Mine Fumings and Miners' Ill Health, 1880s-1910s: The Hazard of Nitroglycerine Fumes

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Early twentieth century Australian miners said of their health that 'their lungs have been burnt out of them' by fumes.[1] This paper explores what they meant and what responses were made to this observation on ill health and work hazard. This case study is of affected miners on the Western Australian goldfields from the establishment of the fields in the 1880s to the end of the first boom, by 1910. In that time fumings contributed significantly to the toll of work injuries and fatalities among miners. Understanding these fumings and the responses to them requires a broad canvas, stretching round the international mining world of the 1880s-1900s.

Mine fumes – also named smoke or gas – have a long history of killing. In the coalmining industry blackdamp or choke damp (a mixture of gases containing a high level of carbon dioxide and little oxygen), firedamp (mostly methane), white damp (carbon monoxide), stink damp (hydrogen sulphide) and afterdamp (mostly carbon monoxide) have caused many of the world's biggest mine disasters.[2] Organic matter – chiefly the coal itself – has been the major source of these toxic coalmine gases. While coal mine fumings were well known, the exact identification of the gases causing them occurred mostly in the period under examination in this paper.[3] On the other hand, metal mines faced a much smaller threat from poisonous fumes of organic origin. Instead danger has come from two other sources: fumes produced by eglycerin explosions (notably carbon dioxide, carbon monoxide and oxides of nitrogen); and by metallurgical processing, lead poisoning being the best-known example and, on the goldfields, cyanide poisoning. This paper focuses on fumings from explosives used in metal mining (that is, on the gases generated by blasting) as distinct from the effects of mine dust on the health of workers.

Fumings in Western Australia

In Western Australia fumings caused 30 goldmine fatalities in the years from 1889 (when the first identified mine fatality occurred in the colony) to 1910. That number constituted 5 per cent of all mine accident fatalities (which totalled 611).[4] The killer fumes were either the product of nitroglycerine explosion and/or combustion (causing 21 fatalities) or cyanide (causing 9 fatalities). On the Witwatersrand Goldfields in South Africa, fuming deaths involving nitroglycerine were much more numerous, as many as 40 deaths in one year.[5] There were 21 fuming deaths in Queensland metalliferous mines from 1877 to 1910 but only four of them were related to the use of nitroglycerine.[6] In NSW mines between 1883 and 1899 there were 11 deaths from fuming.[7] Mine fumes were lethal on all fields but the particular gases that were present varied from case to

case, as did the reasons for their existence. It was a complex picture and one that needed the chemists' expertise to untangle.

These mine fatalities were only the tip of an iceberg. As well as killing, fumes made most late nineteenth and early twentieth century miners ill. Although the ill health was transitory it was frequently repeated, often on multiple occasions. Yet it has tended to be discounted as constituting ill health because the illness was not, for the most part, chronic or progressive and did not result in visits to doctors or significant loss of work time. Nevertheless it remained the norm in miners' health (or rather ill-health) through the period under examination here.

Figure 1: '*Members of the Royal Commission 1905 and Assistants engaged in experimental blasts at the Kalgurli Gold Mines, Limited Kalgoorlie, showing the smoke jacket and air hose, and air bags'*

Source: *Report of the WA Royal Commission on the Ventilation and Sanitation of Mines*, 25 February 1905, p. 100.

A glimpse at the general state of WA miners' health is exposed in their 1904 evidence given at a Western Australian Royal Commission on the Ventilation and Sanitation of Mines (1905).[8] The Commission tackled the hazards of mine fumings and miners' dust disease (phthisis) as well as issues of public hygiene – infections and the threat of enteric (typhoid) fever outbreaks. A good deal of time was spent discussing underground sanitary closets and the possible presence of miners' hookworm disease (ankylostomiasis). In the first years of the twentieth century, considerable alarm in Britain about ankylostomiasis and phthisis, particularly among Cornish miners, echoed around the mining world and was picked up in WA.[9] According to Catherine Mills' analysis of the development of statutory hygiene provisions in British mining (1890-1914), it was an era of 'evidence-based intervention' when government officials

identified potential hazards, 'undertook experimental investigations, [and] kept in touch with new techniques, and foreign practice'.[10] In Western Australia this was certainly the case and the government officials who exemplified this era – Mines Minister Henry Gregory, State Mining Engineer Alexander Montgomery, President of the Central Board of Health, Dr Ernest Black, and Government Analyst and Chief Inspector of Explosives, Edward Mann – were the most influential voices on the 1905 Commission.[11] Gregory established the Commission and the three senior officials constituted half its commissioners.

Figure 2: *'Flashlight photograph showing Smoke Jacket and Air Hose, and illustrating method of sampling air in connection with experimental blasts at Kalgurli Gold Mines Limited, Kalgoorlie, and cage used for tests on animals'.*

Source: *Report of the WA Royal Commission on the Ventilation and Sanitation of Mines,* 25 February 1905, p. 100.

Dr Black expressed the dominant view of his medical colleagues in insisting that sanitation needed greater attention and that mine fumes of organic origin were 'specially harmful'.[12] As it turned out, the Commission's attention to sanitation was an unnecessary diversion from the very real threats from inadequate mine ventilation. Ankylostomiasis had not, and did not take hold in WA mines. Typhoid was a past threat because effective sanitation systems had been established in the new goldfields towns and the operation of the goldfields water scheme had mostly overcome the dire water shortages of the past. Personal and public hygiene in mining communities did not require the heavy hand of an extended state bureaucracy; instead the miners themselves, their families, enterprising women who ran boarding houses and local governments all played their parts in the ongoing generally healthy life of goldfields communities. In contrast, mine ventilation and high underground dust levels did require government

interventions in order to halt (or at least slow) the burgeoning epidemic of miners' phthisis. This intervention was slow in coming. On the hazard of fumings, however, the Commission did better, allowing Chief Inspector of Explosives and Government Analyst, Edward Mann, to pursue an 'evidence-based intervention', undertake 'experimental investigations', strengthen his understandings of and contacts with 'foreign practice', and over the next years, lessen the fuming danger and miners' ill health from this cause.[13]

The Commission heard evidence on the ubiquity of fumings in Australian mining. Almost every one of the 68 miners who testified had experienced the effects of fumes either in WA or in other parts of Australia where they had previously mined.[14] It was simply not possible for a miner to avoid all fumes at all times. As one miner put it, 'If a man is frightened of smoke he has no business below'.[15] Miner after miner testified before the Commission to the toxic effects of mine fumes as observed in others and experienced themselves: feeling faint, 'giddy', 'queer', 'bad', 'done up', 'knocked out'; falling over and losing consciousness; feeling sick and vomiting; experiencing frequent headaches, that were sometimes 'violent' or 'splitting'.[16] One miner said that he 'became almost helpless, though not unconscious'.[17] Another reported 'a swimming sensation in the head, and the candle was still burning'.[18] Two witnesses told of seeing men fall down after leaving work.[19] After 25 years of mining in Queensland, New South Wales and Western Australia, William Finney provided a detailed description:

> The symptoms produced by fumes were a heaviness of the head and loss of capacity for any thought or quickness of action. One became feeble and wobbled about, the same as when under the influence of drink, He had not noticed any palpitation of the heart, but sometimes there was shortness of breath, vomiting, and at times severe headache.[20]

Those who worked in or near cyanide either in the surface plant or mullocking underground told of 'qualms', shivering, vomiting, headaches, feeling faint and losing consciousness, in addition to the often chronic rashes and other skin eruptions.[21] A battery hand with 17 years experience in Victoria and WA testified that, as well as 'violent' headaches, 'he had suffered from the fumes of cyanide, something like "barcoo", the symptoms being an inability to eat without vomiting; there were also sores or breaking out on the skin, which he had had for four years'.[22]

Most miners made light of these fumings. Implicit in their words was the view that these incidents were just part of the job, the sickness trivial. James Hosking, for instance, a miner with fourteen years' experience in South Australia and Western Australia, described one occasion when he and others had been overcome by dynamite fumes at the North Star Gold Mine at Malcolm. He passed out and was brought to the surface where he was revived in the fresh air. He was, he recalled, fit to work again 'within a couple of days'. Being fumed was 'a rather queer sensation but this would seldom remain long'.[23] He remembered that incident and other similar ones but seemed to discount them as illnesses. Another miner said: 'Men were affected by a slight headache, just sufficient to send them home … He had never known of anyone being really ill for any length of time owing to the fumes'.[24] And others said: 'Personally he

had suffered for a few days, although he had never lost a day's work';[25] 'a little sick but not enough to lose any time';[26] 'now and again he had suffered a little';[27] 'he only lost a shift';[28] 'personally he had not lost any time beyond a day'.[29]

Figure 3: The M-S-A *Gas mask patented USA and Canada in 1920 and 1921* (It is uncertain when these masks were introduced in WA but they were being experimented with from the first decade of the twentieth century).

Source: Photograph Miners' Hall of Fame, Kalgoorlie 2011, Courtesy Sandy Duncan.

These fuming experiences occurred more often in some mines than others but were rarely one-off in each miner's experience. Hugh Gordon, who had mined for ten years, mostly in WA but originally in Broken Hill, said he had 'often' been overcome by fumes from explosives.[30] Another miner told of headaches every two or three shifts

in some periods.[31] A Boulder doctor reported disproportionate headaches among miners on Monday mornings on their return to work after Sunday off.[32] Miners worked on in their allotted location even where continuing work for a full shift proved impossible. 'A man did not mind working temporarily in a bad place', one said of working on a rise that he had to leave every hour to recover in order to continue his shift.[33] Men worked in these conditions because they did not believe they had a choice. As one explained, 'it was simply a matter of bread and butter'.[34]

Transitory dizziness, unconsciousness, nausea, headaches, indigestion and rashes went largely unnoted not least because miners wished it so. They took as few days off work as possible and, for the most part, did not complain publicly that their employment was causing this ill health. If they wanted to keep their jobs they had to be circumspect. One miner recalled men being cautioned for not returning to the face soon enough after firing and then being later discharged for a different reason.[35] He said of one mine management's attitude to complaints: 'if a man spoke too much it was a case of "go".'[36] An underground manager explained what generally happened when a miner could not cope with mine fumes:

> When men came off work one could tell from their colour whether they were bad. A man did not say anything to the management, but drew his pay and left the mine; they worked two or three days, and then lost one, and ultimately went away.[37]

The men kept the matter to themselves.

The 23 local goldfields medical practitioners who gave evidence to the Commission all reported treating cases of sickness from the fumes of explosives and cyanide but most had seen only a small number, just the most acute of the fuming cases and the cases of severe chronic illness, most often cyanide rashes. After eight years in Cue Dr Taylor had more than the usual experience and listed the symptoms of fumings as 'a general weakness, debility, headache and general malaise, the headache being something awful; perhaps for a few days they were off work'. During that time he had seen 20 dynamite poisoning cases with the worst symptom a 'splitting headache' which was relieved by vomiting.[38] Dr Blanchard, also of Cue, remembered one acute case of cyanide poisoning and a few chronic cases of rashes among men working in the cyanide plant. He had seen just 'a few' cases of fumes from explosions resulting in symptoms of intense headache and nausea.[39]

Medical men who practised in mining centres outside Kalgoorlie-Boulder and Cue generally had limited experience on the fields and were much more comfortable and authoritative speaking of infections and sanitation than of the effects of fumings. Only four of the doctors – the most long-standing and all practicing in Kalgoorlie-Boulder – were able to speak with much substance and confidence on the cases of mine fumings they had treated.[40] They had seen enough of them to have something to say.

Goldfields doctors were ambivalent as to whether mining was a healthy occupation, most agreeing with Kalgoorlie's Dr Erson that 'miners were no more unhealthy than the rest of the community'.[41] Yet most also judged it to be a job for

young men and a number warned that miners' health was being undermined by 'long working in a vitiated atmosphere'.[42] Typical comments were:

- the conditions of life underground were not very favourable for building up a good system.[43]
- The effect of vitiated air on men's health underground was to wreck their constitution. … they lost their appetite and weight, and became run down, and were then more liable to other affections.[44]
- [Mining] was not an unhealthy occupation when it was not carried on for too long a period; otherwise it told on the constitution.[45]

They were alluding to the combination of adverse atmospheric conditions underground: the fumes certainly, but also the dust and the temperature extremes and variations. It was in older miners that doctors saw the damage being done over time.

The doctors saw almost nothing of the sickness caused by recurring fumings because miners did not seek medical help for the problem. Instead they turned to patent medicines and/or alcohol to remedy this transient but recurring ill health. Patent medicines promising relief from the effects of 'impure air' were constantly advertised in this period. If numbers of advertisements are any indication, Bile Beans for Biliousness, obtainable 'from all chemists and storekeepers', seems to have been the most popular of these cures for 'off-colour' miners.[46] Typical of the times, advertisements targeting miners contained printed personal endorsements from other miners. For instance, Bile Beans trumpeted the transformation in Mr William Wright, miner of Black Flag in WA:

> … for four or five months my life was a perfect misery; continuous headaches, pains in the back, shoulders in fact pains all over, After taking two boxes I can safely say I feel quite a new man.[47]

They equally achieved a 'perfect cure' for Mr John Graham who was made sick by 'unwholesome inhalation' around the cyanide vats.[48] Another well advertised remedy for everything including miners' ailments was Dr Mackenzie's Pink Pills for Pale People, although goldfields advertising for this product primarily targeted women. Patent purges were popular for headaches as for all ailments, the idea being to clean all impurities from the body.[49] The other even more popular remedy for faintness and nausea was a dose of whisky or brandy, and undoubtedly a regular cleansing ale or two or three at the end of shift appealed to men who had earlier felt 'bad'.

In these ways miners coped with the recurring ill health and particularly the headaches they experienced when 'they had got a whiff of the smoke'.[50] British occupational physician, Thomas Oliver, displayed a far greater understanding than did any WA doctor of 'the notorious "nitro-glycerine headache" '. Perhaps it was more obvious to him because the British workers he studied were employed in the manufacture of explosives.[51] Oliver recommended treatment with strong coffee and a linseed poultice applied to the back of the neck.[52] Whether goldfields doctors prescribed any symptomatic relief for headaches is not known but what is certain is that miners would not consult a doctor on such a matter unless the headaches were so debilitating

that they caused significant loss of work time. Self-medication was the more likely option.

The end result of miners' sufferance and managements' downplaying or denial of the problem was an understatement of the occurrence of fuming accidents. The 1905 Commission concluded that the 'numerous instances' where miners 'became sick and even unconscious from bad air, but have recovered very quickly when brought into a better atmosphere' were 'not considered worth regarding as accidents'.[53] They were not deemed accidents within miners' culture and nor were they classified as accidents statistically. In the early decades of the twentieth century accidents causing lost work time of less than two days were not reported in official Mines Department statistics.[54] So these innumerable fumings, which were described but then mostly dismissed by miners at the 1905 Commission, disappeared from sight. The concept of 'accident' itself, with its connotations of unforeseeable and unintended random incidents, militated against risk reduction; how much more was this the case when recurring incidents could not even reach the threshold for registration as an accident. Only where fumes killed or came close to killing were incidents registered.

The international scene

There were many such major incidents in WA but nowhere near as many as on the Witswatersrand: in WA one or two deaths a year; on the Rand around forty. It is therefore unsurprising that it was South African researchers who published the most significant reports detailing the fume hazards from nitroglycerin explosions and the best appropriate treatment. In fact the South African industry saw so many fumings that some Johannesburg mining engineers in the early twentieth century argued that the sickness and death caused by fumes extended as far as causing miners' lung disease (phthisis).[55]

Nitroglycerine explosions in Britain were, in contrast, 'few and far between'.[56] The fact that Britain chiefly mined coal, an industry which relied on blasting powder, perhaps explains why British researchers were not in the forefront of this aspect of mine safety research. In 1906 the Samuel Report on the UK Workers' Compensation Act successfully recommended the inclusion of 'poisoning by nitrous fumes' in the schedule of compensable diseases. These poisonings were, however, occurring not among miners or construction workers using explosives but among manufacturing workers in explosives and chemicals factories.[57]

When Alfred Nobel harnessed the explosive power of nitroglycerine in dynamite and then gelignite in the 1860s and 1870s, and made them reasonably safe to manufacture and transport, the world's engineering projects were revolutionised.[58] For mining, tunneling and quarrying, these explosives provided the 'ideal of portable force', as one expert put it.[59] Named 'giant powder' (after its trade name) by miners in the American west, dynamite (and later gelignite) was essential in the metal mining industry driving deep underground through hard rock.[60] By 1883 Australia used 50 percent of all the dynamite consumed in the British Empire, most of it supplied from Nobel's giant explosives factory at Ardeer in Scotland.[61] Gelignite, more powerful than

dynamite, proved even more popular. By 1902 WA mining used four times more gelignite than dynamite.[62] Nevertheless, in the hard rock of WA's goldfields, 'very heavy blasting' was required.[63] This consumption of particularly large quantities of explosives elevated the threat of fumings.

American hard rock mining (as well as railroad construction) was also a major early consumer of dynamite, and it was an American surgeon, Thomas Darlington, a company doctor employed to attend to both mine and railroad workers in Arizona, who wrote one of the earliest papers on the particular health danger of the fumes released by nitroglycerine explosives, not when they accidentally exploded or burnt, but when their explosion occurred as intended. He reported in 1890 on over 1,300 cases of asphyxia and poisoning among workers constructing the New Croton Aqueduct in the years 1885-87. Cases were mostly acute and a few chronic. Darlington attributed the asphyxia from which the men quickly recovered when removed to fresh air, to the carbonic acid gas (that is, carbon dioxide) and nitrogen dioxide produced by the explosions.[64] However, he reported, that was not the end of the matter, as some workers experienced ongoing symptoms: headache, cough, indigestion and disturbance of the nervous system (giddiness, trembling, increased heart rate, flushing and throbbing around the temples). He suggested that unexploded fragments of the nitroglycerine itself caused these continuing symptoms. He also noted that where the nitroglycerine burned and did not explode, or only partly exploded, poisoning was worse. He had seen a whole shift 'knocked out' in this way. He recommended better mine ventilation and that each workman should carry a vial of spirits of ammonia as an immediate restorative.[65]

Darlington's 1890 observations appear to have been astute and should have been an important warning for the mining industry that a potentially deadly, new component had been added to the composition of mine fumes. While Darlington did not identify nitrous fumes as the new culprit he clearly signaled that, even when nitroglycerine explosives functioned as intended by their makers and users, they produced in practice an additional fuming danger. The mining world appears to have missed Darlington's warning. For instance, the much-consulted *Manual of Mining* published in 1892 by M.C. Ihlseng, Professor of Engineering at the Colorado State School of Mines, stated that 'In ore-mines carbonic acid and sulphureted hydrogen are the only gases met with'.[66] Ihlseng quoted other mining experts to the effect that nitroglycerine's danger lay not in its combustion (which was said to produce only 'innocuous and inoffensive' gases) but in its tendency to explode in the process of transport.[67] Ihlseng's statements were surprisingly incorrect. Darlington's warning does not appear to have been heard in the USA, let alone as far away as Britain or Australia.

Understanding nitroglycerine's effects was complicated by the distinction between the effects of burning and exploding dynamite, gelignite or blasting gelatin. Nitroglycerine was designed to explode not burn, so burning nitroglycerine was unintended and highly dangerous. The burning danger should have been well known as it was first reported in the British literature in 1879 after a fatal accident during the construction of the Severn Tunnel.[68] Burning nitroglycerine produced potentially lethal nitrous fumes.

The Mt Charlotte disaster

The danger of burning nitroglycerine was forcibly demonstrated in the WA mining industry in 1897 when the accidental burning of dynamite killed six miners, one of the worst accidents in the industry's WA history. On 1 April 1897, miners were sinking the main shaft at Mt Charlotte (Kalgoorlie) goldmine. It was approaching midnight. At the 300ft level a box containing seven or eight detonator caps sat beside a candle box holding loose plugs of dynamite, and there Charlie Milson prepared the charges to send down in a bucket to John Rowe who was laying them at the bottom of the shaft 80ft below the level. For lighting, each miner had a candle held in a tin spider. Milson hooked his spider inside the box of dynamite in order to see what he was doing as he prepared each charge, but the candle fell into the dynamite sticks and set the paper in which they were wrapped on fire. Investigations established the 22½-23lbs of dynamite burnt and that probably 35lbs had been sent down to the level. This fire also caused the detonator caps to explode.[69] The miners rang for the cage to take them to the surface but then, fearing that the fire would trigger a dynamite explosion, instead raced up the 300ft ladderway. Several other miners working at the 200ft level joined them in the race to the top. Unfortunately, as Frank McAdam testified before he died, 'the smoke was following us up all the way'.[70] This smoke contained nitrous fumes from the burning nitroglycerine and these fumes poisoned the miners. John Rowe who had been working at the very bottom of the shaft was saved because he had to remain below until brought up in a bucket (in the comparatively fresh air of the down-cast compartment of the shaft) because he was working 80ft below the end of the ladderway.[71]

At the shaft head the men coughed, spat and lay exhausted. John Witchcraft, one of those who subsequently died, went off to find a bottle of brandy for everyone to have a drink before they returned to their camps, apparently having recovered. No doctor was alerted. When the underground manager, John Greenhall saw Charlie Milson back at his camp Milson said, 'Oh John, I wish I was dead', but Greenhall reassured him, 'there's nothing amiss; the men are all right'.[72] But they were not. No one understood that the symptoms of poisoning from nitrous fumes were delayed in their onset. Charlie Milson was the first to die, admitted to hospital at around 10.30 on the following morning and dying two hours later. The diagnosis was 'capillary bronchitis'. At this point the other miners, while ill, were 'expected to recover' although several were admitted to hospital at the insistence of one doctor.[73] John Murphy and Ken Wilson also died that following day with John Witchcraft dying on the day after and then James McGauchie on the day after that. Of those most severely affected and admitted to hospital only Frank McAdam remained alive. He was discharged 'cured' after a week but died of 'capillary bronchitis' a month after the accident.[74]

The inquest blamed Charlie Milson's carelessness for the accident and the Mines Department condemned the men for panicking and, by implication, causing their own deaths by racing up the ladderway and therefore staying in the path of the fumes. The Coroner questioned the adequacy of management control over the mine's operation during night shift, as well as the failure to call a doctor to attend the scene.[75] The Mines Department reported that management had failed to handle explosives safely (in accordance with regulations), allowing too large a quantity to be sent below and to be

improperly stored.[76] But neither the inquest nor the subsequent departmental investigation dealt explicitly with the particular threat from nitrous fumes. Yet the six miners' fatal illnesses were textbook cases. After exposure the miners felt ill and coughed violently, then apparently recovered only to be overtaken several hours later by shortness of breath, a worsening cough, followed by collapse leading to death from oedema of the lungs.

Burning nitroglycerine was a very serious mishap, a potential disaster, in mining. The Mt Charlotte disaster impressed this fact on miners and mine managers throughout the WA goldfields. The potential danger from the generation of fumes by exploding nitroglycerine was slower to be understood although Darlington had pointed the way a decade before. After all, detonating nitroglycerine explosives was at the core of the industry's success, so it is perhaps not surprising that it took some further time before the industry understood fully that nitrous fumes were part of the cocktail of gases generated by the regular explosions on which it depended.

Changes in understanding were incremental. For Thomas Oliver in 1905 nitrous fumes were produced only in a 'missfire' [sic].[77] By 1911, however, Edward Mann was in a position to explain that the hazard was not such an unusual exception.

> Nitroglycerine explosives do not produce the gases which, theoretically, should be the final resultant of their detonation, and which are comparatively harmless; … they … have fallen short of this ideal.[78]

South African and Western Australian research

It was in the first decade of the twentieth century (that is approximately 30 years after Nobel began production and marketing) that research findings were published on the ways in which nitroglycerine explosives 'fell short'; the ways in which 'imperfect' explosions produced poisonous fumes. The most important of these studies were those of Drs Donald Macaulay and Louis Irvine from the Witwatersrand.[79]

Macaulay and Irvine made clear that most mine poisonings from nitroglycerine explosives involved mixed gases – chiefly carbon dioxide, carbon monoxide and oxides of nitrogen. Nitrous fumes were, they warned, 'very common and frequently fatal'. And it was the imperfect explosion and partial burning of nitroglycerine explosives when carbon monoxide combined with oxides of nitrogen that created the greatest danger. Mann, in Western Australia, was on the same track as Macaulay and Irvine and found himself matching their findings as he read their published reports. He ascribed 'imperfect' explosions to several factors – the nature of the rock, the brands of explosives, including their wrappers, and the methods of firing.[80] In 1909-10 he officially collaborated with the Transvaal researchers to give more precision to the analysis of the gases released in explosions.

Mann extensively reported his own and Macaulay and Irvine's findings to the State mining industry.[81] He particularly stressed the 'insidious' effects of nitrous fumes, pointing out that 'miners' candles continued to burn brightly despite a build-up in nitrous fumes so men thought they were 'perfectly safe' and then, after initial recovery, they could not assume that they had in fact recovered.[82] The word 'insidious' to

describe the symptoms of poisoning from nitrous fumes was used repeatedly to warn against complacency. Britain's 1906 Samuel report noted 'the insidious onset of symptoms' where a worker walked away from his workplace apparently recovered only to collapse a day or two later with acute congestion of the lungs.[83] And, even if the fuming was not severe enough to be life threatening, Mann stressed, nitrous fumes often caused continuing weakness with headaches and lassitude.[84] He set out to get these messages to mine managements and miners themselves.

Macaulay and Irvine, and Mann, were as keen to promote effective treatment of these fumings as they were to explain the incidents. When unconscious, semi-conscious or distressed miners were brought to the shaft head after fumings, the most common initial response from workmates gathered around was to revive them with a shock soaking of cold water and then doses of whisky or brandy. Macaulay and Irvine insisted that these treatments, although they were 'venerable usages' with 'the authority of nearly every textbook', were wrong and should cease.[85] Both responses added to the body's shock. If alcohol continued to be administered, they warned, 'there is certain death in the bottle'.[86] Local WA goldfields doctors did endorse alcohol as an initial stimulant but also aromatic spirits of ammonia, *sal volatile*.

Macaulay and Irvine listed the practical steps to be taken immediately by mineworkers and management. The injured should be set down in a warm place and kept warm, no matter whether they appeared flushed or hot or clammy;[87] they should not be left lying at the shaft head until medical assistance arrived; and artificial respiration should be administered. Subsequently, Mann recommended Sylvester's Method and detailed it for the WA industry. The South African doctors also called for a suit of safety and therapeutic devices to be located and prominently signposted at every shaft head. *Sal volatile* as well as two oxygen cylinders plus masks should be available and used immediately. It was essential for the men to vomit, so a solution of sulphate of zinc should also be available and used immediately. For the rescue itself, individual mines should acquire safety helmets, respirators and smoke jackets. The date such equipment was first introduced into WA mines is not known, though photographs published in the report of the 1905 *WA Commission on the Ventilation and Sanitation of Mines*, show that the devices were being actively investigated at the beginning of the twentieth century (Figs. 1, 2 and 3). It was also recommended that a doctor should attend every case and the affected men kept under observation even if they had apparently recovered and wished to go home. Macaulay & Irvine were responding to their Witwatersrand experience where it was common for African ('native') miners who had been affected by fumes to return to their compounds only to be discovered dead the next day, the deaths being then registered simply as pneumonia.

Once the miner was removed to hospital, the medical profession had well-established treatments for coal gas poisonings, predominantly for carbon monoxide poisoning, and these were applied from the start on the goldfields: 'perfect rest in the recumbent position', then 'external application of warmth' and 'mustard plasters applied over the heart and around the ankles'.[88] 'Liberal' bloodletting should follow artificial respiration.[89] The South African mine doctors extended these accepted treatments. Ammonia should be given in repeated doses. Poulticing should follow wet

cupping of the chest. A 'jacket mustard-water fomentation, applied very hot and changed every hour' was recommended. And saline infusions could usefully accompany the bloodletting.[90] I do not know the extent to which these treatments were systematically or fully applied beyond the Witwatersrand although in WA they became well known and were therefore likely to have been widely tried. In Britain and Europe injections of ether and the administration of chloroform were also popular but the South African doctors did not support them.

By 1910-11 the work of these researchers and mining experts had clarified for the metal mining industry the nature and extent of the fuming hazard from nitroglycerine explosives as well as the appropriate safety and medical regimes to counter the hazard. This mining knowledge proved useful in World War I when in 1915 gassings became an instrument of warfare on the Western Front. As doctors scrambled to apply the latest and best treatments to the war casualties, those with experience in treating mine fuming patients were prominent in the professional discussion. In this context Dr Irvine reported in the *British Medical Journal* on the South African mining experience.[91] At the start of another war in 1939 a retired senior British Army Medical Corps officer, reviewing the state of medical knowledge on fumings from explosives, commented that the research findings of the early twentieth century still stood.

> Notwithstanding the colossal scale on which explosives were used during the [last] war, no epoch-making discoveries were made, and none have been made since.[92]

Conclusions

The definitive research findings of the early twentieth century researchers in the Transvaal, Western Australia, and elsewhere, answered the questions made urgent by the high incidence of fumings caused by nitroglycerin explosives. These answers lessened the risk for miners, reducing the numbers of major accidents and fatalities from this particular cause. Fumings became less frequent and less severe although they did not entirely disappear in the era of underground mining.

Subsequent clinical research has suggested that exposures to even low levels of fumes, if occurring over months or years, can have long-term adverse health outcomes, specifically in the development of an emphysema-like condition.[93] It is not possible for several reasons to know if these limited clinical findings applied to the mining workforce generally. The ubiquity of tobacco usage among miners in this period complicates the picture. More important, however, is the absence (in Western Australia at least and no doubt in other mining jurisdictions) of the epidemiological database needed to test the clinical indications. The very numerous fuming incidents of this period did not become fuming accidents and therefore did not enter the official record. Without these contemporary statistics the question must remain open. Partly hidden from public and official view, the full toll on miners' health of nitroglycerine fumes will never be completely known.

Endnotes

[1] E.A. Mann, *Gassing. The Cause and Prevention of the ill effects due to the Inhalation of Noxious Fumes by Miners*, West Australian Department of Mines, Office of the Chief Inspector of Explosives and Government Analyst, Bulletin no. 2, Perth, 1906, p. 8.
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[3] See, for instance, 'Poisoning by Carbonic Oxide [carbon monoxide]. The Snaefell Mining Disaster', *British Medical Journal*, 2, 1957, 2 July 1898, pp. 32-34.
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[15] J.C. Morrison, 'With the Underground Worker', *Western Mail*, 21 January 1911; reprinted *West Australian*, 13 October 1913.
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[17] *Ibid*., evidence of C.S. Mincham, p. 321.
[18] *Ibid*., evidence of F.H. Bowen, p. 352.
[19] *Ibid*., evidence of D. Morcom, p. 228; Finney, p. 237.
[20] *Ibid*., evidence of W. Finney, p. 237.
[21] Ibid., evidence of R.J. Coon, p. 227; J. Hosking, p. 232; H. Gordon, p. 234; A. Hansen, p. 235; J. Jack, p. 248; I. Fletcher, p. 258; A. Anstey, p. 281; A. Fairfull, p. 285.
[22] *Ibid*., evidence of I. Fletcher, p. 258
[23] *Ibid*., evidence of J. Hosking, p. 232.
[24] *Ibid*., evidence of E. Alcock, p. 284.
[25] *Ibid*., evidence of W. Jenkins, p. 257.
[26] *Ibid*., evidence of G. Bradshaw, p. 300.
[27] *Ibid*., evidence of W. Alderson, p. 300.
[28] *Ibid*., evidence of F.H. Bowen, p. 352.
[29] *Ibid*., evidence of J. Ford, p. 301.
[30] *Ibid*., evidence of H. Gordon, p. 234.
[31] *Ibid*., evidence of J. Dower, p. 340.
[32] *Ibid*., evidence of Dr J.A. Bissett, p. 469.
[33] This experience occurred at the Wheel of Fortune North GM. *ibid*., evidence of H. Gordon, p. 234.

[34] *Ibid*., evidence of T. Medlam, p. 320.
[35] *Ibid*., evidence of W. Finney, p. 238.
[36] *Ibid*., p. 237.
[37] *Ibid*., evidence of A. Fairfull, p. 285.
[38] *Ibid*., evidence of Dr D. Taylor, p. 242.
[39] *Ibid*., evidence of Dr D.F. Blanchard, p. 240.
[40] Drs F.L.P. Sawell, G.W. Barber, E.G.L. Erson, and H.O. Irwin had all practiced for some years in Kalgoorlie-Boulder.
[41] *Ibid*., evidence of Dr E.G.L. Erson, p. 483.
[42] *Ibid*., evidence of Dr B.S. Wills, p. 327.
[43] *Ibid*., evidence of Dr E.J.T. Crutchley, p. 359.
[44] *Ibid*., evidence of Dr T.P. McKell, p. 278.
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[48] *Ibid.,* 4 June 1901, p. 5; 22 July 1902, p. 42.
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[71] WAMD file 3196/98; *Western Argus*, 8 April 1897, p. 4.
[72] *Western Argus*, 8 April 1897, p. 13.
[73] *Western Mail*, 9 April 1897, p. 4.
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