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DUSTS NOT OTHERWISE SPECIFIED (DUST NOS) AND OCCUPATIONAL HEALTH ISSUES

Position Paper





PREPARED BY
AIOH Exposure Standards Committee
Update May 2014

AUTHORISATION
This position paper has been prepared by the AIOH Exposure Standards Committee and authorised by the AIOH Council.

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AUSTRALIAN INSTITUTE OF OCCUPATIONAL HYGIENISTS

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Australian Institute of Occupational Hygienists Inc (AIOH)

The Australian Institute of Occupational Hygienists Inc. (AIOH) is the association that represents professional occupational hygienists in Australia. Occupational hygiene is the science and art of anticipation, recognition, evaluation and control of hazards in the workplace and the environment. Occupational hygienists specialise in the assessment and control of:

- Chemical hazards (including dusts such as silica, carcinogens such as arsenic, fibrous dusts such as asbestos, gases such as chlorine, irritants such as ammonia and organic vapours such as petroleum hydrocarbons);
- Physical hazards (heat and cold, noise, vibration, ionising radiation, lasers, microwave radiation, radiofrequency radiation, ultra-violet light, visible light); and
- Biological hazards (bacteria, endotoxins, fungi, viruses, zoonoses).

Therefore the AIOH has a keen interest in the potential for workplace exposures to dusts, as its members are the professionals most likely to be asked to identify associated hazards and assess any exposure risks.

The Institute was formed in 1979 and incorporated in 1988. An elected governing Council, comprising the President, President Elect, Secretary, Treasurer and three Councillors, manages the affairs of the Institute. The AIOH is a member of the International Occupational Hygiene Association (IOHA).

The overall objective of the Institute is to help ensure that workplace health hazards are eliminated or controlled such that worker exposures are minimised. It seeks to achieve this by:

- Promoting the profession and principles of occupational hygiene in industry, government and the general community.
- Improving the practice of occupational hygiene and the knowledge, competence and standing of its practitioners.
- Providing a forum for the exchange of occupational hygiene information and ideas.
- Promoting the application of occupational hygiene principles to improve and maintain a safe and healthy working environment for all.
- Representing the profession nationally and internationally.

More information is available at our website – http://www.aioh.org.au.

Consultation with AIOH Members

AIOH activities are managed through committees drawn from hygienists nationally. This position paper has been prepared by the Exposure Standards Committee, with comments sought from AIOH members generally and active consultation with particular members selected for their known interest and/or expertise in this area. Various AIOH members were contributors in the development of this position paper. Key contributors included: Ian Firth and Alan Rogers.

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List of Abbreviations and Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AIOH	Australian Institute of Occupational Hygienists
ARRB	Australian Road Research Board
AS	Australian Standard
BEI	Biological exposure index
BHP	Broken Hill Proprietary
BOHS	British Occupational Hygiene Society
CEN	European Committee for Standardization
COAD	Chronic obstructive airways disease
COPD	Chronic obstructive pulmonary disease
COSHH	Control of substances hazardous to health
FEV_1	Forced expiratory volume in one second
GOLD	Global Initiative for Chronic Obstructive Lung Disease
g/m^3	grams per cubic metre
HSE	Health and Safety Executive (United Kingdom)
IARC	International Agency for Research into Cancer
IOM	Institute of Occupational Medicine
ISBN	International Standard Book Number
ISO	International Organization for Standardization
µm	microns or micrometres (10^{-6} m)
mg/m^3	milligrams (10^{-3} gm) per cubic metre
mL	millilitre (10^{-3} litre)
MAK	Maximum workplace concentrations (Germany)
MIRMgate	Minerals Industry Risk Management Gateway
mppcf	million particles per cubic foot
NEI	Not elsewhere included
NHMRC	National Health and Medical Research Council
NIOSH	National Institute for Occupational Safety and Health
NOAEL	No observed adverse effect level
NOHSC	National Occupational Health and Safety Commission
NOS	not otherwise specified
NSW	New South Wales
OEL	Occupational Exposure Limit
OH&S	occupational health & safety
PAPR	powered air purifying respirator
PDM	personal dust monitor
ppcc	particles per cubic centimetre
PPE	personal protective equipment
PVC	Poly vinyl chloride
SWA	Safe Work Australia
TLV	threshold limit value
TWA	time weighted average
UK	United Kingdom
USA	United States of America
WES	workplace exposure standard
WHO	World health organization

AIOH Position on Dusts Not Otherwise Specified (Dust NOS) and Occupational Health Issues

Summary

Dust exposures are the bane of many industries, none more so than the tunnelling, construction, mineral extraction and processing industries or those handling or working with dry powders. Low content crystalline silica mineral dust is the most common example of dusts not otherwise specified (Dust NOS), deriving from rock and soil and being ubiquitous, arising from vehicle traffic, drilling, blasting, crushing, grinding, screening and other such activities. Natural organic dusts free of harmful bacteria or biological toxins and synthetic organic dusts such as polymers may also fit into this classification.

Safe Work Australia (SWA, 2013b) *Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants* recommends that "*Where no specific exposure standard has been assigned and the substance is both of inherently low toxicity and free from toxic impurities, exposure to dusts should be maintained below 10 mg/m^3, measured as inhalable dust (8 hour TWA).*" While there are workplace exposure standards (WESs) for the various components of dust, such as respirable crystalline silica, and dusts and fumes containing toxins, such as lead, there are no specific WESs for inhalable and respirable substances that are insoluble or poorly soluble in water, of inherently low toxicity and free from toxic impurities, although most State jurisdictions do promulgate limit values for these.

The Safe Work Australia value of 10 mg/m^3 (inhalable dust) listed above was first introduced in 1990 and has not been subject to update or review since then. It is now somewhat out of date given the findings reported in contemporary published research papers covering the areas of animal testing, human epidemiological studies and regulatory movements overseas.

There are still information gaps for health aspects of dust of both inherently low toxicity and free from toxic impurities. However, workers may be susceptible to a number of dust-related respiratory diseases, including inflammatory reaction in the lung, when dust levels are excessive, resulting in chronic obstructive pulmonary disease (COPD) caused by both the respirable and inhalable dust fractions. Workers are certainly susceptible to irritation of the eyes, nose and throat, due primarily to high levels of the inhalable fraction of dust.

Due to a number of technical variables, including particle size distribution and surface area in the dust cloud, the AIOH thus recommends that two 'Dust NOS' trigger values (expressed as an 8-hour TWA) be adopted to protect workers from potentially serious health effects due to insoluble or poorly soluble (in water) dusts of inherently low toxicity (free from toxic impurities), for which there is no other listed applicable WES:

- 5 mg/m^3 for the inhalable fraction (measured using the Australian Standard method, AS 3640); and
- 1 mg/m^3 for the respirable fraction (measured using the Australian Standard method, AS 2985).

A trigger value is not an exposure standard but is considered a reasonably practicable criterion for implementing exposure controls. The term 'reasonably practicable' is defined by Safe Work Australia (2013d). If choosing to monitor only a single fraction of the dust due to factors such as discomfort and impedance of the worker, then such selection needs to be done on the basis of knowledge as to the fraction (inhalable or respirable) that is likely to have the greatest likelihood of exceeding the associated trigger value.

Available monitoring data from the Australian minerals industry indicates that controlling dust levels below the above trigger values may not always be achievable. While respirable dust levels may be more readily controlled below 2.5 mg/m^3, in some specific operations inhalable dust levels have been found to be higher than 10 mg/m^3, particularly in underground operations, and are often much higher than respirable dust levels. In this instance the sampling of the inhalable fraction would take precedence.

The fact that dust exposures are above the recommended trigger values indicates that controlling such dust is no simple matter. This paper therefore references practical control measures that can be implemented to aid in achieving conformance with the recommended trigger values above; reducing exposures so far as is reasonably practical. Where suitable controls cannot be readily implemented to adequately reduce exposures, an effective respiratory protection program should be implemented.

What is ‘Dust NOS’?

Dust usually comprises solid particles formed by crushing or other mechanical forces on a parent material, which are generally greater than 0.5 microns (µm) in particle size (Pickford *et al*, 2013). According to the International Organization for Standardization (ISO 4225: 1994), dust is "*small solid particles, conventionally taken as those particles below 75 µm in diameter, which settle out under their own weight but which may remain suspended for some time*". According to the *Glossary of Atmospheric Chemistry Terms* (Calvert, 1990), dust is "*Small, dry, solid particles projected into the air by natural forces, such as wind, volcanic eruption, and by mechanical or man-made processes such as crushing, grinding, milling, drilling, demolition, shovelling, conveying, screening, bagging, and sweeping. Dust particles are usually in the size range from about 1 to 100 µm in diameter, and they settle slowly under the influence of gravity*." For the purposes of this paper, we are considering dust derived from such workplace processes or tasks as vehicle traffic, blasting, crushing, grinding, milling, drilling, demolition, shovelling, conveying, screening, bagging, sweeping, sieving, riffling, calcining, drying and handling of dry finely divided materials (eg. powders), or working with objects that have surfaces contaminated with such dusts. These are often associated with mineral dust exposures in the tunnelling, mineral extraction and processing industries, as well as in agriculture and some chemical manufacturing and shaping processes involving polymers.

The focus of this paper is on the prevention of health effects due to respirable and inhalable ‘Dust NOS’, which is insoluble or poorly soluble in water, of inherently low toxicity and free from toxic impurities, and does not have a listed applicable workplace exposure standard (WES). The American Conference of Governmental Industrial Hygienists (ACGIH, 2013) define low toxicity particles as being “*not cytotoxic, genotoxic, or otherwise chemically reactive with lung tissue, and do not emit ionizing radiation, cause immune sensitisation, or cause toxic effects other than by inflammation or the mechanism of ‘lung overload’*.”

To classify dusts as being ‘free from toxic materials’ requires analysis of the dusts to determine that such toxics are less than the prescribed level. There are other papers in this series that deal with some dusts that fall outside this classification of ‘free from toxic materials’, such as respirable crystalline silica, asbestos and dusts and fumes containing toxins such as lead. It should be noted that Safe Work Australia has listed a number of dusts that have a WES based on the original ACGIH® general ‘Nuisance Particulates’ limit of 10 mg/m^3 for total dust. These include: aluminium (metal dust & oxide); barium sulphate; calcium carbonate (limestone & marble); calcium silicate; calcium sulphate (gypsum & plaster of Paris); cellulose (paper fibre); diatomaceous earth (uncalcined); emery (dust); kaolin; magnesite; magnesium oxide (fume); pentaerythritol; perlite dust; Portland cement; rouge dust; silica gel; silicon; silicon carbide; starch; and titanium dioxide.

How do we measure it?

The most likely route of uptake of dust to cause a health effect is via inhalation. Air monitoring using a gravimetric sampler is thus the common method for measuring personal exposures to ‘Dust NOS’. Pickford *et al* (2013) provide detail on sampling for dust and other aerosols.

The hazard posed by dust is often a function of particle size, although the recent review by Cherrie *et al* (2013) indicates that particle surface area per unit volume may be better related to lung inflammatory effects and subsequent loss in lung function. At this stage in time there is no suitable instrument by which to measure personal dust exposures in terms of surface area in the practical world of work environments. As such the occupational hygienist is in part restricted to the use of a particle size selective sampling device. The International Organization for Standardisation (ISO 7708: 1995) and the European Standardisation Committee (CEN, EN481: 1993) have defined three criteria for biologically-relevant size-selective aerosol sampling, primarily for studies of workers exposed to hazardous dust in industrial situations: respirable dust; thoracic dust and total inhalable dust. Wherever possible, the current ISO/CEN definitions for these criteria should be adhered to.

Gravimetric sampling using personal samplers as per the requirements of Australian Standards, AS 3640 and AS 2985, is recommended and in some instances mandated. These two Australian standards for sampling and gravimetric determination of inhalable and respirable dust, respectively, are consistent with the current ISO/CEN definitions. The thoracic fraction is currently seldom determined and there are few exposure limits incorporating it.

In situations where monitoring for respirable crystalline silica is being undertaken, it is relatively easy to extend the investigation to include monitoring for the respirable mass (mg/m^3) by recording the pre and post sampling weight of the collection filter.

Real time direct reading and data logging monitoring instruments may also be an alternative for investigative purposes of identifying dust sources and checking the efficacy of engineering controls. Such direct reading instruments should be calibrated against a primary dust standard (eg. Arizona road dust).

Hazards associated with dust

Besides a reduction in visibility (with potential safety implications), dust in air can result in contamination in the nose and in the tubes leading to the lungs (ie. inhalable dust), which often causes physical discomfort and irritation (runny nose, sneezing, watering eyes, coughing), in turn causing rhinitis or bronchitis.

Not all of the dust that is breathed in will get into the lungs. The larger particles (up to 100 µm) are filtered out in the nose and the tubes leading to the lungs (the bronchi and bronchioles). These particles are coughed up, spat out or swallowed. The larger dust particles that are trapped in the upper airways are termed ‘inhalable’ dust (which when measured includes the respirable fraction).

The particles that can enter deep into the lungs are called ‘respirable’ and ‘thoracic’ dust. These particles are normally too fine to see unless specific lighting conditions exist. The thoracic fraction (less than 25 µm, 10 µm median cut point) is the mass fraction that penetrates beyond the larynx. The respirable fraction (less than 10 µm, 4.0 µm median cut point) is the mass of inhaled particles penetrating to the non-ciliated, smallest, airways of the lung (the gas exchange region).

Much of the dust that gets into the lungs is cleared out by the lung's own defence system; macrophage cells ingest particulates (which includes dusts) and then carry them out of the lungs. Proteins in the lungs can also 'neutralise' some particulates. This mechanism can be overwhelmed by large amounts of dust and some dusts, crystalline silica for instance, damage macrophages.

With the advent of modern diagnostic techniques there is increasing evidence that long-term exposure to many dusts previously considered inert can contribute to chronic obstructive airways disease (COAD), or chronic obstructive pulmonary disease (COPD), as discussed in more detail in the 'Risk of Health Effects' section. The term COPD encompasses the diseases chronic bronchitis and emphysema, which are characterized by the lung airways becoming narrowed, leading to limitation of lung airflow and shortness of breath (dyspnoea).

Major uses / potential for exposure (in Australia)

Highest exposures to dust are likely to be associated with tunnelling and underground mining activities, although high dust concentrations can also be associated with surface mining operations, particularly around haul roads and crushing and screening activities. Construction activities, agriculture and some manufacturing processes (eg. carbon black, pottery), particularly for those that handle or work with dry powders, can also contribute to high dust exposures.

While there is a considerable amount of data for respirable dust exposure, inhalable and thoracic exposures have not been as well characterised. Also, most dust exposure data linked to risk of COPD is available from the mining industry, particularly for coal mining. Coal dust has its own specific WES and hence is not considered as a 'Dust NOS'. However it provides a good example of exposure conditions that are likely to exist in other mining and quarrying operations.

Tunnel construction workers, shotcreting operators, tunnel boring machine workers and shaft drilling workers can frequently exceed current total dust (22-57%) and respirable dust (7-57%) exposure standards (Bakke *et al*, 2002). Average respirable dust levels have been determined as being 1.5, 1.9 and 2.1 mg/m^3 in Australian underground coal mines[1] (highest in Queensland), and less than or equal to 0.6 mg/m^3 in surface coal mines (Bofinger *et al*, 1996; Kizil & Donoghue, 2002; Cliff & Kizil, 2002). Longwall coal miners are among the highest respirable dust exposure groups, with 6.9 to 15.6% of samples exceeding 3 mg/m^3 (Kizil & Donoghue, 2002; Cliff & Kizil, 2002). About 1.6% of other underground coal miners and 0.8% of coal workers in surface operations have been found to exceed the 3 mg/m^3 respirable coal limit (Cram, 2003). Average respirable dust exposures for BHP Billiton Illawarra Coal operations ranged between 0.1 to 0.9 mg/m^3, while inhalable dust average exposures ranged from 0.3 to 16 mg/m^3 (McFadden & Davies, 2004). For longwall mining in general, face workers (shearer operators, chock operators and general face workers) tend to have higher dust exposures than workers who spend less time at the face (Kizil & Donoghue, 2002; Cliff & Kizil, 2002). Inhalable dust levels in coal mines have been found to be higher than 10 mg/m^3, and on average much higher than respirable dust levels, with an average ratio respirable to inhalable of 0.12, ranging from 0.04 to 0.33 (McFadden & Davies, 2004).

Glossop (2005) found the ratio of respirable to inhalable to be often 0.1 or less in Australian open-cut mining and processing plants (4 different types of mines and ores). As the level of dust increased, the ratio of respirable to inhalable dropped, that is the inhalable fraction became more dominant and the rate determining contaminant. Okamoto *et al* (1998) measured respirable and inhalable dust concentrations in 1644 dusty workplaces, finding the same phenomenon. Statistical analyses showed that the respirable to inhalable ratio varied substantially, depending on the type of work, being smaller at lower inhalable dust concentrations. The ratio was highest in welding workplaces and lowest in foundries, the ratio ranging from 0.03 to 0.44 for inhalable concentrations ranging from 2 to 10 mg/m^3. Jennings and Flahive (2005) concluded for coal mining, that inhalable dust concentrations can be very high and cannot be predicted from respirable dust measurements. The Institute of Occupational Medicine (IOM) experience (and other published values) suggests that inhalable dust concentrations are usually 2 to 5 times respirable concentrations. The relationship between inhalable and respirable dust concentrations will depend on the size distribution of the aerosol, which reflects the physical properties of the parent material and the manner in which it is broken down to dust size particles.

Risk of health effects

The generic group 'Dusts NOS' is in part defined as containing substances associated with the observation of a long history indicating little adverse effect when under reasonable control. Thus the information on health effects is not very extensive and usually limited to subtle changes in lung function associated with long term exposures. Dusts that have been found to be associated with more extensive health outcomes have been historically removed and given their own specific WES. The observation of such slight but ongoing changes in lung function is often difficult to detect against the background rate of such disease associated with population ageing and other environmental agents such as tobacco smoking and airborne allergens. Some recent well designed epidemiological studies that include the effect of confounders allow the observation of such changes in lung function in working populations.

The lung's clearance mechanism can be overloaded by excessive respirable dust resulting in compromised clearance of dust in the lung and cellular inflammation, leading eventually to airways disease. A relation between occupational exposure to dust and loss of ventilatory lung function (measured for example by the forced expiratory volume in one second (FEV_1)) is well established.

[1] Note that there are many published examples of coal dust concentrations in mines, hence their use as examples of exposure potential in this paper. There are specific WESs assigned for coal dust exposures.

Coal Dust:

Although coal is not considered a 'Dust NOS', the effects of coal dust inhalation demonstrate the potential for exposure to other forms of 'Dust NOS' to lead to various health effects. Wang *et al* (1999) found that several variables of the coal mine environment were associated with excess decline in FEV_1, including work in roof bolting, exposure to explosive blasting, and to control dust spraying water that had been stored in holding tanks. They also found that use of respiratory protection appeared to reduce the risk of decline in FEV_1.

An IOM report on coalminers, found that 35 years exposure to 4 mg/m^3 respirable dust could lead to 17% of non-smoking workers experiencing an FEV_1 loss of almost a litre, compared with 10% in a non-dust exposed population (Cowie *et al*, 1999).

A report for the UK Health and Safety Executive (HSE) (Miller *et al*, 2006) has shown that risks of respiratory ill health (eg. decline in FEV_1) in relation to cumulative dust exposure calculated for underground coalminers are reasonable predictors of risks in other dust exposed populations. They found that while there were no associations between lung function levels and time in dusty jobs for opencast workers, there was a significant association between levels of FEV_1 and cumulative exposure to respirable dust for coal, talc and PVC workers.

Periodic health screening and the results of epidemiology studies in the NSW coal mining industry indicate adherence to current maximum exposure levels for dust is sufficient to maintain a healthy industry workforce (Cram *et al*., 2005). In a review of relevant literature Jennings and Flahive (2005), also considering air sampling data from NSW coal mines, found that while there was good evidence behind the NSW respirable coal dust standard, there was insufficient evidence for assessing the effects of inhalable coal dust.

With regard to coal dust and cancer, Jennings and Flahive (2005) found limited reports of cancer in the upper airways (larynx, pharynx, buccal cavity) for coal miners, and while these reports were few in number there was no significant research identifying a causal relationship. As it is, IARC (1997) has determined that there is insufficient evidence to classify coal dust as a carcinogen.

Crystalline Silica Dust:

Crystalline silica, like coal, has a specific WES and provides another example of the subtle effects on lung function that were historically masked by the overriding effects of silicosis due to long term high dust exposures. Evidence suggests that chronic levels of silica-containing mineral dust that do not cause disabling silicosis may cause the development of chronic bronchitis, emphysema, and/or small airways disease that can lead to airflow obstruction, even in the absence of radiological silicosis (Hnizdo & Vallyathan, 2003).

Glossop (2005) noted the absence of new cases of silicosis and that the only cases of respiratory disease now being recorded in Western Australia's MINEHEALTH (health surveillance) program are for COPD. While most of the COPD is probably mainly associated with tobacco smoking, there is likely to be some disease from exposure to mineral dust.

Longitudinal studies documenting the association between COPD and occupational exposures have been performed in coal miners, hard-rock miners, tunnel workers, concrete-manufacturing workers, a cohort of non-mining industrial workers, and several community-based populations. Most of these studies reported an annual decline in FEV_1 due to occupational exposures (after adjustment for age and smoking) of 7 to 8 mL/year. In heavily exposed workers, the effect of dust exposure may be greater than that of tobacco smoking alone (Balmes *et al*, 2003). The American Thoracic Society has concluded that occupational exposures account for 10-20% of either symptoms or functional impairment consistent with COPD (Balmes *et al*, 2003).

Other Low-Toxicity Dusts:

The prevalence of COPD is appreciably higher in smokers and ex-smokers than in non-smokers, in those over 40 years than those under 40, and in men than in women (GOLD, 2011). Although smoking is the best-studied COPD risk factor, it is not the only one and there is consistent evidence from epidemiologic studies that non-smokers may develop chronic airflow obstruction. There is also a contribution due to exposure to organic and inorganic dusts, chemical agents and fumes, and due to genetic risk factors (GOLD, 2011).

Epidemiological studies in other dust producing industries such as PVC polymer production, carbon black manufacture and refractory ceramic fibre manufacture have reported slight loss in respiratory function and increased reporting of respiratory symptoms such as cough and sputum production associated with long-term increased dust exposures.

Cherrie *et al* (2013) consider that the epidemiological and toxicological evidence gathered over the past 20 or more years suggests that COPD or other lung injury may occur at levels of long-term exposure below present day trigger values for low-toxicity dusts (10 and 4 mg/m^3 for inhalable and respirable dust respectively, in Britain).

It can be concluded that while there are still information gaps for health aspects of insoluble or poorly soluble (in water) dust of inherently low toxicity and free from toxic impurities, workers may be susceptible to a number of dust related respiratory diseases, and are certainly susceptible to irritation of the eyes, nose and throat.

Available controls

If controlling dust was a simple matter, dust problems in the tunnelling, mineral extraction and processing industries would have been solved some time ago. Most underground dust control methods yield only 25% to 50% reductions in respirable-sized dust, which may not be enough to achieve compliance with dust standards. However, using the hierarchy of controls, occupational exposure to dusts can be controlled by:

- Process control – Control of the mining process itself in mineral extraction and processing provides good examples of process methods used to control dust generation. For example, if the speed of rotation of cutting drums of a continuous coal miner is reduced and then the tram speed is increased, dust generation can be reduced without losses in productivity. In longwall mining, dust generation can be reduced by cutting coal in one pass (rather than two) across the face and tramming back without cutting or by a clean-up cut (Armstrong & Menon, 1997). Remote controlled mining equipment, which removes the operator from the hazardous environment, is also becoming a reality.
- Efficient ventilation – Areas with activities likely to generate harmful dust-in-air concentrations should be enclosed if practicable, and well ventilated (exhaust ventilation). An alternative to source containment and ventilation is worker enclosure; eg. provide cabs on vehicles or enclosed control rooms with filtered / pressurised / air-conditioned air supply. Where ventilation systems are installed, these systems should be maintained in good working order and should be operated in the correct manner to provide optimum protection from dust/mist/fume exposure. Note that ventilation for underground mining is a special case, often regulated by local legislation and often under different jurisdictions for coal and metalliferous mines.
- Containment of dusts and the solids that generate these. Some mines, particularly in the USA, use a stilling shed (roof and 3 sides enclosed) for containment of dust from primary crusher dump points.
- Suppression of dusts – The use of water as a mist / spray to reduce dust is widely practiced; eg. on haul roads, at dump points (eg. primary crusher), on drills, etc. Water may also be used as a cover (eg. on tailings). Surfactants may facilitate the efficacy of water as a dust suppressant (Olson & Veith, 1987; Foley *et al*, 1996).
- Good housekeeping - The maintenance of a high standard of housekeeping will minimise exposure to dust. Methods of wet cleaning (eg. hosing) should be used where practicable.
- Provision and sensible use of personal protective equipment (PPE) – Half-face respirators and/or PAPR helmets fitted with P1 particulate filters, when worn correctly, will normally provide adequate protection against dust exposures. Full-face respirators fitted with a P2 particulate filter or an air-line may be required for some extremely dusty jobs. In all cases the respiratory protection program should follow the requirements of AS/NZS 1715, "*Selection, Use and Maintenance of Respiratory Protection Devices*".
- Administrative controls - A reduction of level and duration of exposure of employees to dusts may be achieved by work organisation and limits on overtime. The principle of periodic rotation of employees both through and in areas with potentially harmful dust exposures is an acceptable practice; this should be restricted however, only to plant trained employees.
- Inspection and maintenance routines for engineering controls, and periodic formal review of the practicality of engineering controls, are essential administrative controls. The periodicity of these activities will vary according to the health risk associated with the hazard being controlled and the functionality of the control being used.
- The provision of regular education and training, the conduct of workplace and employee in-air monitoring, and health surveillance of employees may also be considered a part of the controls for mitigating dust exposures to non-harmful levels. PPE should be used as a last resort, where other control measures have been unsuccessful.

The 'erosiveness' or dusting potential of an unpaved road is dependent on a number of road and traffic related factors (Thompson & Visser, 2002), providing a number of points of control for road dust:

- Wind speed at the road surface – wind sheer is especially important – lower vehicles with many wheels tend to cause more dust;
- Number of vehicles using the road, or traffic volume;
- Particle size distribution of the wearing course;
- Restraint of road fines – related to compaction of the road surface, cohesiveness and bonding of the surface material and durability of the material;
- The amount of imported fines (spillage) on the road; and
- Climate – in particular, humidity, number of days with rain, mean daily evaporation rates and the prevailing wind speed and direction.

The following documents provide good advice on control of dust in the workplace:

- Hazard Prevention and Control in the Work Environment: Airborne Dust, WHO/SDE/OEH/99.14, available from http://www.who.int/occupational_health/publications/airdust/en/.
- Handbook for Dust Control in Mining. NIOSH Information Circular 9465, available from http://www.cdc.gov/niosh/mining/works/coversheet1041.html.
- The European Network for Silica Good Practice Guide, providing task sheets that provide a set of detailed technical recommendations to reduce exposure in specific industrial settings, available from http://www.nepsi.eu/agreement-good-practice-guide/good-practice-guide.aspx.

- Keeping Coal Miners Healthy at Work: An Occupational Hygiene Manual for the Coal Mining Industry. 3rd Revision - Edited by J Henderson. Coal Services Health & Safety Trust, available from http://www.hstrust.com.au/MessageForceWebsite/Sites/326/Files/20545_Keeping_Coal_Miners_Healthy_At_Work_Rev3.pdf.
- Dust Control Handbook for Industrial Minerals Mining and Processing. NIOSH Report of Investigations 9689, available from http://www.cdc.gov/niosh/mining/works/coversheet1765.html.

History of applicable legislation and exposure standards

The first schedule of Australian national exposure standards (NHMRC, 1958) provided a scale of values for siliceous dusts depending on the "Free silica" content, with a value of 700 ppcc (particles per cubic centimetre of air, based on counts with the Owen's Jet Dust Counter) being listed for the lowest category (1% to 10%) of crystalline silica.

The revised schedule of 1964 added "Mineral Dusts N.E.I." (not elsewhere included) with a value of 700 ppcc of air 'based on counts with the Owens Jet Dust Counter' (NHMRC, 1964). In 1970 and 1975, booklets listing "*Atmospheric Contaminants*" were distributed (NHMRC, 1970 & 1975). The 1970 booklet listed a respirable gravimetric value for siliceous dust based on the following formula; "*Recommended value = 25/(% Respirable free silica + 5) milligram/cubic metre*", and for "*Inert or 'nuisance' dusts the total dust concentration of the atmosphere breathed should not significantly exceed 15 milligrams of dust per cubic metre of air*". The 1975 booklet reduced the value of "*inert or nuisance dusts*" to 10 milligrams of dust per cubic metre of air (the term 'inert or nuisance dusts' was not defined, although committee members would have been aware of the definition of 'Inert or Nuisance Particulates' by the ACGIH since 1965 and the listing of examples in Appendix D in the 1968 TLV listings). The sampling basis for the NHMRC value was a horizontal elutriator as the primary sampler to determine the comparative performance of secondary size selectors such as the miniature cyclone.

In 1977 the listing was simplified as 'Nuisance dusts', "*the average concentration of the air breathed should not exceed 10 milligrams of dust per cubic metre of air*" (NHMRC, 1977).

In 1980 there was a shift in approach after the publication of the 1979 ACGIH TLV list for most substances, with an additional listing for 'substances for which different values are used in Australia' (NHMRC, 1980). As such, the formula method for determining the value for crystalline silica dusts was changed to a set respirable quartz value of 0.2 mg/m^3. However the Australian value for nuisance dusts was omitted and hence could be considered as defaulting to the ACGIH value of "Nuisance Particulates 30 mppcf (million particles per cubic foot) or 10 mg/m^3 of total dust <1% quartz, or, 5 mg/m^3 respirable dust". Following submissions from a number of Australian occupational hygienists the NHMRC added the statement "it is also believed that an upper limit of 5 mg/m^3 of 'respirable' dust, where respirable silica does not exceed 0.2 mg/m^3, is reasonable from a comfort viewpoint" (NHMRC, 1982). This value and statements continued in 1983 and was republished but not necessarily endorsed by the then new federal body, the National Occupational Health and Safety Commission (NOHSC), "*in the interests of providing significant information in occupational health and safety*" (NHMRC, 1983; NOHSC, 1986).

It was not until five years after the formation of the NOHSC that an updated exposure standard list was published (NOHSC, 1990a) and a further five years until amendments were added (NOHSC, 1995a). In both instances the value for 'Dusts Not Otherwise Classified' was listed as '*10 mg/m^3 measured as inspirable dust'* (now termed inhalable dust). This considerable delay in updating the exposure standards was in the main due to the difficulties experienced in arriving at a consensus decision on each listed substance via the complicated multi-layered tripartite committee-decision making system that had been implemented under the NOHSC legislation.

Current applicable legislation and exposure standards

In all Australian, UK, USA, and many other country jurisdictions, it is management's legal responsibility under various OH&S legislation to identify and control workplace dust exposure issues; to ensure that workplace dust concentrations are safe and without risk to the health and safety of employees, as far as "reasonably practicable", which was broadly interpreted in part as maintaining exposures to less than the occupational exposure standard.

The Safe Work Australia (2013a) publication "Workplace Exposure Standards for Airborne Contaminants" does not contain a WES for inhalable or respirable dust NOS. However, their published "Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants" (SWA, 2013b) states that "*Where no specific exposure standard has been assigned and the substance is both of inherently low toxicity and free from toxic impurities, exposure to dusts should be maintained below 10 mg/m^3, measured as inhalable dust (8 hour TWA).*" The rationale for selection of this value was not provided in the early Australian documentation (NOHSC, 1990b, 1995b, 1996b), but according to NOHSC committee members present at that time it was adopted from the ACGIH® Time Weighted Average (TWA) guidance value of 10 mg/m^3 measured as total dust (ACGIH, 1990) without adjustment for the then recently introduced ISO/CEN dust penetration/deposition definition.

While in the past there was a respirable 'general' dust standard of 5 mg/m^3, no such standard now exists in Australian exposure standards (SWA, 2013c), although various State regulators still retain a respirable dust standard varying between 2.5 and 5 mg/m^3.

For example, in NSW mines the specified limit for respirable dust, other than quartz-containing dust, is 2.5mg/m^3 (17 December 2004 NSW Government Gazette Notice).

The ACGIH® (2013) believes that even biologically inert, insoluble, or poorly soluble particles may have adverse effects and suggests that airborne concentrations should be kept below 3 mg/m^3 for respirable particles, and 10 mg/m^3 for inhalable particles, until such time as a TLV® is set for a particular substance. For the ACGIH®, non-specific dust limits date back to 1952, and the original criteria seem to have been visibility and comfort. The 10 and 5 values were introduced in 1971, and a summary of their criteria given in the TLV® documentation is that they are applicable:

- For substances with long history of little adverse effect when under reasonable control;
- Characteristics of lung-tissue reaction from inhalation:
    - Architecture of air spaces remains intact
    - No significant collagen (scar tissue) formed
    - Tissue reaction is potentially reversible;
- High levels may reduce visibility, cause unpleasant deposits in the eyes, ears and nose or injure the skin or mucous membranes.

The UK HSE "*The Coal Mines (Control of Inhalable Dust) Regulations 2007"* specifies an exposure limit of 3 mg/m^3 for respirable coal dust (HSE, 2012). However, within the UK, the legislative background is that the definition in COSHH Reg 2 of a substance hazardous to health contains two catch-all provisions. A substance which is not covered by any other part of the definition is regulated by COSHH if it is a dust present at more than 10 mg/m^3 inhalable or 4 mg/m^3 respirable (both 8-hr TWA), or if it is a substance which "*because of its chemical or toxicological properties and the way it is used or is present in the workplace creates a risk to health*". The 10 and 4 values are not occupational exposure limits in the normal sense, but trigger concentrations above which the regulations apply. They were derived from ACGIH TLVs® of 10 and 5 mg/m^3, but they were changed to 10 and 4 in the UK in 1997 to maintain the same level of control when the CEN definition of respirable was adopted.

The MAK Commission in Germany has adopted a respirable "General Dust Threshold Limit Value" for "granular biopersistent dusts" of 0.3 mg/m^3 for a substance density of 1 g/cm^3 (the limit is online at http://onlinelibrary.wiley.com/doi/10.1002/3527600418.mbe0230fst/full). It presumably reflects the belief that effects on lung function for this sort of dust are related to the volume of dust inhaled rather than the mass. It seems that the intention is that if a dust has a density of "A" g/cm^3, then 0.3 mg/m^3 would then be multiplied by "A" to give a respirable limit in mg/m^3. This would equate to the same volume of dust as 0.3 mg/m^3 of a substance of density 1 g/cm^3. It would give, for example, limits of about 0.6mg/m^3 for graphite, 0.7 mg/m^3 for bauxite, 0.8 mg/m^3 for many silicates, 1.2 mg/m^3 for titanium dioxide, and 1.7 mg/m^3 for haematite, all respirable. The limit "*is intended to prevent inflammation due to impaired clearance mechanisms and hence exclude an elevated risk of lung cancer, pulmonary fibrosis and chronic inflammatory disease due to particulate matter of low toxicity*."

The introduction and implementation of respirable dust exposure standards has resulted in considerable reduction in the fibrosis-causing diseases associated with pneumoconiosis. However in so doing this, it has allowed the observation that after adjustment for the confounding of ageing and tobacco smoking, the more subtle airways diseases may be associated with long-term exposure to dusts at a level less than the values used to control fibrosis. There is no evidence that adherence to a respirable mineral dust standard alone would necessarily protect against adverse health effects from inhalable size particles of mineral dust, although a reduction in the exposure to respirable dust would be associated with a subsequent reduction in inhalable dust levels and associated risk.

Cowie *et al* (1999) noted that a reduction in the average coal dust concentration from 2 mg/m^3 to 1 mg/m^3 would be associated, over a 35-year working lifetime, with a 2.5% reduction in the prevalence of small FEV_1 deficits in both non-smokers and current smokers; prevalence of large deficits would be reduced by around 1.5% among non-smokers and 2% among current smokers.

Jennings and Flahive (2005) suggest that at present, the application of a default inhalable dust standard of 10 mg/m^3 in the coal industry may provide some protection against eye, nose and throat irritation and potentially lower respiratory tract effects.

Various research carried out at the Institute of Occupational Medicine (IOM, 2011) have succeeded in developing a mathematical model of the quantitative toxic effects of inhaled dusts including coal dust, silica and chemically inert dusts. These studies demonstrated that surface area is a major determinant of the toxicity of inhaled chemically inert dusts, and suggest that if there is a threshold for adverse effects it may be lower than the current limit values. Their estimate of the no adverse effect level (the NOAEL) for titanium dioxide, based on avoiding the impairment of dust clearance and the beginning of inflammation, was estimated as 1.3 mg/m^3, very similar to the German MAK value.

IOM (2011) considers that the current UK "*limit values for respirable and inhalable dust (4 and 10 mg/m^3, respectively) are unsafe and it would be prudent to reduce exposures as far below these limits as is reasonably practicable*." Until safe limits are put in place, IOM advises that employers should aim to keep exposure to respirable dust below 1 mg/m^3 respirable and inhalable dust below 5 mg/m^3.

This is a position supported by a number of senior occupational hygienists with considerable experience in dusty industries as well as researchers (Cherrie *et al*, 2013).

Note also that current ACGIH TLV's for some of the Safe Work Australia listed dusts with WES's based on the original ACGIH® general limit of 10 mg/m^3 for total dust are now much lower. For instance: aluminium (metal & insoluble compounds) – 1 mg/m^3 as respirable dust; kaolin – 2 mg/m^3 as respirable dust; and Portland cement – 1 mg/m^3 as respirable dust.

AIOH recommendation

Based on the available information, the AIOH recommends that two 'Dust NOS' trigger values (expressed as an 8-hour TWA) be adopted to protect workers from potentially serious health effects due to insoluble or poorly soluble in water dusts of inherently low toxicity (free from toxic impurities), for which there is no other listed applicable WES:

- 5 mg/m^3 for the inhalable fraction; and
- 1 mg/m^3 for the respirable fraction,

as measured using the Australian standard methods, AS 3640 and AS 2985, respectively.

These trigger values have been selected to protect against lung overload and subsequent inflammation associated with exposure to a large number of dusts for which there are currently no WES values. A trigger value is not an exposure standard but is considered a reasonably practicable criterion for implementing exposure controls. The term 'reasonably practicable' is defined by Safe Work Australia (2013d).

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