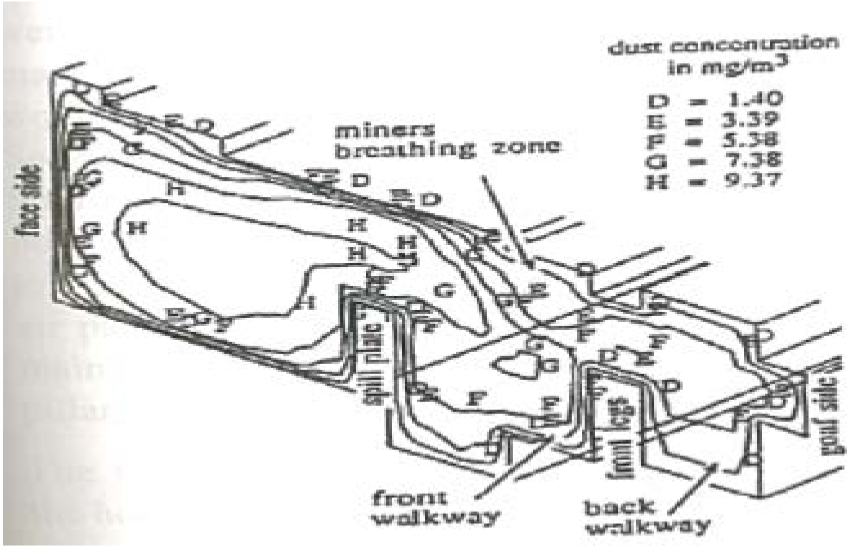

Fig. 3. Dust concentration contours across longwall face 50 metres downwind of the shearer power loader.

Such results prompted the following observation “clearly an effective solution to airborne dust must be developed and implemented to realise the full potential of longwall mining utilising shearer power loaders.”

Of the 12 operating coal mines in Queensland 9 have fully operational longwall faces with the others planning to introduce them (Monash University and University of Illinois; Final Report for Queensland Department of Natural Resources and Mines, 2016). Eleven Queensland miners have recently been diagnosed with black lung and 18 have so far been recommended for further tests. Beyond that there are increasing numbers needing close attention.

However, as stated earlier the problem isn’t restricted to Australia and Abi Millar of Mining and Technology Market and Customer Insight, along with the National Institute for Occupational Safety and Health (NIOSH) highlighting that in the USA, whereas only 0.08% of all miners were diagnosed with progressive massive fibrosis in 2000, by 2012 this figure had risen to 3.23% of working miners in Kentucky, Virginia and West Virginia, the highest level since the 1970s (See Fig. 4)

Fig. 4. Prevalence of severe black lung disease among miners in Kentucky, Virginia and West Virginia with 25 years or more of work experience (Nat. Inst. for Occupational Safety and Health)

Whilst there are many factors contributing to this situation, some of the more obvious are:

- Recommended respirable exposure limits too high.
- Inadequate ventilation and dust control regimes.
- Increasing use of high dust generating equipment such as shearer power loaders and continuous miners.
- Inadequate and ineffective health screening of mine workers at entry and regularly during their working lives.
- Poor enforcement of existing regulations.
- Mine workers exposed to dusty conditions over longer shift times and work schedules.
- Exposure of mine workers to higher than anticipated levels of crystalline silica.
- If having addressed all these issues, miners are consistently exposed to high levels of respirable dust the compulsory use of personal protection equipment may not be adequately enforced.

Finally, it's worthwhile reporting the very recent perspective of a team of eight medical professionals on this coal mining industry's health challenge in Australia (Zosky G R, et al, 2016). They recommend:

- "Standardisation of coal dust exposure limits, with harmonisation to international regulations;
- Implementation of a national screening program for at-risk workers, with use of standardised; questionnaires, imaging and lung function testing

- Development of appropriate training materials to assist general practitioners in identifying pneumoconiosis, and
- A system of mandatory reporting of coal miners' pneumoconiosis to a centralised occupational lung disease register".

Their closing paragraph is also worth reiterating – "it is unacceptable that any new cases of this disease should be occurring in Australia in 2016, and our aim should be to eliminate it altogether.

USA's Mine Safety and Health Administration Experience and Action.

Lung diseases caused by chronic and longstanding exposure to respirable coal dust, known collectively as black lung, is still occurring in the USA despite the fact they are preventable. According to the US Department of Labour's "Black Lung Program Statistics, 2012", more than 10,000 miners died from black lung from 1995 to 2004. It is also claimed, as stated earlier, that young miners are currently showing evidence of advanced and seriously debilitating lung disease from excessive dust exposure.

Until very recently the standards prevailing in the US required mine operators to continuously maintain the average concentration of respirable dust to which miners were exposed every shift at or below 2.0 mg/m3. If the respirable coal dust contained more than 5% quartz, the standard was reduced to 10 divided by the quartz percentage (based on a quartz TLV of 0.1 mg/m3).

Mine operators were also required to collect bimonthly respirable dust samples and submit them to the US Department of Labour's Mine Safety and Health Administration (MSHA) for analysis to assess compliance with the required standards. However, due to the delay in analysing samples these results were not known for at least a week, which doesn't allow for timely corrective action when conditions are unsatisfactory.

Fig. 5. Gough section of a coal worker's lung showing CWP with progressive massive fibrosis (Zosky G R et al, 2016).

However, even with these standards and requirements Coal Miners Pneumoconiosis continues to occur. In recent years the incidence of the disease has increased and in some cases it has progressed rapidly to the most severe condition known as Progressive Massive Fibrosis (see Fig 5)

Knowing that there are no means of curing Coal Miners Pneumoconiosis and the only effective way of preventing it is by reducing exposure to respirable coal mine dust the MSHA is revising its requirements by introducing its "Final Rule" legislation and following is a summary of its provisions:

- As from August 1st, 2016 the standard for respirable coal mine dust was lowered from 2.0 mg/m3 to 1.5 mg/m3 at underground and surface coal mines and from 1.0 mg/m3 to 0.5 mg/m3 for intake air in underground mines.
- As of February 1st 2016 mine operators must use the "Continuous Personal Dust Monitor" (CPDM) to record the exposure of underground coal miners at greatest risk This new sampling device measures continuously in real-time the levels of respirable dust concentrations thus giving almost instantaneous values for inspection and, if necessary, immediate corrective action by the mine operator as required by the new legislation.
- MSHA inspectors will also take single, full shift samples periodically to determine compliance.
- The final rule also requires spirometry testing, occupational history and symptom assessment in addition to periodic examination of chest X-rays by properly qualified personnel.
- These new provisions also require certified persons to perform dust sampling, maintain and calibrate sampling equipment. Certification involves attending an MSHA course and passing its examination with certified persons being re-examined every three years.

Urgency of dealing with the Coal Workers Pneumoconiosis (CWP) Challenge in Australia.

The recent outbreak of CWP amongst Queensland's coal miners is indicative of a very serious and growing challenge to those responsible for the "Duty of Care" of coal industry's underground miners. The existing regulatory standards prevailing in Queensland and New South Wales of 3.0 mg/m3 and 2.5 mg/m3 of respirable coal mine dust respectively are well above the standards recently enacted in the USA.

The Queensland Government's recent review of its coal mine workers' health scheme (Final Report, July 2016) revealed many systemic failures and deficiencies including:

- Lack of appropriately trained medical advisors.
- Too few highly qualified B-readers for interpreting X-rays resulting in large numbers of worker medicals waiting assessment.
- Poor conduct of spirometry with poorly calibrated equipment and use of untrained staff.
- Questionable decisions regarding precautionary measures for those at high risk of excessive dust exposure.

As stated by the Honourable Dr Lyneham, Queensland's Minister for Natural Resources and Mines, "every worker has a right to go to work and return home safe and healthy" whilst emphasising the three key action areas of prevention, early detection and a safety net for CWP sufferers.

Prevention requires more rigorous attention to the suppression of respirable dust on power loading longwall faces and, if having done so, the situation is still unsatisfactory exposed workers need to be supplied with personal protective equipment.

Early detection requires prompt attention to the results of spirometry testing and interpretation of X-rays by suitably qualified persons. The need to diagnose early signs of disease is paramount and those workers affected must be removed from tasks exposing them to high dust concentrations and if necessary from underground mining.

Finally, the safety net for CWP sufferers requires appropriate employment opportunities for those able to continue working and appropriate care facilities and services for those unable to do so.

The Health Hazard of Diesel Engine Exhaust Exposure in Underground Mines.

If anyone doubts the seriousness of health risks to those living and/or working in environments polluted by diesel exhaust products they should read one of many articles published on the topic in one of the many medical journals. As an example here are a couple of extracts from such an article (Krivoshto, I. N, J, 2008)

- Primary Care Physicians should be aware of the acute and chronic deleterious health effects from diesel exhaust and its potential to exacerbate other chronic disease states.
- The majority of patients who present to urban primary care clinics and emergency departments will have had significant chronic exposure to diesel exhaust because most use and/or live near busy streets and highways.

Bearing in mind such serious community concerns one wonders how much more serious are the health challenges facing those working in underground mines where diesel-powered equipment predominate.

The extent of the challenge to the global mining industry was emphasised in 2012 following the publication of the National Institute for Occupational Safety and Health (NIOSH) and the National Cancer Institute's (NCI) 20-year "Diesel Exhaust in Miners Study" which involved over 12,000 miners in eight US non-metal underground mines. It reported that the underground miners most heavily exposed to diesel engine exhaust fumes were three to five times more likely to develop lung cancer than those exposed to the lowest levels (Attfield MD., et al, 2012).

However, these were non-metal miners, whereas our concern is for underground miners who in addition to being exposed over extended periods to diesel exhaust fumes, could also be variously exposed to radon daughters, asbestos fibres, crystalline silica, arsenic and/or nickel compounds, all of whom are listed by the IARC as "Carcinogenic to humans".

Soon thereafter the World Health Organisation's (WHO) International Agency for Research on Cancer (IARC) changed its categorisation of diesel exhaust from Group 2A to "Carcinogenic to Humans, Group1", based on the results of numerous epidemiological and toxicological studies over the previous decade.

In a detailed analysis of this challenge as it affects underground miners in Western Australia (Jones, I. O, 2015) the author highlighted the fact that in the older, less efficient engines more soot particles are produced. These soot particles whilst unwanted, serve a useful purpose by providing free surfaces for the condensed gases which formulate in the dilution zone beyond the tailpipe as well as adsorbing unwanted gaseous products (Uhmer U., et al, 2011). Researchers investigating such conditions in the dilution zone have clearly identified a tri-modal distribution of particulates as shown in Fig 6.

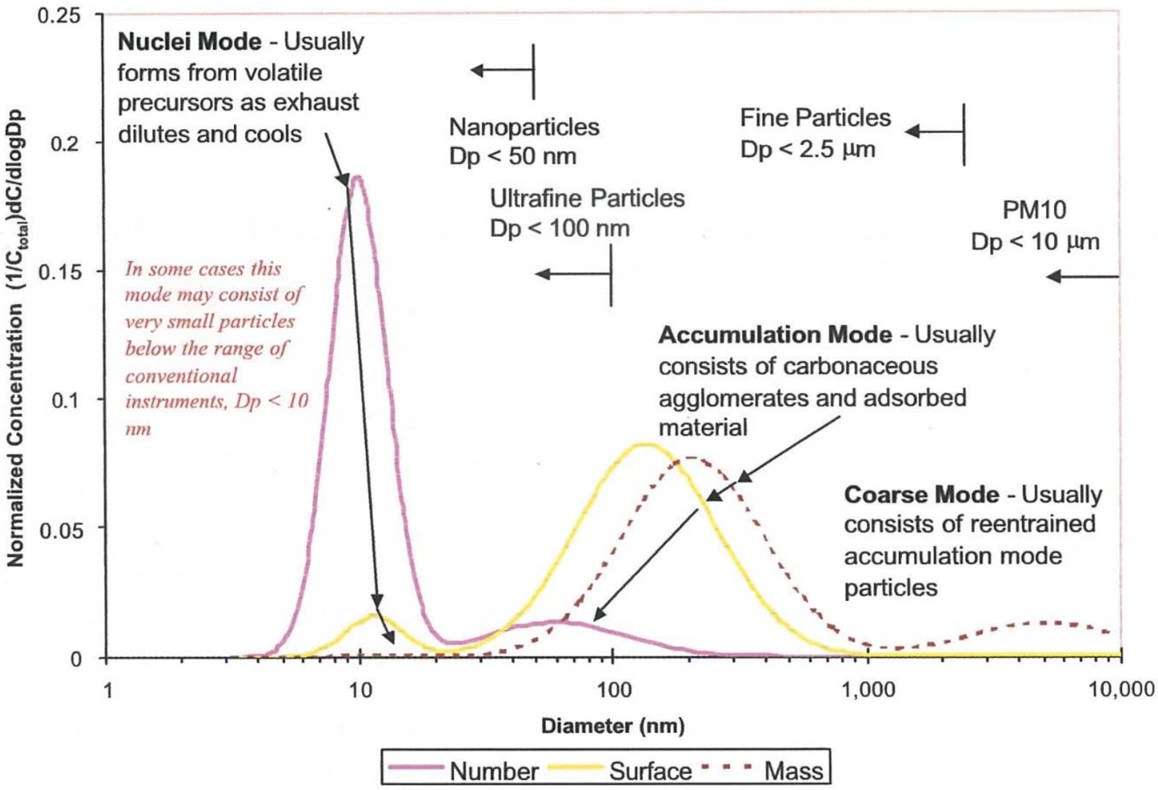

Fig. 6. Typical diesel engine particle size distribution by mass, number and surface area. D_p = particle diameter, C_{total} = total concentration (Kittelson and Watts, 2002 and Kittleson and Kraft, 2014)

In analysing this challenge as it affects underground miners in Western Australia (Jones I O, 2015) reference was made to a number of major contributing factors including:

- One of the many complexities associated with assessing the hazard to humans of working in close proximity to diesel engines is the manner conditions vary with different engine types. As pointed out in a recent research paper (Scheepers and Vermeulen, 2012) "diesel engines have progressed from traditional technology (< 1986) for which particulate matter was uncontrolled through transitional systems with progressively advanced technology resulting in lower particulates, NOx and hydrocarbon emissions to "new diesel" technology characterised by integration of wall-flow diesel particulate filter and diesel oxidation catalysts".

- The complex physical and chemical dynamics occurring in the dilution plume as the exhaust products cool in the ambient air beyond the tailpipe. With the newer more efficient engines which produce significantly less, highly adsorbent, soot particles the discharged toxic gases cool and condense on available surfaces, or if supersaturated, nucleate to form a new range of ultra-fine nano-scale volatile organic compounds (VOCs). These due to their number, surface area and toxicity also present a serious health hazard.
- The predominance of cascading, or series ventilation systems at Western Australian's underground metal mines compound the problem of achieving satisfactory air-quality control at work sites. Series ventilation systems involve the transport of ore and waste rock in main intake airways, using diesel powered trucks (up to 600 kW), thus continuously polluting the fresh air being drawn into the mine with diesel engine exhaust emissions. That apart, each mine has numerous other diesel powered items of equipment such as personnel carriers, boggers and jumbo drill-rigs; all adding to the in-mine pollution and it is within this environment that underground miners spend up to 12 hours each working day.
- The inadequacy of existing exposure metrics which currently only involves adhering to the guideline of maintaining the mass of elemental carbon below 0.1 mg/m3 for an eight hour shift. That apart, particulate/aerosol size and surface area defined as "lung deposited surface area" (LDSA) is a much better measure of the health impact of nanoparticles and ultra-fine aerosols (Bugarski and Timko, 2007). But whereas the LDSA is a better measure of conditions within which miners work, increasing efforts are also being directed to identify biomarkers which personalise the assessment, thus indicating the influence of exposure on the health of each individual.
- Diesel engine exhaust emissions include both carbonaceous particulates and a range of gases of which two are particularly difficult to control and manage; nitric oxide (NO) and nitrogen dioxide (NO2). Both can cause short-term (acute|) and long-term (chronic) pulmonary and cardiac health problems (Caudia, Bugarski and Patts, 2005) Of these NO2 is extremely toxic as evidenced by its recently reduced eight-hour TWA by the American Conference of Government Hygienists (ACGIH) from 3 ppm to 0.2 ppm
- Whilst there is no universally accepted metric for assessing the health effect of exposure to diesel engine exhaust emissions, the challenge of finding one is complicated by the wide range of possible health effects. The currently available biomarkers include Urinary 1 –hydroxypyrene as the most comprehensive biomarker for PAH exposure and the measurement of induced DNA damage by the analysis of blood samples using the alkaline Comet assay (Huawei Duan. et al, 2016).
- There is also very recent evidence of diesel engine exhaust exposure having long-term effects on blood-brain barrier function and integrity, which could lead to the onset or progression of neurological disorders (Nejad, S. H., et al, J, 2015).

Needless to say, research is continuing with various epidemiological and clinical studies in an attempt to better define internal measures of absorbed dose rather than the use of external exposure metrics.

An interesting consequence of the introduction of new technology engines is that elemental carbon will be greatly reduced whilst the genotoxic compounds may still be present although at much lower levels and many of the low volatile compounds will no longer be adsorbed to carbon cores (Scheepers, T J, et al, 2012). Many of these compounds will not remain in the gaseous phase and will either become part of an organic condensate in the nucleation mode or adsorb to other solids in the engine exhaust such as metal oxides or sulphate particles. Either way they will appear in the workplace atmospheres as ultrafine particles which may alter their lung uptake and bioavailability.

Risk Reduction and Control Measures.

Suffice it to say that long-term exposure to diesel engine exhaust has a deleterious effect on human health and is an issue of continuing and growing concern to regional health authorities world-wide.

All the more reason for being concerned about the health and wellbeing of our underground miners working in close proximity to diesel powered equipment in confined spaces in series ventilated mines.

However, the challenges are so varied and complex that no mining operation can be considered to typify the industry norm. There are, for example, a plethora of diesel engines in current use from U.S. EPA Tier 1- 4 with a variety of after-treatment devices installed in tailpipes. Couple that with the fact that each mine will have its own Diesel Emissions Management Plan defining its maintenance strategies, fuel and lubricants to be used etc., and not forgetting that each mine ventilation system will have its own characteristics, one soon realises that those responsible for each mining operation must exercise their own “Duty of Care” for their employees.

This requires management and mine workers to be kept informed of the health hazards and what is and/or can be done to minimise their effect. They should for example realise that fine carbonaceous particulates below 2.5 microns and ultrafine particles with diameters below 100 nm are particularly hazardous since they are small enough to travel deep into the lungs and for a given mass their surface areas increase with decreasing size.

That apart, toxic and carcinogenic organic compounds readily adsorb onto the surfaces of these fine particles and are thus carried with them into the alveolar sacs where they can be absorbed through the lung tissue and adversely affecting the cardiovascular system and/or other organs and possibly contributing to the development of Parkinson’s disease and brain inflammation etc.

Bearing in mind there is currently no agreement on the most appropriate and relevant metric for assessing the health hazard of Diesel engine emission exposure the best we can do is to use one of many newly developed battery operated “multi-metric” real-time monitors that record size distribution, number concentration and lung-deposited surface area of particulates which correlate well with inflammatory lung response (Wierzbicks et al, 2014). Hopefully the industry will also support and participate in applied research exploring the use of other metrics with particular reference to biomarkers.

In the final analysis, however, it is important to acknowledge that the problem of air quality control in most underground metal mines where diesel-powered mobile equipment predominate is exacerbated by a flawed ventilation system. Having the excavated ore and rock transported out of the mine in the intake airway ramp continually pollutes the fresh air supply. This fundamental flaw in mine ventilation practice needs urgent attention with consideration being given to developing hybrid/parallel ventilation circuits at existing mines or alternatively reversing the ventilation so that fresh air is delivered to the deepest production unit which otherwise would suffer the worst level of particulate, gaseous and heat pollution.

Whilst accepting these proposed actions have cost implications and some technical challenges, let's not forget that our first-priority issue should always be the health, safety and wellbeing of our mineworkers.

In mines yet to be developed, as stated in the Department of Mines and Petroleum "Guideline for the Management of Diesel Emissions in Western Australian mining operations", endorsed by its Mining Industry Advisory Committee, only parallel ventilation circuits should be employed.

Conclusions.

The seriousness of these respiratory health issues in Australian underground mines cannot be over-emphasised as evidenced by the re-emergence of coal miners' pneumoconiosis (black lung) in Queensland and the increasing global concern regarding the impact of diesel engine exhaust exposure on human beings.

As stated in the Department of Mines and Petroleum's "Accident and Incident Investigation Manual (Third Edition 1996) the Duty of Care involves taking all reasonable care to minimise foreseeable risk of injury to an employee. In this context injury must of necessity include injurious or adverse health effects. This manual also states that such a duty covers the provision of:

- Safe systems of work
- Safe premises or work places
- Safe plant and equipment
- Mandatory reporting to a central authority.

Bearing in mind the current level of knowledge on the respiratory health issues relating to the long-term exposure of underground miners to excessive concentrations of coal dust and/or diesel engine exhaust products one cannot but be critical of the industry's shortcomings in discharging its duty of care for its employees.

Rectifying the situation will need:

For underground metal mines with diesel-powered mobile equipment.

- Improved mine ventilation design for underground metal mines where diesel-powered mobile equipment predominate, in order to eliminate or minimise polluting the fresh air intake, by using parallel ventilation circuits in new mines and taking steps to minimise the problem in existing mines as mentioned earlier.
- Ensuring better qualified and experienced Ventilation Officers are available and appointed to assist management in the design of best-practice ventilation systems and developing "Risk-based Hygiene Management Plans" as suggested in the newly proposed "Code of Practice for Ventilation in Western Australian mining operations.

- Review current standards and guidelines relating underground miners' exposure to diesel engine exhaust pollutants with a view to adopting more stringent standards and monitoring regimes and continuing research into the development of appropriate bio-markers for personalising risk assessment.
- Establish better resourced and upgraded regulatory regimes with more emphasis being placed on the supervision of mining operator' compliance with legislative requirements.

For underground coal mines.

- Review current standards and guidelines relating to underground miners' exposure to respirable coal dust with the intention of bringing them into line with more appropriate and recently developed standards and legislative requirements in the USA.
- Efficient dust suppression systems installed and maintained on all power loading equipment with special attention being paid to longwall faces equipped with Single or Double-drum Shearers.
- The introduction of more stringent monitoring and recording regimes and screening programs, including storage of data at a central repository accessible to workers, government agencies and employers as recently recommended by Australian clinicians (Zosky G R, et al, 2016).
- Digital radiography to ILO standards should be performed on miners exposed to coal or coal and silica dust at the commencement of employment, and at least every three years thereafter. These images should be assessed by Royal Australian and New Zealand College of Radiologists who can assess to ILO standards (Zosky G R, et al, 2016).
- Establish mandatory reporting of those diagnosed with pneumoconiosis to a centralised occupational lung disease register and the development of training materials for General Practitioners to assist with the care of at-risk current or retired mine workers (Zosky G R ,et al, 2016).

General.

- Encourage and assist with funding applied research into all aspects of respirable-related health of mine workers.
- Provide mine workers with personal protective equipment if and when the air quality is questionable or known to be sub-standard.
- Ensure the highest level of communication with employees in an attempt to inform and educate them of the risks associated with their work and actions necessary to minimise them.

Finally, it is important to recognise that Black Lung disease is not limited to underground workers as evidenced by the recent confirmation of the first case of the disease amongst open-cut coal mine workers in Queensland.

As mentioned earlier, the recently enacted Final Rule legislation in the USA, which lowers the standard for respirable coal mine dust to 1.5 mg/m3, is equally applicable to underground and surface coal mines.

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