

National standards, codes of practice and related guidance

Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment NOHSC 3008(1995) 3rd Edition

Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:3008(1995)] 3rd Edition (Updated for Amendments)

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- [POLICY STATEMENT](#)
- [FOREWORD](#)
- [PREFACE](#)
- [1. INTRODUCTION](#)
- [2. UNLISTED SUBSTANCES](#)
- [3. PROHIBITION OF THE USE OF SUBSTANCES](#)
- [4. WORKLOAD CONSIDERATIONS](#)
- [5. EXPOSURE DURATION](#)
- [5A. ALTERED WORKSHIFTS](#)
- [6. EXCURSION LIMITS](#)
- [7. MONITORING OF EXPOSURE](#)
- [8. BIOLOGICAL MONITORING](#)
- [9. ODOUR THRESHOLDS](#)
- [10. SIMPLE ASPHYXIANTS](#)
- [11. EFFECTS ON THE SKIN](#)
- [12. SENSITISERS](#)
- [13. CARCINOGENS](#)
- [14. AIRBORNE PARTICULATES](#)
- [15. MIXTURES OF SUBSTANCES](#)
- [16. REFINED PETROLEUM SOLVENT MIXTURES](#)
- [17. FUMES AND GASES FROM WELDING AND CUTTING PROCESSES](#)
- [18. THERMAL DECOMPOSITION PRODUCTS OF PLASTICS](#)
- [19. EXPRESSION OF EXPOSURE STANDARDS](#)
- [20. MINERAL OIL ADDITIVES](#)
- [APPENDIX 1: TERMS OF REFERENCE OF THE EXPOSURE STANDARDS EXPERT WORKING GROUP](#)
- [APPENDIX 2: MEMBERSHIP OF THE EXPOSURE STANDARDS EXPERT WORKING GROUP](#)
- [APPENDIX 3: ISSUES AND SUBSTANCES UNDER REVIEW ISSUES](#)
- [APPENDIX 6: CHEMICAL SYMBOLS](#)
- [APPENDIX 7: AMENDMENTS TO THE GUIDANCE NOTE ON THE INTERPRETATION OF EXPOSURE STANDARDS FOR ATMOSPHERIC CONTAMINANTS IN THE OCCUPATIONAL ENVIRONMENT](#)
- [GLOSSARY OF TERMS](#)

POLICY STATEMENT

These exposure standards are guides to be used in the control of occupational health hazards. They should not be used as fine dividing lines between safe and dangerous concentrations of chemicals. They are not a measure of relative toxicity and should not be applied in the control of community air pollution. Interpretation of the exposure standards should be undertaken by an appropriately qualified and experienced person.

The guidance note included in this publication contains the fundamental philosophy and principles for the application of these exposure standards. However, as the criteria for establishing an exposure standard vary for different substances, it is essential that the latest relevant documentation 1,2,3 be consulted before the exposure standards are used.

The National Commission recognises that the Commonwealth, State and Territory governments or other organisations may incorporate the exposure standards into their own occupational health and safety programs. The National Commission does not oppose their use as such. However, these organisations should take into consideration the foregoing principles and the acknowledged limitations of individual exposure standards.

The National Occupational Health and Safety Commission has declared *Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment* and has adopted a *Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment*.

National standards declared by the National Commission under s.38(1) of the *National Occupational Health and Safety Commission Act 1985* (Cwlth) are documents which prescribe preventive action to avert occupational deaths, injuries and diseases. Most national standards deal with the elimination/reduction or management of specific workplace hazards. In appropriate circumstances, national standards may take the form of national model regulations.

The expectation of the Commonwealth Government and the National Commission is that national standards will be suitable for adoption by Commonwealth, State and Territory governments. Such action will increase uniformity in the regulation of occupational health and safety throughout Australia and contribute to the enhanced efficiency of the Australian economy.

The expectation of the National Commission is that guidance notes will provide detailed information for use by unions, employers, management, health and safety committee representatives, safety officers, occupational health and safety professionals and others requiring guidance.

It should be noted that National Commission documents are instruments of an advisory character, except where a law, other than the National Occupational Health and Safety Commission Act, or an instrument made under such a law, makes them mandatory. The application of any National Commission document in any particular State or Territory is the prerogative of that State or Territory.

Reference

1. American Conference of Governmental Industrial Hygienists (ACGIH), *Documentation of the Threshold Limit Values and Biological Exposure Indices*, 5th Edition, ACGIH, Cincinnati, Ohio, 1986.
2. American Conference of Governmental Industrial Hygienists (ACGIH), *Documentation of the Threshold Limit Values and Biological Exposure Indices*, 6th Edition, ACGIH, Cincinnati, Ohio, 1991.
3. National Occupational Health and Safety Commission, *Documentation of the Exposure Standards* [NOHSC:10003(1995)], Australian Government Publishing Service, Canberra, 1995.

FOREWORD

The National Occupational Health and Safety Commission is a tripartite body established by the Commonwealth Government to develop, facilitate and implement a national occupational health and safety strategy.

This strategy includes standards development, the development of hazard-specific preventive strategies, research, training, information collection and dissemination and the development of common approaches to occupational health and safety legislation.

The National Commission comprises representatives of the peak employee and employer bodies - the Australian Council of Trade Unions (ACTU) and Confederation of Australian Industry (CAI) - as well as the Commonwealth, State and Territory governments.

Consistent with the National Commission's philosophy of consultation, tripartite standing committees have been established to deal with issues relating to standards development, research and the mining industry. Expert groups have been established to provide advice to the standing committees on those items with which the National Commission is concerned.

Note: The *Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:3008(1995)], has been published as a component part of the National Commission's printed publication - *Exposure Standards for Atmospheric Contaminants in the*

Occupational Environment (3rd edition 1995). This document was published as a National Commission Standard and also contains the printed tables of the *National Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:1003(1995)]. The fulltext of the Guidance Note is reproduced here with the exception of Appendix 4 and Appendix 5 and the tables for the Exposure Standards. All of the information in the tables and the Appendices (the substance names, the standards and synonyms) are presented as the Exposure Standards Database and are not reproduced here.

PREFACE

While supporting the concept that exposure to chemical agents should be kept as low as practicable, the National Occupational Health and Safety Commission recognises that, in practice, guidance in the form of exposure standards may be used by occupational health and safety practitioners, employers and employees or their representatives, and regulatory agencies to assist them in ensuring that workers are adequately protected from substances that may impair health or cause undue annoyance.

To this end, the Exposure Standards Working Group, under the auspices of the Standards Development Standing Committee (SDSC), has been charged with the task of reviewing and recommending occupational exposure standards for individual chemical substances following consideration of the best available technical data from Australian and a range of overseas sources. The terms of reference of the Exposure Standards Working Group are detailed at Appendix 1 of the National Commission's *Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:3008(1995)]. Membership of the Exposure Standards Working Group and SDSC is given at Appendix 2 of the guidance note. All requests for interpretations of exposure standards should be made in writing and directed to the Secretary of the Exposure Standards Working Group.

The exposure standards listed in this publication represent airborne concentrations of individual chemical substances which, according to current knowledge, should neither impair the health of nor cause undue discomfort to nearly all workers. The exposure standards serve as guides only, and have no legal status unless they are specifically incorporated into Commonwealth, State or Territory legislation. In recommending appropriate exposure standards, the National Commission has been guided by the standards and experience of a number of Australian and overseas organisations.^{1,2,3,4,5,6}

A great number of the adopted exposure standards have been obtained from the American Conference of Governmental Industrial Hygienists' list of threshold limit values.² These values have been considered by the National Commission and those found to be acceptable were adopted. A smaller number of substances have been reviewed in detail by the Exposure Standards Working Group and appropriate values assigned.

This third edition of the *Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:1003(1995)], replaces the second edition which was published in October 1991. This current edition incorporates the exposure standards declared by the National Commission in March 1994 and March 1995 pursuant to section 38(1) of the *National Occupational Health and Safety Commission Act 1985* (Cwlth).

Among the adopted exposure standards, there are a number of substances which the Exposure Standards Working Group has identified as requiring further review. These substances are listed in Appendix 3 of the guidance note and are identified as under review in the Exposure Standards Database. To assist the Exposure Standards Expert Working Group in its consideration of these substances, interested parties are encouraged to submit any relevant information on these substances. Such submissions should ideally be accompanied by actual exposure data and a description of any observed health effects. An indication of whether the monitoring data refers to an eight-hour time-weighted average or short term exposure, and a brief description of the work procedures involved, would also be useful.

Proposed changes and additions to the National Commission's *Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:1003(1995)] are not included in this publication but have been published separately.⁷ The notation 'Ch' in the final column of the printed version of the adopted national exposure standards indicates those substances for which the Exposure Standards Working Group has proposed additions/changes to the existing standards. This notation is also found in the exposure standards database on Worksafe-Disc.

Reference

1. National Health and Medical Research Council (NHMRC), Approved Occupational Health Guide: Threshold Limit Values (1983-84), Commonwealth Department of Health, Canberra, 1983.
2. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values and Biological Exposure Indices 1994-95, ACGIH, Cincinnati, Ohio, 1994.
3. Health and Safety Executive (U.K.), Occupational Exposure Limits 1995, Guidance Note EH40, HMSO, London, 1995.
4. Swedish National Board of Occupational Safety and Health, Occupational Exposure Limit Values, Ordinance AFS 1990:13, Sweden, 1990.
5. Deutsche Forschungsgemeinschaft (DFG), List of MAK and BAT Values 1994, Report No. 30, Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, VCH Verlagsgesellschaft mbH, Weinheim, Federal Republic of Germany, 1994.
6. Ministerie van Sociale Zaken en Werkgelegenheid, De Nationale MAC-lijst 1992, P 145, Ministerie van Sociale Zaken en Werkgelegenheid, Den Haag, Netherlands, 1993.
7. National Occupational Health and Safety Commission, Proposed National Exposure Standards for Atmospheric Contaminants in the Occupational Environment, Australian Government Publishing Service, Canberra, 1995.

1. INTRODUCTION

1.1 The air inhaled at work should not contain chemical agents at concentrations which produce adverse effects on health, safety or well-being. To assist occupational health and safety practitioners, employers and employees or their representatives, and regulatory agencies to secure workplace atmospheres which are as free as practicable from hazardous contaminants, the National Commission has produced *Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:1003(1991)], which is included in this publication.

1.2 The exposure standards detailed in this publication represent airborne concentrations of individual chemical substances which, according to current knowledge, should neither impair the health of nor cause undue discomfort to nearly all workers. Additionally, the exposure standards are believed to guard against narcosis or irritation which could precipitate industrial accidents.

1.3 Except where modified by consideration of excursion limits, exposure standards apply to long term exposure to a substance over an eight-hour day, for a five-day working week, over an entire working life.

1.4 The exposure standards do not represent 'no-effect' levels which guarantee protection to every worker. Given the nature of biological variation and the range of individual susceptibility, it is inevitable that a very small proportion of workers who are exposed to concentrations around or below the exposure standard may suffer mild and transitory discomfort. An even smaller number may exhibit symptoms of illness.

1.5 It follows from the foregoing that the exposure standards are not fine dividing lines between satisfactory and unsatisfactory working conditions, but rather that they are best used to assess the quality of the working environment and indicate where appropriate control measures are required.

1.6 The exposure standards listed in this publication only consider absorption via inhalation and are valid only on the condition that significant skin absorption cannot occur.

1.7 For a few substances, usually the more potent probable and established human carcinogens, it is not currently possible to assign an appropriate exposure standard. For these substances, exposure should be controlled to the lowest practicable level. Biological monitoring may provide a more reliable indication of workplace exposure for these substances.

1.8 The evaluation of hazards posed by atmospheric contaminants in the working environment is often a complex task, requiring the consideration of a large number of variables which determine the magnitude of a particular hazard. For this reason, it is essential that those persons responsible for such assessments are fully aware of all of the issues canvassed in this document and have appropriate qualifications and experience in occupational hygiene.

1.9 The relationship between various exposure standards should not be used as a general measure of their relative toxicity. This is because, among other things, the values for different substances are often established with regard to different biological effects such as irritation or systemic toxicity. Similarly, the exposure standards should not be used as a basis for the evaluation of community air quality, or for long term, non-occupational exposures.

1.10 **Note:** Exposure standards for micro-organisms or radioactive substances are not detailed in this publication. However, practical guidance for these substances is available.^{1,2,3,4}

Reference

1. Lacey, J. and Crook, B., 'Fungal and actinomycete spores as pollutants of the workplace and occupational allergens', *Annals of Occupational Hygiene*, vol. 32, pp. 515-33, 1988.

2. American Conference of Governmental Industrial Hygienists (ACGIH), 'Guidelines for assessment and sampling of saprophytic bioaerosols in the indoor environment', ACGIH Committee on Bioaerosols, ACGIH pub. no. 3180, Cincinnati, Ohio, 1990.

3. National Health and Medical Research Council (NHMRC), *Recommended Radiation Protection Standards for Individuals Exposed to Ionising Radiation*, Commonwealth Department of Health, Canberra, June 1980.

4. International Commission on Radiological Protection (ICRP), *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 26, *Annals of the ICRP*, vol. 1, no. 3, 1977.

2. UNLISTED SUBSTANCES

2.1 Most substances used in industry have not been assigned exposure standards. This does not imply that these substances are safe or non-hazardous.

2.2 In many cases there is insufficient information on the health effects of these unlisted substances to allow the National Commission to assign an exposure standard, even on a tentative basis. In other instances, the use of the substance does not lead to significant airborne levels of contaminant, or its use is so restricted that an exposure standard is not warranted.

2.3 It is a good general policy to keep the exposure to any substance as low as is practicable, irrespective of whether present information indicates it is hazardous or not. Some substances previously thought to be comparatively safe have subsequently been found to pose serious long term health risks.

2.4 All substances should therefore be handled with care, whatever their nature, partly in case future experience shows them to present a hazard which could have been prevented or limited by the

application of sensible control measures, and partly because insufficient information may be known about their effects in the presence of other substances.

2.5 Appendix 4 of the printed guidance note provides a list of synonyms and trade names, and should be consulted when a first attempt to locate a chemical in the printed list of adopted national exposure standards is unsuccessful. Both synonyms and preferred names are searchable terms within the Exposure Standards Database.

2.6 Appendix 5 of the printed guidance note provides a substance index sorted by the Chemical Abstracts Service Registry Number (CAS No.). CAS Nos are searchable terms within the Exposure Standards Database.

3. PROHIBITION OF THE USE OF SUBSTANCES

3.1 There are a number of substances whose industrial use has resulted in considerable and serious occupational disease. Accordingly, the risk to health associated with the use of these substances is such that their continued use cannot be justified, especially where suitable substitutes exist. For this reason, the direct use of the following substances or their salts should be prohibited:

Substance	Reason
4-Aminodiphenyl	Carcinogenicity
Amosite (brown Asbestos)	Carcinogenicity
Benzidine	Carcinogenicity
bis(Chloromethyl) ether	Carcinogenicity
Crocidolite (blue asbestos)	Carcinogenicity
2-Naphthylamine	Carcinogenicity
4-Nitrodiphenyl	Carcinogenicity

3.2 These substances should not be mined, or manufactured or incorporated into new products or processes, and should not be used for any purpose other than for bona fide research. Where these substances occur as a contaminant or by-product in an industrial process, such a process should be strictly controlled to prevent worker exposure.

3.3 In some instances, exposure standards have been assigned to these substances because of their existence as a result of past use or because of their occurrence as trace contaminants in process materials. Safe handling practices applicable to some of these materials have been detailed in National Commission guidance notes or codes of practice. 5,6

Reference

5. National Occupational Health and Safety Commission, 'Guide to the Control of Asbestos Hazards in Buildings and Structures' [NOHSC:3001(1988)], in Asbestos: Code of Practice and Guidance Notes, Australian Government Publishing Service, Canberra, 1988.

6. National Occupational Health and Safety Commission, 'National Code of Practice for the Safe Removal of Asbestos' [NOHSC:2002(1988)], in Asbestos: Code of Practice and Guidance Notes, Australian Government Publishing Service, Canberra, 1988.'

4. WORKLOAD CONSIDERATIONS

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

4.2 Heavy or strenuous work increases lung ventilation, thereby increasing the uptake of airborne contaminants.⁷ Similarly, heavy physical work under adverse climatic conditions, such as excessive humidity or heat, or work at high altitudes, may lead to an increased uptake of contaminants. It is therefore of particular importance that any evaluation of the working environment considers the lung ventilation rate where there is a significant airborne concentration of contaminant.

Reference

7. Astrand, I., 'Effect of physical exercise on uptake, distribution and elimination of vapours in man', in Fiserova-Bergerova, V. ed., *Modelling of Inhalation Exposure to Vapours: Uptake, Distribution and Elimination*, vol. 2, chapter 5, CRC Boca Raton, Florida, 1983.

5. EXPOSURE DURATION

5.1 Except for short term exposure limits, or where a peak value has been assigned, the exposure standards for airborne contaminants are expressed as a time-weighted average (TWA) concentration of that substance over an eight-hour working day, for a five-day working week. During periods of continuous daily exposure to an airborne contaminant, these TWA exposures permit excursions above the exposure standard provided they are compensated for by equivalent excursions below the standard during the working day.

5.2 However, it is not necessarily acceptable to expose workers to concentrations significantly higher than the exposure standard solely because the exposure is for less than an eight-hour day or because the exposure occurs only occasionally. Permissible variations in the exposure standard for such situations are dependent on such factors as the acute effects of short term exposures, or on the relationship between accumulation and elimination of the body burden of the material or its metabolites, and should only be accepted in the light of expert advice.

5.3 Where workers have a working day longer than eight hours or unusual shift rotations are in effect, the TWA exposure standard may need to be reduced by a suitable factor to ensure adequate worker protection. Such factors require specialist consideration and expert advice should be sought in the specification of modified exposure standards. 8, 9, 10, 11, 12

Reference

8. Roach, S.A., 'A most rational basis for air sampling programs', *Annals of Occupational Hygiene*, vol. 20, pp. 65-84, 1977.

9. Roach, S.A., 'Threshold Limit Values for Extraordinary Work Schedules', *American Industrial Hygiene Association Journal*, vol. 39, pp. 345-48, April 1978.

10. Koizumi, A., et al, 'Evaluation of the Time-Weighted-Average of Air Contaminants with Special Reference to Concentration Fluctuation and Biological Half-time', *American Industrial Hygiene Association Journal*, vol. 41, pp. 693-99, October 1980.

11. Hickey, J.L.S. and Reist, P.C., 'Application of occupational exposure limits to unusual work schedules', *American Industrial Hygiene Association Journal*, vol. 38, pp. 613-21, November 1977.

12. Rappaport, S.M., Spear, R.C. and Solvin, S., 'The influence of exposure variability on dose-response relationships', presented at Inhaled Particles Conference, Cambridge, 1985.

5A. ALTERED WORKSHIFTS

Introduction

Adjustment of 8-hour Time Weighted Average Exposure Standards for Altered Workshifts

5A.1 Exposure standards for airborne contaminants are assigned for conventional workshifts, that is, eight-hour working day, five-day working week. These standards may be inappropriate where there are altered workshifts. To provide people working altered workshifts with at least an equivalent degree of protection as there is for people working conventional workshifts, the 8-hour Time Weighted Average (TWA) exposure standard may need to be reduced by a suitable factor.

5A.2 Considering whether to reduce exposure standards by a suitable factor is part of the duty of care of an employer and should be considered during the assessment and control processes as required by hazardous substances regulations implemented by jurisdictions in accordance with the National Occupational Health and Safety Commission's Model Regulations for Control of Workplace Hazardous Substances.

Substances Assigned Peak Limitation or Short Term Exposure Limit (STEL) Values

5A.3 No adjustment is necessary for Peak Limitation and Short Term Exposure Limit (STEL) values. This is because adverse effects due to acute over-exposure are already accounted for by existing STEL or Peak Limitations.

Short Exposure Periods Or Shifts

5A.4 8-hour TWA exposure standards should not be adjusted upwards when considering shorter exposure periods or shifts (for example, exposure to 8 times the TWA for one hour and zero exposure for the remainder of the shift). This is because data on the mode of action of the substance, its target organ, absorption and excretion rates may not be fully understood for high exposures of short duration.

5A.5 In circumstances where short exposure periods or shifts are encountered the general excursion limitations described in Chapter 6, paragraph 6.8 still apply and adherence to these general limitations should be maintained. The general limitations do not supersede any STEL or Peak Limitation value which may be assigned.

Models For Adjusting 8-Hour TWA Exposure Standards

5A.6 Several mathematical models have been proposed for adjusting exposure standards for use during altered work shifts. These models include the 'Brief and Scala Model'⁽¹⁾, the US 'Occupational Safety and Health Administration (OSHA) Model'⁽²⁾ and the 'Pharmacokinetic Model' of Hickey and Reist⁽³⁾. All models provide valid methods for adjusting exposure standards. The main difference is the degree of conservatism. Selection of a model will depend on the information available and the expertise of the practitioner. It should be emphasised that adjustment of exposure standards may be complex and there is no scientific consensus on a universal adjustment regime.

5A.7 It should be noted that exposure standard values do not represent a fine line between safe and dangerous exposures and therefore the application of precise adjustments is not appropriate.

5A.8 Where an exposure standard is set close to the Limit of Detection there may be difficulties in measuring exposure and demonstrating compliance if the value of the exposure standard is adjusted downwards.

The Exposure Standards Expert Working Group recommends the Brief and Scala Model be used for calculating adjustments to the exposure standards.

1. Brief and Scala Model

5A.9 The Brief and Scala Model⁽⁴⁾ is based on the number of hours worked per 24 hour day and the period of time between exposures. This model is intended to ensure that the daily dose of the toxicant under an altered workshift is below that for a conventional shift to take account of the lessened time for elimination.

Information required: hours worked per 24 hour day.

Features include: involves a simple calculation;

most conservative model;

no detailed knowledge about the substance is needed.

Formula:

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

where **h** = hours worked/day

Worked examples:

Example 1

Substance:	Exposure Standard:	Workshift:
Ethyl alcohol	1000 ppm, 8 -hour TWA	12 hours

Solution

$$\begin{aligned} \text{Adjusted exposure standard for 12-hour workshift} &= \frac{8 \times (24 - \mathbf{12}) \times \text{Exposure Standard (8-hour TWA)}}{16 \times \mathbf{12}} \\ &= \frac{8 \times (24 - \mathbf{12}) \times 1000 \text{ ppm}}{16 \times \mathbf{12}} \\ &= 500 \text{ ppm (12-hour TWA)} \end{aligned}$$

Example 2

Substance:	Exposure Standard:	Workshift:
Chlorine	1 ppm, Peak Limitation	12 hours

Solution

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

Example 3

Substance:	Exposure Standard:	Workshift:
Methyl ethyl ketone	150 ppm, 8-hour TWA; 300 ppm STEL	12 hours

Solution

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

2. OSHA Model

5A.10 The US Occupational Safety and Health Administration (OSHA) Model⁽²⁾ categorises air contaminants into one of six categories based on their toxic effects. Depending on the type of toxic effect, an appropriate adjustment procedure (including no adjustment) is selected and applied to the substance's exposure limit. This model is intended to ensure that for substances with acute or chronic toxicity, the daily dose or the weekly dose, respectively, during an altered workshift does not exceed the dose obtained in a conventional 8-hour workshift⁽²⁾. This model is not recommended for use in Australia as it relies on a substance categorisation system and exposure standards used in the United States.

3. Pharmacokinetic Model (of Hickey And Reist)

5A.11 There are several different pharmacokinetic models. These models take into account the expected behaviour of the hazardous substance in the body based on knowledge of the properties of the substance. The Hickey and Reist model⁽³⁾ requires knowledge of the substance's biological half-life. Pharmacokinetic models are less conservative than the Brief & Scala or OSHA Models, usually recommending less reduction of the established exposure. Whereas pharmacokinetic models are theoretically more exact than the simpler models, their lack of conservatism may not allow adequately for the unknown adverse effects on the body from nightwork or extended shifts that might affect how well the body metabolises and eliminates the substance.

PREFERRED MODEL FOR ADJUSTMENT OF 8-HOUR TWA EXPOSURE STANDARDS

5A.12 The Exposure Standards Expert Working Group recommends the Brief and Scala Model be used for calculating adjustments to the exposure standards. The Brief and Scala Model is preferred because it is simple to use, takes into account both increased hours of exposure and decreased exposure free time, is more conservative than the OSHA Model or Pharmacokinetic Model of Hickey and Reist and is suitable for the Australian exposure standards of the National Occupational Health and Safety Commission.

5A.13 The Working Group, however, have not excluded the use of the Pharmacokinetic Model of Hickey and Reist but are of the view that this model is less conservative, requires more involved calculations and should only be used by practitioners with appropriate expertise, that is, occupational hygienists. Moreover, the practitioner, in applying the Pharmacokinetic Model of Hickey and Reist, should have a good understanding of the toxicology and pharmacokinetics of that substance as well as the rationale for the exposure standard. The OSHA model is not recommended for use in Australia as it relies on a substance categorisation system and exposure standards used in the United States.

REFERENCES

1. Brief R, Scala R. Occupational Exposure Limits for Novel Work Schedules. American Industrial Hygiene Association Journal. 36:467-469, 1975.

2. Paustenbach D. Occupational Exposure Limits, Pharmacokinetics and Unusual Work Shifts. In Patty's Industrial Hygiene and Toxicology, Vol III, Eds Cralley & Cralley, New York, John Wiley & Sons, 11-277, 1985.

3. Hickey J, Reist P. Application of Occupational Exposure Limits to Unusual Work Schedules. American Industrial Hygiene Association Journal. 38:613-621, 1977.

FURTHER READING

Department of Minerals and Energy Western Australia. Discussion Paper Unusual Work Shifts and Occupational Exposure Standards. J Oosterhof, 1993.

Roach S. Threshold Limit Values for Extraordinary Work Schedules. American Industrial Hygiene Association Journal. 39:345-348, 1978.

6. EXCURSION LIMITS

6.1 The exposure standards for airborne contaminants are expressed as a TWA concentration over an entire eight-hour working day. However, during this eight-hour averaging period, excursions above the TWA exposure standard are permitted providing these excursions are compensated for by equivalent excursions below the standard during the working day. However, because some substances can give rise to acute health effects even after brief exposures to high concentrations, it is evident that excursions above the TWA concentration should be restricted.

6.2 The permissible frequency of these excursions, their magnitude and duration should be based upon a number of factors such as the nature of the contaminant, its cumulative effects and whether brief exposures can produce acute effects.

- **PEAK LIMITATION**

6.3 For some rapidly acting substances and irritants, the averaging of the airborne concentration over an eight-hour period is inappropriate. These substances may induce acute effects after relatively brief exposure to high concentrations and so the exposure standard for these substances represents a maximum or peak concentration to which workers may be exposed. Although it is recognised that there are analytical limitations to the measurement of some substances, compliance with these 'peak limitation' exposure standards should be determined over the shortest analytically practicable period of time, but under no circumstances should a single determination exceed 15 minutes.

- **SHORT TERM EXPOSURE LIMIT**

6.4 Some substances can cause intolerable irritation or other acute effects upon brief overexposure, although the primary toxic effects may be due to long term exposure through accumulation of substances in the body or through gradual health impairment with repeated exposures. Under these circumstances, exposure should be controlled to avoid both acute and chronic health effects.

6.5 Short term exposure limits (STELs) provide guide-lines for the control of short term exposure. These are important supplements to the eight-hour TWA exposure standards which are more concerned with the total intake over long periods of time. Generally, STELs are established to minimise the risk of the occurrence in nearly all workers of:

- intolerable irritation;
- chronic or irreversible tissue change; and

- narcosis to an extent that could precipitate industrial accidents,

provided the TWA exposure standards are not exceeded. STELs are recommended for those substances only when there is evidence either from human or animal studies that adverse health effects can be caused by high short term exposure.

6.6 STELs are expressed as airborne concentrations of substances, averaged over a period of 15 minutes. This short term TWA concentration should not be exceeded at any time during a normal eight-hour working day. Workers should not be exposed at the STEL concentration continuously for longer than 15 minutes, or for more than four such periods per working day. A minimum of 60 minutes should be allowed between successive exposures at the STEL concentration.

- GUIDANCE ON GENERAL EXCURSION

6.7 In practice, the actual concentration of an airborne contaminant arising from a particular industrial process may fluctuate widely with time, with some of the major excursions giving rise to a significant proportion of the overall exposure.

6.8 Even where the TWA exposure standard is not exceeded, there should be some control of concentration excursions. A practical approach to control has been developed, based on observations of the variability in concentrations observed in industrial environments. A process is not considered to be under reasonable control^{13, 14} if short term exposures exceed three times the TWA exposure standard for more than a total of 30 minutes per eight-hour working day, or if a single short term value exceeds five times the TWA exposure standard. It should be emphasised that guidance of this type, aimed at placing some restraint on concentration excursions, is not directly health-based and does not supersede any STEL or peak limitation set.

6.9 Where adequate toxicological or epidemiological data allows the assignment of a STEL, the STEL will supersede this guidance on general excursion.

Reference

13. Leidel, N.A., Busch, K.A. and Crouse, W.E., Exposure Measurement, Action Level and Occupational Environment Variability, pub. no. 76-131, NIOSH, Cincinnati, Ohio, 1975.

14. American Conference of Governmental Industrial Hygienists (ACGIH), TLVs: Threshold Limit Values and Biological Exposure Indices for 1994-95, ACGIH, Cincinnati, Ohio, 1994.

7. MONITORING OF EXPOSURE

7.1 The exposure standards detailed in this publication refer to airborne concentrations of chemical substances in the breathing zone of the worker, determined by 'personal sampling'.

7.2 The airborne concentration of contaminants may vary considerably at different times and from place to place. Air samples taken at fixed locations in the working environment, that is, 'static samples', are only of limited use in assessing the risks posed to workers from a particular contaminant. Static samples may be essential in the design of, or when assessing the effectiveness of, control measures. In some cases, fixed continuous monitors in suitable positions may also be provided to give early warning of leaks or other generators of high concentrations which could subsequently lead to worker exposures exceeding the standard. However, such fixed position monitoring should not be regarded as indicative of actual worker exposure.

7.3 The proper evaluation of worker exposures may require a substantial commitment of personnel, sampling equipment and analytical resources,¹⁵ the optimum use of which may be achieved with an appropriate sampling strategy. To protect the health of workers, exposure measurements should be made from unbiased and representative samples of actual worker exposure. Such a sampling strategy

usually encompasses selection of workers for personal monitoring as well as sampling times. The strategy should also address issues such as sampling and analysis errors, statistical analysis of exposure data and the determination of the need for regular exposure measurement. Detailed routine sampling strategies for individual substances are a complex subject and a complete discussion of the theory and characteristics is beyond the scope of this guidance note. However, practical guidance is available in *Monitoring Strategies for Toxic Substances*¹⁶ and *Occupational Exposure Sampling Strategy Manual*.¹⁷

7.4 The assessment of received dose may require that personal monitoring be complemented by biological monitoring of exhaled breath or body fluids in order to take full account of such factors as absorption by routes other than inhalation (for example, by skin contamination or ingestion), biological variations and personal habits.

Reference

15. National Institute for Occupational Safety and Health (USA), NIOSH Manual of Analytical Methods, 4th edition, DHHS (NIOSH) pub. no. 94-113, August 1994.

16. Health and Safety Executive (UK), Monitoring Strategies for Toxic Substances, Environmental Hygiene 42, HMSO, January 1989.

17. National Institute for Occupational Safety and Health (USA), Occupational Exposure Sampling Strategy Manual, DHEW (NIOSH), pub. no. 77-173, 1977.

8. BIOLOGICAL MONITORING

8.1 The assessment of the airborne concentration of a particular contaminant and the subsequent comparison with the appropriate exposure standard(s) is usually the primary technique in the evaluation of the working environment. However, in some situations this approach may be complemented by the use of biological monitoring techniques which measure the levels of the substance or its metabolite(s) in body fluids, such as sweat, urine or blood, or in exhaled breath.

8.2 Workers differ from each other in size, fitness, personal hygiene, work practices, smoking habits, alcohol and drug usage, and nutritional status. There are thus differences between individuals in uptake, metabolism and excretion of toxic substances, and in response to a particular toxic hazard. ¹⁸ Biological monitoring has the specific advantage that it can take account of these differences, enabling individual risk assessments to be made. As such, in certain circumstances, biological monitoring serves as a useful adjunct to atmospheric monitoring in assessing actual occupational exposure.

8.3 For a limited number of substances, the application of biological monitoring can be particularly useful in suggesting the degree of skin absorption and, in some cases, can identify unknown or unexpected exposures which cannot be predicted from atmospheric monitoring alone. However, biological monitoring does have limitations, particularly in regard to the collection and preservation of samples and the interpretation of results. There is limited knowledge of suitable and definitive biological tests for most substances.

8.4 As this publication is primarily concerned with exposure standards for atmospheric contaminants, values for biological indices for individual substances have not been included, although some values may be included in a later edition. There are, however, a number of useful documents which address both the individual biological values ^{19,20} and the techniques by which they are determined.

^{21,22,23,24,25,26,27}

Reference

18. Gompertz, D., 'Assessment of Risk by Biological Monitoring', British Journal of Industrial Medicine, vol. 38, pp. 198-201, 1981.

19. American Conference of Governmental Industrial Hygienists (ACGIH), Documentation of the Threshold Limit Values and Biological Exposure Indices, 6th Edition, ACGIH, Cincinnati, Ohio, 1991.
20. Deutsche Forschungsgemeinschaft (DFG), List of MAK and BAT Values 1994, Report No. 30, Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, VCH Verlagsgesellschaft mbH, Weinheim, Germany, 1994.
21. Health and Safety Executive (UK), Health Surveillance by Routine Procedures, Guidance Note MS 18, HMSO, London, 1981.
22. Health and Safety Executive (UK), Laboratory Methods for Biological Monitoring, 2nd edn., HMSO, London, 1985.
23. Wilson, J.K., 'Breath analysis - physiological basis and sampling technique', Scandinavian Journal of Work, Environment and Health, vol. 12, no. 3, pp. 174-192, June 1986.
24. Commission of the European Communities, Biological Indicators for the Assessment of Human Exposure to Industrial Chemicals, Commission of the European Communities, vol. 1, 1983, vol. 2., 1984, vol. 3, 1986, Brussels.
25. Deutsche Forschungsgemeinschaft (DFG), Analyses of Hazardous Substances in Biological Materials, vols. 1 and 2, Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, VCH Verlagsgesellschaft mbH, Weinheim, Germany, 1985.
26. Halperin, W., Schulte, P.A. and Greathouse, D.G., eds., 'Conference on medical screening and biological monitoring for the effects of exposure in the workplace, July 1984, Part I', Journal of Occupational Medicine, vol. 28, no. 8, pp. 543-782, August 1986.
27. Mason T.J., Prorok P.C. and Costlow R.D. eds., 'Conference on medical screening and biological monitoring for the effects of exposure in the workplace, July 1984, Part II', Journal of Occupational Medicine, vol. 28, no.10, pp. 901-1124, October 1986.

9. ODOUR THRESHOLDS

9.1 Many chemical substances have a distinctive odour which indicates the presence of the substance in the working environment. While this odour perception serves as a useful warning signal, in most instances this perception may convey little information about the potential hazard associated with the atmospheric contaminant.

9.2 While a large number of odour thresholds have been determined, there are a number of problems associated with their use. These problems include:

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

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

9.4 Odour perception may be useful as a warning signal, however, its use is limited and should not replace the objective measurement of the airborne concentration of the particular substance.

Reference

28. Ruth, J.H., 'Odour thresholds and irritation levels of several chemical substances: a review', American Industrial Hygiene Association Journal, vol. 47, pp. 142-151, 1986.

10. SIMPLE ASPHYXIANTS

10.1 Simple asphyxiants are gases which, when present in an atmosphere in high concentrations, lead to a reduction of oxygen concentration by displacement or dilution. It is not appropriate to recommend an exposure standard for each simple asphyxiant, rather it should be required that a sufficient oxygen concentration be maintained.

10.2 The minimum oxygen content in air should be 18 per cent by volume under normal atmospheric pressure. This is equivalent to a partial pressure of oxygen (P_{O_2}) of 18.2 kPa (137 mm Hg). At pressures significantly higher or lower than the normal atmospheric pressure, expert guidance should be sought.

10.3 Atmospheres deficient in oxygen do not provide adequate sensory warning of danger and most simple asphyxiants are odourless. Unconsciousness and death can rapidly ensue in an environment which is deficient in oxygen. There have been a considerable number of deaths among inappropriately protected workers who have entered confined spaces or tanks before these spaces were adequately vented or gas-tested. Australian Standard AS 2865-1995 *Safe Working in Confined Spaces* details precautions which should be observed in such environments.²⁹

10.4 Many of the simple asphyxiants can also present an explosion hazard and this should be taken into account in limiting the concentration of the asphyxiant. The tables below give specific examples of simple asphyxiants, although they are not meant to be all-inclusive lists.

10.5 Examples of asphyxiants which may present an explosion hazard:

Chemical CAS No.

Acetylene 74-86-2
Ethane 74-84-0
Ethylene 74-85-1
Hydrogen 1333-74-0
Methane 74-82-8
Propane 74-98-6
Propylene 115-07-1

10.6 Examples of asphyxiants which are not expected to present an explosion hazard:

Chemical CAS No.

Argon 7440-37-1
Helium 7440-59-7
Neon 7440-01-9
Nitrogen 7727-37-9

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

Reference

29. Standards Australia AS 2865-1995 Safe Working in a Confined Space, Standards Australia, Sydney, 1995.

11. EFFECTS ON THE SKIN

- SKIN ABSORPTION

11.1 For most substances in the occupational setting, the main route of entry into the body is via inhalation. However, certain chemical substances such as aniline, nitrobenzene, phenols and certain pesticides can readily penetrate the intact skin and thus become absorbed into the body. Frequently, there will be no accompanying skin damage. In some instances this dermal absorption can pose a far greater danger than inhalation exposure.

11.2 The adopted national exposure standards listed in the publication only consider absorption via inhalation, and are valid only on the condition that significant skin absorption cannot occur. In some instances, special measures may be required to prevent absorption through the skin. Chemical compounds requiring such precautions are specified by the notation `Sk' in column 6 of the printed listing of the adopted national exposure standards, a skin absorption notation is provided in the database version of the exposure standards.

11.3 Skin absorption can result from local contamination, for example, from a splash onto the skin or clothing, or, in some rare cases, from exposure to very high atmospheric concentrations of vapour. In addition, some vehicles, such as solvents, can accelerate or alter the rate of skin absorption. Serious effects can result with little or no warning and it is necessary to take special precautions to prevent skin contact when handling these substances.

11.4 Where biological monitoring methods are available for such materials, it may be important to employ these for personnel surveillance in addition to any air monitoring program. Biological monitoring is discussed in more detail in Chapter 8.

- OTHER EFFECTS ON THE SKIN

OTHER EFFECTS ON THE SKIN

11.5 Many substances can be injurious by their direct effect on the skin and mucous membranes, whether or not they are also absorbed in significant amounts. Solvents degrease the skin, thereby rendering the individual more vulnerable to the effects of the solvents and other substances. Some corrosive substances cause particularly serious injuries to the eyes and skin. Other substances, for example, derivatives of coal tar and certain dyes and drugs, by either coming into direct contact with the skin or reaching there by the systemic circulation, may react with selected wavelengths of natural or artificial light to cause dermatitis or other health effects.

11.6 Substances which may cause physical damage to the skin or eyes are not noted in this publication. However, it is good practice to avoid any unnecessary contact with all chemical substances.

11.7 **Note:** An initiative of the National Commission which addresses occupational skin disorders may lead to more detailed advice on this issue. 30

Reference

30. National Occupational Health and Safety Commission, National Strategy for the Prevention of Occupational Skin Disorders [NOHSC:4002(1989)], Australian Government Publishing Service, Canberra, 1989.

12. SENSITISERS

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

12.2 Following the induction of a sensitised state, an affected individual may subsequently react to exposure to minute levels of that substance. Although low values have been assigned to strong sensitising agents, compliance with the recommended exposure standard may not provide adequate protection for a hypersensitive individual.^{31,32} Persons who are sensitised to a particular substance should not be further exposed to that substance.

12.3 Substances which are known to act as sensitisers are designated by the notation 'Sen' in column 6 of the printed list of adopted national exposure standards, the database version of the exposure standards provides a sensitiser notice against the substance. Such a designation indicates that caution should be exercised in the industrial use of these substances.

Reference

31. de Silva, P., 'Nearly all workers', Annals of the American Conference of Governmental Industrial Hygienists, vol. 12, pp. 161-66, 1985.

32. Lewis, T.R., 'Identification of sensitive subjects not adequately protected by TLVs', Annals of the American Conference of Governmental Industrial Hygienists, vol. 12, pp. 167-172, 1985

13. CARCINOGENS

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

13.2 The incidence of cancer is usually dose related; the greater the exposure to the chemical carcinogen the higher the risk of developing the cancer associated with that chemical. Accordingly, the smaller the exposure the lower the probability of a cancer developing.

13.3 Because of the limitations of both epidemiological and animal studies at very low dosage, 'no effect' levels of exposure cannot be confidently identified for carcinogenic substances at the present time. Nevertheless, there do appear to be practical thresholds for most carcinogens at which the effects cannot be distinguished against the natural background,³³ although for some of the more potent carcinogens elimination of exposure is the only recommendable goal.

13.4 Since some carcinogenic substances are unavoidable in particular industrial processes, and to some extent also occur in nature, it may be impossible to eliminate exposure to these substances completely. For this reason the following general guide-lines should be observed:

- Substances which have been identified as carcinogens should be replaced, where possible, by substances which are not carcinogenic and are less hazardous.
- Engineering controls, such as exhaust ventilation, process enclosure and/or improved work practices, should be implemented to eliminate or minimise worker exposure. As skin absorption can be a significant source of exposure for some carcinogens, particular attention may need to be given to plant hygiene and the selection of appropriate skin protection.
- Routine air monitoring, or biological monitoring where appropriate, should be employed in the workplace to ensure exposure is being maintained at the minimum which can be practically achieved, and in all cases below the appropriate exposure standard. Because the levels of

exposure may be very low, analytical methods of appropriate sensitivity should be employed. The frequency at which monitoring is undertaken is determined by the magnitude of the potential exposure and the reliability of the process controls.

- Where exposure to these substances cannot be eliminated by the use of process control techniques, the use of personal protective equipment may be required. The selection of appropriate protective equipment will be determined not only by the nature and magnitude of the potential exposure, but also by the particular chemical and physical characteristics of the substance and the nature and magnitude of its carcinogenic effect.
- All personnel likely to be exposed to carcinogenic substances should receive adequate information regarding the hazards, and training in minimisation of risk.

13.5 Although exposure to potentially carcinogenic substances should be eliminated or reduced to as low a level as is practicable, the use of exposure standards can, in many cases, act as a useful guide to the efficiency of engineering controls and the work practices which have, or need to be, implemented to reduce worker exposure.

13.6 To this end, where there is sufficient information to allow the assignment of exposure standards, these are given as a guide to good practice. However, because of the incompleteness of our knowledge of carcinogens, it is at present not possible to reliably estimate the risk posed by some carcinogenic substances. Therefore, compliance with these exposure standards should not preclude further efforts to reduce worker exposure.

13.7 Chemical substances which have been identified as suspected or established carcinogens, or substances associated with industrial processes which have been identified as suspected or established carcinogens, have been highlighted in the list of adopted exposure standards. The Commission of the European Communities (EEC) system of classification of carcinogenic substances³⁴ is used to indicate the strength of the causal association between these substances and the development of cancer. (Note: The categorisation of individual substances by the Exposure Standards Working Group may vary from the EEC assignment in some instances.) A detailed description of the criteria used in this classification system is available in *A Guide to the Classification of Carcinogens, Mutagens and Teratogens under the Sixth Amendment*,³⁵ which is based on the interpretation, for human exposure at the workplace, of the findings of the International Agency for Research on Cancer on carcinogenesis. The three categories, with the appropriate levels of control required, are described below.

(a) Category 1

Established human carcinogens are those substances known to be carcinogenic to humans. There is sufficient evidence to establish a causal association between human exposure to these substances and the development of cancer.

Under the circumstances where substitution of less hazardous materials is technically not feasible, the use of these carcinogenic substances should be controlled to the highest practicable standard by the application of effective engineering control techniques and, where necessary, complemented by the use of appropriate personal protective equipment. Routine monitoring of the workplace is essential for indication of control performance. In some cases, health surveillance and biological monitoring can indicate exposure and thus reveal the need for re-assessment of the control measures and work practices. For some substances, specific control measures have been detailed in codes of practice.^{5,6,36}

(b) Category 2

Probable human carcinogens are those substances for which there is sufficient evidence to provide a strong presumption that human exposure might result in the development of cancer. This evidence is generally based on appropriate long term animal studies, limited epidemiological evidence or other relevant information.

These substances should be treated as if they are carcinogenic to humans. Under the circumstances where substitution of less hazardous materials is not possible, exposures to these substances should be minimised to the lowest practicable levels. This should be achieved by the application of effective

engineering control measures, revised work practices and, where necessary, complemented by the use of appropriate personal protective equipment. A program of routine air monitoring should be implemented to ensure that the process controls and work practices implemented are effective in minimising exposure. In some cases, health surveillance and biological monitoring can indicate exposure and thus reveal the need for re-assessment of the control measures and work practices.

(c) Category 3

Substances suspected of having carcinogenic potential are those substances which have possible carcinogenic effects on humans but in respect of which the available information is not adequate for making a satisfactory assessment. There is some evidence from appropriate animal or epidemiological studies, but this is insufficient to place the substance in Category 2.

Because these substances may be re-assigned to a more stringent category in the light of future research, their use should be reviewed and they should be used with caution. Exposures should be kept as low as practicable and in no cases should they exceed the established exposure standards.

Reference

33. Doll, R. and Peto, R., The Causes of Cancer: Quantitative Estimates of Avoidable Risks of Cancer in the United States Today, Oxford University Press, Oxford, United Kingdom, 1981.

34. Commission of the European Communities (EEC), Classification and Labelling of Dangerous Substances, Council Directive 79/831/EEC, Sixth Amendment, Brussels, 1986.

35. European Chemical Industry Ecology and Toxicology Centre, A Guide to the Classification of Carcinogens, Mutagens and Teratogens under the Sixth Amendment, technical report no. 21, Brussels, February 1986.

5. National Occupational Health and Safety Commission, 'Guide to the Control of Asbestos Hazards in Buildings and Structures' [NOHSC:3001(1988)], in Asbestos: Code of Practice and Guidance Notes, Australian Government Publishing Service, Canberra, 1988.

6. National Occupational Health and Safety Commission, 'National Code of Practice for the Safe Removal of Asbestos' [NOHSC:2002(1988)], in Asbestos: Code of Practice and Guidance Notes, Australian Government Publishing Service, Canberra, 1988.

36. National Occupational Health and Safety Commission, National Code of Practice for the Safe Use of Vinyl Chloride [NOHSC:2004(1990)], Australian Government Publishing Service, Canberra, 1990.

14. AIRBORNE PARTICULATES

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

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

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

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

14.3 Most industrial dusts contain particles of widely ranging size. The behaviour, deposition and fate of any individual particle after entry into the human respiratory system and the response that it elicits depends on the nature and size of the particle.

14.4 Only part of the total quantity of dust which is present in the worker's breathing zone is inhaled. This part is designated as the 'inspirable fraction' of dust and is governed by the flow rates in the nose and mouth areas, as well as the airflow around the head. Practically all of the smaller particles will be inhaled, while the inhalability of the larger particles decreases rapidly as a function of increasing aerodynamic diameter.

14.5 The larger particles in the inspirable fraction of dust are deposited in the nose, pharynx and larynx. Some of the smaller particles reach the tracheobronchial tree or even the alveolar region of the lung where gas exchange occurs.

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

- **Inspirable Dust**

Inspirable Dust

14.7 At present there is intense debate concerning size- selective sampling of airborne dusts.

14.8 In 1983 the International Organization for Standardization (ISO) 37 proposed definitions for both 'respirable' and 'inspirable' dust. In 1985 the American Conference of Governmental Industrial Hygienists (ACGIH) 38 recommended a different set of criteria for size-selective aerosol sampling. The following tables give values for the classification of inspirable particles into mass fractions according to the ISO definition and the nominal inspirable particulate mass (IPM) sampling efficiency criteria adopted by ACGIH.

Inspirable Mass Fraction (ISO TR 7708)

Particle equivalent aerodynamic diameter (μ) Inspirability (per cent)

0	100
10	73
30	52
60	34
100	20
185	0

Inspirable Mass Sampling Efficiency (ACGIH)

Particle equivalent aerodynamic diameter (μ) IPM sampling efficiency (per cent)

0	100
10	77
30	58
60	51
100	50
185	not defined

14.9 Taking into account the approximations and uncertainties inherent in standardising human inhalation and deposition curves and the practicalities involved in workplace sampling, it is believed that the difference between the two sets of recommendations is relatively small compared with their general agreement in approach.

14.10 However, it is important to realise that different types of currently available sampling devices conforming to these definitions can give significantly different results if a predominance of very large particles, that is, >30-50 μ aerodynamic diameter, is present in the atmosphere being sampled. In other words, under these conditions a device which samples in accordance with the ACGIH definition may give higher results than the device which samples in accordance with the ISO definition.

14.11 In its recent publication on sampling methods for inspirable dust, Standards Australia 39 has addressed these issues and this document should be consulted for more detail on these techniques and appropriate sampling devices.

14.12 'Inspirable' dust as measured by the method described in the above-mentioned document 39 derives from 'inspirability' and 'inspirable mass fraction' as defined by ISO or from 'inspirable particulate mass fraction' as defined by ACGIH. Some authorities use the terms 'inhalable' or 'total inhalable'.

Reference

37. International Organization for Standardization (ISO), Air Quality - Particle Size Fraction Definitions for Health Related Sampling, ISO TR 7708, Switzerland, 1983.

38. American Conference of Governmental Industrial Hygienists (ACGIH), Particle Size-selective Sampling in the Workplace, ACGIH, Cincinnati, Ohio, 1985.

39. Standards Australia, AS 3640-1989 Workplace Atmospheres - Method for Sampling and Gravimetric Determination of Inspirable Dust, Standards Australia, Sydney, 1989.

- Respirable Dust

Respirable Dust

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

14.14 The definition of 'respirable' dust is that detailed by Standards Australia 40 and conforms with the definition adopted by the British Medical Research Council (BMRC) and the recommendation of the Pneumoconiosis Conference held in Johannesburg in 1959. 41 This recommendation states that the respirable fraction is defined by a sampling efficiency curve which depends on the settling velocity of the particle and which passes through the points indicated in the following table.

Respirable Mass Fraction**Particle equivalent aerodynamic diameter (μ) Respirability (per cent)**

0	100
1	98
2	92
3	82
4	68
5	50
6	28
7	0

14.15 The above sampling efficiency curve is known as the 'Johannesburg curve' and practical devices exist which sample according to this curve.⁴⁰

Reference

40. Standards Australia, AS 2985-1987 Workplace Atmospheres: Method for Sampling and Gravimetric Determination of Respirable Dust, Standards Australia, Sydney, 1987.

41. Orenstein, A.J., ed., Proceedings of the 1959 Pneumoconiosis Conference, Johannesburg, Churchill, London, 1960.

- SILICA

SILICA

14.16 Silica is a name which collectively describes various forms of silicon dioxide, including both the crystalline and non-crystalline (amorphous) forms of silica. While amorphous silica can be transformed into crystalline forms such as tridymite and cristobalite by heating to high temperatures (approximately 870° and 1470° respectively),⁴² it is generally only the crystalline forms of silica which are fibrogenic*. The temperature at which amorphous silica can be converted to crystalline forms such as tridymite and cristobalite is very dependent upon pressure and chemical environment. For instance, significant quantities of cristobalite can be formed at temperatures as low as 450° in the presence of sodium carbonate or sodium chloride flux, that is, calcining.⁴³

14.17 **Note:** An Expert Working Group on Crystalline Silica has been established under the auspices of the Standards Development Standing Committee (SDSC) to review the exposure standards for different forms of crystalline silica. At present, no values have been recommended by the SDSC and exposure should be kept as low as practicable.

14.18 The forms of crystalline silica which are under review are shown in the following table.

Type of Crystalline Silica	CAS No.	Respirable Fraction
Quartz	[14808-60-7]	Under review
Cristobalite	[14464-46-1]	Under review
Silica flour†	[14808-60-7]	Under review
Tridymite	[15468-32-3]	Under review
Fused silica	[60676-86-0]	Under review
Tripoli	[1317-95-9]	Under review

14.19 The airborne concentration of crystalline silica should be determined in the manner specified in Methods for Measurement of Quartz in Respirable Airborne Dust by Infra-red Spectroscopy and X-ray Diffractometry.⁴⁵

14.20 Different types of amorphous silica, with their respective exposure standards, are shown in the following table.

Type of amorphous Silica	CAS No.	Respirable Fraction	Inspirable Fraction
Diatomaceous earth (uncalcined)+	[61790-53-2]	-	10 mg/m ³
Fumed silica‡	[7631-86-9]	2 mg/m ³	-
Precipitated silica	-	-	10 mg/m ³
Silica fume‡ (thermally generated)	-	Under review	(See Appendix 3)
Silica gel	-	-	10 mg/m ³

ASBESTOS

14.21 Asbestos is the generic name used for the fibrous form of a group of naturally occurring mineral silicates of the serpentine and amphibole series⁴⁶ including the fibrous serpentine mineral, chrysotile (white asbestos), and the amphiboles known in fibrous forms as actinolite, amosite (brown asbestos), anthophyllite, crocidolite (blue asbestos) and tremolite.

14.22 The average fibre concentration of the air breathed by a worker throughout a working shift, as calculated from measurements made in accordance with the National Commission's *Guidance Note on the Membrane Filter Method for Estimating Airborne Asbestos Dust*⁴⁷ [NOHSC:3003(1988)], over a sampling period of not less than four hours, during which one or more samples may be taken, should not exceed the values in the following table.

Type of Asbestos	CAS No.	TWA Exposure Standard
Crocidolite (blue asbestos)	[12001-28-4]	0.1 fibres per mL of air
Amosite (brown asbestos)	[12172-73-5]	0.1 fibres per mL of air
Chrysotile (white asbestos)	[12001-29-5]	1.0 fibres per mL of air
Other forms	[1332-21-4]	0.1 fibres per mL of air
Any mixture of these, or where the composition is unknown		0.1 fibres per mL of air

SYNTHETIC MINERAL FIBRES

14.23 Synthetic mineral fibres (SMF), described in international literature as man-made mineral fibres (MMMMF), is a collective term used to describe fibres such as fibreglass, rockwool and ceramic fibres. The biological effects of these fibres are determined by the fibre diameter and length and chemical nature.

14.24 For respirable fibres, the National Commission has adopted a TWA exposure standard of 0.5 fibres per mL of air be applied to synthetic mineral fibres (ceramic fibres, glassfibre and rockwool).⁴⁸ The airborne concentration of SMF should be determined in accordance with the National Commission's *Guidance Note on the Membrane Filter Method for the Estimation of Airborne Synthetic Mineral Fibres*⁴⁹ [NOHSC:3006(1989)].

14.25 For non-respirable fibres, in situations where almost all the airborne material is fibrous, a secondary, yet complementary, TWA exposure standard of 2 mg/m³ (inspirable dust) is proposed. This proposed secondary standard is established to minimise upper respiratory tract irritation from non-respirable fibres. It is not to take precedence over the respirable fibre standard.

Reference

42. Frondel, C., *Systems of Mineralogy*, vol. 3 (silica minerals), John Wiley and Sons Inc, New York, pp. 3-5, 1962.

43. Abrams, H. K., 'Diatomaceous earth silicosis', *American Journal of Industrial Medicine*, vol. 18, pp. 591-597, 1990.

44. International Agency for Research on Cancer (IARC), *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans - Silica and Some Silicates*, vol.42, pp. 41-42, IARC, Lyon, 1987.
45. National Health and Medical Research Council (NHMRC), *Methods for Measurement of Quartz in Respirable Airborne Dust by Infra-red Spectroscopy and X-ray Diffractometry*, NHMRC, Canberra, 1984.
46. World Health Organization (WHO), International Agency for Research on Cancer (IARC), *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man: Asbestos*, vol. 14, p. 14, IARC, Lyon, 1977.
47. National Occupational Health and Safety Commission, 'Guidance Note on the Membrane Filter Method for Estimating of Airborne Asbestos Dust' [NOHSC:3003(1988)], in *Asbestos: Code of Practice and Guidance Notes*, Australian Government Publishing Service, Canberra, 1988.
48. National Occupational Health and Safety Commission, 'National Standard for Synthetic Mineral Fibres' [NOHSC:1004(1990)], in *Synthetic Mineral Fibres: National Standard and National Code of Practice*, Australian Government Publishing Service, Canberra, 1990.
49. National Occupational Health and Safety Commission, 'Guidance Note on the Membrane Filter Method for the Estimation of Airborne Synthetic Mineral Fibres' [NOHSC:3006(1989)], in *Technical Report on Synthetic Mineral Fibres and Guidance Note on the Membrane Filter Method for the Estimation of Airborne Synthetic Mineral Fibres*, Australian Government Publishing Service, Canberra, 1989.

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

+ Commercial diatomite products are marketed in many grades. Diatomite for filtering is typically 'calcined' and therefore may contain a significant proportion of crystalline silica. 44

† (Some extremely fine grades of silica sand (crystalline silica) are marketed as 'silica flours' and have trade names such as Min-U-Sil. 44

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

- EXPOSURE STANDARDS FOR DUSTS NOT OTHERWISE CLASSIFIED

EXPOSURE STANDARDS FOR DUSTS NOT OTHERWISE CLASSIFIED

14.26 Not all dusts have assigned exposure standards. However, it should not be assumed that this indicates that these unlisted dusts do not represent a hazard to health.

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

14.28 Where no specific exposure standard has been assigned and the substance is both of inherently low toxicity and free from toxic impurities, the recommended exposure standard for dust in general should be 10 mg/m³, measured as inspirable dust. However, this general exposure standard should not be applied where the particulate material contains other substances which may in themselves be toxic or cause physiological impairment at lower concentrations. In such circumstances, the exposure standard

for the more toxic components should be applied. For example, where a dust contains asbestos or more than one per cent crystalline silica, such as quartz, cristobalite or tridymite, the exposure to these materials should not exceed the appropriate value for these substances.

14.29 Providing the airborne particulate does not contain other hazardous components, compliance with the exposure standard for dusts in general should prevent impairment of respiratory function even over many years of exposure.

15. MIXTURES OF SUBSTANCES

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

15.2 Although the following proposals have been made to deal with mixtures, in several specific cases, the application of exposure standards to environments containing mixtures of contaminants requires considerable caution. The interaction of any particular mixture of substances should be assessed by either toxicologists, occupational hygienists or physicians after specific toxicological consideration of all substances involved.

- INDEPENDENT EFFECTS

INDEPENDENT EFFECTS

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

- ADDITIVE EFFECTS

ADDITIVE EFFECTS

15.4 When the body is exposed to two or more contaminants, an additive effect is obtained when contaminants have the same target organ or the same mechanism of action. In this situation, the total effect upon the body equals the sum of effects from the individual substances. For substances which are purely additive, conformity with the standard results when

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

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

15.5 For example, consider an atmosphere containing:

- 35 ppm toluene (exposure standard 100 ppm),
- 25 ppm xylene (exposure standard 80 ppm), and
- 20 ppm 1,1,1-trichloroethane (exposure standard 125 ppm).

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

$$\frac{35}{100} + \frac{25}{80} + \frac{20}{125} = 0.8$$

15.6 Since the sum of the contribution from each substance does not exceed one, the exposure standard for the airborne mixture is not exceeded.

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

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

- SYNERGISM AND POTENTIATION

SYNERGISM AND POTENTIATION

15.9 Sometimes the combined effect of multiple exposure is considerably greater than the sum of the effects from the individual components. This phenomenon can be one of synergism or potentiation. Synergism * occurs when both chemicals have an effect individually and a more than additive effect when together. Potentiation * is when one chemical has an effect but the second chemical does not but enhances the effect of the former chemical on combined exposure.

15.10 An example of a synergistic effect is the combined effect of solvents such as n-hexane and methyl ethyl ketone (MEK) on the nervous system. 51, 52 In combination, the damage caused by simultaneous high concentrations of both these solvents is far greater than the sum of either of these substances acting alone.

15.11 Interaction can also arise from exposures via routes other than inhalation. For example, imbibed alcohol increases the narcotic effects of inhaled trichloroethylene. Interaction effects may also occur in connection with exposure to entirely different environmental factors such as simultaneous exposure to chemical agents and physical factors, such as light, heat and noise. 53, 54 Smoking of tobacco is known to have a synergistic effect in combination with, for example, inhaled particulates.

15.12 At present the understanding of interaction effects is incomplete. The knowledge that such effects can occur is reason to maintain the concentrations of individual substances as low as is practicable under complex exposure conditions.

Reference

* As an aid to memory, *synergism* can be thought of as @ + 2 = 6; *potentiation* as 2 + 0 = 6.

51. Holmberg, B. and Lundberg, P., 'Exposure Standards for Mixtures', Annals of the American Conference of Governmental Industrial Hygienists, vol. 12, pp. 111-18, 1985.

52. Vouk, V.B. et al, 'Methods for assessing the affects of chemicals', scope 30 IPCS Joint Symposia 6, John Wiley and Sons Inc, New York, 1987.

53. Fechter, L.D., 'Interactions between noise exposure and chemical asphyxiants: evidence for potentiation of noise induced hearing loss', Proceedings of the 5th International Congress on Noise as a Public Health Problem, Stockholm, August 21-25 1988.

54. Paran'ko, N.M. and Belitskaya, E.N. 'Experimental study of the combined effect of chromium trioxide aerosol and noise on the cardiovascular system', Proceedings of the 5th International Congress on Noise as a Public Health Problem, Stockholm, August 21-25 1988.

16. REFINED PETROLEUM SOLVENT MIXTURES

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

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

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

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

16.5 The petroleum solvent mixtures which have been assigned exposure standards are listed in the following table. These values were derived from typical compositional data of samples supplied to the Australian Institute of Petroleum Occupational Hygiene Committee by Australian manufacturers. Users should recognise that these are only approximate values. These values should only be used as guidance for the control of exposure on condition that toxic components, such as benzene and n-hexane, are not present, and detailed solvent composition data are not available.

Substance	CAS No.	TWA Exposure Standards (mg/m³)
Mineral turpentine -		480 (R)
Petrol (gasoline) -		900 (R)
White spirits	[8052-41-3]	790 (R)

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

Reference

(R) indicates value under review.

17. FUMES AND GASES FROM WELDING AND CUTTING PROCESSES

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

17.2 The composition of the fume depends upon:

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

17.3 The amount of the fume generated depends on:

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

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

17.5 Technical Note 7⁽¹⁾ produced by the Welding Technology Institute of Australia should be consulted for detailed information on fume generation and control.

17.6 When assessing a particular welding or cutting process, consideration should be given not only to the airborne concentration of toxic metals, such as chromium and nickel, which may arise from the parent metal or electrode, but also to the concentration of toxic gases which may be generated by the process. In addition to complying with the individual exposure standards for specific contaminants, the fume concentration in the breathing zone (which is inside a welder's helmet when a helmet is worn) should not exceed 5 mg/m³ TWA. Sampling for welding fume should be carried out in accordance with the appropriate Australian Standard⁽²⁾.

Referenced Documents

1. Welding Technology Institute of Australia, Technical Note 7 Health and Safety in Welding, Sydney, 1994.
2. Standards Australia, AS 3853.1-1991 Fume from Welding and Allied Processes Part 1: Guide to Methods for Sampling and Analysis of Particulate Matter and AS 3853.2-1991 Fume from Welding and Allied Processes Part 2: Guide to Methods for the sampling and Analysis of Gases. Standards Australia, Sydney.

18. THERMAL DECOMPOSITION PRODUCTS OF PLASTICS

18.1 When subject to the normal melt processing temperatures, usually 200-300°C, most plastics would produce complex mixtures of small quantities of toxic vapours, usually at concentrations

considerably below their exposure standards. 55, 56, 57, 58 However, irritant aerosols and gases can also be produced which may cause complaints of sensory irritation if the process is not controlled properly.

18.2 All plastics emit toxic and irritant fumes with increasing temperatures. However, the evolution rate and composition of the fumes emitted vary for different plastics and are strongly temperature dependent. Some common examples include thermoplastics such as polyvinylchloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS), acrylonitrile-butadiene-styrene (ABS) copolymer, and polytetrafluoroethylene (PTFE).

18.3 Pyrolysis products, given off at higher temperatures, 59 require special consideration. The health effects of hot-wire cutting of PS foams and PVC and PE films have been studied. 60, 61, 62 Polymer fume fever has been shown to be caused by the pyrolysis products of PTFE (teflon). 63

18.4 This issue is being considered by the Exposure Standards Working Group (See Appendix 3). At present, no exposure standard has been recommended and exposure should be kept as low as practicable.

Reference

55. Rigby, L.J., 'The collection and identification of toxic volatiles from plastics under thermal stress', *Annals of Occupational Hygiene*, vol. 24, no. 4, pp. 331-45, 1981.
56. Sangha, G.K., Matijak, M. and Alarie, Y., 'Toxicologic evaluation of thermoplastic resin at and above processing temperatures', *American Industrial Hygiene Association Journal*, vol. 42, pp. 481-5, 1981.
57. Barrow, C.S., Alarie, Y. and Stock, M.F., 'Sensory irritation and incapacitation evoked by thermal decomposition products of polymers and comparisons with known sensory irritants', *Archives of Environmental Health*, vol. 33, March/April, pp. 79-88, 1978.
58. Hoff, A. et al, 'Degradation products of plastics - polyethylene and styrene-containing thermoplastics - analytical, occupational and toxicologic aspects', *Scandinavian Journal of Work Environment and Health*, vol. 8, Suppl. 2, 1982.
59. Hilado, C.J. and Cumming, H.J., 'Relative toxicity of pyrolysis gases from materials: effects of chemical composition and test conditions', *Fire and Materials*, vol. 2, no. 2, pp. 68-76, 1978.
60. Cook, W.A., 'Industrial hygiene evaluation of thermal degradation products from PVC films in meat-wrapping operations', *American Industrial Hygiene Association Journal*, vol. 41, pp. 508-12, 1980.
61. Boettner, E.A. and Ball, G.L., 'Thermal degradation products from PVC film in food-wrapping operations', *American Industrial Hygiene Association Journal*, vol. 41, pp. 513-522, 1980.
62. Hofmann, H. and Oettel, H., 'Experiments on toxicity hazards with expanded polystyrene', *Fire International*, vol. 25, pp. 20-28, July 1969.
63. Arito, H. and Soda, R., 'Pyrolysis products of tetrafluoroethylene and polyfluoroethylenepropylene with reference to inhalation toxicity', *Annals of Occupational Hygiene*, vol. 20, pp. 247-55, December 1977.

19. EXPRESSION OF EXPOSURE STANDARDS

19.1 The following sections refer to the data presented in the National Commission's *Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment* [NOHSC:1003(1995)].

- CHEMICAL NOMENCLATURE

CHEMICAL NOMENCLATURE

19.2 The chemical names used in this publication conform with the nomenclature rules of the International Union of Pure and Applied Chemistry (IUPAC) or with common usage. In some cases, abbreviations may be used. An agent will only be listed under one name, and some of its other names, that is, its generic, chemical, common and trade names, will be cross-referenced in the index of synonyms which appears at Appendix 4 of the printed guidance note. This appendix should be consulted when a first attempt to locate a chemical is unsuccessful. Access via either the preferred name or the synonym is available in the Exposure Standards Database.

19.3 With the exception of 'iso' and 'cyclo', all prefixes, for example, o-, m-, p-, bis, n-, sec-, tert-, N-, are disregarded when listing the main entries in alphabetical order.

- CAS NUMBER

CAS NUMBER

19.4 The CAS No. is a unique numerical identifier which is assigned to each individual chemical entity. This number, which has the format [xxxxxx-xx-x], consisting of up to nine digits, has no chemical significance other than to unambiguously identify a particular substance, particularly in computerised literature retrieval systems.

19.5 Most substances in the exposure standard listing are quoted with their CAS No. However, this number is not usually assigned to mixtures of unknown or varying composition, to broad classes of compounds or to the various physical forms of a particular substance.

19.6 Appendix 5 of the printed guidance note lists substances addressed in this publication sorted by CAS No.

- UNITS FOR EXPOSURE STANDARDS

UNITS FOR EXPOSURE STANDARDS

19.7 In the lists of exposure standards in this publication, the airborne concentrations of gases, vapours and particulate contaminants are expressed gravimetrically as milligrams of substance per cubic metre of air, (mg/m³). For gases and vapours the concentration is also, with a few exceptions, indicated in parts per million (ppm) by volume. Where both gravimetric and volumetric values are given, the volumetric (ppm) value is exact and should be used as it is not affected by changes in temperature and pressure.

19.8 Because the gravimetric units of mg/m³ are affected by temperature and pressure variations, all exposure standards are expressed relative to standard conditions of 25° Centigrade and 1 atmosphere pressure (101.3 kPa).

19.9 The following conversion formula can be used to convert from ppm to mg/m³:

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

Where 24.4 = molar volume in litres at 25° and 101.3 kPa.

19.10 In some instances, especially with organo-metallic compounds, the exposure standard is expressed in terms of the major elemental component of the substance or the chemical species upon which the analytical determination is based. An explanation of the chemical symbols used in the list of adopted exposure standards appears at Appendix 6. For example, the exposure standard for tin oxide or

inorganic tin is considerably higher than that for organo-tin compounds, although both are expressed in terms of an elemental tin concentration.

20. MINERAL OIL ADDITIVES

20.1 The 8-hour time weighted average exposure standard for oil mist of 5 mg/m³ applies to oil mists from highly refined mineral oils. Most formulated products in use are based on highly refined mineral oils plus additives for the purpose of enhancing their properties in specific processes and preventing decomposition. Additives could include; antioxidants, bearing protectors, wear resisters, dispersants, detergents, emulsifiers, viscosity-index improvers, pour-point depressors and antifoaming and rust-resisting agents.

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

20.3 The composition of these oils can also change in the process of use. They can become contaminated or breakdown. Processes involving cutting of metals, plastics, etc, causes the mineral oil to become contaminated by fine swarf. Contamination may also occur via metabolic by-products from bacteria or fungi. Heating can cause chemical changes to the oil and produce toxic thermal degradation products such as carbon monoxide as in overheating compressors.

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

20.5 The chapter on Oil Mist, Refined Mineral, in the National Occupational Health and Safety Commission's Documentation of the Exposure Standards [NOHSC:10003]⁽¹⁾ describes the effects of workplace exposure to mineral oils. Skin contact with mineral oil products should be recognised as an additional route of exposure.

REFERENCED DOCUMENT

1. National Occupational Health and Safety Commission, 'Oil Mist, Refined Mineral' Documentation of the Exposure Standards [NOHSC:10003(1995)], Australian Government Publishing Service, Canberra, 1995.

APPENDIX 1: TERMS OF REFERENCE OF THE EXPOSURE STANDARDS EXPERT WORKING GROUP

A1.1 The terms of reference of the Exposure Standards Expert Working Group were determined by the National Commission's Executive at its 17th meeting on 29 September 1988. These terms of reference are:

Consider and recommend options to the Standards Development Standing Committee (SDSC) on occupational exposure standards for atmospheric contaminants based on consideration of the best available technical data from Australian and overseas sources.

Note: The terms of reference are under review.

APPENDIX 2: MEMBERSHIP OF THE EXPOSURE STANDARDS EXPERT WORKING GROUP

A2.1 Membership of the Exposure Standards Expert Working Group at January 1995 comprised the following members.

Ms L Onyon (Chairperson)	Manager Existing Chemicals, Chemical Assessment Division, Worksafe Australia
Dr A Bonin	Head Toxicological Unit, Research, Science and Statistics Division, Worksafe Australia
Dr S Corbett	Manager Environmental Health Section, Epidemiology Branch, New South Wales Health Department
Dr C Grygorcewicz	Senior Occupational Hygienists, Occupational Health Division, Department of Industrial Affairs (South Australia)
Mr G Odgers	Research Officer, URCOT (Victoria)
Mr A Rogers	Head, Occupational Hygiene and Safety Unit, Research, Science and Statistics Division, Worksafe Australia
Mr G Saunders	Coordination Chemical Safety Unit, WorkCover Authority (New South Wales)
Dr N Stacey	Executive Director, Research, Science, and Statistics Division, Worksafe Australia
Mr N Wendt	Occupational Health and Safety Coordinator, BHP Australia Coal Limited (Queensland)
Ms D Wilcocks (Secretary)	Senior Professional Officer, Chemical Regulatory Instruments, Chemical Assessment Division, Worksafe Australia

A2.2 Individual members were nominated to the Exposure Standards Expert Working Group on the basis of their expertise in specific occupational health and safety areas. The recommendations of the Exposure Standards Expert Working Group are subject to review by the tripartite Standards Development Standing Committee and the National Commission, where the social, economic and technological implications of these recommendations are considered.

A2.3 All requests for interpretations of exposure standards should be made in writing and directed to the Secretary of the Exposure Standards Expert Working Group.

A2.4 The provisions of this publication may not necessarily reflect the views of individual members of the Exposure Standards Expert Working Group.

APPENDIX 3: ISSUES AND SUBSTANCES UNDER REVIEW ISSUES

ISSUES

A3.1 The following issues have been identified by the Exposure Standards Expert Working Group as requiring further review.

Issue	Details
Altered work shifts	How should exposure standards be adjusted for working schedules markedly different from the normal eight-hour day, five-day working week?
Approach on excursion	The toxicological basis and analytical practicability limits of various approaches.
Thermal decomposition	Patterns of thermal decomposition and the products of plastics toxicology of products thereof.

SUBSTANCES

A3.2 Substances listed in the following table have been identified by the Exposure Standards Expert Working Group as requiring further review.

A3.3 The Exposure Standards Expert Working Group will be collecting and evaluating relevant occupational health data on these substances. Draft documentation will be prepared to assist the Exposure Standards Expert Working Group in its consideration of these substances.

A3.4 Interested parties are encouraged to submit any relevant information on these substances. Ideally such submissions should be accompanied by actual exposure data and a description of any observed health effects. An indication of whether the monitoring data refers to an eight-hour time-weighted average or short term exposure, and a brief description of the work procedures involved would be useful. Submissions on these substances should be sent to the following address:

The Chief Executive Officer
National Occupational Health and Safety Commission
GPO Box 58
SYDNEY NSW 2001
Attention:
Secretary
Exposure Standards Expert Working Group
Chemical Assessment Division

- SUBSTANCES REQUIRING REVIEW
- SUBSTANCES REQUIRING REVIEW

Substance	Reason for Review
Acetaldehydes	Sensory irritation
Atrazine	Chronic systemic effects
Fluorine	Irritant effects
Formaldehyde	Irritant effects
Heptachlor	Carcinogenicity
Isopropyl alcohol	Sensory irritation
Lead, inorganic	Chronic intoxication
Mercury, aryl	Effects on central nervous system
Mercury, inorganic	Effects on central nervous system
4,4'-Methylene bis (2-chloroaniline)	Suitability for an exposure standard
Methyl hydrazine	Review of exposure standard
Methyl isobutyl ketone	Study of skin absorption
Methyl n-butyl ketone	Study of skin absorption
1-Methyl-2-pyrrolidone	Establishment of exposure standard
Methylene chloride	Study of skin absorption
Mica	Pneumoconiotic potential
Mineral turpentine	Typical composition of the solvent
Nickel and compounds	Carcinogenic potential
Niobium/rare earths	Establishment of exposure standard
Nitrogen dioxide	Respiratory effects
Paraquat	Study of skin absorption
PCBs	Carcinogenicity
Petrol (gasoline)	Typical composition of the solvent
Phosphine	Respiratory effects
Propylene glycol monomethyl ether	Study of skin absorption
Propylene oxide	Carcinogenicity

Rubber fumes and dust	Establishment of exposure standard
Talc	Health effects of talc containing no asbestos fibres
Toluene	Study of skin absorption
Triethanolamine	Carcinogenicity
Turpentine (wood)	Study of skin absorption
Vinyl chloride, monomer	Carcinogenicity
Vinylidene chloride	Carcinogenic potential
White spirits	Typical composition of the solvent
Wood dust	Health effects from dust of Australian woods
Xylene	Study of skin absorption

APPENDIX 6: CHEMICAL SYMBOLS

A6.1 This appendix provides an explanation of the chemical symbols used in the National Commission's Adopted Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:1003(1995)].

Al	Aluminium
Al ₂ O ₃	Aluminium oxide
Ag	Silver
As	Arsenic
Ba	Barium
C	Carbon
Cd	Cadmium
CN	Cyanide
Co	Cobalt
CO	Carbon monoxide
CO ₂	Carbon dioxide
Cr	Chromium
CrO ₃	Chromium trioxide (Chromic acid)
Cu	Copper
F	Fluoride
Fe	Iron
Fe ₂ O ₃	Iron (III) oxide
H	Hydrogen
Hg	Mercury
In	Indium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
NCO	Isocyanate
Ni	Nickel
O	Oxygen
Os	Osmium
Pb	Lead

Pb ₃ (AsO ₄) ₂	Lead arsenate
Pt	Platinum
Rh	Rhodium
Sb	Antimony
Se	Selenium
Sn	Tin
Te	Tellurium
Tl	Thallium
U	Uranium
V	Vanadium
V ₂ O ₅	Vanadium pentoxide
W	Tungsten
Y	Yttrium
Zn	Zinc
Zr	Zirconium

APPENDIX 7: Amendments to Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment

The *Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment [NOHSC:3008(1995)] 3rd Edition* has been amended. This consolidation incorporates the amendments set out in the following schedule.

Schedule of Amendments Included in Consolidation

TITLE	Declaration Executed	Notice Gazetted
Altered Workshifts: Amendments to the Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment (June 1996) (PDF 26kB)	April 1996	June 1996
Amendments to the Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment (April 1997) (PDF 28kB)	March 1997	April 1997

GLOSSARY OF TERMS

Airborne contaminant An airborne contaminant is a potentially harmful substance that is either naturally absent from air or is present in an unnaturally high concentration, and to which workers may be exposed in their working environment.

Biological exposure index * The index provides a warning level of biological response to a substance or agent, or warning levels of the substance or agent or its metabolite(s) in the tissues, fluids or exhaled air of an exposed worker. This index is to be used only in conjunction with designated exposure standards or codes of practice and not as a sole method for exposure control.

Breathing zone The worker's breathing zone is described by a hemisphere of 300 mm radius extending in front of their face and measured from the midpoint of an imaginary line joining the ears.

Dusts Dusts are solid particles generated and dispersed into the air by, for example, handling, crushing and grinding of organic or inorganic materials such as rock, ore, metal, coal, wood and grain.

Equivalent aerodynamic diameter (EAD) The EAD of a particle of any shape or density is defined as the diameter of a sphere of unit density, that is, 1.0 g/cm^3 , which exhibits the same aerodynamic behaviour as the particle in question.

Exposure standard An exposure standard represents an airborne concentration of a particular substance in the worker's breathing zone, exposure to which, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers. The exposure standard can be of three forms; time-weighted average (TWA), peak, or short term exposure limit (STEL).

Exposure standards - general excursion Where a 'peak' or STEL is not specified for an exposure standard, and provided that the eight-hour TWA exposure standard is not exceeded, short term exposures should not exceed three times the TWA exposure standard for more than a total of 30 minutes per eight-hour working day and under no circumstances should the short term values exceed five times the exposure standard.

Exposure standard - peak A maximum or peak airborne concentration of a particular substance determined over the shortest analytically practicable period of time which does not exceed 15 minutes.

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

Exposure standard - time-weighted average (TWA) The average airborne concentration of a particular substance when calculated over a normal eight-hour working day, for a five-day working week.

Fumes Fumes are formed when the material from a volatilised solid condenses in cool air. Fumes are extremely fine - usually less than 1.0 micrometer in diameter. In most cases the hot vapour reacts with the air to form an oxide. Fumes are often associated with molten metals, especially in processes such as welding. At high fume concentrations, agglomeration of particles may result in particles with much larger dimensions.

Gases Gases are formless fluids that expand to occupy the space or enclosure in which they are confined. Examples are nitrogen, oxygen and carbon dioxide of the air.

Mists Mists are suspended liquid droplets generated by condensation of vapour back to the liquid state or by breaking up as a liquid into a dispersed state, such as by splashing or atomising. Mist is the term applied to a finely divided liquid suspended in the atmosphere. Examples are an oil mist produced during cutting and grinding operations, acid mists from electroplating, acid or alkali mists from pickling operations, paint spray mist in painting operations and the condensation of water vapour to form a fog.

Personal samples Atmospheric samples collected within the breathing zone of the worker are called personal samples.

Physical agents Physical agent refers to energy-related agents such as heat and cold, vibration, noise and electromagnetic radiations of all kinds and their associated fields.

Practicable Practicable has the same meaning as 'practicable' in Victoria, Queensland, Western Australia and the Northern Territory 'reasonably practicable' in New South Wales, South Australia and the Australian Capital Territory and 'a reasonable precaution' in Tasmania.

Smoke Smoke consists of carbon or soot particles or tarry droplets less than 0.1 micrometer in size, and suspended in air, which results from the incomplete combustion of carbonaceous materials such as coal or oil.

Static samples For the purpose of this document, static samples are samples taken at fixed locations, commonly between 1 and 2 metres above floor level.

Threshold limit value (TLV) TLV is a proprietary name registered by the American Conference of Governmental Industrial Hygienists (ACGIH) and refers to airborne concentrations of substances or levels of physical agents to which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect.

Vapour Vapour is the gaseous form of a substance which is normally in the solid or liquid state at room temperature and pressure.

Reference

* This index is to be used only in conjunction with designated exposure standards or codes of practice and not as a sole method for exposure control.