# SUPERSEDED: Interpretation of Workplace exposure standards for airborne contaminants

Guidance

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# 1. Introduction

This Guide provides advice on the application of workplace exposure standards for airborne contaminants (exposure standards) in the workplace. It should be read in conjunction with Safe Work Australia's *Workplace Exposure Standards for Airborne Contaminants*, which is available at: https://www.safeworkaustralia.gov.au/doc/workplace-exposure-standards-airborne-contaminants-2024

That document contains a complete list of all agreed exposure standards that are mandatory under the Work Health and Safety (WHS) Regulations, as well as critical information relating to their interpretation.

Exposure standards are also available from the Hazardous Chemicals Information System (HCIS) online database, which can be accessed from the Safe Work Australia website or at https://hcis.safeworkaustralia.gov.au/

## 1.1 Exposure to chemicals in the workplace

Exposure to substances or mixtures in the workplace can occur through inhalation, absorption through the skin or ingestion. Most exposure occurs through the inhalation of vapours, dusts, fumes or gases. For some chemicals, absorption through the skin may also be a significant source of exposure.

The response of the body from exposure to substances and mixtures depends on the nature of the substance, the health effects it can cause and the amount of the substance or mixture absorbed by the body. Individuals also have differing abilities to metabolise chemicals which can cause considerable variation in the toxic effects between people. The extent to which a person is exposed depends on the concentration of the substance or mixture in the air, the amount of time exposed and the effectiveness of controls. Substances and mixtures may cause immediate acute health effects or it may be decades before effects on the body become evident.

Exposure standards have been established in Australia for approximately 700 substances and mixtures. However, there are many other substances and mixtures hazardous to human health and used in workplaces that do not have a mandatory exposure standard established. Exposure standards are updated occasionally and may not always reflect the latest research or state of knowledge on the hazardous effects of chemicals. Exposure standards do not identify a dividing line between a healthy or unhealthy working environment. Natural biological variation and the range of individual susceptibilities mean some people might experience adverse health effects below the exposure standard. Therefore, exposure standards should not be considered as representing an acceptable level of exposure to workers. They establish a statutory maximum upper limit.

All reasonably practicable steps must be taken to eliminate or minimise exposure to a level well below the exposure standard. Sections 17 and 19 of the WHS Act require that the risks posed by exposure to substances in the workplace are eliminated or kept as low as is reasonably practicable.

For this reason, it is important the airborne concentration of a substance or mixture hazardous to health is kept as low as is reasonably practicable to minimise the risk to health, regardless of whether or not there is an exposure standard or what the value of the exposure standard is.

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Where there is no mandatory exposure standard established in Australia, other established exposure standards or action levels should be used by a PCBU to assist minimising exposure to chemicals.

Exposure measurement must not be used as an alternative to controlling exposure by putting in place hazard controls. Air monitoring is best done after control measures have been put in place.

Compliance with the WHS legislation will require being able to demonstrate all reasonably practicable hazard controls are in place and effective and that attempts have been made to eliminate or minimise exposure, as well as not exceeding the relevant exposure standard.

Exposure standards are not designed to be applied to situations outside of a workplace or to the exposure of people, like bystanders or nearby residents, not directly engaged in the work involving the hazardous chemical. However, the WHS Act also requires a PCBU to minimise risk to third parties. This is regardless of whether an exposure standard has been established or not. The primary focus should always be on eliminating or, if this is not possible, minimising exposure through use of hazard controls.

A person conducting a business or undertaking must manage the risks associated with using, handling and storing hazardous chemicals at a workplace. The Code of practice: *Managing Risks of Hazardous Chemicals in the Workplace* provides guidance on a four step risk management approach involving the key steps of hazard identification, risk assessment, risk control and review.

Information about the hazards of a chemical should be available from the label or Safety Data Sheet (SDS) for most substances or mixtures.

## 1.2 What are the duties relating to airborne contaminants in the workplace?

There are specific requirements to manage risks rising from exposure to chemicals under the WHS Regulations, including those associated with exposure standards, airborne contaminants and asbestos.

Some of the major duties are outlined below.

| Who | Duties | Provisions |
|---|---|---|
| A person who conducts a business or undertaking | ensure, so far as is reasonably practicable, workers and other people are not exposed to health and safety risks arising from the business or undertaking. | WHS Act<br>s 19 |
| | eliminate health and safety risks so far as is reasonably practicable, and if this is not reasonably practicable, minimise those risks so far as is reasonably practicable. | |
| | manage risks under the WHS Regulations, including those associated with using, handling and storing hazardous chemicals safely, airborne contaminants and asbestos. | WHS Regulations<br>r 48 |
| | ensure that no person at the workplace is exposed to a substance or mixture in an airborne concentration that exceeds the exposure standard for the substance or mixture. | WHS Regulations<br>r 49 |

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| Who | Duties | Provisions |
|---|---|---|
| | • ensure that air monitoring is carried out to determine the airborne concentration of a substance or mixture at the workplace to which an exposure standard applies if:<br>o the person is not certain on reasonable grounds whether or not the airborne concentration of the substance or mixture at the workplace exceeds the relevant exposure standard, or<br>o monitoring is necessary to determine whether there is a risk to health.<br>• ensure that the results of air monitoring carried out above are:<br>o recorded, and kept for 30 years after the date the record is made, and<br>o readily accessible to persons at the workplace who may be exposed to the substance or mixture. | WHS Regulations<br>r 50 |
| | • ensure that:<br>o exposure of a person at the workplace to airborne asbestos is eliminated so far as is reasonably practicable, and<br>o if it not reasonably practicable to eliminate exposure to airborne asbestos—exposure is minimised so far as is reasonably practicable.<br>• ensure that the exposure standard for asbestos is not exceeded at the workplace.<br>Note This is not required in an area that is enclosed to prevent the release of respirable asbestos fibres and negative pressure is used in accordance with Regulation 477. | WHS Regulations<br>r 420 |

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## 1.3 Other reasons to measure airborne contaminants and asbestos

In addition to the requirements of Regulation 50 that a PCBU must ensure air monitoring is carried out if it is not certain whether or not the concentration of an airborne contaminant exceeds the relevant exposure standard or to determine whether there is a risk to health, air monitoring can also be used for a number of other reasons including:

- helping to choose the best exposure minimisation controls
- checking existing controls are working effectively
- choosing the right level of respiratory or personal protective equipment if other controls do not eliminate or sufficiently minimise exposure

- checking exposure levels after a process or production method has changed
- determining whether health monitoring for workers is required
- investigating complaints by workers
- determining workers that have been or are being exposed to hazardous chemicals
- complying with advice or a direction or notice of improvement issued by a regulator or occupational hygienist.

The WHS Regulations have specific requirements relating to the risk of exposure to airborne asbestos. For further information, see the Code of practice: *How to Safely Remove Asbestos*.

## 1.4 What are exposure standards?

Exposure standard means an exposure standard listed in the *Workplace Exposure Standards for Airborne Contaminants* and represents the airborne concentration of a particular substance or mixture that must not be exceeded.

There are three types of exposure standard:

8-hour time-weighted average (TWA)

short term exposure limit (STEL).

peak limitation

### 8-hour Time Weighted Average Exposure Standard

An eight-hour time-weighted average exposure standards is the average airborne concentration of a particular substance permitted over an eight-hour working day and a 5-day working week. These are the most common types of exposure standards.

Note: 8-Hour TWA exposure standards may require adjustment where work shifts exceed 8 hours or for greater than a 5-day working week. See Chapter 4 of this Guide for advice on how this can be done.

It is preferable to keep exposure limits continually below the 8-hour TWA exposure standard. However, during periods of continuous daily exposure to an airborne contaminant, the 8-hour TWA exposure standard allows short term excursions above the exposure standard provided they are compensated for by extended periods of exposure below the standard during the working day.

In practice, the actual concentration of an airborne contaminant arising from a particular process may fluctuate significantly with time. Even where the TWA exposure standard is not exceeded, excursions over the 8-hour TWA exposure standard should be controlled. A process is not considered to be under reasonable control

[1,2] if short term exposures exceed three times the TWA exposure standard for more than a total of 30 minutes per eight-hour working day, or if a single short term value exceeds five times the 8-hour TWA exposure standard.

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## Short Term Exposure Limit (STEL)

A short term exposure limit is the time-weighted maximum average airborne concentration of a particular substance permitted over a 15 minute period.

Some substances or mixtures can cause intolerable irritation or other acute effects upon brief exposure, although the primary toxic effects may occur with long term exposure through accumulation of the substance or mixture in the body or through gradual health impairment with repeated exposures.

The STEL provides limits only for the control of short term exposure. STELs are important supplements to the eight-hour TWA exposure standards which are more concerned with the total intake over long periods of time. Generally, STELs are established to minimise the risk of:

- intolerable irritation
- irreversible tissue change
- narcosis to an extent that could precipitate workplace incidents

STELs are recommended where there is evidence that adverse health effects can be caused by high short term exposure.

A STEL should not be exceeded at any time during a working day even if the eight-hour TWA average is within the TWA exposure standard. Exposures at the STEL should not be longer than 15 minutes and not be repeated more than four times per day. There should be at least 60 minutes between successive exposures at the STEL.

## Peak Limitation

Peak limitation exposure standards are a maximum or peak airborne concentration of a particular substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

For some rapidly acting substances and mixtures the averaging of the airborne concentration over an eight-hour period is not appropriate. These substances may induce acute effects after relatively brief exposure to high concentrations, so the exposure standard for these substances represents a maximum or peak concentration to which workers may be exposed.

A Peak limitation exposure standard must not be exceeded at any time.

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## 1.5 Units for exposure standards

The airborne concentrations of gases, vapours and particulate contaminants are expressed gravimetrically as milligrams of substance per cubic metre of air, ($mg/m^3$). For gases and vapours the concentration is usually indicated in parts per million (ppm) by volume. Where both gravimetric and volumetric values are quoted, the volumetric (ppm) value is exact as its value is not affected by changes in temperature or pressure and should be used as the common means of reference to the exposure standard.

As the gravimetric units of $mg/m^3$ are affected by temperature and pressure variations, all exposure standards are expressed relative to standard conditions of 25ºC and 1 atmosphere pressure (101.3 kPa)*.

The following conversion formula is used to convert from ppm to $mg/m^3$:

$$Concentration\ in\ mg\ /\ m^3 = \frac{molecular\ weight\ \times concentration\ in\ ppm}{24.4}$$

Where 24.4 is the standard molar volume in litres at 25°C and 101.3 kPa.

Definitions of terms used in this Guide are included in Appendix A.

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* *Editorial Note: Health and Safety Executive sourced Exposure Standards are based upon a conversion temperature of 20°C. For these substances the molar volume is 24.05526.*

# 2. Complying with exposure standards

## 2.1 How air monitoring is conducted

To conduct an effective air monitoring program requires training, specialist knowledge and a high level of competency and experience. Interpretation of the results of air monitoring and decisions about whether or not a workplace is complying with exposure standards can be complex. A sound understanding of the nature of contaminant concentrations in the workplace, the statistics relevant to their measurement and the interpretation of measurement results is required. Engaging the services of an expert in air monitoring, like a qualified occupational hygienist, to design, perform and interpret the results of a suitable air monitoring program, may be needed to determine compliance with exposure standards.

If a consultant is engaged to assess compliance with an exposure standard or the effectiveness of hazard controls, it is recommended to ask to see evidence of his or her qualifications, experience and competence. Sampling can be carried out by another competent person, under supervision of an occupational hygienist.

The Australian Institute of Occupational Hygienists (www.aioh.org.au) can be contacted to help find a qualified occupational hygienist who may be able to help.

To get the most effective information, air monitoring should be arranged on a day when normal processing activities are taking place. An air monitoring program will usually last for a day, but can take longer if a variety of work processes need examining and, depending on the extent of monitoring required, the nature of the processes and the type of laboratory analyses required.

## 2.2 What will a consultant do?

The consultant will use their expertise and judgement to work out an air monitoring strategy and advise how many workers, and in what areas, will be surveyed and over what period of time.

Exposure measurements should be made from unbiased and representative samples of actual worker exposure. The monitoring program should also address issues like the nature and duration of a process, sampling and analysis errors, statistical analysis of exposure data and the determination of the need for regular exposure measurement.

Detailed routine monitoring strategies for airborne contaminants are complex and a complete discussion of the theory and characteristics is beyond the scope of this Guide. However, further information is available in *Monitoring Strategies for Toxic Substances*[3]*, Occupational Exposure Sampling Strategy Manual*[4] and *A Strategy for Assessing and Managing Occupational Exposures*[5]. Further information on air monitoring is available in the following references[6,7, 8,9,10].

Where monitoring of airborne contaminants is used to estimate a worker's exposure compared to the exposure standard, the monitoring must be conducted in the breathing zone of the person, also known as 'personal monitoring'. If respiratory protective equipment (RPE) must be worn, air monitoring samples should be taken outside the RPE. Breathing zone samples are usually obtained by fastening a sampling device, like a special meter or collection tubes to a shirt or jacket lapel. Air sampling often involves drawing air through a device and a sampling pump may also be required to be worn.

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Air samples taken at fixed locations in the working environment, also known as ‘static samples’, do not provide personal exposure information and their use should be limited to tasks like assessing the effectiveness of process hazard control measures. In some cases, fixed continuous monitors can be used to give early warning of leaks or other contaminating sources which could subsequently lead to worker exposures above the exposure standard. Analysis of samples taken in the workplace should be carried out by a NATA-accredited laboratory. The National Association of Testing Authorities (NATA) accredits laboratories and regularly carries out reaccreditation audits of the laboratories. A list of accredited laboratories is available from the NATA web site (www.nata.com.au).

## 2.3 Determining compliance

Air monitoring must be carried out if is not certain on reasonable grounds whether or not the level of airborne contaminant exceeds the relevant exposure standard; or it is necessary to determine whether there is a risk to health. Where it has been determined that air monitoring is required, it should be conducted after exposure controls have been put in place**.** In many cases, compliance with the regulations can be achieved through the application of basic, well-known exposure controls.

Expert judgement and advice may be required to determine if compliance with the regulations for exposure standards is being achieved. Where air monitoring is required, it is often necessary to conduct a number of exposure measurements, often involving multiple workers. Compliance can be demonstrated only when the exposure of individual workers or groups of workers is known, with an accepted degree of certainty, to be below the exposure standard.

Where it has been determined that RPE must be worn to minimise the risk of exposure to (an) airborne contaminant(s), the protection provided by the RPE can be taken into account when determining compliance with an exposure standard, provided all other reasonably practicable higher order controls in the hierarchy of control measures have been implemented, and the RPE is worn correctly.

The hierarchy of control measures ranks ways to control risks from the highest level of protection and reliability to the lowest (Figure 1). Further guidance on the hierarchy of control

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measures can be found in the *model Code of Practice: How to manage work health and safety risks*.

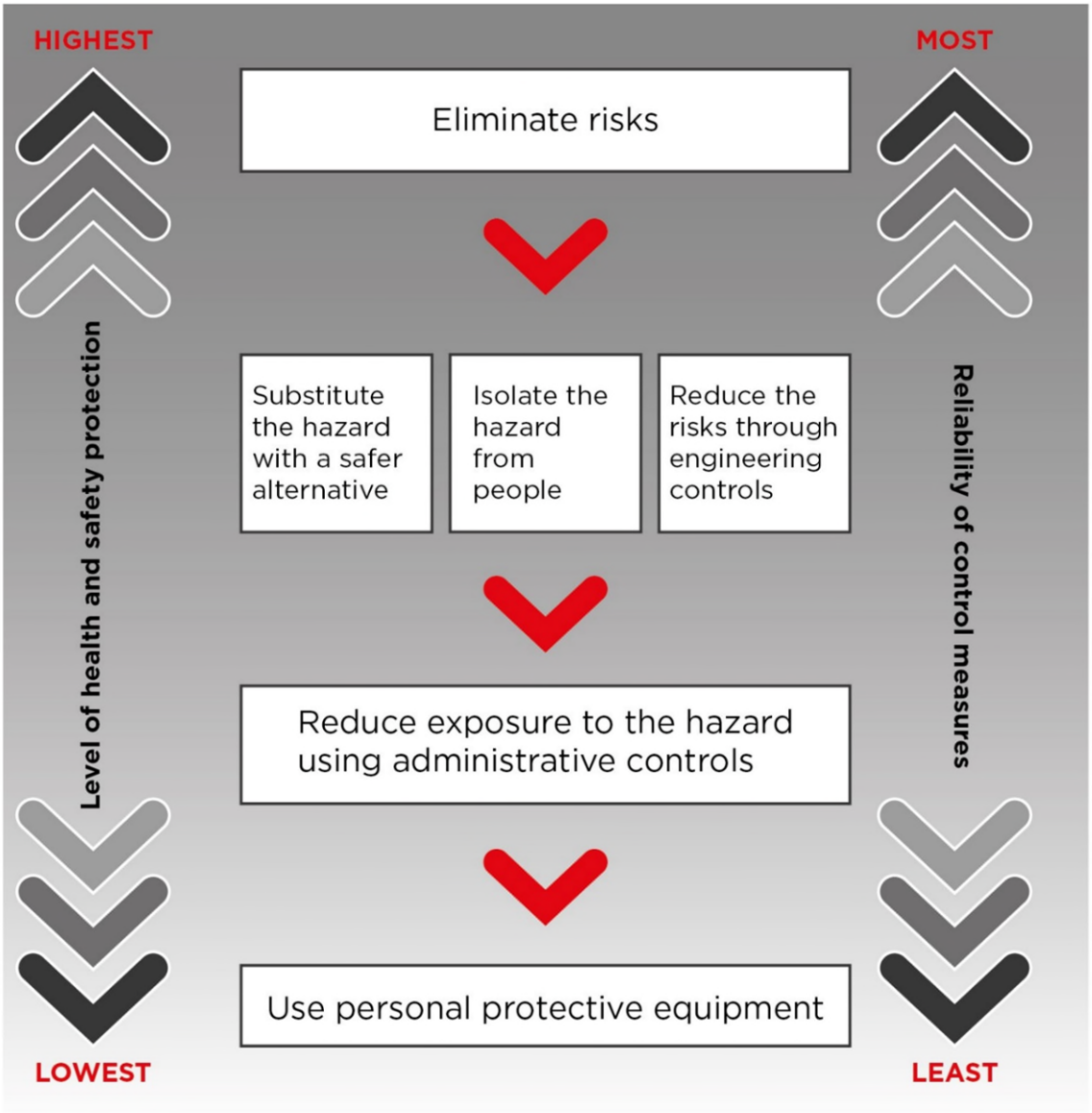


**Figure 1 The hierarchy of control measures**

If safety concerns have been raised or an inspector has determined air monitoring is required, negotiation may be required with the regulator and workers about what extent of monitoring is required.

## 2.4 Qualitative tools and methods for estimating exposure

Mathematical models can sometimes be used to estimate airborne contaminant levels in the workplace. However, as parameters like the source of chemical generation, airflow rates of ventilation and extraction systems and limitations of the model must be understood, use of this type of exposure modelling to predict the potential for worker exposure should only be carried out by an occupational hygienist or other suitably qualified person. For example, the

software “IH Mod”[11] provides several mathematical models in Excel spreadsheets that can be used to calculate airborne concentrations of chemicals.

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Air flow measurements and smoke tubes can be effectively used to review performance of ventilation systems to aid in ensuring compliance. Other tools, for example dust lamps, may enable particle clouds that are invisible in normal lighting conditions to be seen and also give an indication of the effectiveness of ventilation systems in controlling airborne contaminants.

## 2.5 What should an air monitoring report contain?

A detailed written report should be provided and may contain information on several of the following areas, including:

- the background and purpose of the air monitoring program
- the process(es) evaluated, the work patterns and the workers and hazards involved
- the control measures in place and how they are performing
- photographs and diagrams, where necessary
- what measurements were taken and how sampling was carried out
- how and where samples were analysed, what method was used and the test results, including the 8-hour time weighted average concentrations calculated
- an interpretation of the test results and comparisons with exposure standards
- an opinion on compliance and what the results mean – has, or is, the exposure standard likely to be exceeded?
- an opinion on the risks to workers
- advice on relevant industry practice and known effective control measures
- recommendations for hazard control improvements to reduce exposure or further monitoring that may be required.

## 2.6 Health monitoring

The assessment of the airborne concentration of a particular contaminant and the subsequent comparison with the appropriate exposure standard(s) is usually the primary technique in the evaluation of the working environment. For some hazardous chemicals, health monitoring may also be required to assess risks to workers who may be exposed. Health monitoring, which may include biological monitoring, takes into account all routes of exposure and not just exposure by inhalation of airborne contaminants. Guidance on health monitoring can be found in the following documents, available from the Safe Work Australia website at www.swa.gov.au.

- *Health monitoring for exposure to hazardous chemicals – Guide for workers*
- *Health monitoring for exposure to hazardous chemicals – Guide for persons conducting a business or undertaking*
- *Health monitoring for exposure to hazardous chemicals – Guide for medical practitioners*
- *Hazardous chemicals requiring health monitoring*

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# 3. Adjustment of exposure standards for extended work shifts

Some exposure standards need to be adjusted to account for greater exposure that occurs during extended work shifts and to comply with the WHS Regulations.

## 3.1 Adjustment of 8-hour Time Weighted Average exposure standards for extended work shifts

An 8-hour TWA exposure standard is based on exposure that occurs in an 8-hour working day, 5-day working week. Where workers have a working day longer than eight hours, a working week longer than 40 hours or work shift rotations in excess of either 8 hours a day or 40 hours a week, the TWA exposure standard may need to be adjusted to compensate for the greater exposure during the longer work shift and the decreased recovery time between shifts.

## 3.2 Substances assigned Peak Limitation or Short Term Exposure Limit (STEL) values

Peak limitation or STEL exposure standards must not be adjusted because the adverse effects due to acute over-exposure are already accounted for.

## 3.3 Short exposure periods or shifts

8-Hour TWA exposure standards must not be adjusted upwards for shorter exposure periods or work shifts (for example, exposure to 8 times the TWA for one hour and zero exposure for the remainder of the shift). This is because the health effects from high exposures for short periods may not be fully understood.

Where short exposure periods or shifts are encountered, the general excursion limitations described in Chapter 1 apply.

## 3.4 Models for adjusting 8-Hour TWA exposure standards

Several mathematical models can be used for adjusting exposure standards for extended work shifts. These models include the 'Brief and Scala Model'[12], the US 'Occupational Safety and Health Administration (OSHA) Model'[13], the 'Pharmacokinetic Model' of Hickey and Reist[14], and the Quebec Model[15]. All models provide valid methods for adjusting exposure standards. The main difference is the degree of conservatism. Selection of a model will depend on the information available and the expertise of the person applying it. In some jurisdictions specific guidance is also provided by regulators, for example, the Simtars Model in the Queensland Mining Industry[16] and the WA Mining Industry Model[17].

Methods for adjusting the 8-hour TWA exposure standard are discussed in Appendix B of this Guide.

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The use of adjustment models other than the Brief and Scala model should only be done by an appropriately qualified health and safety professional as the use of other models requires a sound understanding of the toxicology and pharmacokinetics of the substance as well as the rationale for setting the exposure standard.

Exposure standard values do not set the distinction between safe and unsafe exposures and therefore the application of precise adjustments is not appropriate.

Where an exposure standard is set close to an analytical limit of detection there may be difficulties in measuring exposure and demonstrating compliance with the WHS Regulations if an exposure standard is adjusted downwards.

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# 4. Other factors affecting exposure

Exposure standards relate to exposure via the inhalation of substances or mixtures in the air. Other factors can affect the level of exposure of a substance or mixture, or affect the overall health effect that occurs because of exposure.

The hazards and risks associated with other types of exposure (ingestion, absorption, and injection) must also be managed. For more information on managing risks from other types of exposure, refer to the Code of practice: *Managing Risks of Hazardous Chemicals in the Workplace*, in addition to the label and SDS.

## 4.1 Workload considerations

Exposure standards have been established on an eight-hour exposure timeframe, during work of normal intensity, under normal climatic conditions and where there is a sixteen-hour period between shifts to permit elimination of absorbed contaminants.

It is important to note that the conditions under which a person is exposed to a chemical can increase the amount of the chemical that the person absorbs and increase the risk. For example, people who are exposed during strenuous activity breathe more heavily and can absorb more of the chemical[18]. The individual characteristics of the worker, heart rate, respiration rate, diet, and whether they are a smoker can also be factors that increase the risks for workers. These factors need to be considered when assessing risks to workers who may be exposed.

## 4.2 Skin absorption

The main route of entry into the body is via inhalation however certain substances like aniline, nitrobenzene, phenols and certain pesticides can readily penetrate the intact skin and be absorbed into the body. Frequently there will be no accompanying skin damage and in some instances, dermal absorption can pose a far greater danger than inhalation exposure.

Exposure Standards only consider absorption via inhalation and are valid only on the condition significant skin absorption does not occur. In some cases, special measures may be required to prevent absorption through the skin. Substances requiring such precautions are specified by the notation ‘Sk’ in column (5) of table 1 in the *Workplace Exposure Standards for Airborne Contaminants*.

Skin absorption can result from a splash onto skin or clothing, or, in rare cases, from exposure to very high concentrations of vapour or fume. In addition, some substance carriers, like solvents, can accelerate or alter the rate of skin absorption. Serious effects can result with little or no warning and it is necessary to take special precautions to prevent skin contact when handling these substances.

Where skin absorption is significant and biological monitoring methods are available for assessing an individual’s uptake or response to such substances, the necessity to undertake biological monitoring in addition to an air monitoring program should be considered.

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## 4.3 Exposure to mixtures of substances – combined effects

Exposure standards are usually applicable to airborne concentrations of single pure substances. In practice, however, a working environment may contain a number of airborne contaminants and exposure to these additional substances, either simultaneously or sequentially, could give rise to an increased hazard to health.

The application of exposure standards to environments containing mixtures of contaminants requires considerable caution. The interaction of different substances should be assessed by toxicologists, occupational hygienists or physicians after specific toxicological consideration of all substances involved.

### Independent effects

Where there is clear toxicological evidence to indicate two or more contaminants have totally distinct effects on the body, then each substance may be separately evaluated against its appropriate exposure standard. For example, since crystalline silica affects the lungs, and inhaled ethanol vapour acts upon the liver and central nervous system, each of these substances may be assessed individually against its appropriate exposure standard. If neither standard is exceeded, the atmosphere within the working environment is deemed to be satisfactory.

### Additive effects

When the body is exposed to two or more contaminants, an additive effect is obtained when contaminants have the same target organ or the same mechanism of action. In this situation,

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the total effect upon the body equals the sum of effects from the individual substances. For substances which are purely additive, conformity with the standard results when:

$$\frac{C_1}{L_1} + \frac{C_2}{L_2} + \ldots + \frac{C_n}{L_n} \leq 1 \quad (1)$$

Where $C_1$, $C_2$ .. $C_n$ are the average measured airborne concentrations of the particular substances 1, 2 .. n and $L_1$, $L_2$ .. $L_n$ are the appropriate exposure standards for the individual substances.

**Example 1:** Consider an atmosphere containing:

- 35 ppm toluene (exposure standard 50 ppm),
- 25 ppm xylene (exposure standard 80 ppm), and
- 20 ppm 1,1,1-trichloroethane (exposure standard 100 ppm).

As all of these substances act primarily on the central nervous system, equation (1) can be applied. The resultant aggregate effect is:

$$\frac{35}{50} + \frac{25}{80} + \frac{20}{100} = 1.2125$$

Since the sum of the contribution from each substance exceeds one, the exposure standard for the airborne mixture is exceeded.

When assessing the hazard from a mixture of airborne contaminants, it is important to identify and quantify all components in the airborne mixture. A number of factors, such as particle size, distribution or solvent vapour pressure, can give rise to substantial variations between the concentration of each component in the parent mixture and that which occurs in air.

Although an example of an additive effect is the general effect of organic solvents on the central nervous system (narcotic or anaesthetic effect), the exposure standards for a number of solvents, like benzene and carbon tetrachloride, have been assigned on the basis of effects other than those on the central nervous system. Therefore, it is essential to refer to the documentation for the specific substances to ascertain the basis of the standard and potential interactions.

## Synergism and potentiation

Sometimes the combined effect of multiple exposures is considerably greater than the sum of the effects from the individual components. This phenomenon can be one of synergism or potentiation.

Synergism occurs when two or more substances or mixtures have an effect individually and where the total effect is greater than the additive effect. Potentiation is where a substance or mixture enhances the effect of another substance or mixture, or a biochemical or physiological effect, for example exposure to ototoxins, can result in damage to hearing or balance functions of the inner ear.

An example of a synergistic effect is the combined effect of solvents like n-hexane and methyl ethyl ketone (MEK) on the nervous system[19,20]. In combination, the damage caused

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by simultaneous high concentrations of both these solvents is far greater than the sum of either of these substances acting alone.

Interaction can also arise from exposures via routes other than inhalation. For example, ingested alcohol increases the narcotic effects of inhaled trichloroethylene. Interaction effects may also occur in connection with exposure to entirely different environmental factors like simultaneous exposure to chemical agents and physical factors, like light, heat and noise. Smoking tobacco is known to have a synergistic effect in combination with, for example, inhaled particulates including asbestos.

## 4.4 Odour thresholds

Many substances have a distinctive odour which indicates the presence of the substance in the environment. While a large number of odour thresholds have been determined[21,22], there are a number of problems associated with their use. These problems include:

- the threshold of odour perception varies over many orders of magnitude between individuals and among different substances
- the presence or absence of an odour may bear no relationship to the harmful biological effects of the substance
- there may be interference from other substances
- a strongly pronounced odour which is observed on initial contact with the substance may completely disappear on repeated or continued exposure or fluctuation of the concentration.

For these reasons, odour thresholds should be treated with caution. The absence of an odour may not indicate a ‘safe’ environment; conversely, the presence of an odour may not indicate a hazard to health.

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# 5. Information relating to specific groups of substances

This chapter provides information on specific substances or mixtures, or specific hazard types. It includes a number of substances that do not have an exposure standard set, but for which guidance values are provided, for example carcinogens, asphyxiants and nuisance dusts.

## 5.1 Carcinogens

Unlike most chronic toxic effects, which usually manifest during the period of exposure, a carcinogenic effect may take many years from the initiating event to a clinical diagnosis of cancer. A diagnosis of cancer may not be made until long after cessation of exposure.

The incidence of cancer is usually dose related ─ the greater the exposure to the carcinogen, the higher the risk of developing the cancer associated with that substance or mixture. Conversely, the smaller the exposure, the lower the probability of developing cancer. Because of the limitations of both epidemiological and animal studies at very low dosage, a “no effect” level of exposure cannot be confidently identified for carcinogenic substances at the present time. Although some carcinogens may have practical thresholds[23], exposure to carcinogens should be eliminated or minimised so far as is reasonably practicable.

Under the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), substances may be allocated one of two categories of carcinogenicity based on the strength of evidence and additional considerations (weight of evidence)[24]:

- Category 1 – Known or presumed human carcinogens
- Category 2 – Suspected human carcinogens.

Category 1 carcinogens are further divided into:

- Category 1A – Known to have carcinogenic potential for humans
- Category 1B – Presumed to have carcinogenic potential for humans.

### Category 1A – Known to have carcinogenic potential for humans

Substances known to have carcinogenic potential for humans are substances for which there is sufficient evidence to establish a relationship between human exposure to these substances and the development of cancer. In these cases, where the substitution of less hazardous materials is technically not possible, the use of the carcinogenic substances should be controlled to the highest practicable standard by the application of effective engineering controls and, where necessary, complemented by the use of appropriate personal protective equipment. Routine monitoring of the workplace is essential to ensure controls are adequate.

### Category 1B – Presumed to have carcinogenic potential for humans

Substances presumed to have carcinogenic potential for humans are those substances where there is sufficient evidence to establish a causal relationship between human exposure to a substance and the development of cancer. This evidence is generally based

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on appropriate long term animal studies, limited epidemiological evidence or other relevant information.

These substances should be treated as if they are carcinogenic to humans. Where substitution of less hazardous materials is not possible, exposure to these substances should be minimised to the lowest practicable level. This can be achieved through effective engineering controls, sound work practices and the use of personal protective equipment. A program of routine air monitoring should be implemented to ensure controls and work practices are effective in minimising exposure. In some cases, health monitoring may also be necessary.

### Category 2– Suspected human carcinogens

Suspected human carcinogens are those substances which have possible carcinogenic effects on humans but the available information is not sufficiently convincing to place the substance in Category 1.

As these substances may be found to be carcinogenic in light of future research, they should be used with caution. Exposures should be eliminated so far as is reasonably practicable and if it is not reasonably practicable to eliminate exposure ─ exposure is minimised so far as is reasonably practicable and in no cases should the exposure standard be exceeded.

Further information on substances or mixtures which have been identified as known or presumed human carcinogens or suspected human carcinogens is available on http://esis.jrc.ec.europa.eu/index.php?PGM=cla

## 5.2 Sensitisers

Some substances such as wood dust, toluene diisocyanate (TDI) and formaldehyde can cause a specific immune response in some people. These substances are called sensitisers and the development of a specific immune response is termed ‘sensitisation’. Exposure to a sensitiser, once sensitisation has occurred, may manifest itself as a skin rash or inflammation or as an asthmatic condition, and in some individuals this reaction can be extremely severe.

After sensitisation occurs, an affected individual may react to very small exposures to the substance. Although low values have been assigned to strong sensitising agents, compliance with the recommended exposure standard may not provide adequate protection for a hypersensitive individual[25,26]. Persons who are sensitised to a particular substance should not be further exposed to that substance.

Substances which are known to act as sensitisers are designated by the notation ‘Sen’. Such a designation indicates caution should be exercised where exposure to these substances can occur.

## 5.3 Ototoxic chemicals

Exposure to some chemicals can result in hearing loss. These chemicals are known as ototoxic substances. Hearing loss is more likely to occur if a worker is exposed to both noise and ototoxic substances than if exposure is just to noise or ototoxic substances alone.

Substances that have been found to have potential ototoxic effects in the workplace include[27] toluene, xylene, n-hexane, organic tin, carbon disulphide, styrene, carbon

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monoxide, organic lead, organophosphate pesticides, lead, manganese, hydrogen cyanide and mercury. Some of these substances can be absorbed through the skin.

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The Code of practice: *Managing Noise and Preventing Hearing Loss at Work* recommends hearing is monitored with regular audiometric testing in situations where workers are exposed to:

- ototoxic substances where the airborne exposure (without regard to respiratory protection worn) is greater than 50 per cent of the workplace exposure standard for the substance, regardless of the noise level
- ototoxic substances at any level and noise with $L_{Aeq,8h}$ greater than 80 dB(A) or $L_{C,peak}$ greater than 135 dB(C)

Work activities where noise and ototoxins are often present include painting, printing, boat building, construction, furniture making, manufacture of metal, leather and petroleum products, fuelling vehicles and aircraft, fire fighting and weapons firing.

## 5.4 Neurotoxins

Neurotoxins are substances that damage or destroy the tissues of the nervous system, especially neurons, the conducting cells of the body's central nervous system. The parts of the nervous system affected include the grey matter, myelin, and the dendrites or axons.

Neurotoxicity can be acute or chronic but the effects are often irreversible. Acute effects occur after a high exposure to a neurotoxin and are rapidly reversible once exposure stops. Chronic effects follow repeated low level exposures and are due to the degeneration of components in the structure of the nervous system.

Symptoms of neurotoxicity include dizziness, euphoria, impaired coordination, sleep disorders, and dementia. Examples of substances that are neurotoxins are lead, mercury, benzene and toluene.

## 5.5 Irritants

An irritant can affect the eyes, mucous membranes or skin. Some irritants may affect more than one part of the body. For example, glutaraldehyde is an irritant to the respiratory tract, skin and eyes. Where an exposure standard has been established on the basis of irritation effects, a Peak limitation exposure standard usually applies. Common irritants with a Peak limitation exposure standard include acetic anhydride, n-butyl alcohol, chlorine, ethyl acrylate, glutaraldehyde, and ozone.

## 5.6 Systemic toxicity

Systemic toxicity is the effect of a substance on the body tissues after absorption into the bloodstream. The effects can be either acute or chronic. Exposure to systemic toxicants can occur via inhalation, absorption through the skin or ingestion. A substance may have more than one health effect and may cause both acute and chronic effects. For example exposure to alcohol can cause intoxication (acute) or cirrhosis of the liver (chronic).

## 5.7 Ocular effects

After direct contact with the eyes, the effect of a substance can vary from eye irritation, ocular disturbances like halo vision to serious eye damage. Substances that can cause damage to the eyes include acids, alkalis, organic solvents, detergents and some metallic salts. Acid and especially alkali (caustic) burns may cause permanent damage such as opacity of the eye.

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## 5.8 Simple asphyxiants

Simple asphyxiants are non-toxic gases which, when present in an atmosphere in high concentrations, lead to a reduction of oxygen concentration by displacement or dilution. It is not appropriate to recommend an exposure standard for simple asphyxiants but it is essential sufficient oxygen concentration is maintained.

The minimum oxygen content in air should be 19.5 per cent by volume under normal pressure. This is equivalent to a partial pressure of oxygen ($PO_2$) of 19.8 kPa (148.2 mm Hg). At pressures significantly higher or lower than the normal pressure, expert guidance should be sought.

Atmospheres deficient in oxygen do not provide adequate sensory warning of danger and most simple asphyxiants are odourless. Unconsciousness and death can rapidly ensue in an environment which is deficient in oxygen. There have been a considerable number of deaths among inappropriately protected workers who have entered confined spaces or tanks before these spaces were adequately vented or gas-tested. The WHS Regulations and the *Confined Spaces Code of Practice* detail the precautions which should be observed in such environments.

Many asphyxiants may also present an explosion hazard and should be taken into account in limiting the concentration of the asphyxiant. Examples of asphyxiants which may present an explosion hazard include acetylene, ethane, ethylene, hydrogen, methane, propane, and propylene.

Other asphyxiants which are not flammable and do not present an explosion hazard include argon, helium, neon, and nitrogen.

The most common asphyxiant is carbon dioxide. It gives no warning of its presence in asphyxiating concentrations and can have toxic effects at concentrations which do not cause asphyxiation.

### Carbon monoxide

Table 1 provides guidelines for the control of short term excursions above the 8-hour TWA exposure standard. It is based on the toxicokinetic properties of carbon monoxide. The

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values should be considered in conjunction with the 8-hour TWA exposure standard for carbon monoxide.

**Table 1:** Guidelines for the control of short-term excursions for carbon monoxide

| Concentration[(a)] (ppm) | Total exposure[(b)] (min) |
|---|---|
| 200 | 15 |
| 100 | 30 |
| 60 | 60 |

(a) Short-term excursions should never exceed 400 ppm.

(b) This duration represents the sum of exposures at this level over an 8-hour workday, and *assumes no other exposure to carbon monoxide*.

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## 5.9 Airborne particulates

Airborne contaminants that can be inhaled directly can be classified on the basis of their physical properties either as gases, vapours or particulate matter. Airborne particulates consist of discrete particles and may be further characterised as dusts, fumes, smokes or mists, depending on the nature of the particle and its size. Definitions for each of these terms are given in the Glossary. In common usage, the terms ‘dust’ and ‘particulates’ are often used interchangeably. The factors which determine the degree of hazard associated with a specific airborne particulate are:

- the type of particulate involved and its biological effect
- the concentration of airborne particulates in the breathing zone of the worker
- the size of particles present in the breathing zone
- the duration of exposure (possibly in years).

The chemical composition and physical characteristics of the particulate determine the biological effect of the substance or mixture. The biological effects associated with an airborne particulate may be:

- systemic toxic effects caused by the absorption of the toxic material into the blood, for example, lead, manganese, cadmium and zinc
- allergic and hypersensitivity reactions caused by the inhalation of dusts from materials like flour, grains, some woods and some organic and inorganic chemicals
- bacterial and fungal infections associated with the inhalation of dusts containing viable organisms and/or spores
- fibrogenic reactions in the gas exchange regions of the lung due to the presence of materials like asbestos and quartz
- carcinogenic response due to the presence of, for example, chromates and asbestos
- irritation of the mucous membranes of the nose and throat caused by acid, alkali or other irritating particulates, especially mists.

## Particle size

Most workplace dusts contain particles of widely ranging size. The behaviour, extent of penetration, deposition and fate of a particle after entry into the respiratory system and the response it elicits depend on the nature and size of the particle.

Only part of the total quantity of dust which is present in the worker's breathing zone is inhaled. This part is called the ‘inhalable fraction’ of dust and is governed by the flow rates in the nose and mouth areas, as well as the airflow around the head. Practically all smaller particles will be inhaled, while the number of larger particles inhaled decreases rapidly as a function of increasing aerodynamic diameter. The larger particles in the inhalable fraction of dust are deposited in the nose, pharynx and larynx. Some of the smaller particles reach the tracheobronchial tree or even the alveolar region of the lung where gas exchange occurs.

The deposition of particles can occur during either inhalation or exhalation. Deposited particles may be transported to the digestive tract by means of the mucociliary clearing mechanism of the respiratory tract and, in some cases, subsequently absorbed into the body.

## Inhalable dust

Inhalable dust refers to the particle size entering the mouth and nose during normal breathing. These particles may be deposited in the respiratory tract. The term inhalable dust applies to both non-toxic and toxic dusts.

Inhalable dusts that are toxic have an exposure standard based upon the substance of concern. Where the toxic component of the dust is measured, this is satisfactory as long as the exposure standard for dusts not otherwise classified is not exceeded. Exposure standards for dusts are measured as inhalable dusts unless there is a notation specifying an alternate method, e.g. cotton dust, silica.

Inhalable dusts should be measured according to AS 3640-2009: *Workplace atmospheres – Method for sampling and gravimetric determination of inhalable dust*[7]. The inhalable mass fractions of inhalable dust are defined in ISO 7708[28] and have been adopted by AS 3640 and summarised in Table 2 below:

**Table 2:** Inhalable dust

| Particle equivalent aerodynamic diameter (µm) | Inhalable Convention (per cent) |
|---|---|
| 0 | 100 |
| 5 | 87 |
| 10 | 77 |
| 20 | 65 |
| 30 | 58 |
| 60 | 51 |
| 100 | 50 |

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## Respirable dust

The inhalable fraction of dust entering the respiratory tract may be further divided into 'respirable' and 'non- respirable' fractions. The respirable fraction is composed of the very fine dust which is able to reach the lower bronchioles and alveolar regions of the lung.

Respirable dust is measured by a size selective device according to AS 2985-2009: *Workplace atmospheres – Method for sampling and gravimetric determination of respirable dust*[6]. This Australian Standard also defines respirable dust and adopted the ISO 7708[28] definition of a respirable dust, which is the percentage of inhalable matter collected by a device conforming to a sampling efficiency curve which passes through the points in Table 3 below:

**Table 3:** Respirable dust particle size versus respirability

| Equivalent aerodynamic diameter (µm) | Respirability (per cent) |
|---|---|
| 0 | 100 |
| 2 | 97 |
| 3 | 80 |
| 4 | 56 |
| 5 | 34 |
| 6 | 20 |
| 7 | 11 |
| 8 | 6 |
| 10 | 2 |
| 18 | 0 |

The following substances have an exposure standard based upon the respirable dust fraction:

- Quartz
- Cristobalite
- Tridymite
- Fumed Silica
- Coal dust (<5% silica)
- Soapstone

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## Silica

Silica is a name which collectively describes various forms of silicon dioxide, including both the crystalline and non-crystalline (amorphous) forms of silica. While amorphous silica can be transformed into crystalline forms like tridymite and cristobalite by heating to high temperatures (approximately 870°C and 1470°C respectively)[29], it is generally only the crystalline forms of silica which are fibrogenic[*]. The temperature at which amorphous silica can be converted to crystalline forms like tridymite and cristobalite is dependent upon pressure and chemical environment. For instance, significant quantities of cristobalite can be formed at temperatures as low as 450°C in the presence of sodium carbonate or sodium chloride flux, that is, calcining[30].

The forms of crystalline silica are shown in Table 4 below:

**Table 4:** Forms of crystalline silica

| Type of crystalline silica | CAS No. | Respirable fraction |
|---|---|---|
| Quartz | [14808-60-7] | 0.05 mg/m$^3$ |
| Cristobalite | [14464-46-1] | 0.05 mg/m$^3$ |
| Silica flour[†31] | [14808-60-7] | See quartz |
| Tridymite | [15468-32-3] | 0.05 mg/m$^3$ |
| Fused silica[°] | [60676-86-0] | 0.05 mg/m$^3$ |
| Tripoli | [1317-95-9] | 0.05 mg/m$^3$ |

The airborne concentration of crystalline silica should be determined in the manner specified in Methods for Measurement of Quartz in Respirable Airborne Dust by Infra-red Spectroscopy and X-ray Diffractometry.[32]

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[*] A fibrogenic dust is a dust, for example, crystalline silica and asbestos, which, after deposition in the gas exchange region of the lung, causes increase of fibrotic (scar) tissue. With dust of this kind, only particles which are capable of penetrating to this region of the lung are of concern in determining the hazard to health.

[†] (Some extremely fine grades of silica sand (crystalline silica) are marketed as 'silica flour' and have trade names such as Min-U-Sil.

[°] Fused silica is a solid form of quartz. When it is an airborne contaminant, the exposure standard for the respirable fraction of quartz applies.

Different types of amorphous silica, with their respective exposure standards, are shown in Table 5 below:

**Table 5:** Forms of amorphous silica

| Type of amorphous silica | CAS No. | Respirable fraction | Inhalable fraction |
|---|---|---|---|
| Diatomaceous earth (uncalcined)[+] | [61790-53-2] | - | 10 mg/m$^3$ |
| Fumed silica[‡] | [7631-86-9] | 2 mg/m$^3$ | - |
| Precipitated silica | [112926-00-8] | - | 10 mg/m$^3$ |
| Silica fume[‡] (thermally generated) | – | 2 mg/m$^3$ | - |
| Silica gel | [112926-00-8] | - | 10 mg/m$^3$ |

## Asbestos

Asbestos means the asbestiform varieties of mineral silicates belonging to the serpentine or amphibole groups of rock forming minerals including the following:

(a) actinolite asbestos;

(b) grunerite (or amosite) asbestos (brown);

(c) anthophyllite asbestos;

(d) chrysotile asbestos (white);

(e) crocidolite asbestos (blue);

(f) tremolite asbestos;

(g) a mixture that contains 1 or more of the minerals referred to in (a) to (f).

The average fibre concentration of the air breathed by a worker throughout a working shift, as calculated from measurements made in accordance with the National Occupational Health and Safety Commission's *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Fibres (2nd Edition)*[33], over a sampling period of not less than

[+] Commercial diatomite products are marketed in many grades. Diatomite for filtering is typically 'calcined' and therefore may contain a significant proportion of crystalline silica.

[‡] Fumed silica is produced synthetically by a vapour phase hydrolysis of Silicon tetrachloride. Silica fume is the by-product of a high temperature process when elemental silicon is produced by reacting coke and silica sand (crystalline) in an electric arc furnace.

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four hours, during which one or more samples may be taken, must not exceed the values in Table 6 below:

**Table 6:** Types of Asbestos

| Type of asbestos | CAS No. | TWA exposure standard |
|---|---|---|
| Crocidolite (blue asbestos) | [12001-28-4] | 0.1 fibres per mL of air |
| Amosite (brown asbestos) | [12172-73-5] | 0.1 fibres per mL of air |
| Chrysotile (white asbestos) | [12001-29-5] | 0.1 fibres per mL of air |
| Other forms | [1332-21-4] | 0.1 fibres per mL of air |
| Any mixture of these forms, or where composition is unknown | | 0.1 fibres per mL of air |

Work with all forms of asbestos has been prohibited since 31 December 2003, with limited exceptions; however there is still a significant amount of asbestos present in structures, plant and equipment in workplaces.

The WHS regulations also require that workers who are likely to be exposed to asbestos are informed of the health risks and that health monitoring is provided to prior to starting work with asbestos.

Guidance on the management and control and removal of asbestos can be found in the Codes of practice: *How to manage and control asbestos in the workplace*[34] and *How to safely remove asbestos*[35].

## Man-made vitreous fibres

Man-made vitreous (silicate) fibres (MMVF) is a generic name used to describe an inorganic fibrous material manufactured primarily from glass, rock, minerals, slag and processed inorganic oxides. Other names for MMVF include Synthetic Mineral Fibres (SMF), manufactured vitreous fibres, man-made mineral fibres (MMMF), machine-made mineral fibres and synthetic vitreous fibres. Due to lessened concern for adverse health effects from some of these fibres and low biopersistent fibres being developed by industry, the workplace exposure standard has been reviewed for glass, rock and slag wool fibres by removing the requirement for the fibre in air measurement. For these fibres of lower safety concern, the inhalable fraction must not exceed 2 mg/m$^3$ (TWA). All other fibres, such as refractory ceramic fibres or any other biopersistent fibres such as special purpose glass fibres, are still subject to a time-weighted average limit of 0.5 fibres/mL of air **and** a complementary limit of 2 mg/m$^3$ for inhalable dust.

Where the fibre in air measurement is required for refractory ceramic fibres, this should be measured in accordance with the National Occupational Health and Safety Commission's *Guidance Note on the Membrane Filter Method for the Estimation of Airborne Synthetic Mineral Fibres* [NOHSC:3006(1989)][36], over a sampling period of not less than four hours, during which one or more samples may be taken. The airborne concentration of inhalable fibres should be determined using an appropriate method such as that in AS 3640-2009: *Workplace atmospheres – Method for sampling and gravimetric determination of inhalable dust*[7].

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For applications where MMVF is combined with other material such that the proportion of respirable fibres is extremely low or is difficult to measure because of the larger portion of non-fibrous MMVF material, it is appropriate to apply the exposure standard for nuisance dusts of 10 mg/m$^3$, measured as inhalable dust (8-hour TWA).

Exposure standards must not exceed the values in Table 7 below.

**Table 7:** Exposure standards of man-made vitreous fibres

| Type of man-made vitreous fibre | Respirable fraction (TWA) | Inhalable fraction[3](TWA) |
|---|---|---|
| Refractory Ceramic Fibres (RCF)[1] | 0.5 fibres/mL of air | 2 mg/m$^3$ |
| Special purpose glass fibres[2] | 0.5 fibres/mL of air | 2 mg/m$^3$ |
| High biopersistence MMVF[5] | 0.5 fibres/mL of air | 2 mg/m$^3$ |
| Glass wool[2] [4] | - | 2 mg/m$^3$ |
| Rock (stone) wool[2] [4] | - | 2 mg/m$^3$ |
| Slag wool[2] [4] | - | 2 mg/m$^3$ |
| Continuous glass filament[2] [4] | - | 2 mg/m$^3$ |
| Low biopersistence MMVF[6] | - | 2 mg/m$^3$ |

[1] Man-Made Mineral Fibres (MMVF) with random orientation, alkaline oxide and alkali earth oxide ($Na_2O+K_2O+CaO+MgO+BaO$) content less or equal to 18% by weight.

[2] As described in IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 81, Man-Made Vitreous Fibres, pp. 45-54, 2002, IARC Press, Lyon, France.

[3] In situations where almost all the airborne material is fibrous, an inhalable dust exposure standard of 2 mg/m$^3$ (8-hour TWA) must also be applied to minimise mechanical irritation from largely non-respirable fibre. This inhalable standard is **not** to take precedence over the respirable fibre standard, where it is applicable. For those applications where MMVF is combined with other material such that the proportion of respirable fibres is extremely low or is difficult to measure because of the larger portion of non-fibrous material, it is appropriate to apply the exposure standard for nuisance dusts of 10 mg/m$^3$, measured as inhalable dust
(8-hour TWA).

[4] MMVF with random orientation, alkaline oxide and alkali earth oxide ($Na_2O+K_2O+CaO+MgO+BaO$) content greater than 18% by weight.

[5] Any MMVF which have not been tested according to the test protocol *Methods for the Determination of the Hazardous Properties for Human Health of Man Made Mineral Fibres*, April 1999 and Note Q in EC Regulation No. 1272/2008 page 353/335 (CLP regulations) or fibres which have been tested and failed to comply with these tests.

[6] Any MMVF which have been tested according to the test protocol *Methods for the Determination of the Hazardous Properties for Human Health of Man Made Mineral Fibres*, April 1999 and Note Q in EC Regulation No. 1272/2008 page 353/335 and found to comply with these tests.

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## Nanomaterials

Engineered, or manufactured, nanomaterials are particles that have at least one dimension between approximately 1 nm and 100 nm, and are manufactured to have specific properties or composition.

While there are hundreds of manufactured nanomaterials in existence, there are currently only two Australian exposure standards relating to specific nanomaterials. The Workplace Exposure Standard for carbon black is 3 mg/m$^3$ (8-hour TWA) and the Workplace Exposure Standard for fumed silica is 2 mg/m$^3$ (8-hour TWA).

Exposure to nanomaterials should be eliminated or minimised so far as reasonably practicable through containment of materials, local exhaust ventilation (LEV) and work processes.

## Exposure standards for dusts not otherwise classified (nuisance dusts)

Not all dusts have assigned exposure standards. However, it should not be assumed these dusts do not present a hazard to health.

In addition to the specific physiological effect related to the unique properties of a particulate, high concentrations of dust in the workplace may cause unpleasant deposition of dust in the ears, eyes and upper respiratory tract and reduce visibility in the workplace. In addition, the mechanical action of these dusts, or the cleaning procedures necessary for their removal, may cause injury to the skin or mucous membranes.

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).

However, the exposure standard for dusts not otherwise classified should not be applied where the particulate material contains other substances which may be toxic or cause physiological impairment at lower concentrations. In these circumstances, the exposure standard for the more toxic substance should be applied. For example, where a dust contains asbestos or crystalline silica, like quartz, cristobalite or tridymite, exposure to these materials should not exceed the appropriate value for these substances.

Providing the airborne particulate does not contain other hazardous components, compliance with the exposure standard for dusts not otherwise classified should prevent impairment of respiratory function.

## Refined petroleum solvent mixtures

Petroleum products consist of complex mixtures of hydrocarbon compounds which share similar chemical and physical properties. Petroleum solvents are often distinguished on the basis of the boiling range of the mixture, while the actual composition of the product is determined by the crude feed stock from which the product is derived and the subsequent processing and blending.

Refined petroleum solvents are usually mixtures of straight and branched-chain alkanes (paraffins), cyclic alkanes (naphthenes), alkenes (olefins) and the aromatics (for example, benzene and its homologues). Due to different manufacturing processes and the complexity of the mixtures, detailed information on the exact solvent composition may not be available from the manufacturers nor may it be necessary for the assessment of occupational

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exposure. Where a CAS number is available for specific blend, this is the best way to search HCIS for information on these mixtures, as various naming protocols could be used.

While the components of these petroleum products share some similar physical and chemical characteristics, the toxicological properties of these components can be quite different. For this reason, where generic standards are not available or when toxic components are known to be present, it is usually necessary to determine the airborne concentration of each of the major or toxic components and compare these with the appropriate individual exposure standard.

The volatility of the various components in the liquid solvent mixture will determine the relative concentrations of these components found in the vapour state. For this reason, it is necessary when determining the airborne concentration for solvent mixtures to measure the concentration of the individual toxic components, for example, benzene and n-hexane, which more strongly influence the toxicological properties of the solvent mixture. In most instances it will be the proportion of these components which will determine whether the applicable exposure standards have been exceeded. Information regarding the concentrations of toxicologically significant components of the solvent mixture can be obtained from the supplier or refining company or the SDS.

The petroleum solvent mixtures which have been assigned exposure standards are listed in Table 8 below. Users should recognise these are only approximate values and data for other petroleum solvent mixtures is available on HCIS. These values should only be used on the condition that toxic components, like benzene and n-hexane, are not present, and detailed solvent composition data are not available.

**Table 8:** Petroleum solvent mixtures

| Substance | CAS No. | TWA exposure standards (mg/m$^3$) |
|---|---|---|
| Mineral turpentine | | 480 |
| Petrol (gasoline) | | 900 |
| White spirits | [8052-41-3] | 790 |

Rubber solvent is not included in this table because its composition can vary widely from supplier to supplier.

## Mineral oil additives

The 8-hour time weighted average exposure standard for oil mist of 5 mg/m$^3$ applies to oil mists from highly refined mineral oils. Most formulated products in use are based on highly refined mineral oils plus additives for the purpose of enhancing their properties in specific processes and preventing decomposition. Additives may include antioxidants, bearing protectors, wear resistors, dispersants, detergents, emulsifiers, viscosity-index improvers, pour-point depressors and antifoaming and rust-resisting agents.

Cutting fluids are one of the main mineral oil products which produce mists during use. These compounds are usually a combination of mineral oil and emulsifiers along with a complex additive package including many of the above additives and biocides.

The composition of these oils can also change in the process of use and can become contaminated or break down. Processes involving the cutting of metals, plastics, etc. causes the mineral oil to become contaminated by fine swarf. Contamination may also occur via

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metabolic by-products from bacteria or fungi. Heating can cause chemical changes to the oil and produce toxic thermal degradation products.

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Where oils contain significant quantities of contaminants or additives, the mixture's formula may need to be used to derive an exposure standard more suited to the application, or exposures to the additives/contaminants should be determined separately and taken into account in assessing exposure.

Skin contact with mineral oil products should be recognised as an additional route of exposure.

Used mineral oils can be more hazardous than new oils due to decomposition products.

## Fumes and gases from welding and cutting processes

The fumes and gases arising from welding and cutting processes may contain a number of contaminants.

The composition of the fumes depends on:

- consumables: electrodes or filler metals, heating or shielding gases and fluxes
- material: chemical composition of material being cut or welded and of any protective coating (e.g. galvanising) or primer paint, (e.g. lead-based paints)
- operating conditions, e.g. temperature and current.

The amount of the fumes generated depends on:

- process and thermal conditions, e.g. amperage, voltage, gas and arc temperatures and heat input which may vary with the welding position, degree of enclosure and the degree of skill of the welder
- consumables
- materials
- duration of welding or cutting.

Fumes from gas welding and cutting are generally lower than fumes from electric welding and cutting. Exceptions to this include processes involving heavy cutting and gouging. In addition, the welding/cutting arc may cause reactions which produce oxides of nitrogen, carbon monoxide and other gaseous contaminants. The intense ultraviolet radiation emitted from some arcs may also give rise to significant quantities of ozone.

When assessing a particular welding or cutting process, consideration should be given to the airborne concentration of toxic metals and the concentration of toxic gases which may be generated by the process. In addition to complying with the exposure standards for specific contaminants, the fume concentration in the breathing zone (which is inside a welder's helmet when a helmet is worn) must not exceed 1 mg/m$^3$ TWA. Sampling for welding fume should be carried out in accordance with the appropriate Australian Standard[9]. Further information on controlling the risks associated with fumes and gases produced in the welding process is included in the *Welding Processes Code of Practice*.

## Thermal decomposition products of plastics

When subject to the normal melt processing temperatures, usually 200-300°C, most plastics produce toxic vapours, usually at concentrations considerably below their exposure standards[37,38,39,40]. However, irritant aerosols and gases can also be produced which may cause complaints of sensory irritation if the process is not adequately controlled.

All plastics emit toxic and irritant fumes with increasing temperatures. However, the evolution rate and composition of the fumes emitted vary for different plastics and are temperature

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dependent. Some common examples include thermoplastics like polyvinylchloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS), acrylonitrile-butadiene-styrene (ABS) copolymer, and polytetrafluoroethylene (PTFE).

Pyrolysis products, given off at higher temperatures require special consideration[41]. The health effects of hot-wire cutting of PS foams, PVC and PE films have been studied[42,43,44]. Polymer fume fever has been shown to be caused by the pyrolysis products of PTFE (Teflon)[45].

An extensive review of thermal degradation products of various plastics was carried out by the Nordic Expert Working Group[46]. However, no exposure standard has been recommended and exposure should be minimised so far as reasonably practicable.

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# 6. Appendix A – the meaning of key terms

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| Term | Definition |
|---|---|
| **NATA-accredited laboratory** | means a testing laboratory accredited by NATA or recognised by NATA either solely or with someone else. |
| **Airborne contaminant** | means a contaminant in the form of a fume, mist, gas, vapour or dust, and includes microorganisms. |
| **Breathing zone** | means a hemisphere of 300 mm radius extending in front of a person's face and measured from the midpoint of an imaginary line joining the ears. |
| **Dusts** | means solid particles generated and dispersed into the air by, for example, handling, crushing and grinding of organic or inorganic materials such as rock, ore, metal, coal, wood and grain. |
| **Exposure standard** | means an exposure standard in the *Workplace Exposure Standards for Airborne Contaminants*. It represents the airborne concentration of a particular substance or mixture that must not be exceeded. The exposure standard can be of three forms:<br>a. 8-hour time-weighted average;<br>b. peak limitation; or<br>c. short term exposure limit. |
| **Peak limitation** | means a maximum or peak airborne concentration of a particular substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes. |
| **Short term exposure limit (STEL)** | means the airborne concentration of a particular substance calculated as a time-weighted average over 15 minutes. |
| **Fumes** | Fumes are extremely fine - usually less than 1.0 micrometer in diameter. Fumes are formed when the material from a volatilised solid condenses in cool air. In most cases the hot vapour reacts with the air to form an oxide. Fumes are often associated with molten metals, especially in processes like welding. At high fume concentrations, agglomeration of particles may result in particles with much larger dimensions. |
| **Gases** | are formless fluids that expand to occupy the space or enclosure in which they are confined. Examples are nitrogen, oxygen and formaldehyde. |
| **Mists** | are suspended liquid droplets generated by condensation of vapour back to the liquid state or by breaking up as a liquid into a dispersed state, such as by splashing or atomising. Mist is the term applied to a finely divided liquid suspended in the atmosphere. Examples are an oil mist produced during cutting and grinding operations, acid mists from electroplating, acid or alkali mists from pickling operations, paint spray mist in painting operations and the condensation of water vapour to form a fog. |
| **Personal monitoring** | Air monitoring samples collected within the breathing zone of the worker are called personal samples. |

| | |
|---|---|
| **Physical agents** | Physical agent refers to energy-related agents like heat and cold, vibration, noise and electromagnetic radiations of all kinds and their associated fields. |
| **Smoke** | Smoke consists of carbon or soot particles or tarry droplets less than 0.1 micrometres in size, and suspended in air, which results from the incomplete combustion of carbonaceous materials like coal or oil. |
| **Static monitoring** | For the purpose of this Guide, static monitoring means samples of air taken at fixed locations, commonly between 1 and 2 metres above floor level. |
| **Substance** | means a chemical element or compound in its natural state or obtained or generated by a process:<br>a. including any additive necessary to preserve the stability of the element or compound and any impurities deriving from the process; but<br>b. excluding any solvent which may be separated without affecting the stability of the element or compound or changing its composition. |
| **8-hour time-weighted average (TWA)** | the average airborne concentration of a particular substance when calculated over a normal eight-hour working day. |
| **Vapour** | Vapour is the gaseous form of a substance which is normally in the solid or liquid state at room temperature and pressure. |

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# 7. Appendix B – Models for adjusting exposure standards

This appendix contains a brief description of different types of models for adjusting 8-hour TWA exposure standards for airborne contaminants.

### *Brief and Scala Model*

The Brief and Scala Model[13] is based on the number of hours worked per 24-hour day and the period of time between exposures. This model is intended to ensure the daily dose of the toxicant under an altered work shift is below that for a conventional shift to take account of the reduced time for elimination i.e. recovery time between exposures.

The Brief and Scala Model is recommended for calculating adjustments to exposure standards. This model is preferred because it:

- is simple to use
- takes into account both increased hours of exposure and decreased exposure free time, and
- is more conservative than other models.

Daily adjustment formula:

$$\text{Adjusted exposure standard (TWA)} = \frac{8 \times (24 - \mathbf{h}) \times \text{Exposure standard (8-hour TWA)}}{16 \times \mathbf{h}}$$

Where **h** = hours worked per day

The Brief and Scala model is based upon the 40-hour work week. The formula takes into account both the period of exposure and period of recovery.

Weekly adjustment formula:

$$\text{Adjusted exposure standard (TWA)} = \frac{40}{\mathbf{h}} \times \frac{(168 - \mathbf{h})}{128} \times \text{Exposure standard (8-hour TWA)}$$

Where **h** = hours worked per week

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Worked examples of the weekly adjustment formula are provided in the examples below.

Example 2: The worker works a normal 5 shifts a week and 12 hours per shift.

Substance: Ethyl alcohol

Exposure Standard: 1000 ppm, 8-hour TWA

Work shift: 12 hours

Solution:

Adjusted exposure standard for 12-hour shift =

$$\frac{8 \times (24 - \mathbf{12}) \times \text{Exposure standard (8-hour TWA)}}{16 \times \mathbf{12}}$$

$$= \frac{8 \times (24 - \mathbf{12}) \times 1000 \text{ ppm}}{16 \times \mathbf{12}}$$

= 500 ppm (12-hour TWA)

Example 3: The worker works a normal 5 shifts a week and 12 hours per shift.

Substance: Chlorine

Exposure Standard: 1 ppm, Peak limitation

Work shift: 12 hours

Solution:

No adjustment of the exposure standard is made for substances assigned with a Peak limitation.

Example 4: The worker works a normal 5 shifts a week and 12 hours per shift.

Substance: Methyl ethyl ketone

Exposure Standard: 150 ppm, 8-hour TWA; 300 ppm STEL

Work shift: 12 hours

Solution:

No adjustment of the STEL is made. The 12-hour TWA will reduce to 75 ppm using a similar calculation to that used for ethyl alcohol.

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Example 5: The worker works 7 days a week and 8 hours per day.

Substance: Ethyl alcohol

Exposure Standard: 1000 ppm, 8-hour TWA

Work shift: 8 hours

Solution:

Adjusted exposure standard for 56-hour week = $\frac{40}{\mathbf{56}} \times \frac{(168 - \mathbf{56})}{128}$ x Exposure standard (8-hour TWA)

= $\frac{40}{\mathbf{56}} \times \frac{(168 - \mathbf{56})}{128} \times 1000$

= 625 ppm (56-hour per week TWA)

### *OSHA Model*

The US Occupational Safety and Health Administration (OSHA) Model[13] categorises air contaminants into one of six categories based on their toxic effects. Depending on the type of toxic effect, an appropriate adjustment procedure including no adjustment should be selected and applied to the substance's exposure limit. This model is intended to ensure that, for substances with acute or chronic toxicity, the daily dose or the weekly dose during an altered work shift does not exceed the dose obtained in a conventional 8-hour work shift.

### *Pharmacokinetic Model*

There are several different pharmacokinetic models available. These are suitable for application to exposure standards based on accumulated body burden. These models take into account the expected behaviour of the hazardous substance in the body based on knowledge of the properties of the substance. These models use information such as the biological half-life of a substance and exposure time to predict body burden. The use of pharmacokinetic models can be complicated by the lack of biological half-lives for many substances.

The most widely used pharmacokinetic model is the Hickey and Reist model[14] which requires knowledge of the substance's biological half-life, the hours worked per day and hours worked per week. The Hickey and Reist model like other pharmacokinetic models assumes the body is one compartment i.e. a homogeneous mass.

Pharmacokinetic models are less conservative than the Brief and Scala or OSHA models, usually recommending smaller reductions of the exposure standard. While pharmacokinetic models are theoretically more exact than other models, their lack of conservatism may not allow adequately for the unknown adverse effects on the body from night work or extended shifts that might affect how well the body metabolises and eliminates the substance.

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### *Quebec Model*

The Quebec Model[16] developed by the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) is based on the OSHA Model and uses the most recent toxicological data to assign substances into categories. Depending on the category assigned, a recommendation will be made that:

- no adjustment is made to the exposure standard,
- a daily or weekly adjustment, or
- the most conservative of the daily or weekly adjustments where both apply.

The Quebec Model is supported by a comprehensive technical guide[15] and a selection tool to assist in determining the most appropriate adjustment category.

Caution must be applied when using the Quebec Model to ensure that exposure standards published by Safe Work Australia are used.

For further information on adjusting exposure standards see IRSST[15], Department of Minerals and Energy WA[17], SIMTARS[16], Roach (1978)[47], Eide (1989)[48], Brief and Scala (1986)[12], Verma (2000)[49], Lapare et al (2003)[50] and Paustenbach (2000)[13].

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# 8. Appendix C – Document change log

| Date | Action |
|---|---|
| **July 2025** | • Section 1, paragraph 3 – update to reflect change from HSIS to HCIS<br>• Section 5.8, paragraph 2 – correction of an error in the values relating to oxygen partial pressure<br>• Section 5.9, Refined petroleum solvent mixtures – update to reflect change from HSIS to HCIS |
| **September 2024** | • Table 4 – Updated respirable crystalline silica exposure standards values<br>• Table 4 – Footnote for ‘Fused silica’ added<br>• Section 5.9, Fumes and gases from welding and cutting processes – amended welding fumes (not otherwise classified) exposure standard value and removed outdated references. |
| **March 2024** | • Section 2.2, paragraph 4 – updated to reference respiratory protective equipment (RPE)<br>• Section 2.2, paragraph 5 – NATA web site reference updated<br>• Section 2.3 – several updates made to this section |
| **April 2013** | Original document published |

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