Qld State Development, Natural Resources and Agricultural Industry Development Committee Public Consultation

Mineral and Energy Resources and Other Legislation Amendment Bill 2020 (Qld)

Submission

by

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[redacted]

Executive Summary.

Whilst this submission generally applauds the provisions in the *Mineral and Energy Resources and Other Legislation Amendment Bill 2020* (Qld) (the Bill) – the requirement that statutory office holders be employees, and not contractors is a retrograde step – forcing poorly trained personnel to take statutory responsibility for the actions of contractor consultants. This vice is not restricted to Ventilation Officers, but forcing Site Senior Executives, Open Cut Examiners and Underground Mine Managers to be *only* employees, not contractors, deprives the mine of the capacity to engage the services of highly trained and competent personnel to fill statutory offices. This will be hard felt during the absence of office holders during sickness or holidays.

Moreover, the Bill missed the opportunity to do so much. The *Recognised competencies for coal mining statutory positions in Queensland*, should be aligned with the requirements of the *Professional Engineers Act 2002* (Qld). Diesel powered plant, machinery and equipment should be totally prohibited in underground mine workings for development and production where personnel are working. Qld should at least adopt the new NSW requirement of the *Work Health and Safety (Mines and Petroleum Sites) Amendment Regulation 2019* (NSW), which imposed a workplace exposure standard of 0.1 milligram per cubic metre of air for diesel particulate matter.

Contents.

1. Introduction.

The *Mineral and Energy Resources and Other Legislation Amendment Bill 2020* (Qld) (the Bill) requires *inter alia* that statutory office holders be employees, and not contractors. This appears to be simply the pursuit of Australian Labor Party (ALP) political ideology. The many vices in the regulation of the Qld Coal Industry are not caused by statutory office holders being contractors, and will not be addressed by ensuring that statutory office holders are all employees. The Bill misses the point, and misses the opportunity to make a real meaningful difference to Qld coal mining practices. The main vices flow from a generally low level of competency mandated for statutory office holders, and regulatory failures. Politically inspired 'spin' will fix nothing.

Whilst there are few Australian studies evaluating the "gap" between the conditions set in regulatory approvals for resource projects and the subsequent compliance with those approvals and regulatory regimes, the experience in New Zealand suggests that the gap is acute.[1] The Report of the Parliamentary *Inquiry into the re-identification of Coal Workers' Pneumoconiosis in Queensland* suggests not merely a compliance gap, but grave regulatory capture.[2] Moreover, the report observes that: "The sampling technology used in gravimetric personal dust monitors has remained largely unchanged since the 1960s",[3] and that: "No person or entity has ever been prosecuted in Queensland for failing to meet a health and safety obligation in relation to respirable dust".[4] The Parliamentary Committee did not appear to accept that this meant that there were no instances of noncompliance that could be prosecuted.

2. Policy Objective.

The Explanatory Notes to the Bill,[5] offer a *clarification of appointment requirements for statutory office holders* observing that:

> The policy objective is to ensure that statutory office holders under the Coal Mining Safety and Health Act 1999 can make safety complaints, raise safety issues, or give help to an official in

[1]Marie Brown, Bruce D Clarkson, Barry J Barton and Chaitanya Joshi, 'Ecological compensation: an evaluation of regulatory compliance in New Zealand', (2013) 31 (1) *Impact Assessment and Project Appraisal* 34.
[2] Coal Workers' Pneumoconiosis Select Committee, Parliament of Queensland, *Inquiry into the re-identification of Coal Workers' Pneumoconiosis in Queensland* (Report No. 2, 55th Parliament, May 2017) 251.
[3] Ibid 127.
[4] Ibid 130.
[5] *Mineral and Energy Resources and Other Legislation Amendment Bill 2020* (Qld), Explanatory Notes, 2 (26 February 2020) <https://www.parliament.qld.gov.au/docs/find.aspx?id=5620T157>.

> relation to a safety issue without fear of reprisal or impact on their employment. The Coal Mining Safety and Health Act 1999 provides for the appointment of statutory office holders for coal mining operations.
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> These positions are safety critical roles and are important in managing risks to the safety and health of coal mine workers to whom they owe a responsibility. Currently, the Coal Mining Safety and Health Act 1999 does not prescribe particular persons who may be appointed, for example this may include a contractor or service provider, or an employee of a contractor of service provider. The Bill amends the Coal Mining Safety and Health Act 1999 to clarify that only persons who are employees of a coal mine operator may be appointed as certain statutory office holders.

As stated, the policy objective appears to be predicated on the basis that *only* employee statutory office holders (and not contractor statutory office holders) will raise safety issues. This is so misconceived as to be laughable. Moreover, this incentive does not appear to be related to a general push against 'sham contracting' – but more a deeply held political belief that employees are easier to unionise than contractors, and union fees are an important source of revenue for Unions, and Unions contribute funds to the ALP.

3. Statutory Office Holders.

In broad terms, the Bill proscribes contractors, and mandates the employee-only regime for each of the following statutory office holders.

Site Senior Executive (SSE) (Clause 4)
Additional Site Senior Executive during temporary absence (Clause 5)
Open Cut Examiner (Clause 6)
Underground Mine Manager (Clause 7)
Ventilation Officer (Clause 8)
Assumption of Ventilation Officer duties during temporary absence (Clause 9).

The competencies required for statutory coal mining positions are determined by the Coal Mining Safety and Health Advisory Committee. As at January 2018, the *Recognised competencies for coal mining statutory positions in Queensland*,[6] demand the qualifications listed in Table 1 below.

[6] Coal Mining Safety and Health Advisory Committee, *Recognised competencies for coal mining statutory positions in Queensland*, (2018, January) <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0018/240633/coal-competencies.pdf>.

Table 1.Mandated Competencies for Selected Statutory Office Holders.

Site Senior Executive
A statutory legislation exam, as administered by the Board of Examiners, and • RIIRIS601D (previously RIIRIS601A, MNCG1003A) or • MINE7033 or • GMIRM. In addition, the Site Senior Executive, or a person named in a senior position under s 55 of the *Coal Mining Safety and Health Act 1999* (Qld), must obtain the competency unit • RIIWHS601D (previously RIIOHS601A, MNCG1107A) or • MINE7041.
Open Cut Examiner
RIIRIS402D (previously RIIRIS402A, MNCG1002B, MNCG1002A); and • Open-cut Examiner's Certificate granted under the *Coal Mining Act 1925* (Qld) or • Open Cut Examiner's Certificate of Competency granted under the *Coal Mining Safety and Health Act 1999* (Qld).
Underground Mine Manager
RIIRIS601D (previously RIIRIS601A, MNCG1003A), MINE7033 or GMIRM; and • First Class Mine Manager's Certificate of Competency granted under the *Coal Mining Act 1925* (Qld); or • First Class Mine Manager's Certificate of Competency granted under the *Coal Mining Safety and Health Act 1999* (Qld).
Underground Ventilation Officer
RIIRIS402D (previously RIIRIS402A, MNCG1002B, MNCG1002A); and • RIIUND603D (previously RIIUND603A, MNCU1109A or MNC.U109.A) or • Possession of equivalent competency to RIIUND603D (previously RIIUND603A, MNCU1109A or MNC.U109.A)
From 11 November 2019, Ventilation Officers appointed at an underground coal mine are required to have a certificate of competency. Transitional provisions allow a 3-year window for coal mine operators to action this requirement.

The management hierarchy for coal mining assumes that competent skilled professionals are charged with individual tasks within their area of competency, and that manager and management systems supervise their work. The regulator is assumed to supervise the managers.

Sadly, this is an illusion. In Qld, coal mines are largely left to self-regulate. Gunningham and Sinclair (2017),[7] contrast management-based regulation of occupational health and safety with government-imposed regulation. Management regulation involves companies developing their own process and management system standards and developing internal planning and management practices designed to achieve regulatory or corporate goals. Gunningham and Sinclair (2017) conclude that in the mining industry, management-based regulation is vulnerable to failure for a variety of often interrelated reasons, which included low levels of trust between workers and management and the inability to overcome a combination of mine management resistance, middle management inertia and the unwillingness of deputies to take managerial responsibility and implement management systems at the mine site.[8]

Mining companies are corporations and tend to look primarily at profit. It is their nature (Reich, 2008).[9] They will ignore any hazards not measured to embarrassing levels and presenting widespread public condemnation. It was that widespread public condemnation that led to incentives designed to curtail Coal Workers' Pneumoconiosis in Queensland – not any action by mine managers, or the regulator or the Unions – all of whom could have and should have done more. The most concerning vices in Qld coal mining are related to mine ventilation – and the Bill misses them all.

4. Mine Ventilation.

Mine ventilation is one of the most demanding tasks in mining. It needs specialist high level skills and training. It carries enormous responsibility. The risk to workers from poisonous atmosphere or from explosions caused by the ignition of gas or dust is extreme. If the person charged with the ventilation duties gets it wrong, severe adverse consequences may follow. Multiple deaths may occur. Yet mine ventilation is not always well resourced. It is often the job on a mine site that not many people want. The duties of Ventilation Officers often overlap those of Occupational Hygienists and other personnel, in dealing with the occupational hazards listed in Table 2 (below).

[7] Neil Gunningham, & Darren Sinclair, 'Trust, culture and the limits of management-based regulation: Lessons from the mining industry', In Peter Drahos (ed) *Regulatory Theory: Foundations and Applications* (pp.711-724). ANU Press, 2017), 711-712.
[8] Ibid, 720-721.
[9] Robert Reich, *Supercapitalism: the transformation of business, democracy, and everyday life,* (Scribe, Carlton North, 2008), 142-194.

Table 2. Atmosphere and Environmental Hazards.

Category	Hazard
Atmospheric contaminants	Dust, respirable crystalline silica, inhalable dust, respirable dust, respirable synthetic mineral fibre, blast residue, nitrogen dioxide (NO2), CO, CO2, diesel particulate matter (DPM and nDPM), abrasive blasting.
Safety and Health	Self-rescuer, resuscitation equipment, atmospheric monitoring, health surveillance, PPE.
Radiation	Dose, collective effective dose, committed effective dose, contamination level, does constraint, dose limit, and controlled area. Radiation PPE.
Noise	Noise level, noise exposure, peak noise level, action noise level, noise reduction and abatement.
Heat	Hot work procedures, ambient temperature, air temperature, humidity.
Water	Stagnant, potable, dust control water, wetting down.
Weather	Shelter, protection, PPE.
Hygiene and Sanitation	Eating places, washrooms, change rooms, hand basins, toilets, sewage.
Hazardous substances	Registers, containers, labelling, enclosed systems, MSDS, engineering and ventilation controls, atmospheric monitoring, health surveillance, PPE.
Explosives	Explosive coal dust, explosive coal seam gas, and the manufacture, storage, transport, supply, use and disposal of blasting compounds.

The submission to the Queensland Parliament *Coal Workers' Pneumoconiosis Select Committee* by the Mine Ventilation Society of Australia (MVSA) advocated a national approach mandating a competent Atmosphere and Environment Officer (AEO) with duties to address all the occupational hazards included in Table One (above). The AEO would manage resource project atmosphere and environs at all mining, oil and gas facilities, including underground mines, surface mines and quarries. The concerns of any smaller entities complaining that they cannot afford to hire a dedicated competent AEO for their operation could be met by the capacity of any entity to hire a full or part time competent AEO on contract.

Yes, contract. The skill and expertise in mine ventilation is divided between on-site employee Ventilation Officers and contractors offering specialist services to mining companies. The Bill will allow a situation where the statutory office holder employee ventilation officer with only the basic skills demanded by the *Recognised competencies for coal mining statutory positions in Queensland*,[10] assumes the responsibility for the statutory duties (including the new industrial manslaughter provisions) and the contractor with all the expertise, who is really running the ventilation circuit at the mine, is absolved of all responsibility because that contractor is not the statutory office holder.

[10] Above, N 6.

5. Mine Ventilation Law.

Not all Australian States and Territories adopted the Commonwealth Model *Work Health and Safety Act 2011* (Cth) (WHSA) or the Commonwealth Model *Work Health and Safety Regulation 2011* (Cth) (WHSR) for harmonisation of workplace health and safety. There are many problems in creating a national legislative standard and the harmonisation of mining legislation. Creating a unified workplace health and safety scheme sounds good, but may not be achievable, because every polity wants to do things their own way – and often say they don't want to lower their own standards by joining a national scheme.

In some states, mining is totally exempted from the model legislation. In others, some of the provisions of WHSA have been weaved into State mining legislation. In some jurisdictions, coal, hard rock mining and quarries are covered under the same legislation. Other jurisdictions have separate provisions for coal mining hard rock mines and quarries. In some jurisdictions, coal seam gas is classed as a petroleum gas. Whether harvested as an ancillary byproduct of coal mining or vented to the atmosphere in order to reduce the hazards it may pose, coal seam gas may come under oil and gas legislation, as well as legislative provisions relating to coal mining. In some jurisdictions, general pieces of legislation cover all resources, in addition to legislative provisions relating to specific facets.

Management systems are designed to deal with the many risks that may be encountered in mining operations. Any failure of mine operational management systems is likely to have consequences that pose a risk to personnel, mine infrastructure, and the environment – and all risks are assessed and managed in that light. Management systems are mandated by legislation in ‘the mining States’ – Queensland, New South Wales, and Western Australia. In other jurisdictions without comprehensive legislative provisions, the in-house corporate and site-specific management systems may be utilized, particularly by the larger resource houses.

Employed under an overarching management system, the Legal and Regulatory Compliance Management System (LRCMS) for resource projects lists the Statutes, Regulations, By-Laws, Codes of Practice, Hazard Management Plans, Trigger Action Response Plans (TARPs), and Standard Operating Procedures (SOPs) amongst the other requirements with which the project must comply in its operations. A Work Breakdown Schedule assigns the responsibilities to specific personnel for compliance. Each Australian jurisdiction has different legislative obligations for management systems (and the duties and responsibilities which are mandated for personnel can overlap).

Mine ventilation is dealt with comprehensively in some jurisdictions, with specific duties assigned to specific personnel, including a Ventilation Officer. In other jurisdictions, there is no Ventilation Officer and the duties and responsibilities for mine ventilation are assigned to other personnel. In some jurisdictions, there are few or no legislative provisions relating to mine ventilation. Everyone on a mine site, not just the Ventilation Officer, should understand the statutory and other obligations of a Ventilation Officer. All mine workers have to breathe the same air.

Harvesting mining, oil and gas resources occurs in one of the most politically charged arenas. Special interest groups often attack resource projects by holding them to account against what may seem to be very exacting standards of compliance with legislative provisions. Coal mining has been a particular focus of these groups. Resource professionals need to accept that they are coming under increasing scrutiny, and ensure projects comply in minute detail with any provisions governing their operations.

6. Queensland.

Queensland did adopt the *WHSA*. However, pursuant to Schedule 1(2) of the *Work Health and Safety Act 2011* (Qld), the *WHSA* does not apply to a coal mine, a hardrock mine or petroleum and gas operating plant.

Queensland has for coal mining the *Coal Mining Safety and Health Act 1999* (Qld) and the *Coal Mining Safety and Health Regulation 2017* (Qld). For quarries and hard rock mines, the *Mining and Quarrying Safety and Health Act 1999* (Qld) and the *Mining and Quarrying Safety and Health Regulation 2017* (Qld). For petroleum and gas, (including coal seam gas); the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) and Regulations.

In Queensland, a Ventilation Officer is a statutory position in underground coal mines, but *not* for open cut coal mines. The ventilation provisions for underground coal mines are comprehensive and reasonably effective. There are no provisions for ventilation in open cut coal mines.

The *Mining and Quarrying Safety and Health Regulation 2017* applies to quarries and both underground and open cut hard rock mines. Reg 48 provides that ventilation at a mine be of a sufficient volume, velocity and quality to achieve a healthy atmosphere.

7. Best Ventilation Practice.

Generally, Principle 3, set by the Initiative for Responsible Mining Assurance (IRMA)[11] mandates an intent for operating companies to engage with stakeholders to ensure that mining is planned and carried out in a manner that maintains or enhances environmental values and avoids or minimizes impacts to the environment and communities. IRMA identifies the following environmental risks to mining operations.[12]

- Chapter 3.1—Water Quality: To protect water quality and avoid harm to human health, ecosystems and future water uses.
- Chapter 3.2—Water Quantity: To maximize efficiency of water-use and minimize off-site impacts to the environment through the adoption of leading water management strategies and practices throughout the full mine life cycle.
- Chapter 3.3—Mine Waste Management: To eliminate off-site contamination, minimize short- and long-term risks to communities and the environment, and protect future land uses.
- Chapter 3.4—Air Quality: To protect and maintain pre-mine air quality conditions.
- Chapter 3.5—Noise: To preserve the amenity or health and well-being of nearby noise receptors, properties, and communities.
- Chapter 3.6—Greenhouse Gas Emissions: To minimize climate change impacts through increased energy efficiency, reduced energy consumption, and reduced emissions of greenhouse gases.
- Chapter 3.7—Protected Areas: To respect, support and strengthen the effectiveness of legally designated protected areas.
- Chapter 3.8—Biodiversity Outside Officially Protected Areas: To avoid contributing to the global loss of biodiversity.
- Chapter 3.9—Cyanide: To protect human health and the environment through the responsible management of cyanide.
- Chapter 3.10—Mercury Management: To protect human health and the environment through the responsible management of mercury.

This list should not be in any way seen as exhaustive. Each site, and mining operation has its own particular environmental risks, and these must be identified early in the mine planning

[11] Initiative for Responsible Mining Assurance ('IRMA'). (2016, April 5). *IRMA Standard for Responsible Mining – IRMA-STD-001 – Draft v2.0.* <www responsiblemining net>.
[12] Ibid, 12.

process, or as soon as they arise in operations. The failure to identify any environmental risks, and manage them within the mine risk management processes can have far reaching, and expensive consequences that may include closure of the mine.

It should not be assumed that toxic gases affect mine workers only in underground mines, or that all dust, fumes and toxic gases, including blast fumes and diesel particulate matter vent to the atmosphere in open cut mines. Better standards may have prevented the incidents in Queensland open cut coal mines in March that saw coal mine workers overcome by blast fumes,[13] and hospitalised, and toxic clouds of dust and blast fumes impacting upon the wider community.[14] These incidents only add weight to the protests by special interest groups wanting to close down all coal mines.

Figure 1. Orange blast fume plume over Muswellbrook after a blast at BHP's Mt Arthur Coal Mine (from Lamacraft, 2014).

Figure 1 (above) shows an orange blast fume plume over Muswellbrook after a blast at BHP's Mt Arthur Coal Mine. As for the incidents in Queensland dealt with above, this is not a good

[13] Cole Latimer, 'Blast fumes injure miners', *Australian Mining* (online at 05 April 2011) <https://www.australianmining.com.au/news/blast-fumes-injure-miners/>.
[14] Rory Callihan, 'Queensland locals fuming as mine blasts send toxic clouds into neighbourhood', *The Australian* (online at 05 October 2011) <http://www.theaustralian.com.au/national-affairs/state-politics/queensland-locals-fuming-as-mine-blasts-send-toxic-clouds-into-neighbourhood/story-e6frgczx-1226158548213>.

look and the appointment of a competent Atmosphere and Environment Officer (AEO) may prevent these incidents, which in the new age of increasing public scrutiny may impact upon the mine's social licence to operate.

A similar incident at the Collinsville coal mine in 2012 caused mining at night to be temporarily suspended, because of the perception that the major problem with the gases was at night, when atmospheric conditions and temperature inversions held them in place. During the day, because they are produced in fairly low concentrations, they disperse naturally very quickly.[15] Also, not a good look.

Figure 2. Gas rises from the ground at the Collinsville open cut coal mine (from Wordsworth, 2012).

The ultimate objective of the regulatory schemes within which blasts must be conducted, and the management plans that govern them is the optimization of blasting operations, whilst ensuring that they are conducted safely. This is achieved by constant monitoring, assessing, analysis, review and audit. Optimisation seeks to improve the blasting performance, to minimise the overall cost, and maximize the value of the resulting outputs. The appearance of distinctly orange coloured fumes after an ANFO blast may indicate too little FO in at least some of the ANFO. These fumes can also appear where properly mixed ANFO has become wet and has absorbed blasthole water.

The Queensland Mining Safety and Health Commissioner Stewart Bell (as he then was) was reported as saying that 62 people were taken to hospital in 2011 when fumes from open cut mines went beyond exclusion zones.[16] A Safety Alert[17] and a Guidance Note[18] sought to rectify the problem. In addition, from 1 January 2017, two new recognised standards sought to drive

[15] Matt Wordsworth, 'Toxic mine gas sparks work suspension', *ABC News* (online at 3 April 2012) <http://www.abc.net.au/news/2012-04-02/toxic-mine-gas-sparks-work-suspension/3926516>.
[16] Fidelis Rego, 'Miners deny gas impact from open cut blasts', *ABC News* (online at 05 October 2011) <http://www.abc.net.au/news/2011-10-05/miners-deny-gas-impact-from-open-cut-blasts/3299686>.
[17] Queensland Government, Department of Natural Resources and Mines, 'Prevention and management of blast fumes' (Explosives safety alert no. 44, Version 2, 15 March 2011) <https://www.dnrm.qld.gov.au/mining/safety-and-health/alerts-bulletins-search-tool/alerts-bulletins-search/alerts-bulletins/explosives/prevention-management-blast-fumes#>.
[18] Queensland Government, Department of Natural Resources and Mines, *Guidance Note – QGN 20: Management of oxides of nitrogen in open cut blasting*, (2011) <http://dnrm.qld.gov.au/__data/assets/pdf_file/0010/212500/qld-guidance-note-20-mgmt-oxides-nitrogen.pdf>.

best practice monitoring and control of respirable dust in coal mines.[19] These apply to open cut and underground coal mines. Unfortunately, in the demand for greater production, mines often only comply with the minimum legislative requirements. The compliance cost of the measures recommended below is small compared to the impacts upon workers and the wider community, and the cost of lost production if a high potential incident or serious accident closes the mine.

Queensland and New South Wales have comprehensive underground coal mine ventilation legislation that works reasonably well, but could be improved. The open cut coal and hard rock mine ventilation legislation leaves much to be desired. Western Australia has simple, clear, comprehensive and effective mine ventilation legislation that applies to all mining methods and resources. The other states and the ACT and NT have little to offer to the equation.

The best features from each of the best legislative schemes recommends the WA requirement for a Ventilation Officer for open cut and underground mines and quarries regardless of the resource and extending the NSW requirement for regular 12 monthly ventilation audits by a licensed ventilation auditor to all mining methods and resources. These measures should be an Australasian wide legislative requirement.

Although not included in the *Recognised competencies for coal mining statutory positions in Queensland,* set by the Coal Mining Safety and Health Advisory Committee (2018),[20] because of the demands of the RPEQ process mandated by the *Professional Engineers Act 2002* (Qld) and the *Professional Engineers Regulation 2003* (Qld), all 'professional engineering services'[21] (as defined in Schedule 1 of the Act) must be performed by a *PPEQ* or under the direct supervision of an *PPEQ* accredited in the same area of engineering. But in relation to Mine Ventilation Engineering, which area of engineering is it under which the *PPEQ* must be accredited?

At first view, Mine Ventilation Engineering is not the province of mechanical, civil or structural engineers, although they could work on mine ventilation assignments, under the direct supervision of a 'Mine Ventilation Engineer', but there is no *PPEQ* defined as such.

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[19] Queensland Government, Business and industry portal, *Regulatory changes* (2016) <https://www.business.qld.gov.au/industry/mining/safety-health/mining-safety-health/medicals/pneumoconiosis/regulatory-changes>.
[20] Above N 6.
[21] The definition broadened by the *Professional Engineers and Other Legislation Amendment Act 2014* (Qld) from 'construction or production activity' to 'construction, production, operation or maintenance activity'.

Several mechanical, civil and structural engineers are known to be working in Mine Ventilation Engineering and issuing Certificates testifying to the 'structural adequacy' of parts of Ventilation Control Devices ('*VCDs*') and the 'mechanical' functioning of parts of ventilation systems.

The *Coal Mining Safety and Health Regulation 2017* (Qld) demand more than the assessment of the structural adequacy of the thickness of component parts of *VCDs* or the mechanical functioning of parts of ventilation systems. Ventilation systems should as far as possible be tested and evaluated in situ, as a complete ventilation system, not component-by-component. Two Qld Safety Bulletins (No 107/2011 and 127/2005) make this clear – as do the Pressure Ratings for *VCDs* and the other relevant parts of the *Coal Mining Safety and Health Regulation 2017* (Qld).

There is no 'Mine Ventilation Engineering' discipline recognised by *The AusIMM* or 'Mine Ventilation Engineering' area of engineering recognised by the *Board of Professional Engineers Queensland*. It was generally thought that Mine Ventilation Engineering came exclusively under Mining. However, that does not appear to be the case.

In WA, a Ventilation Officer must have a diploma or degree in Mining Engineering, where Mine Ventilation is a substantial part of the curriculum; or the equivalent as recognised by the State WA Chief Mining Engineer.[22] The other jurisdictions have other, mostly lower standards of competency for a Ventilation Officer.

8. DPM and nDPM.

Diesel engines produce exhaust particles, which are known as Diesel Particulate Matter (DPM). When breathed in these increase the risk of developing long-term health problems, including lung cancer and possibly bladder cancer. Morin et al (2008) note that diesel soot concentrations of 10-100 µg/cm2 applied to a cell culture monolayer are equivalent to instant dust inhalation of 10-100 g by a human of 70 kg.[23] Simon Ridge, Executive Director Resources Safety for

[22] *Mines Safety and Inspection Regulation 1995* (WA) s 9.4.
[23] Jean-Paul Morin et al, 'Prevalidation of in vitro continuous flow exposure systems as alternatives to in vivo inhalation safety evaluation experimentations: outcome from MAAPHRI-PCRD5 research program', (2018) 60 (2-3) *Experimental and Toxicologic Pathology* 195-205.

Western Australia and Chair of the Mining Industry Advisory Committee (MIAC) noted that newer technology diesel engines produce high quantities of smaller-sized diesel particles of less than 100 nanometres, known as Nano Diesel Particulate Matter (nDPM). He added that "nDPM is difficult to capture with diesel particulate filters, as it is like a gas and travels further in the mine". When inhaled, nDPM can pass through lung walls into the bloodstream and enter cells. Importantly, nDPM absorbs and transports more toxic and carcinogenic substances. Research shows that occupational exposure affects human DNA and the resulting genetic effects may be passed on to the children of exposed workers.[24] In his paper presented to the *Hard Rock Mine Ventilation Conference 2013,* Dr Patrick Glynn, from the CSIRO (Winner of New Inventors Award for the project with ACARP and Peak3 - June 2010) noted:[25]

- With increasing research into the clinical effects of breathing air with diesel particulate matter, the indications at this point are that there is likely to be no safe level of ingestion of DPM.

- The recommended DPM mass level of 0.1mg/m^3 is also being questioned, as with the aim of reducing DPM mass, engine manufacturers have improved the combustion efficiency of diesel engines by the introduction of common rail and turbo-charging to achieve this reduction.

- An unwanted outcome of the improved diesel engine efficiency was an increase in the number of diesel particulates with over a 50% reduction in average diesel particulate size.

- This reduction in DPM size is of particular concern as larger DPM <2.5 micron coated with poly aromatic hydrocarbons (PAH) (a known carcinogen) will effect a minority of the population, whereas the smaller DPM <100 nanometre can cross the lung membrane barrier into the bloodstream, and this has the potential for health effects on 100% of the population.

In a study for Work Safe Australia, Jackson, Lopata, Elms, and Wright (2009)[26] noted:

> There are currently two engineered nanomaterials for which Australian National Exposure Standards have previously been established, i.e. the time-weighted average (TWA) for fumed

[24] Western Australia DMIRS, 'Nano Diesel Particulate Matter Research Underway', (2017) 5 (2) *Resources Safety Matters* 36-37.
[25] Dr Patrick Glynn, 'Understanding DPM and the Scale of the Problem' (paper presented to the IQPC *Hard Rock Mine Ventilation Conference 2013,* 26 - 28 February 2013, Holiday Inn, Perth, Australia), (2013) 12 *WOMP e-Journal.*
[26] N Jackson, A Lopata, T Elms, & P Wright, 'Engineered Nanomaterials: Evidence on the Effectiveness of Workplace Controls to Prevent Exposure', *Safe Work Australia* (November 2009) <https://www.safeworkaustralia.gov.au/system/files/documents/1702/engineerednanomaterials_evidence_effectiveness_workplacecontrolstopreventexposure_2009_rtf.doc>.

> silica and carbon black is 2 and 3 mg/m^3, respectively. The fact that these have been established indicates that there is evidence of safe levels of exposure to some engineered nanomaterials, however for most engineered nanomaterials the evidence is lacking.
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> …
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> There are also few publications of nanomaterial quantitative risk assessments; an example is that of Kuempel et al. (2006) for ultrafine titanium dioxide (TiO_2), ultrafine carbon black and diesel exhaust particulates. The authors concluded that established quantitative risk assessment methods are useful in estimating occupational exposure risk to ultrafine and fine particles and provide a scientific basis for the evaluation of potential risk of exposure to engineered nanomaterials.

Many think that the scientific basis for the evaluation of potential risk of exposure to nDPM is well established and should not be awaiting the further generic examination of 'engineered nanomaterials' at large.

Despite general provisions in the laws of various Australian polities demanding that risks to workers be risk managed and reduced to a generic standard 'as low as is reasonably achievable' (ALARA) or some other like provision, and despite the dangers presented by DPM and nDPM being well known, there is presently no specific Australian standard for DPM or nDPM. Chang, and Xu (2017)[27] note:

> In order to minimize DPM health hazards, the DPM concentration should be maintained below an acceptable standard. Germany, Canada and the USA have already set their limit or standard for DPM exposure for mining industries. Germany sets the DPM limit for underground noncoal mines and other surface workplaces at 0.3 and 0.1 mg/m^3, respectively. The Canada Centre for Mineral and Energy Technology sets the standard of DPM at 0.75 mg/m^3. In the US, the Mine Safety and Health Administration (MSHA) has an exposure standard of DPM for metal/nonmetal mines of 0.16 mg/m^3 (measured as total carbon). The development of regulations and standards for the DPM exposure in underground mines is still in its early stage in Australia. Currently, the official limit for DPM exposure for underground mines is still not established, and the level of regulation in different states varies. In Australia, many regulatory agencies have considered 0.1 mg/m^3 (measured as elemental carbon, TWA) of DPM as a recommended exposure limit, and this is also recommended by the Australian Institute of Occupational Hygienists (AIOH). (references omitted)

[27] Ping Chang & Guang Xu, 'A review of the health effects and exposure-responsible relationship of diesel particulate matter for underground mines', (2017) 27 (5) *International Journal of Mining Science and Technology* 831-838.

Chang, and Xu (2017) were speaking of DPM, not nDPM. For nDPM, which presents greater risks, but the situation seems to be bogged-down in a technical soup concatenating all 'nanomaterials'.

Figure 3 contains images illustrating the effects of nano particles on human cells.

A. Particles sized at 5,000 nanometres (5 micrometres) remain outside the cell.

B. A few particles at 200 nanometres (0.2 micrometres) have entered the cell.

C. Particles at 70 nanometres (0.07 micrometres) which is at nDPM size, enter and damage the cell.

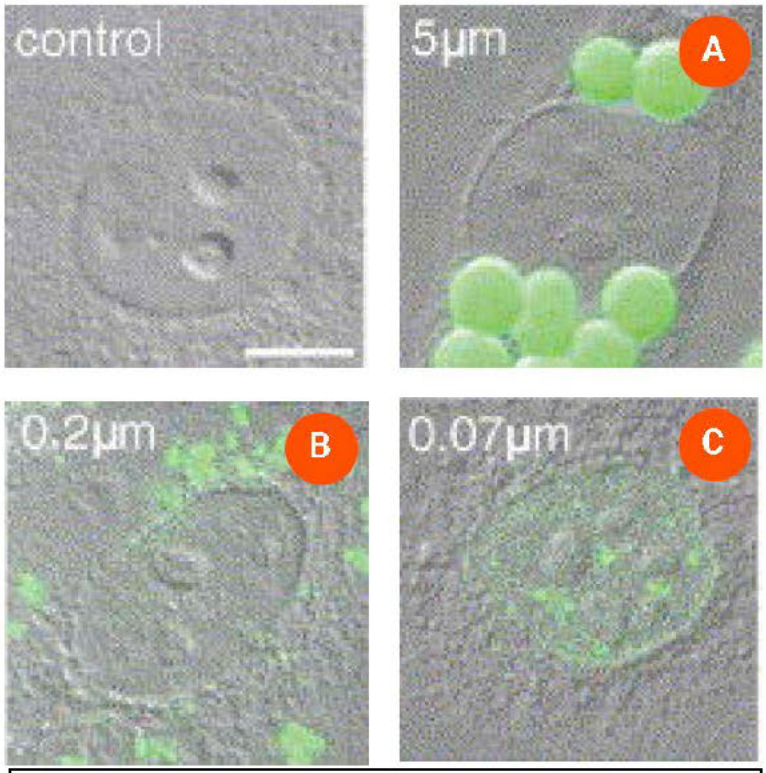

Figure 3. The effects of nanoparticles on human cells (from Western Australia DMIRS, 2017).

There are provisions in some State laws setting ventilation levels for mines using diesel powered equipment and vehicles. In Western Australia, these are a ventilating volume rate for diesel units of 0.03 – 0.05 m^3s per kw x number of units. Not more than 2 000 ppm of carbon monoxide or more than 1 800 ppm of the oxides of nitrogen for each diesel unit. In Queensland, the exposure standard assigned to the contaminant in NOHSC:1003.

In NSW, the exposure standard for contaminants (including DPM and nDPM) was in the *Workplace Exposure Standards for Airborne Contaminants* and as low as is reasonably practicable. However, recently the *Work Health and Safety (Mines and Petroleum Sites) Amendment Regulation 2019* (NSW) imposed a workplace exposure standard of 0.1 milligram per cubic metre of air for diesel particulate matter with a 12-month transition period provided. Qld did not follow.

In the Northern Territory, a safe oxygen level must be maintained, and the concentration of flammable gas, vapour, mist or fumes must not exceed 5% of the LEL for the gas, vapour, mist

or fumes. Combustible dust cannot present a hazard. Otherwise the exposure standard for contaminants (including DPM and nDPM) in *the Workplace Exposure Standards for Airborne Contaminants*. In South Australia, a level of 19.5% oxygen must be maintained in ventilated air. The level must not exceed 5% LEL for gas, vapour, mist or fumes. Otherwise the exposure standard for contaminants (including DPM and nDPM) in *the Workplace Exposure Standards for Airborne Contaminants*.

In Tasmania, a "safe level" of oxygen in ventilated air must be maintained, and air flow for the ventilation current is determined by the aggregate number diesel units by maximum rated output. Otherwise the exposure standard for contaminants in *the Workplace Exposure Standards for Airborne Contaminants.*

Victoria has not adopted the Commonwealth Model *Work Health and Safety Act 2011* (Cth) (WHSA). The regulation of all mines for all mining methods and all resources is left to the *Occupational Health and Safety Regulation 2007* (Vic). The provisions relating to mine ventilation contained in Part 5.3 are encapsulated in seven sentences. The principal obligation is to ensure "the air does not pass through so many work areas that it becomes unfit to breathe". The slightly more comprehensive provisions dealing with confined spaces do not apply to mines.

The ACT adopted the *WHSA 2011* (ACT), but the *WHS Regulation 2011* (ACT) do *not* include Chapter 10 applying to mining. The confined spaces provisions of the *WHS Regulation 2011* (ACT) do not apply to a mine shaft or the workings of a mine. There is no mining and only a couple of quarries in the ACT. For matters otherwise falling within the Commonwealth domain, Onshore and in coastal waters, the states and territories own and allocate mineral and petroleum rights, administer operations, including OH&S and collect royalties on production. Beyond the coastal waters (seaward of 3 three nautical miles of the territorial sea) to the outer limits of Australia's continental shelf, mineral and petroleum rights are held by the Commonwealth, but administered jointly with the relevant state or territory.

9. Measuring DPM and nDPM.

In his paper *Nano Diesel Particulate Matter – A Review*,[28] Professor Michael Tuck observed:

> Measuring and determining the overall toxicity of diesel exhaust is difficult but essential to ensure compliance with established threshold limit values and to enable exposure to be monitored and

[28] Professor Michael Tuck, *Nano Diesel Particulate Matter – A Review.* (Minesafe International 2017, Paper No.44). The Australasian Institute of Mining and Metallurgy, Carlton VIC 3053 Australia, 3.

> recorded effectively. A number of substances are typically used as surrogates for the assessment of the exposure as a whole, Noll et al (2006), Tuck (2014). Direct reading electronic instruments or colorimetric tubes are often used for the gaseous components to measure concentrations of CO2, CO, NOx gases and where significant amounts of sulphur are present in the fuel, SO2.
>
> Determining the concentration of particulate matter is significantly more complex. The largest part of diesel particulate matter is carbon, and is the usual surrogate measure for overall DPM. Some measurement and analysis methods measure Elemental Carbon (EC) only, whilst others measure both Elemental and Organic Carbon (OC) combined also known as Total Carbon (TC) where (TC= EC+OC) whereas others measure just the combustible carbon. The analytical methods employed usually fall into three categories; gravimetric, coulometric and thermal optical.
>
> Measuring diesel particulate in underground coal mines presents an exclusive problem. A substantial portion of diesel particulate Elemental Carbon is chemically identical to coal dust and the only physical difference between the two is the particle size. This has led to numerous methods for the measurement of diesel particulate, with some being appropriate for hard rock mines whilst others only for underground coal mines. Diesel particulates can be measured either in the general body of the atmospheric air or in the raw diesel exhaust in the tail pipe. (references omitted)

At present the methods employed for measuring ventilation flows, dust and fumes, including DPM and nDPM are mostly completed (if at all) by the use of archaic instruments and processes. In NSW, the lack of a legislated ventilation competency for open cut coal mines, underground and open cut hard rock mines, has enabled those mine operators to largely self-set and monitor the ventilation risks associated with their operations – and regulators merely review the management systems that operators design and implement.

The introduction into underground coal mines of newer digital technologies has been delayed by the need to render them intrinsically safe. Only recently Australia's first tablet device certified for use in underground coal mines was introduced into the Queensland Moranbah North underground coal mine,[29] enabling communication and information gathering and sharing below surface. It took five years to develop. This was followed by the introduction of intrinsically safe smartphones and tablets in the Queensland underground coal mine at Carborough Downs.[30] Digital devices will revolutionize all facets of underground coal mining,

[29] Venessa Zhou, 'Anglo American pioneers underground tech across QLD operations', *Australian Mining* (online at 29 July 2019) <https://www.australianmining.com.au/news/anglo-american-pioneers-underground-tech-across-qld-operations/>.
[30] Venessa Zhou, 'Fitzroy Australia executes digital planning at Carborough Downs', *Australian Mining* (online at 26 August 2019), <https://www.australianmining.com.au/news/fitzroy-australia-executes-digital-planning-at-carborough-downs/>.

including mine vent. It is not just the capacity to "remove underground paperwork and transition to electronic storage of statutory and production reports" that is important – but the capacity to include real time digital measuring and recording equipment in underground coal mines will revolutionise mine ventilation practices and procedures. However, these will only migrate across to open cut coal mines, underground and open cut hard rock mines and quarries in NSW with the introduction of a ventilation competency for these resources and mining methods, with mandated ventilation benchmarks. In other words, mine operators usually will only adopt methods and practices mandated by legislation.

As Robert Reich (2008) observed, corporations exist foremostly to make profits.[31] Within a playing field delineated by regulation, they compete with other corporates for personnel, resources and for sales. Their profits are largely determined by the extent to which they minimise their costs. If corporations spend on incentives not mandated by regulation, they are likely to lose a competitive advantage to other corporations that keep costs lower by only meeting regulatory demands. In that regard, hoping that corporations will become willing become 'good corporate citizens' and adopt 'corporate social responsibility' incentives that cost them money and threaten their competitive advantage is somewhat delusional.[32]

10. Controlling DPM and nDPM.

The most effective control mechanism for any hazard is avoidance, by elimination/substitution.[33] The next effective is reduction. Despite the message from the renown W Edwards Deming that "It is wrong to suppose that if you can't measure it, you can't manage it – a costly myth"[34] – the main driver for the reduction of DPM and nDPM is measurement. Whilst you can manage it, even if you can't measure it, mining companies are corporations and tend to look primarily at profit (Reich, 2008).[35] They will ignore any hazards not measured to embarrassing levels and presenting widespread public condemnation.

Unfortunately, as shown above, in NSW measuring DPM and nDPM is confined mainly by regulation to underground coal mines with a ventilation competency and mandated ventilation standards. However, these do not apply to open cut coal mines, or open cut and underground

[31] Robert Reich, above N 9.
[32] Ibid 142-194.
[33] Professor Michael Tuck, above N 28, 5.
[34] W. Edwards Deming, *The New Economics for Industry, Government, Education.* (2nd Ed). The MIT Press.
[35] Above N 44.

hard rock mines and quarries and even with a rigorous desire to measure DPM and nDPM levels, mine operators are not really able to do so with any precision. The measuring equipment needed is just not yet available.

Moreover, if and when that requisite measuring equipment becomes available, there is no guarantee that mine operators will comply with mandated DPM and nDPM regulatory measuring regimes. As the instances shown above demonstrate, mine operators struggle now to comply with the regulatory regimes for dust, blast fumes and other toxic atmospheric hazards affecting mines sites. Risk Assessment just don't seem sufficient.

Is there another choice? Professor Michael Tuck observes that:[36]

> Within the hierarchy of controls the most effective method is elimination/substitution. For this to be the case there needs to be an alternative to diesel powered vehicles. Two such options exist, electrical drive vehicles (either cable or battery) which is existing technology, or fuel cell technology which is a developing technology. Plans are underway to make mines all electric, an example here being Goldcorp's plan to use battery powered equipment at its proposed Borden development in Ontario Canada, Batten (2016). These are options worth pursuing, however electric powered vehicles do not currently offer the flexibility of diesel power across the whole range of mining methods.
>
> Engineering controls are applicable to the control of both DPM and nDPM. Examples here include:
> 1. Application of existing remote or tele remote technologies to remove operators from proximity to the diesel exhaust emissions
> …

Firstly, it should be noted that apart from the plant, machinery and equipment used in the initial construction of mines, most of the plant, machinery and equipment used in underground coal mining for development or production is electric. No diesels. No DPM or nDPM. The continuous miners, shuttle cars, continuous haulage, longwalls, conveyers, bolters, ventilation fans and equipment and all other equipment are all electric. It is proven technology and could be mandated for use in all underground hard rock mines.

[36] Professor Michael Tuck, above N 28, 5.

As for open cut coal and hard rock mines and quarries, the remote or tele-remote technologies of which Professor Tuck speaks, which remove operators from proximity to diesel exhaust emissions,[37] are now also widely used and proven technologies.

Rio Tinto are acknowledged as the industry leader in remote and tele-remote technologies employing Autonomous Haulage Systems (AHS), with a fleet of AHS trucks and loaders operated on mine sites in the Pilbara from remote access facilities in Perth,[38] Automated Drilling Systems (ADS), and AutoHaul® automating the trains transporting the iron ore to port facilities – all operating since 2017. There are plans to extend the technology to all their operations.[39] BHP is very much chasing the leader and playing 'catch-up' on ADS, which presents Rio Tinto with a competitive advantage. However, the competitive advantage Rio Tinto enjoys is not merely based on ADS, but upon the integration of ADS into its business systems.[40] And it reduces costs. A report by McNab et al (2013) [41] based on conversations with industry representatives, concluded that the introduction of fully ADS fleets could result in a 30 to 40 percent reduction in the workforce of a typical open-cut iron ore mine.[42] Robert Reich would be so pleased!

But it is not only Rio Tinto and BHP chasing automation to save costs. Removing personnel from underground hazardous working areas was cited as by Northparkes Mine as one reason for their adoption of fully automated underground load/haul technologies, which have been successfully employed since 2013.[43] Operator CMOC now run one of the most fully automated underground copper/gold mines in the world.[44]

Why don't all underground mines use electric plant, machinery and equipment or if diesel, utilize it by remote or tele-remote technologies? Answer: they don't have to.

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[37] Ibid.
[38] Rio Tinto, *Mine of the Future™*, (2019) < http://www.riotinto.com/australia/pilbara/mine-of-the-future-9603.aspx>
[39] Len Dodgson, 'Rio Tinto: rolling out the world's first fully driverless mines', *Mining Technology* (online at 31 March 2016) <http://www.mining-technology.com/features/featurerio-tinto-rolling-out-the-worlds-first-fully-driverless-mines-4831021/>.
[40] Ibid.
[41] Karen McNab, et al, 'Exploring the social dimensions of autonomous and remote operation mining: Applying social licence in design' *Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining and the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane* (2013), 8.
[42] Ibid, 16.
[43] NSW Mining, 'Focus on safety at Northparkes Mines, following the 1999 airblast disaster', *YouTube* (online at 16 May 2014) < https://www.youtube.com/watch?v=5A7u6lgl8b0>.
[44] CMOC, *The Northparkes Difference* (2019) < http://www.northparkes.com/>.

11. Submissions and Recommendations.

Whilst this submission generally applauds the provisions in the *Mineral and Energy Resources and Other Legislation Amendment Bill 2020* (Qld) (the Bill) – the requirement that statutory office holders be employees, and not contractors is a retrograde step – forcing poorly trained personnel to take statutory responsibility for the actions of contractor consultants. This vice is not restricted to Ventilation Officers, but forcing Site Senior Executives, Open Cut Examiners and Underground Mine Managers to be *only* employees, not contractors, deprives the mine of the capacity to engage the services of highly trained and competent personnel to fill statutory offices. This will be hard felt during the absence of office holders during sickness or holidays.

Moreover, the Bill missed the opportunity to do so much. The *Recognised competencies for coal mining statutory positions in Queensland,*[45] should be aligned with the requirements of the *Professional Engineers Act 2002* (Qld). Diesel powered plant, machinery and equipment should be totally prohibited in underground mine workings for development and production where personnel are working. Qld should at least adopt the new NSW requirement of the *Work Health and Safety (Mines and Petroleum Sites) Amendment Regulation 2019* (NSW), which imposed a workplace exposure standard of 0.1 milligram per cubic metre of air for diesel particulate matter.

For open cut mines, quarries and oil and gas sites, any new standards will theoretically be a great incentive. However, measuring DPM and nDPM will still present a challenge and the Qld Resource Regulator may need to mandate the type of measuring equipment that needs to be employed by resource sites to measure DPM and nDPM, and to design a DPM and nDPM Management System that sets by regulation the frequency of measurements and the reporting of these measurement. Penalties for noncompliance need to be mandated and monitoring, assessment and enforcement actions by the Resources Regulator will need to be proactive and effective. Sites should not be permitted to largely self-regulate.

[45] Above N 6.

For the operators of underground mines (hard rock and coal), there should be two main choices:

1. If diesel powered, the plant, machinery and equipment must be controlled and operated by remote or tele-remote technologies.

2. If not controlled and operated by remote or tele-remote technologies, the plant, machinery and equipment must be electric.

References.

Legislation, Statutory Instruments and Regulatory Bulletins.

Coal Mining Safety and Health Act 1999 (Qld)
Coal Mining Safety and Health Regulation 2017 (Qld).
Mines Safety and Inspection Regulation 1995 (WA).
Mining and Quarrying Safety and Health Act 1999 (Qld).
Mining and Quarrying Safety and Health Regulation 2017 (Qld).
Occupational Health and Safety Regulation 2007 (Vic).
Petroleum and Gas (Production and Safety) Act 2004 (Qld) and Regulations.
Professional Engineers Act 2002 (Qld).
Professional Engineers and Other Legislation Amendment Act 2014 (Qld).
Professional Engineers Regulation 2003 (Qld).
Work Health and Safety (Mines and Petroleum Sites) Act 2013 (NSW).
Work Health and Safety (Mines and Petroleum Sites) Amendment Regulation 2019 (NSW).
Work Health and Safety (Mines and Petroleum Sites) Regulation 2014 (NSW).
Work Health and Safety Act 2011 (ACT).
Work Health and Safety Act 2011 (Cth).
Work Health and Safety Regulation 2011 (ACT).
Work Health and Safety Regulation 2011 (Cth).
Work Health and Safety Regulation 2017 (NSW).

Coal Workers' Pneumoconiosis Select Committee, Parliament of Queensland, *Inquiry into the re-identification of Coal Workers' Pneumoconiosis in Queensland* (Report No. 2, 55th Parliament, May 2017).

Queensland Coal Mining Safety and Health Advisory Committee, *Recognised competencies for coal mining statutory positions in Queensland*, (2018, January). Retrieved from https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0018/240633/coal-competencies.pdf.

Queensland Government, Business and industry portal, *Regulatory changes* (2016). Retrieved from https://www.business.qld.gov.au/industry/mining/safety-health/mining-safety-health/medicals/pneumoconiosis/regulatory-changes.

Queensland Government, Department of Natural Resources and Mines, *Prevention and management of blast fumes*. (Explosives safety alert no. 44, Version 2, 15 March 2011). Retrieved from https://www.dnrm.qld.gov.au/mining/safety-and-health/alerts-bulletins-search-tool/alerts-bulletins-search/alerts-bulletins/explosives/prevention-management-blast-fumes#.

Queensland Government, Department of Natural Resources and Mines, *Guidance Note – QGN 20: Management of oxides of nitrogen in open cut blasting*, (2011). Retrieved from http://dnrm.qld.gov.au/__data/assets/pdf_file/0010/212500/qld-guidance-note-20-mgmt-oxides-nitrogen.pdf.

Queensland Parliament. *Mineral and Energy Resources and Other Legislation Amendment Bill 2020* (Qld), Explanatory Notes, 2 (26 February 2020). Retrieved from https://www.parliament.qld.gov.au/docs/find.aspx?id=5620T157.

Articles and Books.

Chang, P., & Xu, G. (2017). A review of the health effects and exposure-responsible relationship of diesel particulate matter for underground mines. *International Journal of Mining Science and Technology*, *27*(5), 831-838.

CMOC, (2019) *The Northparkes Difference*. Retrieved from http://www.northparkes.com/.

Glynn, Dr Patrick, 'Understanding DPM and the Scale of the Problem' (paper presented to the IQPC Hard Rock Mine Ventilation Conference 2013, 26 - 28 February 2013, Holiday Inn, Perth, Australia), (2013) 12 *WOMP e-Journal.*

Gunningham, N., & Sinclair, D. (2017). Trust, culture and the limits of management-based regulation: Lessons from the mining industry. In Peter Drahos (ed) *Regulatory Theory: Foundations and Applications* (pp.711-724). ANU Press, The Australian National University, Canberra.

Hopkins, A. (2010). Risk Management and Rule Compliance Decision Making in Hazardous Industries. NRCOHSR Working Paper No 72, Australian National University <http://regnet.anu.edu.au/research/publications/3062/wp-72-risk-management-and-rule-compliance-decision-making-hazardous>.

Initiative for Responsible Mining Assurance ('IRMA'). (2016, April 5). *IRMA Standard for Responsible Mining – IRMA-STD-001 – Draft v2.0.* Retrieved from www.responsiblemining.net.

Jackson, N., Lopata, A., Elms, T., & Wright, P. (2009, November). Engineered Nanomaterials: Evidence on the Effectiveness of Workplace Controls to Prevent Exposure. *Safe Work Australia*. Retrieved from https://www.safeworkaustralia.gov.au/system/files/documents/1702/engineerednanomaterials_evidence_effectiveness_workplacecontrolstopreventexposure_2009_doc.

Lamacraft, T. (2014, February 20), 'BHP blast prompts health warning', *ABC News.* Retrieved from http://www.abc.net.au/news/2014-02-20/bhp-blast-prompts-health-warning/5271338.

McNab, K., Onate, B., Brereton, D., Horberry, T., Lynas, D., & Franks, D. M. (2013). Exploring the social dimensions of autonomous and remote operation mining: Applying social licence in design. *Prepared for CSIRO Minerals Down Under Flagship, Mineral Futures Collaboration Cluster, by the Centre for Social Responsibility in Mining and the Minerals Industry Safety and Health Centre, Sustainable Minerals Institute, The University of Queensland, Brisbane*.

Morin, J. P., Hasson, V., Fall, M., Papaioanou, E., Preterre, D., Gouriou, F., ... & Dionnet, F. (2008). Prevalidation of in vitro continuous flow exposure systems as alternatives to in vivo inhalation safety evaluation experimentations: outcome from MAAPHRI-PCRD5 research program. *Experimental and Toxicologic Pathology*, *60*(2-3), 195-205.

NSW Mining (2014, May 16), Focus on safety at Northparkes Mines, following the 1999 airblast disaster. *YouTube*. Retrieved from https://www.youtube.com/watch?v=5A7u6lgl8b0>.

Reich, Robert B. (2008)., *Supercapitalism: the transformation of business, democracy, and everyday life,* Scribe, Carlton North.

Rio Tinto, (2019) *Mine of the Future™*. Retrieved from http://www.riotinto.com/australia/pilbara/mine-of-the-future-9603.aspx>.

Tuck, M. A. (2017). *Nano Diesel Particulate Matter – A Review*. (Minesafe International 2017, Paper No. 44). The Australasian Institute of Mining and Metallurgy, Carlton VIC 3053 Australia.

Western Australia DMIRS. (2017, August). Nano Diesel Particulate Matter Research Underway. *Resources Safety Matters, 5*(2), 36-37.

Wordsworth, M. (2012, April 3), Toxic mine gas sparks work suspension. *ABC News.* Retrieved from http://www.abc.net.au/news/2012-04-02/toxic-mine-gas-sparks-work-suspension/3926516

Zhou, V. (2019, August 26). Fitzroy Australia executes digital planning at Carborough Downs. *Australian Mining.* Retrieved from https://www.australianmining.com.au/news/fitzroy-australia-executes-digital-planning-at-carborough-downs/.

Zhou, V. (2019, August 29). Anglo American pioneers underground tech across QLD operations. *Australian Mining.* Retrieved from https://www.australianmining.com.au/news/anglo-american-pioneers-underground-tech-across-qld-operations/.