SPECIAL GUIDE

Workplace Exposure Standards and Biological Exposure Indices

November 2017

9TH EDITION

New Zealand Government

WORKSAFE NEW ZEALAND | MAHI HAUMARU AOTEAROA

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Preface

The ninth edition of the *Workplace Exposure Standards and Biological Exposure Indices* has been developed by Worksafe New Zealand (WorkSafe). Input has also been sought from a wide range of interested parties.

This edition supersedes all previous editions and versions, including the January 2002 document entitled *Workplace Exposure Standards* published by the Occupational Safety and Health Service of the Department of Labour, ISBN 0-477-03660-0.

Worksafe will continue to review and revise this document to take into account any significant new toxicological or occupational hygiene information.

Changes in this edition

PAGE	TOPIC	CHANGES
8	Introduction	– Additional comments on Limitations
17	Carcinogens	– More comprehensive definitions for 6.7A and 6.7B carcinogens, reflecting the HSNO definitions
22	Table 5: Reference key	– Additional symbols * and ‡ to indicate substances with WES values adopted in 2017 and substances currently under review, respectively
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Obligations and rights under the Health and Safety at Work Act 2015 (HSWA) and Health and Safety at Work (General Risk and Workplace Management) Regulations 2016

What are the obligations of a person conducting a business or undertaking (PCBU)?

PCBUs must ensure the health and safety of workers doing work for the PCBU and to ensure the health and safety of others whose work is influenced or directed by the PCBU.

PCBUs must also ensure that the health and safety of other persons is not put at risk from the work carried out as a part of the PCBU's business or undertaking.

To achieve this, PCBUs must (so far as is reasonably practicable):

- identify hazards that might give rise to risks to health and safety
- eliminate risks to health and safety
- minimise risks that are not reasonably practicable to eliminate
- provide and maintain a work environment that is without risks to health and safety
- provide and maintain safe plant and structures
- provide and maintain safe systems of work
- ensure the safe use, handling and storage of substances
- provide adequate and accessible facilities for the welfare of workers doing work for the PCBU
- provide the information, training, instructions or supervision necessary to protect all persons from risks arising from work carried out as a part of the conduct of the business or undertaking
- ensure that the health of workers at the workplace is monitored
- ensure that the conditions at the workplace are monitored
- provide adequate and accessible first aid facilities for workers
- provide suitable personal protective equipment and clothing for workers and other persons and ensure that it is used
- engage with workers so workers have a reasonable opportunity to raise health and safety issues and to contribute to the decision-making process.

Do workers and others have obligations and rights?

Yes. Workers and other persons at a workplace are required to take reasonable care to ensure their health and safety and the health and safety of others who are there. This includes considering both the things they do and the things they omit to do (such as not using safety equipment or appropriate exposure controls). They are also required to comply with any reasonable health and safety instruction given by the PCBU.

Workers are also required to co-operate with any reasonable health or safety policy or procedure of the PCBU.

Although it is the PCBU's overall responsibility to ensure a safe working environment, workers do have a responsibility to use the exposure controls and safety equipment provided, and to wear protective clothing as appropriate.

Workers and others should also report to the PCBU any risks or incidents they become aware of so the PCBU can investigate and put safeguards in place.

Workers are entitled to receive, free of charge, protective clothing and equipment if this is necessary to protect them from health and safety risks in the workplace.

Workers are entitled to:

- receive information, supervision, training, and instruction appropriate to the work they are doing, the plant they are using, and the substances they are handling so they can do their job in a safe and healthy manner
- wear their own suitable personal protective clothing and equipment, but the PCBU must ensure that any such clothing and equipment is suitable
- have access to the results of exposure monitoring at the workplace where they may be, or may have been exposed to the health hazard, provided that the exposure monitoring results do not contain any information that identifies or discloses anything about an individual worker
- be provided with a copy of any health monitoring report relating to health monitoring of the worker
- receive reasonable opportunities to participate in workplace health and safety

For further information on health and safety rights and responsibilities in the workplace visit: www.worksafe.govt.nz

Part One

WORKPLACE EXPOSURE STANDARDS FOR AIRBORNE CONTAMINANTS

1.0 Explanation of workplace exposure standards (WES)

IN THIS SECTION:

1.1 Introduction

Target audience

The Workplace Exposure Standards (WES) are intended to be used as guidelines for people qualified in occupational health practice.

PCBUs and people with duties under HSWA and the HSNO Act may use this book as a reference; but it is recommended that specialist advice is sought prior to engaging in monitoring programmes or exposure control.

It is not recommended that untrained persons use WES to determine 'compliance'. Professional judgement is required in making decisions regarding safe levels of exposure to chemical and physical agents found in the workplace.

Legal requirements

WES are an important tool for monitoring the workplace environment. Where hazardous or toxic substances exist in the same environment as workers, and the PCBU is unable to successfully eliminate these substances from working environments, they are required to minimise and monitor worker exposure. The PCBU must also, so far as is reasonably practicable, ensure that the health of workers and the conditions at the workplace are monitored for the purpose of preventing injury or illness of workers arising from the conduct of the business or undertaking.

Section 36 of HSWA requires PCBUs to ensure worker health and safety 'so far as is reasonably practicable'. That duty requires the PCBU to eliminate risks to health and safety, so far as is reasonably practicable. If it is not reasonably practicable to do so, the PCBU must minimise the risks so far as is reasonably practicable. If a PCBU is uncertain on reasonable grounds whether the concentration of a substance exceeds the relevant prescribed exposure standard, regulation 30 of GRWM Regulations requires the PCBU to conduct exposure monitoring to determine the concentration of the substance. Regulation 32 of the GRWM Regulations requires the PCBU to make the results of exposure monitoring available to any person in the workplace who may have been exposed to the health hazard provided that no information that identifies an individual worker is disclosed. A prescribed exposure standard is a workplace exposure standard or a biological exposure index that has the purpose of protecting persons in a workplace from harm to health and that is prescribed in:

a. Regulations
b. A safe work instrument (including a safe work instrument that replaces a workplace exposure standard or biological exposure index in an instrument referred to in paragraph (a), (c), (d) or (e))
c. A control under section 77 or 77A, or an exposure limit under section 77B, of the HSNO Act
d. A group standard approval issued under section 96B of the HSNO Act
e. A notice of transfer under section 160A of the HSNO Act, as in force immediately before 2 July 2006 (when that section of the Act expired), and that was in force immediately before that date.

Regulation 8 of the GRWM Regulations requires the PCBU to review and, as necessary, revise control measures if the results of exposure monitoring carried out under regulation 30 determine that the concentration of a substance hazardous to health at the workplace exceeds a relevant prescribed exposure standard.

In workplaces where a worker is carrying out ongoing work involving a substance that is hazardous to health that is specified in a safe work instrument as requiring health monitoring, regulation 31 of the GRWM Regulations requires the PCBU to ensure that health monitoring is provided to the worker if there is a serious risk to the workers' health because of exposure to the substance. Regulation 39 requires the PCBU to give results of health monitoring of a worker to that worker.

Limitations

Defining an exposure level that will achieve freedom from adverse health effects is the major consideration for assigning these WES. However, compliance with the designated WES level does not guarantee that all workers are protected from discomfort or ill-health. The range of individual susceptibility to hazardous and toxic substances is wide, and it is possible that some workers will experience discomfort or develop occupational illness from exposure to substances at levels below the WES.

WES must not be used to differentiate between safe and inherently hazardous exposure levels. In addition, the numerical value of two or more WES must not be used to directly compare the relative toxicity of different substances as the biological potency and toxicologic effects used to derive a WES are specific to each substance.

When interpreting the risk posed by individual substances, the documentation that supports the WES should be consulted.

Many of the WES values in this book were adopted in 2002 from the ACGIH® from values current at that time. Only a small proportion have been reviewed by WorkSafe and its predecessors since then (these are noted with their applicable publication dates). When applying these WES values it must be considered whether or not more up to date WES values from another organisation would be more appropriate to apply for the purposes of managing health risk. Relevant sources of exposure standards include the Gestis substance database, the ACGIH® and SCOEL.

Substances without a WES

In many cases well-documented data exist to help determine WES. But for some substances, the available toxicological and industrial hygiene information is insufficient to enable highly reliable standard-setting. As such some substances do not have WES. If a substance doesn't have a WES, this should not be taken to mean that it is safe under all conditions, and that no restriction should be placed on its use. Regardless of the substance, it is important to eliminate or minimise the concentration of airborne substances as far as is reasonably practicable.

Routes of entry

Hazardous or toxic substances may enter the body following inhalation, ingestion or skin absorption. But in occupational settings, it is most often the inhalation aspect that is most important, in terms of exposure however this is substance dependent.

Substances listed with a skin notation (skin) are known to have potential for significant skin absorption particularly from liquid, but potentially also from vapour. This should not be ignored, because in these cases the total dose received through all absorption routes can be significantly higher than just that from inhalation (such as might be estimated from the airborne level). This is further discussed in the section on skin absorption (Section 1.8).

Exposure to airborne substances is usually monitored directly with personal air sampling techniques, but in some situations, biological monitoring may be used as a complementary approach. Information on biological monitoring and a list of recommended guideline levels is located in the second part of this document.

Definitions

For definitions used in this document, please see Appendix 1.

1.2 Application of WES

Personal sampling

Monitoring workers' exposure will involve comparison of results against Workplace Exposure Standards and Biological Exposure Indices.

Workplace exposure standards (WES) are values that refer to the airborne concentration of substances at which it is believed that nearly all workers can be repeatedly exposed day after day without coming to harm. The values are normally calculated on work schedules of five shifts of eight hours duration over a 40-hour work week.

In all instances, workplace exposure standards relate to exposure that has been measured by personal monitoring using procedures that gather air samples in the worker's breathing zone. The breathing zone is defined as a hemisphere of 300mm radius extending in front of the face and measured from the midpoint of an imaginary line joining the ears.

Substances with multiple WES (for different periods of exposure) will require monitoring for those specific periods. For example if a substance has a WES-TWA (time weighted average) then exposure for the whole shift needs to be assessed. This does not necessarily mean exposure has to be measured over the whole shift, but if exposure will vary, full shift sampling will provide the most useful data for the risk assessment. If the substance also has a WES-STEL (short term exposure limit), exposure over 15-minutes needs to be assessed. It is important to ensure results are measured and calculated over appropriate time frames when comparing to a specific WES, and that WES are adjusted accordingly for extended workshifts (see section 1.3).

The numerical value of two or more WES must not be used to directly compare the relative toxicity of different substances. Apart from any inconsistency that may result from the information that was available at the time each WES was set, the biological basis for assigning the WES varies. Some WES are designed to prevent the development of ill health after long-term exposure (WES-TWA), others to reduce the possibility of acute effects (WES-Ceiling, WES-EL, WES-STEL).

Assessing exposure

Assessing workers' exposure relies on good sampling strategy in addition to the correct sampling equipment and interpretation of results.

It is recommended that professional help be sought in the development and implementation of a sampling strategy and interpretation of results (eg from an appropriately qualified occupational hygienist).

When carrying out exposures assessments, assessing health risks, or assessing the need for, or effectiveness of controls, the assessor should have competence in:

- the risk assessment process
- the tasks, processes or exposures being assessed
- development of sampling strategy

- selection and use of sampling equipment and sampling media
- sampling methods
- interpretation of data
- criteria on which WES are based
- relevance and application of statistical analysis of exposure data.

Good communication skills, as well as the systematic collection of data and information are essential and reports should present the results and any recommendations clearly and in a style that the PCBU will understand.

The assessor must have a clear understanding of the limitations of their own competencies.

Sampling strategy

Sampling strategy will usually include identifying groups of workers for whom risk and exposure profiles are similar. These groups are called SEGs (similar exposure groups). Choosing a representative unbiased subsample of the SEG should be sufficient for assessing exposure and risk for the whole SEG.

Most worker exposure monitoring will be occasional in that the workers will not wear monitoring equipment all the time (with some exceptions (eg explosive gas meters), which are usually used for safety risk management rather than health risk). The regularity of worker exposure monitoring will depend on the objectives and outcomes of the risk identification and analysis. For example, if the risk identification or analysis indicates that exposure can vary considerably from day to day, then monitoring may need to occur on a more regular basis than an exposure that does not change considerably over time, or an exposure that is well managed.

Monitoring should occur when there are any changes in processes or activities that result in, or may result in, a change to exposure, or if it is not certain whether or not the airborne concentration exceeds the Workplace Exposure Standard (WES) or presents a health risk.

Variation in exposure

Exposure levels are commonly variable even in work that is regular and consistent. Variation in worker exposure arises from variation in work activities, control methods and environmental conditions.

Due to this variation, exposure measured on a single day may not reflect exposure on other days. Even samples from multiple days may not reflect the true variation in exposure that may occur over the long term. With this in mind, the monitoring strategy must be designed to provide sufficient measurements to reflect the risk to the worker from the variation in exposure.

It is very rare for all exposures for a worker to be measured all the time. Frequently only one or two shifts will be sampled and this data will be used to make judgements about exposures over many months or years. If the worker is exposed every day for five years, and their exposure is assessed once a year, then five days of data is being used to make judgements about 1250 days of exposure. Various methods are available for determining an appropriate number of samples to account for variation. Methods include:

- NIOSH[1] Occupational exposure sampling strategy manual (1977)
- at least one employee in five from a properly selected SEG (UK Health and Safety Executive HSG173 (2006)[2]

[1] The National Institute for Occupational Safety and Health (NIOSH) Publication 77-173 *Occupational exposure sampling strategy manual* (1977).

[2] UK Health and Safety Executive HSG173 Monitoring strategies for toxic substances (2006).

- a calculated number of samples based on previous data, using t-statistics and co-efficient of variation (source W501 OH Learning, Measurement of Hazardous Substances, 2009)[3]
- methods of Rappaport, Selvin and Roach (1987) based on the number of samples needed to test the mean exposure of a lognormal distribution of exposures against an exposure standard (source W501 OH Learning, Measurement of Hazardous Substances, 2009)[3]
- South African Mines Occupational Hygiene Programme – sample 5% of workers in an SEG[4]
- >> American Industrial Hygiene Association suggests 6-10 samples are sufficient to give a picture of an exposure profile. In respect to the minimum number of samples to be collected, fewer than six samples in any one SEG leaves a great deal of uncertainty about the exposure profile (AIHA 2006) (source W501 OH Learning, Measurement of Hazardous Substances, 2009).[5]

Statistical analysis of sampling results

Multiple samples generally allow for better understanding of the variation in exposure, and thus provide more detailed information for the risk assessment.

Where multiple samples are taken, application of appropriate statistical analysis to sampling results can be valuable in:

- assessing confidence that the results represent the 'true' exposure profile (the profile you would see if you were to measure the exposure every shift, and you were to measure all workers in the SEG)
- interpreting whether WES are complied with
- managing uncertainties in exposure assessment and health risk assessment.

Application of appropriate statistical analysis to sampling results is important in order to assess how closely the results represent the 'true' exposure profile and can be used to assess compliance with WES and assess risk. For example, the mean (average) exposure calculated may be below a WES, but random variation, sampling and analytical error will introduce some uncertainty around that average. This uncertainty can be described as confidence limits around the average. If the upper confidence limit exceeds the WES, it indicates less certainty around whether the average exposures truly fall below the WES. If the upper confidence limit gives us 95% confidence that the 'true' average falls comfortably below the WES, then that provides a high level of certainty that exposures comply with the WES.

A useful tool for statistical analysis of occupational hygiene samples is the 'IHStats' spreadsheet developed by the American Industrial Hygiene Association.

Which statistics to use for comparison with WES

Average (mean) exposure level is the appropriate parameter for evaluating cumulative exposure for substances that present a long term health risk. In this case the WES-TWA is the appropriate criteria for comparison. The average exposure will usually be calculated as a geometric mean rather than an arithmetic mean, as occupational hygiene exposures are usually log-normally distributed rather than normally (bell curve) distributed. It is necessary to assess the type of distribution so that the correct statistical parameters are used. Confidence limits around the mean should be considered when comparing the result to the WES.

[3] OH Learning W501 Measurement of Hazardous Substances. www.OHlearning.com (2009).

[4] South African Mines Occupational Hygiene Programme codebook (SAMOHP) (2002).

[5] The American Industrial Hygiene Association (AIHA) A Strategy for Assessing and Managing Occupational Exposures, 4th edition (2015).

Peak or high exposures should also be reviewed as part of the risk assessment. Eliminating or reducing peak, or occasional high exposures may produce a significant reduction in average exposure levels.

The 95% upper confidence limit (UCL), and the upper tolerance limit (UTL) (ie the 95% UCL of the 95th percentile of the results) are the appropriate parameters for evaluating exposure to substances that present an acute health risk. In this case the WES-STEL, WES-Ceiling or WES-EL are the appropriate criteria for comparison.

Compliance with WES

When evaluating exposure in relation to a WES, the following points must be considered:

- How representative is the sampling programme in regard to variation in exposure, and how do the results represent the 'true' exposure profile?
- Variability of exposure means that occasional high results can occur even where the exposure is generally well controlled.
- The criteria for setting a specific WES may be for a different health outcome than the risk being assessed. For example the WES may be based on reducing risk of irritation, however risk of more serious adverse effects may be the focus of the health risk assessment, therefore the WES may not be a stringent enough guideline to use in this case.
- Compliance with the designated WES level does not guarantee that all workers are protected from discomfort or ill health due to individual susceptibility.

The above considerations show that assessing compliance with WES isn't necessarily a straight forward process of comparing a sample result, or an average, to a WES.

Various organisations have developed guidelines to address this issue of how to assess WES compliance and whether further control of exposure needs to occur. Organisations that have developed guidance include the British and Netherlands Occupational Hygiene Societies (BOHS/NOHS), the American Industrial Hygiene Society (AIHA), the International Council on Mining and Metals (ICMM), and Utrecht University. A summary of their approaches is given below, but for more detail their documents should be referred to:

- BOHS/NOHS[6] – Assumes a WES may be regarded as complied with if, with 70% confidence, <5% of the exposures in the SEG exceed the WES. An individual worker's exposure complies if there is <20% probability that >5% of their exposure exceeds the WES.
- AIHA[7] – Has a rating scheme that categorises exposures as trivial (very low), highly controlled, well controlled, controlled, poorly controlled based on the estimated 95th percentile of the exposure distribution.
- ICMM[8] provides guidance on rating exposures (eg if a result is less than 50% of the WES), exposures are well controlled below the WES. Results between 50% to 100% of the WES indicate there is potential for breaches of the WES.
- The Utrecht University[9], Institute for Risk Assessment Sciences SPEED (statistical program for the evaluation of exposure data) Excel application assesses whether the within-worker and between-worker exposures are acceptable in relation to the WES. It provides a stepwise approach to the sampling and statistical analysis of data.

[6] British Occupational Hygiene Society and the Netherlands Occupational Hygiene Society, *Testing Compliance with Occupational Exposure Limits for Airborne Substances* (2011).

[7] American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the *Threshold Limit Value and Biological Exposure Indices*. 7th Edition, ACGIH, Cincinnati, Ohio (2015).

[8] International Council on Mining and Metals (ICMM) *Good Practice Guidance on Occupational Health Risk Assessment* (2007).

[9] Utrecht University, Institute for Risk Assessment Sciences, Environmental and Occupational Health Division, Utrecht, The Netherlands Statistical Program for the Evaluation of Exposure Data www.iras.uu.nl/speed/#describe

1.3 Adjustment of WES for extended workshifts

Workplace Exposure Standard Time Weighted Averages (WES-TWA) are derived on an eight hour work day and 40 hour work week. When shifts are longer than this, either over a day or a week, the WES-TWA needs to be adjusted to account for the longer period of exposure and shorter recovery time.

Various models are available to make the adjustment and each may result in a different adjusted WES.

The selection of an appropriate model is dependent on various factors such as: ease of use; availability of an adjustment model for a specific WES; and the availability of relevant toxicology and pharmacokinetics data for pharmacokinetic models. A useful document for discussion on adjustment models is the Australian Institute of Occupational Hygienists' Position Paper on 'Adjustment of Workplace Exposure Standards for Extended Workshifts' (December 2010).

A simple method to use is the Brief and Scala Model. A criticism of the model is that it is generally considered to be excessively protective for some substances. Other models include web based tools such as the IRSST 'Quebec' model. A summary of these models is given below.

When a WES-Ceiling or WES-STEL has been assigned, no correction for shift patterns is required. The exposure level for the appropriate period (instant or 15 minutes) is compared directly with the Ceiling or STEL.

A. BRIEF AND SCALA MODEL

An adjustment is made to the WES by applying the following formula:

Daily exposure adjustment:

$$\text{Adjusted WES-TWA} = \frac{8 \times (24-h) \times \text{WES-TWA}}{16 \times h}$$

Where h = hours worked per day

Seven day work week adjustment:

$$\text{Adjusted WES-TWA} = \frac{40 \times (168-h) \times \text{WES-TWA}}{128 \times h}$$

Where h = hours worked per week

Example of adjusting for an extended work shift using the Brief and Scala model

Substance: Isopropyl alcohol – WES-TWA: 400 ppm, WES-STEL: 500 ppm

Work shift: 12 hours

Adjusted WES-TWA:

$$\frac{8 \times (24-12) \times 400}{16 \times 12} = 200 \text{ ppm (12 hour TWA)}$$

The average exposure over the 12-hour shift would be compared with the 12-hour WES-TWA standard of 200 ppm. No adjustment is required for the WES-STEL.

B. IRSST MODEL (QUEBEC MODEL)

The Quebec Institut de Recherche Robert-Sauve en Sante et en Securite du Travail (IRSST) has developed a computer-based tool to calculate an adjusted TWA. The model makes adjustments of the Quebec WES (called PEVs) as defined in the Quebec Regulation Respecting Occupational Health and Safety (RROHS). Although some of the Quebec WES differ from New Zealand, the adjustment factor is provided in the model, thus that value can be applied to New Zealand WES. The model is available at: www.irsst.qc.ca/en/_outil_100011.html

C. WESTERN AUSTRALIA DEPARTMENT OF MINERALS AND ENERGY MODEL

In this guideline various exposure reduction factors are applied depending on the timeframe for response (immediate, medium or long term), health effect (acute, chronic, irritation, narcosis) and shift length. The appropriate reduction factor is selected and applied to the WES. The model is available at: www.dmp.wa.gov.au/documents/Safety/MSH_G_AdjustmentOfExposureStandardsForExtendedWorkshifts.pdf

D. PHARMACOKINETIC MODELS

There are a number of pharmacokinetic models in use. These models are based on the concept of body burden and how the biological half-life of a substance can have a significant impact on the maximum body burden for a given work schedule. They are based on ensuring that the maximum body burden for an extended work shift doesn't exceed that for an eight hour shift. These models are generally considered more accurate however, they can be very complicated and, as half-lives can vary substantially between different individuals, there are limitations.

1.4 Units of measurement

The concentration of a substance in air is either measured by volume (parts per million, or ppm), or by mass (milligrams per cubic metre of air, or mg/m^3). WES for gases and vapours are expressed in ppm, with the units mg/m^3 also listed. In the case of particulates, the concentration is given in mg/m^3. The following equation, which is based on a temperature of 25°C and a pressure of 760 torr is used to convert ppm to mg/m^3:

$$\text{WES in } mg/m^3 = \frac{\text{WES (in ppm) x gram molecular weight of the substance}}{24.45}$$

1.5 Mixed exposures

Generally, WES are listed for a single substance or a range of compounds. In some instances, a WES has been set for a group of substances (eg petrol vapours).

Often a worker will be exposed to several substances over the working day. Before an assessment of the existing hazards can be made, it is important to determine the airborne concentration of each substance.

Independent effects

If there is evidence to suggest that the actions of hazardous/toxic substances on the body are independent, the concentrations of each individual substance should be compared directly with its own WES value (-TWA, -STEL, or –Ceiling as appropriate).

This is most obvious when two (or more) substances have different toxic actions, and cause adverse effects on different target organs. An understanding of the health basis on which the WES has been set is essential for determining if the substances have independent health effects.

An example is toluene-2,4-diisocyanate and toluene. The toluene-2,4-diisocyanate WES is based on minimising the potential for respiratory tract effects and sensitisation. The toluene WES is based on minimising the potential for central nervous system depression.

Additive effects

If two or more hazardous substances have similar toxicological effects on the same target organ or system, their combined effect should be considered. In this case the combined exposures need to be compared against the TLV of the mixture, as well as each individual substance against its specific WES.

Greater than additive effects

The combined action may be greater than that predicted from the sum of the individual responses (synergistic effect), or a substance that is not itself toxic could enhance the effect of a toxic substance.

The present understanding of synergistic effects is far from complete, and emphasises the need for a prudent approach to be taken with mixed exposures. It is important that the assessment of all exposures should be made in consultation with suitably qualified and experienced persons; especially so with mixed exposures.

1.6 Aerosols

Aerosols encountered in the workplace include airborne particulates (this includes dusts and fumes) and mists.

Dusts are discrete particles suspended in air, originating from the attrition of solids or the stirring up of powders or other finely divided materials. Dusts encountered in the workplace typically contain particles covering a wide range of sizes.

Fumes are very small airborne solid particulates with diameters generally less than 1 m. They may be formed by both thermal mechanisms (eg condensation of volatilised solids, or incomplete combustion) and chemical processes (eg vapour phase reactions). Agglomeration of fume particles may occur, resulting in the formation of much larger particles.

Mists are droplets of liquid suspended in air. They may be formed by the condensation of a vapour, or by mechanical actions such as the atomisation of liquids in spray systems.

Equivalent aerodynamic diameter (EAD)

A parameter used to predict the likely behaviour of a particle in air is its Equivalent Aerodynamic Diameter (EAD). The equivalent aerodynamic diameter of a particle of any shape and density is defined as the diameter of a sphere with a density of 1.0 g/cm^3 which has the same terminal velocity of settling in still or laminarly flowing air as the particle in question.

Health effects of particulates

Airborne particulates are associated with a variety of adverse health effects and may have one or more of the following properties:

- infectious
- carcinogenic
- fibrogenic
- allergenic
- irritative.

The total concentration of the substance in air, either in terms of the weight or number of particles per unit volume, is not the only factor influencing its toxic potential. The toxic potential of a substance is influenced by a number of factors including concentration, particle size, mass, surface area and solubility.

Inhalable and respirable dust

Inhalable dust is the portion (or fraction) of airborne dust that is taken in through the mouth and nose during breathing.

Respirable dust corresponds to the fraction of total inhalable dust that is able to penetrate and deposit in the lower bronchioles and alveolar region.

Unless otherwise stated, the WES for dusts refers to inhalable dust. The WES that apply to particulates not otherwise classified apply to particulates that (i) do not have a specified WES, (ii) are insoluble or poorly soluble in water (or, preferably, in aqueous lung fluid if data are available), and (iii) have low toxicity (ie are not cytotoxic, genotoxic, or otherwise chemically reactive with lung tissue, and do not emit ionising radiation, cause immune sensitisation, or cause toxic effects other than by inflammation or the mechanism of 'lung overload').

Even biologically inert, insoluble, or poorly soluble particulates may have adverse effects and it is recommended that airborne concentrations should be kept below 3 mg/m^3 for respirable particulates and 10 mg/m^3 for inhalable particulates, until such time as a WES is set for a particular substance.

INHALABLE DUST

Criteria defining inhalable mass fractions have been defined by the International Standards Organisation (ISO). The definitions describe collection efficiency curves that pass through the following points:

d	0	10	30	60	100
% inhalable mass fraction	100	77.4	58.3	51.4	50.1

Where d is the equivalent aerodynamic diameter of the particle in μm.

TABLE 1:
Collection efficiency curve for inhalable dust

Different types of sampling devices that are specifically designed to conform to this specification may provide conflicting results if a significant proportion of the particles are larger than approximately 30 µm. At present there is no one acceptable procedure for obtaining a sample that accurately reflects the inhalable mass fraction (under various environmental conditions). However, for the purpose of these standards, the inhalable dust is to be collected according to the method set out in AS 3640-2009: *Workplace Atmospheres – Method for Sampling and Gravimetric Determination of Inhalable Dust*.[10]

The use of either of two personal sampling heads is recommended: the United Kingdom Atomic Energy Authority (UKAEA) sampling head or the IOM inhalable dust sampling head developed by the UK Institute of Occupational Medicine, Edinburgh.

RESPIRABLE DUST

Respirable dust is the proportion of airborne particulate matter that penetrates to the unciliated airways when inhaled. Respirable dust samples are to be collected according to the method set out in the Standards Australia publication AS 2985-2009: *Workplace Atmospheres – Method for Sampling and Gravimetric Determination of Respirable Dust*.[11]

This Standard refers to a sampling efficiency curve that passes through the following points:

d	0	1	2	3	4	5	6	7	10	14	16
Respirability %	100	100	97	80	56	34	20	11	2	0.2	0.1

Where d is the equivalent aerodynamic diameter of the particle in μm.

TABLE 2:
Collection efficiency curve for respirable dust

[10] Standards Australia, AS 3640:2009. *Workplace Atmospheres: Method for Sampling and Gravimetric Determination of Inhalable Dust*. Standards Australia, Sydney, (2009).

[11] Standards Australia, AS 2985:2009. *Workplace Atmospheres: Method for Sampling and Gravimetric Determination of Respirable Dust*. Standards Australia, Sydney, (2009).

1.7 Carcinogens

For cancers induced by exposure to airborne contaminants, the time between the initial exposure and diagnosis of disease is usually several years. This latency period may vary with the particular substance, the intensity and length of exposure, and the individual.

The existence of exposure thresholds defining no-effect levels has been theorised, but such thresholds for humans cannot be precisely identified and confirmed from the evidence provided by epidemiological or animal studies.

Substances which have been identified as confirmed or possible human carcinogens are noted in the WES table (table 5).

Under HSNO legislation, two categories of carcinogens are described. They are used throughout this guideline for HSNO-approved hazardous substances:

6.7A – Substances that are known or presumed human carcinogens

a. a substance for which data indicate sufficient evidence in humans of a causal relationship between exposure to the substance and the development of cancer in humans; or
b. a substance for which data indicate sufficient evidence in animals of a causal relationship between exposure to the substance and an increased incidence of tumours; or
c. a substance for which data indicate:
    i. limited evidence in humans of a positive correlation between exposure to the substance and the development of human cancer; and
    ii. limited evidence in animals that exposure to the substance may lead to an increased incidence of tumours.

6.7B – Substances that are suspected human carcinogens

A substance for which data indicate limited evidence in humans or limited evidence in animals that exposure to the substance may lead to the development of cancer or an increased incidence of tumours, where the strength and weight of the evidence indicate to an expert that the evidence is not sufficient to classify the substance in hazard classification 6.7A.

Substances that are not covered by HSNO legislation, but are carcinogenic to humans, have been noted as such in the WES table (Table 5).

Wherever practicable, substances that have been identified as confirmed or possible workplace carcinogens should be replaced by less hazardous substances. If this is not feasible, the hierarchy of control specified in the GRWM[12] must be strictly applied.

Where appropriate, exposure or biological monitoring should be employed to demonstrate that exposure is being kept to the lowest practicable level. All workers likely to be exposed to carcinogens must receive information about the hazards they face, and training in minimising exposure to those substances.

[12] Regulation 6, which applies to the management of risks that are not practicable to eliminate - the PCBU must minimise risks to health and safety and implement control measures. Minimisation must be achieved by one or more of the following: substitution for a lesser risk, isolation of the hazard giving rise to the risk, or implementing engineering control. If a risk remains, the PCBU must minimise the remaining risk by implementing administration controls and only after the above strategies have been implemented, and a risk still remains, may the remaining risk be minimised by ensuring the provision and use of personal protective equipment.

1.8 Skin absorption

Some substances can penetrate intact skin, and this may result in a higher substance uptake than would have been expected from inhalation only. Uptake through the skin is not usually the most significant route of absorption, but there are exceptions. For example, skin contact with organophosphate pesticides is thought to account for the majority of uptake experienced when working with these substances.

As the WES only takes into consideration the inhalation component, care should be taken when interpreting air sampling results where there is also a possibility of significant uptake through the skin. Respiratory protection may give a false sense of security. This is particularly important where vapour phase skin absorption occurs, as there may be no obvious contact between the skin and the substance. Biological monitoring for exposure may be a useful supplement to air sampling in these situations.

Substances that are considered to have potential for significant skin absorption are identified in the WES table (table 5) with a 'skin' notation.

1.9 Work load

An increase in work load can influence the uptake of a substance by increasing the lung ventilation rates and blood flow.

Exposure standards have generally been derived assuming a moderate work load. This factor should be borne in mind, especially where both the work load and exposure are high. The following table presents lung ventilation rates at different work loads. The table can be used:

1. to indicate if additional care should be taken in interpreting the monitoring results in relation to the WES and
2. to determine the type and effectiveness of respiratory protection.

Information on the limitations of applying the flow rates is provided in AS/NZS 1715:2009 *Selection, Use and Maintenance of Respiratory Protective Equipment*. It should be noted that these ventilation rates represent average values and can vary substantially from individual to individual. Current research on values for peak inspiratory air flow indicate that these are underestimated at present.

ASSESSMENT OF WORK LOAD	AVERAGE VENTILATION RATE LITRES/MINUTE	PEAK INHALATION RATE LITRES/MINUTE
Low (eg writing, typing, small bench tool work, standing while drilling or milling small parts)	11-20	100
Moderate (eg hammering in nails, filing, pneumatic hammering, walking 3.5-5.5 km/h)	20-31	150
High (eg carrying heavy loads, shovelling, digging, pushing or pulling heavy cart, walking 5.5-7.0 km/h)	31-43	200
Very high (eg working with axe, intense shovelling or digging, climbing ladder, stair or ramp, walking in excess of 7 km/h)	43-56	250

TABLE 3:
Lung ventilation rates impacted by workload

1.10 Sensitisers

Exposure to some substances can lead to the development of an allergic sensitisation, usually affecting the skin or respiratory system. High exposures may hasten the onset of the allergy, but once developed in an individual, very low exposures can provoke a significant reaction.

Even though low exposure standards have been specified for known sensitisers, the levels do not necessarily provide adequate protection for an already sensitised person. Avoiding further exposure may be the only option for these individuals.

A number of substances, including acid anhydrides, isocyanates and chromium compounds are known to be both respiratory and skin sensitisers, capable of causing allergic asthma, allergic contact dermatitis, or both. The risk of respiratory versus skin sensitisation may depend on the particular substance, as well as its physical state, exposure route, method of use, and the individual worker.

Substances that are considered to have potential for sensitisation are identified in the WES table (table 5) with a ‘sen’ notation.

1.11 Simple asphyxiants

Some gases and vapours, when they are present in the air in significant concentrations, behave as asphyxiants by reducing the concentration of oxygen.

The oxygen content of air should be maintained at 19.5%-23.5% under normal atmospheric conditions to manage health risks associated with oxygen.

Atmospheres that are deficient in oxygen do not provide adequate sensory warning of danger, and most simple asphyxiants are odourless. In some cases, death can occur in only a few minutes.

Some simple asphyxiants can also present an explosion hazard if present in high volumes. It is therefore essential that the presence, hazards and controls of simple asphyxiants are communicated to workers.

1.12 Ototoxins

Some substances can cause hearing loss either in conjunction with noise exposure, or without concurrent noise exposure. These substances are known as ototoxins and they can affect the cochlea and/or the auditory neurological pathways. They present a risk via the inhalation route of exposure, and some present a risk via skin absorption.

Workplace Exposure Standards have not been adjusted to reflect risk of hearing impairment. As such a cautious approach should be applied when using WES for a substance that has ototoxic potential. In addition risk is likely to be higher if there is exposure to multiple ototoxins. As a combination of exposure to noise and ototoxins has an additive or possibly synergistic effect on risk of hearing loss, occupational noise management programs should consider ototoxin exposure management.

Some aromatic and aliphatic hydrocarbon solvents are known ototoxins and include acrylonitrile, alcohol, carbon disulphide, ethyl benzene, heptane, n-hexane, perchloroethylene, styrene, toluene and trichloroethylene. Other ototoxins include arsenic, carbon monoxide, cobalt, hydrogen cyanide, lead, mercury, organophosphate pesticides, trimethyl tin, manganese and mercury.

1.13 Carbon monoxide (CO)

Exposure to carbon monoxide should be controlled to maintain a carboxyhaemoglobin (COHb) level below 3.5% (the Biological Exposure Index – or BEI – for CO). Under most conditions, this will be achieved if the average level over an eight-hour day does not exceed 25 ppm, but there is also a need to control brief periods of high CO exposure. The following limits on short-term excursions are recommended:

Short-term excursions for CO exposure

CONCENTRATION (PPM)	EXPOSURE PERIOD
200 ppm	15 minutes
100 ppm	30 minutes
50 ppm	60 minutes

TABLE 4:
Exposure periods for varying concentrations of carbon monoxide

The CO level should not exceed 400 ppm at any time during the day (Ceiling value).

2.0
WES values

IN THIS SECTION:

2.1 Table of WES values

The following table (Table 5) lists the WES values set by WorkSafe.

Reference key for workplace exposure standards

KEY	DESCRIPTION
CAS #	CAS Number, a unique numbering identifier is assigned by the Chemical Abstracts Service Registry to each individual chemical.
ppm	Parts of vapour or gas per million of air by volume.
mg/m³	Milligrams of substance per cubic metre of air.
(b)	Biological monitoring recommended.
(f)	Fibres not less than 5 µm and not more than 100 µm in length, less than 3 µm in width and with a length to width ratio of no less than 3:1.
(om)	Sampled by a method that does not collect vapour.
(p)	Polychlorinated Biphenyls (PCBs) are Persistent Organic Pollutants (POPs), which will be phased out in New Zealand by 2016. They are banned from importation, production and use. Exemptions allow for the storage of PCBs for a limited time and for small-scale research/ laboratory use.
(r)	The value for respirable dust.
(w)	A range of airborne contaminants are associated with gas and arc welding. The type of metal being welded, the electrode employed and the welding process will all influence the composition and amount of fume. Gaseous products such as oxides of nitrogen, carbon monoxide and ozone may also be produced. In the absence of specific substances such as chromium, and where conditions do not support the generation of toxic gases, the fume concentration inside the welder's helmet should not exceed 5 mg/m³.
6.7A	Confirmed carcinogen
6.7B	Suspected carcinogen
(skin)	Skin absorption
(sen)	Sensitiser
(bio)	Exposure can also be estimated by biological monitoring.
*	Adopted in 2017
‡	Currently under review

Unless otherwise stated, WES values in the following table for solid particles refer to the inhalable fraction, as opposed to the respirable fraction.

Workplace exposure standards

A		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Acetaldehyde 6.7B	[75-07-0]	20		50	
Acetic acid	[64-19-7]	10	25	15	37
Acetic anhydride	[108-24-7]	Ceiling 5 ppm (21 mg/m³)			
Acetone (bio)	[67-64-1]	500	1,185	1,000	2,375
Acetonitrile (skin)	[75-05-8]	40	67	60	101
Acetylene	[74-86-2]	Simple asphyxiant – may present an explosion hazard			
Acetylene dichloride (1,2-Dichloroethylene)	[540-59-0]	200	793		
Acetylene tetrabromide	[79-27-6]	1	14		
Acetylsalicylic acid (Aspirin)	[50-78-2]		5		
Acrolein	[107-02-8]	0.1	0.23		
Acrylamide (skin) 6.7A	[79-06-1]		0.03		
Acrylic acid (skin)	[79-10-7]	2	5.9		
Acrylonitrile (skin) 6.7A (Vinyl cyanide)	[107-13-1]	2	4.3		
Allyl alcohol	[107-18-6]	2	4.8	4	9.5
Allyl chloride 6.7B	[107-05-1]	1	3	2	6.0
Allyl glycidyl ether (AGE) (skin)	[106-92-3]	5	23	10	47
α Alumina (Aluminium oxide)	[1344-28-1]		10		
Aluminium, as Al Metal dust Pyro powders Welding fumes Soluble salts Alkyls (not otherwise classified)	[7429-90-5]		 10 5 5 5 2		
Aluminium oxide (α Alumina)	[1344-28-1]		10		
2-Aminoethanol (Ethanolamine)	[141-43-5]	3	7.5	6	15
2-Aminopyridine	[504-29-0]	0.5	2.0		
3-Amino-1,2,4-triazole (Amitrole)	[61-82-5]		0.2		
Amitrole (3-Amino-1,2,4-triazole)	[61-82-5]		0.2		
Ammonia, Anhydrous	[7664-41-7]	25	17	35	24
Ammonium chloride fume	[12125-02-9]		10		20
Ammonium perfluorooctanoate (skin) 6.7B	[3825-26-1]		0.1		
Ammonium sulphamate	[7773-06-0]		10		
Amosite (see Asbestos)					
n-Amyl acetate	[628-63-7]	100	532		
sec-Amyl acetate	[626-38-0]	125	665		

A		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Aniline and homologues (skin) 6.7B	[62-53-3]	1	4		
Anisidine (o-, p- isomers) (skin) 6.7B	[29191-52-4]	0.1	0.50		
Antimony and compounds, as Sb	[7440-36-0]		0.5		
Antimony hydride (Stibine)	[7803-52-3]	0.1	0.51		
Antimony trioxide 6.7B	[1309-64-4]		0.5		
Argon	[7440-37-1]	Simple asphyxiant			
‡ Arsenic and soluble compounds, as As 6.7A	[7440-38-2]		0.05		
Arsine	[7784-42-1]	0.05	0.16		
Asbestos (all forms) confirmed carcinogen		0.1 asbestos fibres per millilitre of air, averaged over an 8-hour period. Regulation 9(1) of the Health and Safety at Work (Asbestos) Regulations 2016 (the 'Asbestos Regulations') requires PCBUs with management or control of a workplace to ensure that exposure of a person at the workplace to airborne asbestos is eliminated so far as is reasonably practicable. If it is not reasonably practicable to eliminate exposure to airborne asbestos, exposure must be minimised so far as is reasonably practicable. Regulation 9(2) of the Asbestos Regulations requires PCBUs with management or control of a workplace to ensure that the airborne contamination standard for asbestos is not exceeded at the workplace (however, in relation to an asbestos removal area where class A asbestos removal work is being carried out, the regulations impose a more stringent standard). These requirements work together to ensure that there is a limit to the amount of asbestos that is permitted in the air of a workplace, without implying or meaning that the level delineates what is acceptable for personal exposure. Personal exposure must be eliminated or minimised so far as is reasonably practicable. The WES provided within this guide for asbestos must be applied accordingly.			
Asphalt (petroleum) fumes	[8052-42-4]		5		
Aspirin (Acetylsalicylic acid)	[50-78-2]		5		
Atrazine	[1912-24-9]		5		
Azinphos-methyl (skin)	[86-50-0]		0.2		

B		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Barium, soluble compounds, as Ba	[7440-39-3]		0.5		
Barium sulphate	[7727-43-7]		10		
Benomyl	[17804-35-2]	0.84	10		
Benzene (skin) 6.7A (2010)	[71-43-2]	1		2.5	
p-Benzoquinone (Quinone)	[106-51-4]	0.1	0.44		
Benzoyl peroxide	[94-36-0]		5		
Benzyl butyl phthalate	[85-68-7]		5		

B		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Benzyl chloride 6.7A	[100-44-7]	1	5.2		
‡ Beryllium and compounds, as Be 6.7A	[7440-41-7]		0.002		
Biphenyl (Diphenyl)	[92-52-4]	0.2	1.3		
Borates, tetra, sodium salts Anhydrous Decahydrate Pentahydrate	[1303-96-4]		 1 5 1		
Boron oxide	[1303-86-2]		10		
Boron tribromide	[10294-33-4]	Ceiling 1 ppm (10 mg/m³)			
Boron trifluoride	[7637-07-2]	Ceiling 1 ppm (2.8 mg/m³)			
Bromacil 6.7B	[314-40-9]	1	11		
Bromine	[7726-95-6]	0.1	0.66	0.3	2
Bromine pentafluoride	[7789-30-2]	0.1	0.72		
Bromochloromethane (Chlorobromomethane)	[74-97-5]	200	1,060		
Bromoform (skin)	[75-25-2]	0.5	5.2		
1,3-Butadiene 6.7A	[106-99-0]	10	22		
Butane	[106-97-8]	800	1,900		
Butanethiol (Butyl mercaptan)	[109-79-5]	0.5	1.8		
2-Butanone (bio) (Methyl ethyl ketone, MEK)	[78-93-3]	150	445	300	890
2-Butoxyethanol (skin) (Butyl glycol ether)	[111-76-2]	25	121		
n-Butyl acetate	[123-86-4]	150	713	200	950
sec-Butyl acetate	[105-46-4]	200	950		
tert-Butyl acetate	[540-88-5]	200	950		
Butyl acrylate (sen)	[141-32-2]	10	52		
n-Butyl alcohol (skin)	[71-36-3]	Ceiling 50 ppm (150 mg/m³)			
sec-Butyl alcohol	[78-92-2]	100	303		
tert-Butyl alcohol	[75-65-0]	100	303	150	455
Butylated hydroxytoluene (2,6-Di-tert-butyl-p-cresol)	[128-37-0]		10		
n-Butyl glycidyl ether (BGE) (sen)	[2426-08-6]	25	133		
Butyl glycol ether (skin) (2-Butoxyethanol)	[111-76-2]	25	121		
n-Butyl lactate	[138-22-7]	5	30		
Butyl mercaptan (Butanethiol)	[109-79-5]	0.5	1.8		
o-sec-Butylphenol (skin)	[89-72-5]	5	31		

B		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
p-tert-Butyltoluene	[98-51-1]	10	61	20	121

C		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Cadmium and compounds, as Cd 6.7A (bio)	[7440-43-9]		0.01 0.002(r)		
Calcium carbonate (Limestone, Marble)	[471-34-1]		10		
Calcium chromate, as Cr 6.7A	[13765-19-0]		0.001		
Calcium cyanamide	[156-62-7]		0.5		
Calcium hydroxide	[1305-62-0]		5		
Calcium oxide	[1305-78-8]		2		
Calcium silicate	[1344-95-2]		10		
Calcium sulphate (Gypsum, Plaster of Paris)	[7778-18-9]		10		
Camphor, synthetic	[76-22-2]	2	12	3	19
Caprolactam (dust vapour)	[105-60-2]	5	1 23	10	3 46
Captafol (skin)	[2425-06-1]		0.1		
Captan 6.7B	[133-06-2]		5		
Carbaryl	[63-25-2]		5		
Carbofuran	[1563-66-2]		0.1		
Carbon black 6.7B	[1333-86-4]		3		
Carbon dioxide	[124-38-9]	5,000	9,000	30,000	54,000
Carbon disulphide (skin)	[75-15-0]	10	31		
Carbon monoxide (bio) See section on carbon monoxide	[630-08-0]	25 ppm		Ceiling 400 ppm 200 ppm 15 min 100 ppm 30 min 50 ppm 60 min	
Carbon tetrabromide	[558-13-4]	0.1	1.4		
Carbon tetrachloride (skin) 6.7B (Tetrachloromethane)	[56-23-5]	0.1	0.63		
Carbonyl chloride (Phosgene)	[75-44-5]	0.02	0.08	0.06	0.25
Carbonyl fluoride	[353-50-4]	2	5.4	5	13
Catechol (skin) (Pyrocatechol)	[120-80-9]	5	23		
Cellulose (paper fibre)	[9004-34-6]		10		
Cement (Portland cement)	[65997-15-1]		10		
Chlorinated diphenyl oxide	[55720-99-5]		0.5		

C		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Chlorine	[7782-50-5]	0.5	1.5	1	2.9
Chlorine dioxide	[10049-04-4]	0.1	0.28		
Chloroacetaldehyde	[107-20-0]	Ceiling 1 ppm (3.2 mg/m³)			
Chloroacetone (skin)	[78-95-5]	Ceiling 1 ppm (3.8 mg/m³)			
α-Chloroacetophenone (Phenacyl chloride)	[532-27-4]	0.05	0.32		
Chloroacetyl chloride (skin)	[79-04-9]	0.05	0.23	0.15	0.69
Chlorobenzene (Monochlorobenzene)	[108-90-7]	10	46		
o-Chlorobenzylidene malononitrile (skin)	[2698-41-1]	Ceiling 0.05 ppm (0.39 mg/m³)			
Chlorobromomethane (Bromochloromethane)	[74-97-5]	200	1,060		
2-Chloro-1,3-butadiene (skin) (β-Chloroprene)	[126-99-8]	10	36		
Chlorodifluoromethane	[75-45-6]	1,000	3,540		
1-Chloro-2,3-epoxy propane (skin) 6.7A (Epichlorohydrin)	[106-89-8]	0.5	1.9	1.5	5.8
2-Chloroethanol (skin) (Ethylene chlorohydrin)	[107-07-3]	Ceiling 1 ppm (3.3 mg/m³)			
Chloroethylene 6.7A (Vinyl chloride)	[75-01-4]	5	13		
Chloroform (skin) 6.7B (Trichloromethane)	[67-66-3]	2	9.9		
bis(Chloromethyl) ether 6.7A	[542-88-1]	0.001	0.0047		
Chloropentafluoroethane	[76-15-3]	1,000	6,320		
Chloropicrin (Nitrochloromethane)	[76-06-2]	0.1	0.67		
β-Chloroprene (skin) (2-Chloro-1,3-butadiene)	[126-99-8]	10	36		
2-Chloropropionic acid (skin)	[598-78-7]	0.1	0.44		
o-Chlorostyrene	[2039-87-4]	50	283	75	425
Chlorosulphonic acid	[7790-94-5]		1		
o-Chlorotoluene	[95-49-8]	50	259		
Chlorpyrifos (skin)	[2921-88-2]		0.2		
Chromite ore processing (Chromate), as Cr 6.7A			0.05		
Chromium metal	[7440-47-3]		0.5		
Chromium (II) compounds, as Cr			0.5		
Chromium (III) compounds, as Cr			0.5		
Chromium (III) compounds, as Cr			0.5		

C		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
‡ Chromium (VI) compounds, as Cr (bio) Water soluble (sen) 6.7A Water insoluble (sen) 6.7A			 0.05 0.05		
Chromyl chloride	[14977-61-8]	0.025	0.16		
Chrysotile (see Asbestos)					
Coal dust			3(r)		
Coal tar pitch volatiles, as benzene solubles 6.7A (PPAH, Particulate polycyclic aromatic hydrocarbons)	[65996-93-2]		0.2		
‡ Cobalt metal dust and fume, as Co (bio) 6.7B	[7440-48-4]		0.05		
Cobalt carbonyl, as Co (sen)	[10210-68-1]		0.1		
Copper fume Dusts and mists, as Cu	[7440-50-8]		0.2 1		
Cotton dust, raw			0.2		
Cresol, all isomers (skin)	[1319-77-3]	5	22		
Cristobalite (see Silica-Crystalline)					
Crocidolite (see Asbestos)					
Crotonaldehyde (skin) 6.7B	[4170-30-3]	2	5.7		
Cumene (skin)	[98-82-8]	25	125	75	375
Cyanamide	[420-04-2]		2		
Cyanides, as CN (skin)	[151-50-8]; [143-33-9]		5		
‡ Cyanogen	[460-19-5]	10	21		
Cyanogen chloride	[506-77-4]	Ceiling 0.3 ppm (0.75 mg/m³)			
Cyclohexane	[110-82-7]	100	350	300	1050
Cyclohexanol (skin)	[108-93-0]	50	206		
Cyclohexanone (skin)	[108-94-1]	25	100		
Cyclohexene	[110-83-8]	300	1,010		
Cyclohexylamine	[108-91-8]	10	41		
Cyclopentadiene	[542-92-7]	75	203		
Cyclopentane	[287-92-3]	600	1,720		

D		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
2,4-D	[94-75-7]		10		
Diacetone alcohol (4-Hydroxy-4-methyl-2-pentanone)	[123-42-2]	50	238		
Diallyl phthalate	[131-17-9]		5		
1,2-Diaminoethane (skin) (sen) (Ethylenediamine)	[107-15-3]	10	25		
Diatomaceous earth (not calcined) (see Silica-Amorphous)	[61790-53-2]		10		
Diazinon (skin)	[333-41-5]		0.1		
Diborane	[19287-45-7]	0.1	0.11		
1,2-Dibromomethane (skin) 6.7A (Ethylene dibromide)	[106-93-4]	0.5	3.9		
2-N-Dibutylaminoethanol (skin)	[102-81-8]	2	14		
Dibutyl phenyl phosphate (skin)	[2528-36-1]	0.3	3.5		
Dibutyl phthalate	[84-74-2]		5		
Dichloroacetylene 6.7B	[7572-29-4]	Ceiling 0.1 ppm (0.39 mg/m³)			
o-Dichlorobenzene (skin)	[95-50-1]	Ceiling 50 ppm (301 mg/m³)			
p-Dichlorobenzene 6.7B	[106-46-7]	25	153	50	306
Dichlorodifluoromethane	[75-71-8]	1,000	4,950		
1,3-Dichloro-5,5-dimethyl hydantoin	[118-52-5]		0.2		0.4
1,1-Dichloroethane (Ethylidene chloride)	[75-34-3]	200	810	250	1,010
1,2-Dichloroethane (skin) (Ethylene dichloride)	[107-06-2]	5	21		
1,1-Dichloroethylene (Vinylidene chloride)	[75-35-4]	5	20	20	79
1,2-Dichloroethylene (Acetylene dichloride)	[540-59-0]	200	793		
Dichloroethyl ether (skin)	[111-44-4]	5	29	10	58
Dichlorofluoromethane	[75-43-4]	10	42		
Dichloromethane 6.7B (Methylene chloride)	[75-09-2]	50	174		
1,1-Dichloro-1-nitroethane	[594-72-9]	2	12		
1,2-Dichloropropane (Propylene dichloride)	[78-87-5]	75	347	110	508
Dichloropropene (skin)	[542-75-6]	1	4.5		
2,2-Dichloropropionic acid	[75-99-0]	1	5.8		
Dichlorotetrafluoroethane	[76-14-2]	1,000	6,990		
Dichlorvos (skin)	[62-73-7]	0.1	0.90		

D		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Dicyclohexyl phthalate	[84-61-7]		5		
Dicyclopentadiene	[77-73-6]	5	27		
Dicyclopentadienyl iron	[102-54-5]		5		
Diesel Particulate Matter (DPM) as elemental carbon (2016)			0.1		
Diethanolamine (skin)	[111-42-2]	3	13		
Diethylamine (skin)	[109-89-7]	10	30	25	75
2-Diethylaminoethanol (skin)	[100-37-8]	10	48		
Diethylene glycol	[111-46-6]	23	101		
Diethylene triamine (skin)	[111-40-0]	1	4.2		
Diethyl ether (Ethyl ether)	[60-29-7]	400	1,210	500	1,520
Di(2-ethylhexyl)phthalate (Di-sec-octyl phthalate)	[117-81-7]		5		10
Diethyl ketone	[96-22-0]	200	705		
Diethyl phthalate	[84-66-2]		5		
Diethyl sulphate (skin)	[64-67-5]	0.05	0.32		
Difluorodibromomethane	[75-61-6]	100	858		
Dihydroxybenzene 6.7B (Hydroquinone)	[123-31-9]		2		
Diisobutyl ketone (2,6-Dimethyl-4-heptanone)	[108-83-8]	25	145		
Diisobutyl phthalate	[84-69-5]		5		
Diisodecyl phthalate	[26761-40-0]		5		
Diisononyl phthalate	[28553-12-0]		5		
Diisococtyl phthalate	[27554-26-3]		5		
Diisopropylamine	[108-18-9]	5	21		
Dimethoxymethane (Methylal)	[109-87-5]	1,000	3,110		
Dimethyl acetamide (skin)	[127-19-5]	10	36		
Dimethylamine	[124-40-3]	10	18		
Dimethylaminoethanol	[108-01-0]	2	7.4	6	22
Dimethylaminobenzene (skin) 6.7B (Xylidine, mixed isomers)	[1300-73-8]	0.5	2.5		
N,N-Dimethylaniline (skin)	[121-69-7]	5	25	10	50
Dimethylbenzene (see Xylene)	Various	50	217		
Dimethyl-1,2-dibromo-2, 2-dichloroethyl phosphate (skin) (Naled)	[300-76-5]		3		
Dimethylether	[115-10-6]	400	766	500	958

D		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
N,N-Dimethylethylamine	[598-56-1]	10	30	15	46
Dimethylformamide (skin)	[68-12-2]	10	30		
2,6-Dimethyl-4-heptanone (Diisobutyl ketone)	[108-83-8]	25	145		
1,1-Dimethylhydrazine (skin) 6.7B	[57-14-7]	0.01	0.025		
Dimethylphthalate	[131-11-3]		5		
Dimethyl sulphate (skin) 6.7A	[77-78-1]	0.05	0.26		
Dinitolmide (3,5-Dinitro-o-toluamide)	[148-01-6]		5		
Dinitrobenzene, all isomers (skin)	[528-29-0] [99-65-0] [100-25-4]	0.15	1.0		
Dinitro-o-cresol (skin)	[534-52-1]		0.2		
3,5-Dinitro-o-toluamide (Dinitolmide)	[148-01-6]		5		
Dinonyl phthalate	[84-76-4]		5		
Dioxane (skin) 6.7A	[123-91-1]	25	90		
Diphenyl (Biphenyl)	[92-52-4]	0.2	1.3		
Diphenylamine	[122-39-4]		10		
Diphenylmethane diisocyanate (see Isocyanates)	[101-68-8]		0.02		0.07
Dipropylene glycol methyl ether (skin)	[34590-94-8]	100	606	150	909
Dipropyl ketone	[123-19-3]	50	233		
Diquat	[2764-72-9]		0.5		
Diquat dibromide	[85-00-7]		0.5		
Di-sec-octyl phthalate (Di(2-ethylhexyl)phthalate)	[117-81-7]		5		10
Disulfiram	[97-77-8]		2		
2,6-Di-tert-butyl-p-cresol (Butylated hydroxytoluene)	[128-37-0]		10		
Diuron	[330-54-1]		10		
Divinyl benzene	[1321-74-0]	10	53		

E		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Emery	[1302-74-5]		10		
Enzymes (see Subtilins)					
Epichlorohydrin (skin) 6.7A (1-Chloro-2,3-epoxy propane)	[106-89-8]	0.5	1.9	1.5	5.8

E		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
1,2-Epoxypropane 6.7B (Propylene oxide)	[75-56-9]	5	12		
2,3-Epoxy-1-propanol 6.7B (Glycidol)	[556-52-5]	25	76		
Ethane	[74-84-0]	Simple asphyxiant – may present an explosion hazard			
‡ Ethanedinitrile (EDN) Cyanogen	[460-19-5]	10	21		
Ethanethiol (Ethyl mercaptan)	[75-08-1]	0.5	1.3		
Ethanol (Ethyl alcohol)	[64-17-5]	1,000	1,880		
Ethanolamine (2-Aminoethanol)	[141-43-5]	3	7.5	6	15
Ethion (skin)	[563-12-2]		0.4		
2-Ethoxyethanol (skin) (bio) (Glycol monoethyl ester)	[110-80-5]	5	18		
2-Ethoxyethyl acetate (EGEEA) (skin) (bio)	[111-15-9]	5	27		
Ethyl acetate	[141-78-6]	200	720		
Ethyl acrylate (sen) (skin)	[140-88-5]	Ceiling 5 ppm (20 mg/m³)			
Ethyl alcohol (Ethanol)	[64-17-5]	1,000	1,880		
Ethylamine (skin)	[75-04-7]	10	18		
Ethyl amyl ketone (5-Methyl-3-heptanone)	[541-85-5]	25	131		
Ethyl benzene	[100-41-4]	100	434	125	543
Ethyl bromide (skin) 6.7B	[74-96-4]	5	22		
Ethyl butyl ketone (3-Heptanone)	[106-35-4]	50	234		
Ethyl chloride (skin) 6.7B	[75-00-3]	1,000	2,640		
Ethylene	[74-85-1]	Simple asphyxiant			
Ethylene chlorohydrin (skin) (2-Chloroethanol)	[107-07-3]	Ceiling 1 ppm (3.3 mg/m³)			
Ethylenediamine (skin) (sen) (1,2-Diaminoethane)	[107-15-3]	10	25		
Ethylene dibromide (skin) 6.7A (1,2-Dibromomethane)	[106-93-4]	0.5	3.9		
Ethylene dichloride (skin) (1,2-Dichloroethane)	[107-06-2]	5	21		
Ethylene glycol (vapour and mist)	[107-21-1]	Ceiling 50 ppm (127 mg/m³)			
Ethylene glycol dinitrate (skin)	[628-96-6]	0.05	0.31		
Ethylene glycol methyl ether acetate (skin) (2-Methoxyethyl acetate)	[110-49-6]	5	24		
Ethylene glycol isopropyl ether	[109-59-1]	25	106		
Ethyleneimine (skin) 6.7B	[151-56-4]	0.5	0.88		

E		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Ethylene oxide 6.7A	[75-21-8]	1	1.8		
Ethyl ether (Diethyl ether)	[60-29-7]	400	1,210	500	1,520
Ethyl formate	[109-94-4]	100	303		
Ethylidene chloride (1,1-Dichloroethane)	[75-34-3]	200	810	250	1,010
Ethylidene norbornene	[16219-75-3]	Ceiling 5 ppm (25 mg/m³)			
Ethyl mercaptan (Ethanethiol)	[75-08-1]	0.5	1.3		
N-Ethylmorpholine (skin)	[100-74-3]	5	24		
Ethyl silicate	[78-10-4]	10	85		

F		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Fenthion (skin)	[55-38-9]		0.2		
Ferrovanadium dust	[12604-58-9]		1		
Fibrous glass dust (see Synthetic mineral fibres)					
‡ Flour dust					
Fluorides, as F (bio)			2.5		
Fluorine	[7782-41-4]	1	1.6	2	3.1
Fluorotrichloromethane (Trichlorofluoromethane)	[75-69-4]	Ceiling 1,000 ppm (5,620 mg/m³)			
Formaldehyde (sen) 6.7A (2013)	[50-00-0]	0.5 ppm (8 hour shift) 0.33 ppm (12 hour shift) Ceiling 1 ppm			
Formamide (skin)	[75-12-7]	10	18		
Formic acid	[64-18-6]	5	9.4	10	19
Furfural (skin) 6.7B	[98-01-1]	2	7.9		
Furfuryl alcohol (skin)	[98-00-0]	10	40	15	60

G		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Gasoline (Petrol)	[8006-61-9]	300	890	500	1,480
Glass, fibrous or dust (see Synthetic mineral fibres)					
Glutaraldehyde (sen)	[111-30-8]			0.05	
Glycerin (mist)	[56-81-5]		10		
Glycidol 6.7B (2,3-Epoxy-1-propanol)	[556-52-5]	25	76		

G		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Glycol monoethyl ester (skin) (bio) (2-Ethoxyethanol)	[110-80-5]	5	18		
Grain dust (oat, wheat, barley)			4		
Graphite, all forms except graphite fibres	[7782-42-5]		3(r)		
Gypsum (Calcium sulphate)	[7778-18-9]		10		

H		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Halothane	[151-67-7]	0.5			
Helium	[7440-59-7]	Simple asphyxiant			
Heptane (n-Heptane)	[142-82-5]	400	1,640	500	2,050
2-Heptanone (Methyl n-amyl ketone)	[110-43-0]	50	233		
3-Heptanone (Ethyl butyl ketone)	[106-35-4]	50	234		
Hexachlorocyclopentadiene	[77-47-4]	0.01	0.11		
Hexachloroethane (skin) 6.7B	[67-72-1]	1	9.7		
Hexafluoroacetone (skin)	[684-16-2]	0.1	0.68		
Hexamethylene diisocyanate (see Isocyanates)	[822-06-0]		0.02		0.07
Hexane (n-Hexane) (bio) Other isomers	[110-54-3]	20 500	72 1,760	1,000	3,500
2-Hexanone (skin) (Methyl n-butyl ketone)	[591-78-6]	5	20		
Hexone (Methyl isobutyl ketone)	[108-10-1]	50	205	75	307
sec-Hexyl acetate	[108-84-9]	50	295		
Hexylene glycol	[107-41-5]	Ceiling 25 ppm (121 mg/m³)			
Hydrazine (skin) 6.7B	[302-01-2]	0.01	0.013		
Hydrogen	[1333-74-0]	Simple asphyxiant – may present an explosion hazard			
Hydrogenated terphenyls	[61788-32-7]	0.5	4.9		
Hydrogen bromide	[10035-10-6]	Ceiling 3 ppm (9.9 mg/m³)			
Hydrogen chloride	[7647-01-0]	Ceiling 5 ppm (7.5 mg/m³)			
Hydrogen cyanide (skin)	[74-90-8]	Ceiling 10 ppm (11 mg/m³)			
Hydrogen fluoride, as F	[7664-39-3]	Ceiling 3 ppm (2.6 mg/m³)			
Hydrogen peroxide	[7722-84-1]	1	1.4		
‡ Hydrogen sulphide	[7783-06-4]	10	14	15	21
Hydroquinone 6.7B (Dihydroxybenzene)	[123-31-9]		2		

H		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
4-Hydroxy-4-methyl-2-pentanone (Diacetone alcohol)	[123-42-2]	50	238		
2-Hydroxypropyl acrylate (skin)	[999-61-1]	0.5	2.8		

I		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Indium and compounds, as In	[7440-74-6]		0.1		
Iodine	[7553-56-2]	Ceiling 0.1 ppm (1 mg/m³)			
Iodoform	[75-47-8]	0.6	10		
Iodomethane (skin)	[74-88-4]	2	12		
Iron oxide dust and fume (Fe_2O_3), as Fe	[1309-37-1]		5(w)		
Iron pentacarbonyl, as Fe	[13463-40-6]	0.1	0.23	0.2	0.45
Iron salts, soluble, as Fe			1		
Isoamyl acetate	[123-92-2]	100	532		
Isoamyl alcohol	[123-51-3]	100	361	125	452
Isobutyl acetate	[110-19-0]	150	713		
Isobutyl alcohol	[78-83-1]	50	152		
Isocyanates, all, (as –NCO) (sen)			0.02		0.07
		Note: These values apply to all isocyanates, including prepolymers, present in the workplace air as vapours, mist or dust.			
Isooctyl alcohol (skin)	[26952-21-6]	50	266		
Isophorone 6.7B	[78-59-1]	Ceiling 5 ppm (28 mg/m³)			
Isophorone diisocyanate (skin) (see Isocyanates)	[4098-71-9]		0.02		0.07
Isopropyl acetate	[108-21-4]	250	1,040	310	1,290
Isopropyl alcohol	[67-63-0]	400	983	500	1,230
Isopropylamine	[75-31-0]	5	12	10	24
Isopropyl ether	[108-20-3]	250	1,040	310	1,300
Isopropyl glycidyl ether (IGE)	[4016-14-2]	50	238	75	356

K		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Kaolin	[1332-58-7]	10 mg/m³; and 2 mg/m³ (r)			
Ketene	[463-51-4]	0.5	0.86		

L		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Lead, inorganic dusts and fumes, as Pb (bio) 6.7B	[7439-92-1]		0.1		
	Note: The WES-TWA for Lead, inorganic dusts and fumes, as Pb will change from 0.1 mg/m³ to 0.05 mg/m³ two years from the date of publication of this Special Guide.				
Lead chromate, as Cr 6.7A	[7758-97-6]		0.05		
Limestone (Calcium carbonate)	[471-34-1]		10		
Lindane (skin) 6.7B	[58-89-9]		0.1		
Lithium hydride	[7580-67-8]		0.025		
Lithium hydroxide	[1310-65-2]			1	
LPG (Liquefied petroleum gas)	[68476-85-7]	1,000	1,800		

M		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Magnesite	[546-93-0]		10		
Magnesium oxide fume	[1309-48-4]		10		
Malathion (skin)	[121-75-5]		10		
Maleic anhydride (sen)	[108-31-6]	0.25	1.0		
Man-made mineral fibres (Synthetic mineral fibres)			1 Respirable fibre per millilitre air and 5 mg/m³ Inhalable dust		
‡ Manganese dust and compounds, as Mn Fume, as Mn	[7439-96-5]		1 1		 3
Manganese cyclopentadienyl tricarbonyl, as Mn (skin)	[12079-65-1]		0.1		
Marble (Calcium carbonate)	[471-34-1]		10		
MDI (see Isocyanates)	[101-68-8]		0.02		0.07
MEK (bio) (Methyl ethyl ketone, 2-Butanone)	[78-93-3]	150	445	300	890
Mercury vapour (as Hg) (skin) (bio) Inorganic compounds (as Hg) Alkyl compounds (as Hg)	[7439-97-6]		0.025 0.025 0.01		
Mesityl oxide	[141-79-7]	15	60	25	100
Methacrylic acid	[79-41-4]	20	70		
Methane	[74-82-8]	Simple asphyxiant – may present an explosion hazard			
Methanethiol (Methyl mercaptan)	[74-93-1]	0.5	0.98		
Methanol (skin), (bio) (Methyl alcohol)	[67-56-1]	200	262	250	328
Methomyl	[16752-77-5]		2.5		
Methoxychlor	[72-43-5]		10		

M		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
2-Methoxyethanol (skin)	[109-86-4]	5	16		
2-Methoxyethyl acetate (skin) (Ethylene glycol methyl ether acetate)	[110-49-6]	5	24		
4-Methoxyphenol	[150-76-5]		5		
Methyl acetate	[79-20-9]	200	606	250	757
Methyl acetylene (Propyne)	[74-99-7]	1,000	1,640		
Methyl acetylene-propadiene mixture (MAPP)	[59355-75-8]	1,000	1,640	1,250	2,050
Methyl acrylate (skin)	[96-33-3]	10	35		
Methylacrylonitrile (skin)	[126-98-7]	1	2.7		
Methylal (Dimethoxymethane)	[109-87-5]	1,000	3,110		
Methyl alcohol (skin) (bio) (Methanol)	[67-56-1]	200	262	250	328
Methylamine	[74-89-5]	10	13		
Methyl amyl alcohol (skin) (Methyl isobutyl carbinol)	[108-11-2]	25	104	40	167
Methyl n-amyl ketone (2-Heptanone)	[110-43-0]	50	233		
N-Methyl aniline (skin)	[100-61-8]	0.5	2.2		
Methyl bromide (skin)	[74-83-9]	5	19		
Methyl n-butyl ketone (skin) (2-Hexanone)	[591-78-6]	5	20		
Methyl chloride (skin)	[74-87-3]	50	103	100	207
Methyl chloroform (1,1,1-Trichloroethane)	[71-55-6]	125	680		
Methyl 2-cyanoacrylate	[137-05-3]	2	9.1	4	18
Methylcyclohexane	[108-87-2]	400	1,610		
Methylcyclohexanol	[25639-42-3]	50	234		
o-Methylcyclohexanone (skin)	[583-60-8]	50	229	75	344
2-Methylcyclopentadienyl manganese tricarbonyl, as Mn (skin)	[12108-13-3]		0.2		
Methylene bisphenyl isocyanate (see Isocyanates)	[101-68-8]		0.02		0.07
Methylene chloride 6.7B (Dichloromethane)	[75-09-2]	50	174		
4,4-Methylene bis(2-chloroaniline) (skin) 6.7A (MOCA)	[101-14-4]		0.005		
Methylene bis(4-cyclohexylisocyanate) (see Isocyanates)					
4,4-Methylene dianiline (skin) 6.7A	[101-77-9]	0.01	0.08		

M		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Methyl ethyl ketone (bio) (MEK, 2-Butanone)	[78-93-3]	150	445	300	890
Methyl ethyl ketone peroxide	[1338-23-4]	Ceiling 0.2 ppm (1.5 mg/m³)			
Methyl formate	[107-31-3]	100	246	150	368
5-Methyl-3-heptanone (Ethyl amyl ketone)	[541-85-5]	25	131		
Methyl iodide (skin)	[74-88-4]	2	12		
Methyl isoamyl ketone	[110-12-3]	50	234		
Methyl isobutyl carbinol (skin) (Methyl amyl alcohol)	[108-11-2]	25	104	40	167
Methyl isobutyl ketone (Hexone)	[108-10-1]	50	205	75	307
Methyl isopropyl ketone	[563-80-4]	200	705		
Methyl mercaptan (Methanethiol)	[74-93-1]	0.5	0.98		
Methyl methacrylate (skin) (sen)	[80-62-6]	50	208	100	416
Methyl parathion (skin)	[298-00-0]		0.2		
Methyl propyl ketone (2-Pentanone)	[107-87-9]	200	705	250	881
1-Methyl-2-pyrrolidone (skin)	[872-50-4]	25	103	75	309
Methyl silicate	[681-84-5]	1	6		
α-Methyl styrene	[98-83-9]	50	242	100	483
Methyl-tert butyl ether	[1634-04-4]	25	92	75	275
Metribuzin	[21087-64-9]		5		
Mica	[12001-26-2]		3(r)		
Mineral wool fibre (Synthetic mineral fibres)			1 Respirable fibre per millilitre air and 5 mg/m³ Inhalable dust		
MOCA (skin) 6.7A (4,4-Methylene bis(2-chloroaniline))	[101-14-4]		0.005		
Molybdenum, as Mo Soluble compounds Insoluble compounds	[7439-98-7]		 5 10		
Monochloroacetic acid (skin)	[79-11-8]	0.3	1.2		
Monochlorobenzene (Chlorobenzene)	[108-90-7]	10	46		
Morpholine (skin)	[110-91-8]	20	71		

N		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Naled (skin) (Dimethyl-1,2-dibromo-2,2-dichloroethyl phosphate)	[300-76-5]		3		
Naphthalene	[91-20-3]	10	52	15	79
Neon	[7440-01-9]	Simple asphyxiant			
‡ Nickel metal (sen) Soluble compounds, as Ni (sen)	[7440-02-0]		1 0.1		
Nickel sulphide roasting, fume and dust, as Ni (sen) 6.7A			1		
Nicotine (skin)	[54-11-5]		0.5		
Nitric acid	[7697-37-2]	2	5.2	4	10
Nitric oxide	[10102-43-9]	25	31		
p-Nitroaniline (skin)	[100-01-6]		3		
Nitrobenzene (skin) 6.7B	[98-95-3]	1	5		
p-Nitrochlorobenzene (skin) 6.7B	[100-00-5]	0.1	0.64		
Nitrochloromethane (Chloropicrin, Tricholoronitromethane)	[76-06-2]	0.1	0.67		
Nitroethane	[79-24-3]	100	307		
Nitrogen	[7727-37-9]	Simple asphyxiant			
‡ Nitrogen dioxide	[10102-44-0]	3	5.6	5	9.4
Nitroglycerin (NG) (skin)	[55-63-0]	0.05	0.46		
Nitromethane 6.7B	[75-52-5]	20	50		
1-Nitropropane	[108-03-2]	25	91		
2-Nitropropane 6.7A	[79-46-9]	5	19		
Nitrotoluene (skin)	[88-72-2] [99-08-1] [99-99-0]	2	11		
Nitrous oxide	[10024-97-2]	25	45		
Nonane	[111-84-2]	200	1,050		

O		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Octane	[111-65-9]	300	1,400	375	1,750
Oil mist, mineral	[8012-95-1]		5(om)		10
Osmium tetroxide, as Os	[20816-12-0]	0.0002	0.0016		
Oxalic acid	[144-62-7]		1		2
Ozone	[10028-15-6]	Ceiling 0.1 ppm (0.20 mg/m³)			

P		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Paraffin wax fume	[8002-74-2]		2		
Paraquat	[4685-14-7]		0.1(r)		
Particulate polycyclic aromatic hydrocarbons 6.7A (PPAH, Coal tar pitch volatiles)	[65996-93-2]		0.2		
Particulates not otherwise classified			10 3(r)		
PCBs (Polychlorinated Biphenyls)(p)	[1336-36-3]		0.1		
Pentachloronaphthalene	[1321-64-8]		0.5		
Pentachloronitrobenzene	[82-68-8]		0.5		
Pentachlorophenol (skin) 6.7B	[87-86-5]		0.5		
Pentaerythritol	[115-77-5]		10		
Pentane	[109-66-0]	600	1,770	750	2,120
2-Pentanone (Methyl propyl ketone)	[107-87-9]	200	705	250	881
‡ Perchloroethylene 6.7A (Tetrachloroethylene)	[127-18-4]	50	335	150	1005
Perchloromethyl mercaptan	[594-42-3]	0.1	0.76		
Perlite	[93763-70-3]		10		
Petrol (Gasoline)	[8006-61-9]	300	890	500	1,480
Phenacyl chloride (α-Chloroacetophenone)	[532-27-4]	0.05	0.32		
Phenol (skin)	[108-95-2]	5			
Phenothiazine	[92-84-2]		5		
m- Phenylenediamine o- Phenylenediamine 6.7B p- Phenylenediamine (skin)	[108-45-2] [95-54-5] [106-50-3]		0.1 0.1 0.1		
Phenyl ether vapour	[101-84-8]	1	7	2	14
Phenylethylene (skin) 6.7A (Styrene, monomer)	[100-42-5]	50	213	100	426
Phenyl glycidyl ether (PGE) (sen) (skin) 6.7B	[122-60-1]	1	6.1		
Phenylhydrazine (skin) (sen) 6.7B	[100-63-0]	0.1	0.44		
Phenyl mercaptan	[108-98-5]	0.5	2.3		
Phenylphosphine	[638-21-1]	Ceiling 0.05 ppm (0.23 mg/m³)			
Phorate (skin)	[298-02-2]		0.05		0.2
Phosgene (Carbonyl chloride)	[75-44-5]	0.02	0.08	0.06	0.25

P		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Phosphine	[7803-51-2]	0.3	0.42	1	1.4
Phosphoric acid	[7664-38-2]		1		
Phosphorous (yellow)	[7723-14-0]		0.1		
Phosphorous oxychloride	[10025-87-3]	0.1	0.63		
Phosphorous pentachloride	[10026-13-8]	0.1	0.85		
Phosphorous pentasulphide	[1314-80-3]		1		
Phosphorous trichloride	[7719-12-2]	0.2	1.1	0.5	2.8
Phthalic anhydride (sen)	[85-44-9]	1	16.1		
m-Phthalodinitrile	[626-17-5]		5		
Picloram	[1918-02-1]		10		
Picric acid (2,4,6-Trinitrophenol)	[88-89-1]		0.1		
Pindone (2-Pivaloyl-1,3-indandione)	[83-26-1]		0.1		
Piperazine dihydrochloride	[142-64-3]		5		
Piperidine (skin)	[110-89-4]	1	3.5		
2-Pivaloyl-1,3-indandione (Pindone)	[83-26-1]		0.1		
Plaster of Paris (Calcium sulphate)	[7778-18-9]		10		
Platinum metal Soluble salts, as Pt (sen)	[7440-06-4]		1 0.002		
Polychlorinated Biphenyls (p) (PCBs)	[1336-36-3]		0.1		
‡ Portland cement	[65997-15-1]		10		
Potassium hydroxide	[1310-58-3]		Ceiling 2		
PPAH 6.7A (Particulate polycyclic aromatic hydrocarbons, Coal tar pitch volatiles)	[65996-93-2]		0.2		
Precipitated silica (Silica-Amorphous)			10		
Propane	[74-98-6]	Simple asphyxiant – may present an explosion hazard			
Propane-1,2-diol Vapour and particulates Particulates only	[57-55-6]	150	474 10		
Propargyl alcohol (skin)	[107-19-7]	1	2.3		
β-Propiolactone 6.7B	[57-57-8]	0.5	1.5		
Propionic acid	[79-09-4]	10	30		
Propoxur 6.7B	[114-26-1]		0.5		
Propranolol	[525-66-6]		2		6

P		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
n-Propyl acetate	[109-60-4]	200	835	250	1,040
n-Propyl alcohol (skin)	[71-23-8]	200	492	250	614
Propylene	[115-07-1]	Simple asphyxiant – may present an explosion hazard			
Propylene dichloride (1,2-Dichloropropane)	[78-87-5]	75	347	110	508
Propylene glycol dinitrate (skin)	[6423-43-4]	0.05	0.34		
Propylene glycol monomethyl ether	[107-98-2]	100	369	150	553
‡ Propylene oxide 6.7B (1,2-Epoxypropane)	[75-56-9]	5	12		
n-Propyl nitrate	[627-13-4]	25	107	40	172
Propyne (Methyl acetylene)	[74-99-7]	1,000	1,640		
Pyrethrum (sen)	[8003-34-7]		5		
Pyridine	[110-86-1]	5	16		
Pyrocatechol (skin) (Catechol)	[120-80-9]	5	23		

Q		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Quartz (see Silica-Crystalline)			0.1(r)		
Quinone (p-Benzoquinone)	[106-51-4]	0.1	0.44		

R		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
RDX (skin) (Cyclonite)	[121-82-4]		1.5		
Resorcinol	[108-46-3]	10	45	20	90
Rhodium metal Insoluble compounds, as Rh Soluble compounds, as Rh	[7440-16-6]		1 1 0.01		
Rosin core solder thermal decomposition products as resin acids (colophony) (sen)		Reduce to the lowest practicable level			
Rotenone (commercial)	[83-79-4]		5		
Rouge			10(w)		
Rubber process dust Rubber fume (as cyclohexane soluble material)			6 0.6		
Rubber solvent (Naphtha)		400	1,600		

S		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m3**	**ppm**	**mg/m³**
Selenium and compounds, as Se	[7782-49-2]		0.1		
Silane (Silicon tetrahydride)	[7803-62-5]	5	6.6		
Silica-Amorphous Diatomaceous earth (not calcined) Precipitated silica Silica gel	[61790-53-2]		 10 10 10		
Silica-Crystalline (all forms) 6.7A quartz and cristobalite are confirmed carcinogens (2016)			0.1(r)		
Silica fume			2(r)		
Silica fused	[60676-86-0]		0.2(r)		
Silica gel (Silica-Amorphous)			10		
Silicon	[7440-21-3]		10		
Silicon carbide	[409-21-2]		10		
Silicon tetrahydride (Silane)	[7803-62-5]	5	6.6		
Silver metal Soluble compounds, as Ag	[7440-22-4]		0.1 0.01		
Soapstone			6 3(r)		
Sodium azide	[26628-22-8]	Ceiling 0.11 ppm (0.29 mg/m³)			
Sodium bisulphite	[7631-90-5]		5		
Sodium disulphite	[7681-57-4]		5		
Sodium fluoroacetate (1080) (skin) (bio)	[62-74-8]		0.05		
Sodium hydroxide	[1310-73-2]		Ceiling 2		
Starch	[9005-25-8]		10		
Stearates			10		
Stibine (Antimony hydride)	[7803-52-3]	0.1	0.51		
Stoddard solvent (White spirits)	[8052-41-3]	100	525		
Strontium chromate, as Cr 6.7A	[7789-06-2]		0.001		
Strychnine	[57-24-9]		0.15		
‡ Styrene, monomer (skin) 6.7B (Phenylethylene, Vinyl benzene)	[100-42-5]	50	213	100	426
Subtilisins (Proteolytic enzymes, as 100% pure crystalline enzyme) (skin)	[1395-21-7]; [9014-01-1]		Ceiling 0.00006		
Sucrose	[57-50-1]		10		
Sulfotep (skin)	[3689-24-5]		0.2		
Sulphur dioxide	[7446-09-5]	2	5.2	5	13
Sulphur hexafluoride	[2551-62-4]	1,000	5,970		
‡ Sulphuric acid 6.7A	[7664-93-9]		1		

S		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m3**	**ppm**	**mg/m³**
Sulphur monochloride	[10025-67-9]	Ceiling 1 ppm (5.5 mg/m³)			
Sulphuryl fluoride	[2699-79-8]	5	21	10	42
‡ Synthetic mineral fibres (Man-made mineral fibres)			1 Respirable fibre per millilitre air and 5 mg/m³ Inhalable dust		

T		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
2,4,5-T	[93-76-5]		10		
Talc (containing no asbestos fibres)	[14807-96-6]		2(r)		
Talc (containing asbestos fibres)		Use asbestos standards			
Tantalum metal Oxide dusts	[7440-25-7] [1314-61-0]		5 5		
TDI (see Isocyanates)	[584-84-9] [91-08-7]		0.02		0.07
TEDP (skin) (Sulfotep)	[3689-24-5]		0.2		
Tellurium and compounds, as Te	[13494-80-9]		0.1		
Temephos	[3383-96-8]		10		
Terephthalic acid	[100-21-0]		10		
Terphenyls	[26140-60-3]	Ceiling 0.5 ppm (4.7 mg/m³)			
1,1,1,2-Tetrachloro-2,2-difluoroethane	[76-11-9]	500	4,170		
1,1,2,2-Tetrachloroethane (skin) 6.7B	[79-34-5]	1	6.9		
Tetrachloroethylene 6.7A (Perchloroethylene)	[127-18-4]	50	335	150	1005
Tetrachloromethane (skin) 6.7B (Carbon tetrachloride)	[56-23-5]	0.1	0.63		
Tetraethyl lead, as Pb (skin), (bio)	[78-00-2]		0.1(b)		
1,1,1,2-Tetrafluoroethane (HCF 134a)	[811-97-2]	1,000			
Tetrahydrofuran (skin) 6.7B	[109-99-9]	100	295		
Tetramethyl succinonitrile (skin)	[3333-52-6]	0.5	2.8		
Tetrasodium pyrophosphate	[7722-88-5]		5		
Tetryl (sen) (2,4,6-Trinitrophenyl-methylnitramine)	[479-45-8]		1.5		
Thallium soluble compounds, as Tl (skin)	[7440-28-0]		0.1		
4,4'-Thiobis(6-tert-butyl-m-cresol)	[96-69-5]		10		
Thioglycolic acid (skin)	[68-11-1]	1	3.8		

T		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Thionyl chloride	[7719-09-7]	Ceiling 1 ppm (4.9 mg/m³)			
Thiram	[137-26-8]		1		
Tin metal Oxide and inorganic compounds, except SnH4, as Sn Organic compounds, as Sn (skin)	[7440-31-5]		2 2 0.1		0.2
Titanium dioxide	[13463-67-7]		10		
TNT (skin) (2,4,6-Trinitrotoluene)	[118-96-7]		0.5		
Toluene (skin) (Toluol)	[108-88-3]	50	188		
Toluene-2,4-diisocyanate (see Isocyanates)	[584-84-9]		0.02		0.07
Toluene-2,6-diisocyanate	[91-08-7]		0.02		0.07
o-Toluidine (skin) 6.7B	[95-53-4]	0.2	0.89		
m-Toluidine (skin)	[108-44-1]	2	8.8		
p-Toluidine (skin) 6.7B	[106-49-0]	2	8.8		
Toluol (skin) (Toluene)	[108-88-3]	50	188		
Tributyl phosphate	[126-73-8]	0.2	2.2		
Trichloroacetic acid 6.7B	[76-03-9]	1	6.7		
1,2,4-Trichlorobenzene	[120-82-1]	Ceiling 5 ppm (37 mg/m³)			
1,1,1-Trichloroethane (Methyl chloroform)	[71-55-6]	125	680		
1,1,2-Trichloroethane (skin)	[79-00-5]	10	55		
* Trichloroethylene 6.7A (2017)	[79-01-6]	10	55	25	135
Trichlorofluoromethane (Fluorotrichloromethane)	[75-69-4]	Ceiling 1,000 ppm (5,620 mg/m³)			
Trichloromethane (skin) 6.7B (Chloroform)	[67-66-3]	2	9.9		
Tricholoronaphthalene (skin)	[1321-65-9]		5		
Tricholoronitromethane (Chloropicrin, Nitrochloromethane)	[76-06-2]	0.1	0.67		
* 1,2,3-Trichloropropane (skin) 6.7B (2017)	[96-18-4]	0.005	0.030		
1,1,2-Trichloro-1,2,2-trifluoroethane	[76-13-1]	1,000	7,670	1,250	9,590
Tridymite (see Silica-Crystalline)			0.1(r)		
Triethanolamine	[102-71-6]		5		
Triethylamine (skin)	[121-44-8]	3	12	5	20
Trifluorobromomethane	[75-63-8]	1,000	6,090		
Triglycidyl isocyanurate (TGIC)	[2451-62-9]		0.08		
Trimellitic anhydride (sen)	[522-30-7]	0.005	0.039		

T		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Trimethylamine	[75-50-3]	10	24	15	36
Trimethyl benzene	[25551-13-7]	25	123		
Trimethyl phosphite	[121-45-9]	2	10		
2,4,6-Trinitrophenol (Picric acid)	[88-89-1]		0.1		
2,4,6-Trinitrophenyl-methylnitramine (sen) (Tetryl)	[479-45-8]		1.5		
2,4,6-Trinitrotoluene (skin) (TNT)	[118-96-7]		0.5		
Triorthocresyl phosphate (skin)	[78-30-8]		0.1		
Triphenyl amine	[603-34-9]		5		
Triphenyl phosphate	[115-86-6]		3		
Tripoli (see Silica-Crystalline)			0.1(r)		
Tungsten, as W Insoluble compounds Soluble compounds	[7440-33-7]		5 1		10
Turpentine (wood $C_{10}H_{16}$) (sen)	[8006-64-2]	100	556		

U		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Uranium (natural) soluble and insoluble compounds, as U 6.7A	[7440-61-1]		0.2		

V		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
n-Valeraldehyde	[110-62-3]	50	176		
Vanadium, as V_2O_5 Respirable dust and fume	[1314-62-1]		0.05(r)		
Vegetable oil mists			10		
Vinyl acetate 6.7B	[108-05-4]	10	35	20	70
Vinyl benzene (skin) 6.7A (Styrene, Phenylethylene)	[100-42-5]	50	213	100	426
* Vinyl bromide 6.7A (2017)	[593-60-2]	0.3	1.30		
* Vinyl chloride 6.7A (Chloroethylene) (2017)	[75-01-4]	1	2.6		
Vinyl cyanide (skin) 6.7A (Acrylonitrile)	[107-13-1]	2	4.3		
Vinyl cyclohexene dioxide (skin) 6.7B	[106-87-6]	10	57		
Vinylidene chloride (1,1-Dichloroethylene)	[75-35-4]	5	20	20	79
Vinyl toluene	[25013-15-4]	50	242	100	483

W		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Warfarin	[81-81-2]		0.1		
‡ Welding fume (not otherwise classified)			5(w)		
White spirits (Stoddard solvent)	[8052-41-3]	100	525		
Wood dust, hard (sen) (confirmed/suspected carcinogen depending on hard wood type)			1		
Wood dust, soft (2013)			2		

WOOD SPECIES: HARDWOOD AND SOFTWOOD CLASSIFICATION LIST

Hardwood	Taraire; Tawa; Akeake; Kohekohe; Hinau; Fuchsia; Broadleaf; Black Maire; Rewarewa; Pukatea; Manuka; Kanuka; Mangeao; Pohutukawa; Southern Rata; Northern Rata; Southern Beech; Kowhai; Puriri; Kamahi
Softwood	Kauri; Pine; Silver Pine; Pink Pine; Yellow-Silver Pine; Rimu; Kaikawaka (New Zealand Cedar); Tanekaha; Miro; Matai; Totara; Kahikatea; Macrocarpa

X		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Xylene (o-, m-, p-isomers)	[1330-20-7] [95-47-6] [108-38-3] [106-42-3]	50	217		
m-Xylene a,a'-diamine (skin)	[1477-55-0]		Ceiling 0.1		
Xylidine mixed isomers (skin) 6.7B	[1300-73-8]	0.5	2.5		

Y		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Yttrium metal and compounds, as Y	[7440-65-5]		1		

Z		TWA		STEL	
Substance	**CAS #**	**ppm**	**mg/m³**	**ppm**	**mg/m³**
Zinc chloride fume	[7646-85-7]		1		2
Zinc chromates, as Cr 6.7A	[13530-65-9] [11103-86-9] [37300-23-5]		0.01		
Zinc oxide fume Dust	[1314-13-2]		3(r) 10(r)		10
Zirconium and compounds, as Zr	[7440-67-7]		5		10

‡ BEI for this substance currently under review

TABLE 5: Workplace exposure standards

Part Two

BIOLOGICAL EXPOSURE INDICES

3.0 Biological exposure indices (BEI)

IN THIS SECTION:

3.1 Introduction

Biological monitoring – the measurement of a substance or its metabolites in body fluids such as urine or blood – provides a complementary approach to air monitoring for estimating exposure to workplace contaminants.

Biological monitoring provides a better indication than does air monitoring of the bodily uptake of a chemical, as the monitored parameter is a reflection of not only the air level but also the breathing rate and depth, practice regarding respiratory protection, the absorption from other routes (such as skin and/or inadvertent hand to mouth ingestion), and the efficiency or otherwise of elimination. As such it reveals more about a specific individual's uptake of the chemical and hence their risk. It also reflects any additional non-workplace exposures to the chemical, which can add to risk. (The latter though can serve to complicate assessment of workplace exposure to the chemical.)

The monitoring result is compared to a standard established for the specific substance, termed its **biological exposure index (BEI)**. However there have been fewer BEIs than WESs set, as there is less data directly correlating adverse health effects to blood or urine levels than to air levels. Indeed most BEIs have been set indirectly from the chemical's WES.

Thus a BEI is considered by the ACGIH as a value often corresponding to the WES. That is, if a worker is exposed solely through inhalation, and that exposure is equal to the WES, and he/she is engaged in moderate work, then the BEI represents the expected level of the biological determinant.

This applies where (as in most cases), the BEI has been derived from the observed relationship between the measured air levels and measured biological (eg blood or urine) levels as this knowledge enables extrapolation from a WES to a BEI. However, in some cases (such as with lead), the relationship between the biological level and the potential health effects has been approached more directly (eg by identifying adverse effects as a function of blood lead levels, not air levels).

Other exceptions can be where a WES is set to protect against non-systemic effects such as tissue irritation or respiratory disorders, while a BEI is designed to avoid the risk of systemic effects.

3.2 Exposure periods

Depending on the toxicokinetics of the substance (for example its half life), the results from the biological determination may reflect very recent exposure, the average exposure over the last day(s), or long-term cumulative exposure. The BEIs listed in this document assume that exposure has been reasonably steady and that an eight-hour day, five-day week has been worked. Extrapolation to other exposures can be made, but only with a clear understanding of the relationship between absorption, metabolism, and elimination.

3.3 Effectiveness

Biological monitoring has been widely used to monitor the uptake of cumulative toxins; for example lead, mercury, and organophosphates. (However for the latter the term biological effect monitoring is also used, as the test monitors the cumulative effect of organophosphate insecticides by measuring the level of cholinesterase inhibition.) It also may be employed effectively where there is a significant potential for increased uptake as a result of skin absorption, increased respiratory rate, or exposure outside the workplace (even if there is no change in workplace air levels).

The effectiveness of hazard control measures taken to limit uptake may also in some cases be assessed with follow-up biological monitoring tests. As with air monitoring, the design of the monitoring protocol and interpretation of results should only be done by a person with the appropriate qualifications and experience.

The fact that a BEI has been listed for a particular substance does not imply that biological monitoring is necessary. An appraisal of the exposure should be made before considering monitoring requirements.

3.4 Biological assays

Several conditions must be satisfied for a biological assay to be a reliable indicator of exposure to a substance. The fate of the substance in the human body must have been adequately researched, and a time/concentration relationship must exist. It is not essential for the concentration of the determinant to be zero in cases where there is no occupational exposure, as long as the increase is measurably observable above the background level.

The biological assay must be as sensitive and specific as possible. While the concentration of the major metabolite may be high, and therefore easily detected, if it is a metabolite that is common to several substances, the determination of the unaltered substance, or minor metabolite, may be preferable.

The biological assay is often performed at a remote laboratory, therefore the determinant must be stable in the biological fluid.

3.5 Legal requirements

Regulation 30 of the HSW (GRWM) Regs requires the PCBU to conduct exposure monitoring to determine the concentration of a substance if the PCBU is uncertain on reasonable grounds about whether the concentration exceeds the relevant prescribed exposure standard. As discussed earlier, exposure monitoring and/or biological monitoring may be used to monitor a worker's exposure.

Under most circumstances worker health monitoring will be classed as a health service. This means the rights and duties in the *Code of Health and Disability Services Consumer's Rights* (including consent requirements) will apply.

For further information about the Code of Health and Disability Services Consumer's Rights see the Health and Disability Commissioner website: www.hdc.org.nz

This means a PCBU needs to be proactive in seeking approval, and take responsibility for informing and encouraging workers about monitoring where appropriate. However, consent must be granted voluntarily and without any form of coercion or duress on the part of the PCBU seeking consent.

Regulation 32 of the GRWM Regulations requires the PCBU to ensure the results of exposure monitoring are made available to any person at the workplace who may be, or may have been, exposed to the health hazard. Such results must not contain any information that identifies, or discloses anything about, an individual worker.

Regulation 39 of the GRWM Regulations requires the PCBU to provide the results of health monitoring of a worker to the worker.

3.6 Issues with biological monitoring

Generally a BEI as assessed by only one specific assay method is given for each substance, even though there may be several ways of estimating exposure. Preference has been given to urinary assays over more invasive blood tests, but factors such as the stability of the sample and the possibility of sample

interference should be considered. Cultural sensitivity of the worker towards submitting a particular type of sample may also influence the selection of the biological monitoring procedure. Alternative methods may be available, especially for monitoring exposure to solvents.[13,14]

For the routine surveillance of exposure to some substances, biological monitoring may be preferred over air sampling. For example, if the substance has a long half-life in the body, the biological monitoring assay will give a result that reflects an integrated exposure, with little variation no matter when the sample is taken. In other cases, the corresponding air sampling procedure may, because of the typical work practices or sampling difficulties encountered, give less reliable results than biological monitoring.

Quantitative interpretation of biological monitoring results is often difficult. The overall value of the information may be improved if measurements are obtained from several workers with similar exposure, and/or serial determinations on an individual worker are conducted.

3.7 Information prior to monitoring

Before undertaking a biological monitoring exercise, it is essential that background information be obtained, including data on the pharmacokinetics of the substances, interferences, and 'background' levels of the determinant arising from non-workplace exposures. The following two references are recommended as a source of the relevant background material:

a. *ACGIH Documentation of the Threshold Limit Values and Biological Exposure Indices*[15]

b. *Industrial Chemical Exposure, Guidelines for Biological Monitoring.*[16]

3.8 Sample collection

It is important to observe the timing of the sample collection for each determination. The level of a substance, or its metabolic products, will vary with the time elapsed since the last exposure, and the BEI for some substances is only applicable if the recommended timing of sample collection is closely adhered to.

Assuming that there has been continual exposure over the working day, the following potential sample periods (causing minimal disturbance of working routines) have received most attention. The most appropriate sample period for any given substance depends on how quickly it (or its measured metabolite) is eliminated from the body:

Prior to (next) shift: Following a period of 16 hours with no exposure. (Appropriate for substances 'promptly' but not rapidly eliminated.)

[13] Paustenbach, D.J. 'The History and Biological Basis of Occupational Exposure Limits for Chemical Agents', *Patty's Industrial Hygiene and Toxicology*, 5th Edition, volume 3. John Wiley and Sons (2000).

[14] Lauwerys R.R. and Hoet P. *Industrial Chemical Exposure, Guidelines for Biological Monitoring*. 2nd Edition. ISBN: 0-87371-650-7, (1993).

[15] American Conference of Governmental Industrial Hygienists (ACGIH). *Documentation of the Threshold Limit Values and Biological Exposure Indices*. 7th Edition, ACGIH, Cincinnati, Ohio (2015).

[16] Industrial Chemical Exposure – Guidelines for Biological Monitoring, 3rd edition, R.R. Lauwreys, P. Hoet (2001).

End of shift: The last two hours immediately following the end of the working day. (Appropriate for substances 'rapidly' eliminated, whose measured levels could have fallen substantially if sampling was delayed until just prior to the next shift.)

End of work week: After at least four days with exposure. (Appropriate for substances eliminated more slowly and thus incompletely over 24 hours, causing some accumulation, with the highest levels observed on the last day.)

However, if the exposure has been confined to a portion of the working day, it may be necessary to adjust the timing, but it must be recognised that the estimation of exposure may be compromised.

Other factors may also compromise test results. Contamination of the sample could take place during collection as a result of inadequate cleaning of the skin prior to taking a blood sample, or on other inadvertent contamination of a specimen. Loss of sample integrity on storage and transport may occur through the use of an inappropriate container or storage conditions. Further details of the procedure to be followed for sample collection should be obtained from the laboratory carrying out the analysis.

3.9 Interpretation of results

Biological monitoring data must be interpreted with some caution. Especially useful is to compare any individual's result with their previous results (if any).

There are several reasons why the levels of the determinant may vary between individuals, even under seemingly identical exposure situations. Workers may differ in size, physical fitness and work practices, resulting in differing uptakes, such as through variations in respiration rate/volume and skin contact (and absorption). Further, there may be inter-individual differences in metabolism and elimination rates of the absorbed substance or contaminant.

Further advice on the application of biological monitoring can be obtained from Worksafe.

4.0 Lead biological exposure indices

IN THIS SECTION:

This section should be read in conjunction with WorkSafe's *Guidelines for the Medical Surveillance of Lead Workers*.

The overall objective of the surveillance outlined in the guidelines is to maintain the blood lead levels of all workers below 1.5 μmol/litre whole blood.

Medical surveillance, including blood lead monitoring, is extended to all those working with lead in a process that may result in blood lead levels above 1.5 μmol/litre whole blood.

4.1 Female workers

While it is preferable for all workers' blood lead levels to stay at or below 1.5 μmol/litre whole blood, this value must be more stringent for pregnant women or women planning to become pregnant, because they should be exposed to as little lead as possible. Ideally, these women should have no exposure to lead at all, because the developing foetus is extremely susceptible to this substance. Additionally, accumulated lead can be released from the mothers' bones during times of calcium stress such as pregnancy and lactation.

4.2 Recommended blood lead levels

(This subsection does not include workers who are pregnant, breastfeeding or women of child-bearing age.)

A worker will normally be suspended by a Health and Safety Medical Practitioner where a single blood lead result is 2.4 μmol/litre whole blood or greater.

A worker can return to work if their blood levels achieve 1.93 μmol/litre whole blood or below.

4.3 Upcoming changes to blood lead levels

Two years from the date of publication of this Special Guide the following biological limits will take effect for lead in blood:

- a BEI of 20 μg/dL (0.97 μmol/L) of whole blood
- a suspension (removal) level of 30 μg/dL (1.45 μmol/L) of whole blood for females not of reproductive capacity, and males
- a suspension (removal) level of 10 μg/dL (0.48 μmol/L) of whole blood for females of reproductive capacity, and those pregnant and/or breastfeeding.

5.0
BEI values

IN THIS SECTION:

5.1 BEIs under review

BEIs for the following substances are currently under review:

- Arsenic
- Benzene[1]
- Carbon disulphide[1]
- Carbon monoxide
- Chromium VI (hexavalent chromium)
- Ethyl benzene[1]
- Fluorides
- Mercury (Elemental)
- 4,4-Methylene bis-(2-chloroaniline) (also known as 2,2'-Dichloro-4,4'-methylene dianiline, MOCA, MBOCA)[1]
- 4,4-Methylene diphenyl diisocyanate (MDI)[1]
- Methyl isobutyl ketone (MIKB)
- Pentachlorophenol (PCP)
- Phenol
- Tetrahydrofuran[1]
- Toluene diisocyanate-2,4- or 2,6- or a mixture of these isomers (TDI)[1]
- Toluene[1]
- Trichloroethylene (TCE)

5.2 Table of BEI values

The following table (Table 6) lists the BEI values set by WorkSafe.

EXPOSURE	DETERMINANT	SAMPLING TIME	BEI
Acetone	Acetone in urine	End of shift	50 mg/litre
Arsenic	Sum of inorganic arsenic metabolites in urine	End of shift at end of work week	100 µg/litre
Cadmium	Cadmium in blood Cadmium in urine	Not critical Not critical	0.044 µmol/litre (5 µg/litre) 5 µmol/mol creatinine (5 µg/g creatinine)
Carbon monoxide	Carboxyhaemoglobin in blood	End of shift	3.5% of haemoglobin
Chromium (VI) water-soluble fume	Chromium in urine	End of shift at end of work week	0.6 µmol/litre (30 µg/litre)
Cobalt	Cobalt in urine	End of shift at end of work week	15 µg/litre
2-Ethoxyethanol and 2-Ethoxyethyl acetate	2-ethoxyacetic acid in urine	End of shift at end of work week	100 mg/g creatinine
Fluorides	Fluoride in urine	Prior to shift End of shift	160 µmol/litre (3 mg/litre) 530 µmol/litre (10 mg/litre)
n-Hexane	2,5-hexanedione in urine	End of shift	5 mg/litre
Lead (inorganic)	Lead in blood	Not critical	See section 4 on lead biological exposure indices
Mercury	Mercury in urine	Not critical	0.25 µmol/litre (50 µg/litre)
Methyl alcohol	Methyl alcohol in urine	End of shift	15 mg/litre

[1] Substance does not have a current New Zealand BEI value

EXPOSURE	DETERMINANT	SAMPLING TIME	BEI
Methyl ethyl ketone (MEK)	MEK in urine	End of shift	2 mg/litre
Methyl isobutyl ketone (MIBK)	MIBK in urine	End of shift	2 mg/litre
Organophosphates	Cholinesterase activity in blood		**Recommended Action** If less than 60% of Baseline: suspend from working with pesticides which inhibit cholinesterase activity If less than 80% of Baseline: repeat test to confirm result If greater than 75% of Baseline: permit a previously suspended worker to recommence normal duties
Pentachlorophenol (PCP)	Total PCP (including conjugates) in urine	Prior to last shift of week	1 mg/litre
Phenol	Total phenol in urine	End of shift	250 mg/g creatinine
Sodium fluoroacetate (1080)	Sodium fluoroacetate in urine	End of shift	15 μg/litre
Styrene	Mandelic acid in urine	End of shift	1 g/litre
Trichloroethylene	Trichloracetic acid in urine	End of work week	100 mg/litre
Xylene	Methylhippuric acid in urine	End of shift	1.5 g/litre

TABLE 6: Biological exposure indices

Appendices

IN THIS SECTION:

Appendix 1: Glossary

TERM	DEFINITION
6.7A carcinogen	Known or presumed human carcinogen.
6.7B carcinogen	Suspected human carcinogen.
ACGIH®	The American Conference of Governmental Industrial Hygienists (ACGIH®) is a 501(c) (3) charitable scientific organization, established in 1938, that advances occupational and environmental health. Examples of this include their annual edition of the TLVs® and BEIs® book and Guide to Occupational Exposure Values.
Agglomeration	A mass or cluster.
Allergenic	A term applied to a substance that can cause an allergic response (development of an allergy to it, with allergic symptoms on re-exposure).
Allergic sensitisation	The more often the worker is exposed to an allergen, the more severe the worker's reaction to the allergen becomes. Even at low exposures to the allergen, a sensitivity reaction may occur.
Animal studies	Also known as 'Animal Testing': the practice of using animals in experiments, including for biomedical research or toxicology testing.
Airborne contaminants	Potentially toxic dusts, fibres, fumes, mists, vapours or gases contaminating the air.
Background level	Level of a substance in a worker's biological sample that can occur naturally (without any workplace exposure). The background level can be due to the substance's normal presence in the environment or diet, or produced in the body itself.
(bio)	Exposure can also be estimated by biological monitoring.
Biological assay	Also known as Bioassay, it is a particular type of test or experiment designed to determine the presence and/or concentration of a substance.
Biological exposure index (BEI)	Guidance values for assessing biological monitoring results. It indicates a concentration below which nearly all workers should not experience adverse health effects from exposure to a particular substance.
Carboxyhaemoglobin level	A good indicator of the level of carbon monoxide present in the bloodstream. It is formed when haemoglobin binds preferentially to carbon monoxide instead of oxygen, which can severely reduce the delivery of oxygen to various parts of the body.
Carcinogenic	The description given to those hazardous/toxic substances that can cause cancer or contribute to its development.
CAS #	Short for Chemical Abstract Services Registry Number. This Registry assigns a unique identifying series of numbers to each individual chemical.
Causal relationship	The relationship between an event and another event, where the second event is a consequence of the first, eg exposure to a confirmed cancer-causing agent may, depending on the extent of the exposure, lead to cancer in the exposed person.
Ceiling (WES-Ceiling)	A concentration that should not be exceeded at any time during any part of the working day.
dL	Decilitre. Its volume is one tenth of a litre or 100 millilitres.
Dusts	Discrete solid particles suspended in air. See section on Aerosols for a more detailed definition.
Elimination rate	The calculated (or estimated) rate at which a substance is eliminated from the body.
Epidemiological studies	Studies (of various types) on human populations, which are designed to help identify specific causes of adverse health effects, and the relative contribution of different causes.
Equivalent aerodynamic diameter (AED)	The diameter of a sphere of 'unit density' (1 gram per cm^3) that exhibits the same aerodynamic behaviour as that of the particle (of any shape or density) being measured.

TERM	DEFINITION
Excursion limit (EL)	For many substances with a WES-TWA, there is no WES-STEL. Nevertheless, excursions above the WES-TWA should be controlled, even where the 8-hour WES-TWA is within the recommended limits. Excursion limits apply to those WES-TWAs that do not have WES-STELs. Transient increases in workers' exposure levels may exceed three times the value of the WES-TWA level for no more than 15 minutes at a time, on no more than four occasions spaced one hour apart during a workday, and under no circumstances should they exceed five times the value of the WES-TWA level. In addition, the 8-hour TWA is not to be exceeded for an 8-hour work period.
Fibrogenic	A substance that is known to generate 'fibrotic' reactions in body organs or tissue. This process is also known as fibrosis, which is the development of excessive fibre-like or fibrous tissue, similar to scarring.
Fume	Very small airborne solid particulates with diameters generally less than 1μm. They may be formed by thermal mechanisms (eg condensation of volatilised solids, or incomplete combustion) or chemical processes (eg vapour phase reactions). Agglomeration of fume particles may occur, resulting in the formation of much larger particles.
Gas	A state of matter characterised by low density and viscosity (compared to liquids and solids), and can usually expand and contract with changes in pressure and temperature. Gases can be in the form of individual atoms of an element (eg argon) but more usually comprise molecules, containing more than one atom of one or more elements (eg carbon dioxide).
GRWM Regulations	Health and Safety at Work (General Risk and Workplace Management) Regulations 2016.
Hazardous substance	A substance (in gas, liquid or solid form) that has one, or more, of the following properties: – explosive – flammable – oxidising – toxic (harmful to humans) – corrosive – ecotoxic (harmful to animals, soil, water or air).
HSNO Act	The Hazardous Substances and New Organisms Act 1996.
HSWA	Health and Safety at Work Act 2015.
Infectious	The property of a living (biological) organism that is capable of causing an infection. This can occur when the body is invaded by pathogenic (disease-causing) microorganisms.
Inhalable dust	Portion of airborne dust that is taken in through the mouth and nose during breathing.
Irritative	A substance capable of causing tissue inflammation when it contacts the skin, eyes, nose or respiratory system (usually with associated subjective feelings of irritation and discomfort, as well as objective evidence of inflammation).
Latency period	The period between contact with a chemical substance or biological pathogen and the development of symptoms.
Metabolism	A term used to describe the process by which a substance is changed or 'broken down' in the body, into metabolites (changed substances). These metabolites are usually easier for the body to eliminate than the original substance is, but sometimes can be more toxic. 'Metabolism' is also used more generally to describe the numerous, wide-ranging set of chemical reactions required for the body to function normally.
Mists	Small droplets of liquid suspended in air. See section on Aerosols for a more detailed definition.
mg/m^3	mg = milligrams, and m^3 = cubic metres. mg/m^3 is used for reporting the concentration of solids (like dusts or metal fume) in the worker's atmosphere (as mass per volume of air). It can also be used for reporting airborne concentrations of liquid particles (mists) or even gases, although gases are usually reported in ppm.

TERM	DEFINITION
Pharmacokinetics (or toxicokinetics)	Pharmacokinetics describes the movement of a substance through the body. It includes the processes of absorption, distribution, modification, and elimination of the substance.
Pharynx	A vertically elongated tube that lies behind the nose, mouth and larynx. The middle section, the oropharynx, is located behind the throat. It serves as the upper passageway for the digestive and respiratory tracts, transporting air, water and food as necessary.
ppm	Parts of vapour or gas per million parts of air.
Respirable dust	The fraction of total inhalable dust that is able to penetrate and deposit in the lower bronchioles and alvelolar region of the lungs.
Respiratory system	The complex of organs and structures that performs breathing or respiration. Normally this results in adequate ventilation, where sufficient amounts of ambient air are transported into the terminal regions of the lung, where the exchange of oxygen for carbon dioxide produced by the body occurs. (The oxygen is circulated through the body and the carbon dioxide is exhaled.) The main organs and structures involved in the respiratory system are: – nose – pharynx – larynx – trachea, bronchi and lungs – pleura (membrane surrounding lungs) – blood and nerve supply.
Rubber fume	Any fume that evolves during the blending, milling and curing of natural rubbers or synthetic elastomers.
Rubber process dust	Dust generated during the manufacture of goods using natural rubber or synthetic elastomers.
Safety data sheet	A document that describes the hazardous properties of a substance, ie its identity, chemical and physical properties, health hazard information, precautions for use and safe handling information.
SCOEL	The Scientific Committee on Exposure Limit Values (SCOEL) is a committee of the European Commission established in 1995 to advise on occupational exposure limits for chemicals in the workplace within the framework of Directives 98/24/EC and 90/394/EEC.
Short-term exposure limit (WES-STEL)	The 15-minute time weighted average exposure standard. Applies to any 15-minute period in the working day and is designed to protect the worker against adverse effects of irritation, chronic or irreversible tissue change, or narcosis that may increase the likelihood of accidents. The WES-STEL is not an alternative to the WES-TWA; both the short-term and time-weighted average exposures apply. Exposures at concentrations between the WES-TWA and the WES-STEL should be less than 15 minutes, should occur no more than four times per day, and there should be at least 60 minutes between successive exposures in this range.
(sen)	A substance that can 'sensitise' the skin or respiratory system, inducing a state of hypersensitivity to it, so that on subsequent exposures, an allergic reaction can occur (which would not develop in non-sensitised individuals). It is uncommon to become sensitised to a compound after just a single reaction to it.
(skin)	Skin absorption–applicable to a substance that is capable of being significantly absorbed into the body through contact with the skin.
Substance	A substance identified in this document that has properties making it toxic to human health.
Synergistic effect	This occurs when the combined effect of two chemicals is substantially greater than the sum of the effects of each chemical on their own, eg 2 + 4 = 20 (not 6, which would be a simple additive effect).
Terminal velocity	Terminal velocity occurs when the downward force of an object is equalled by the upward force of the object's drag, making the net force on the object zero. In this state, the velocity (speed) of the object remains constant.
Time-weighted average (WES-TWA)	The average airborne concentration of a substance calculated over an eight-hour working day.

TERM	DEFINITION
Vapour	A vapour is the gaseous form of a substance which at normal temperature and pressure exists predominantly as a liquid or solid. This distinguishes it from compounds which exist as gases at room temperature.
μm	Micrometre, or 'micron'. Its size is 1 millionth of a metre.
μg	Microgram. It is a unit of mass equal to 1 millionth of a gram or 1 thousandth of a milligram.
μmol	Micromole, a unit of measurement for the amount of substance, or chemical amount.
Unciliated airways	In the upper respiratory tract, fine hair-like projections from cells (cilia) 'sweep' in unison to remove or clear fluids and particles. In the unciliated airways, of the lower respiratory tract (the alveolar region) there are no cilia.
Worker's breathing zone	A hemisphere of 300 mm radius extending in front of the worker's face and measured from the midpoint of an imaginary line joining the ears.
Workplace exposure standard (WES)	Workplace exposure standards are values that refer to the airborne concentration of substances, at which it is believed that nearly all workers can be repeatedly exposed to day after day without coming to harm. The values are normally calculated on work schedules of five shifts of eight hours duration over a 40 hour work week.

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ISBN (online) 978-1-98-852748-2

Published: November 2017 Current until: 2019

PO Box 165, Wellington 6140, New Zealand

www.worksafe.govt.nz

WSNZ_1937_DEC 17

ISBN (online) 978-1-98-852748-2

WORKSAFE
NEW ZEALAND | MAHI HAUMARU AOTEAROA

Level 6, 86 Customhouse Quay
PO Box 165, Wellington 6140

0800 030 040 worksafe.govt.nz