ADJUSTMENT OF WORKPLACE EXPOSURE STANDARDS FOR EXTENDED WORK SHIFTS

Position Paper

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

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TABLE OF CONTENTS

Australian Institute of Occupational Hygienists Inc (AIOH) 3
Thirtieth AIOH Council 4
List of Abbreviations and Acronyms 5
AIOH Position on Adjustment of Workplace Exposure Standards for Extended Work Shifts 6
- Summary 6
- What is a Workplace Exposure Standard? 6
- What is an Extended Work Shift? 7
- Common Adjustment Methods 7
- Rules for the Application of Exposure Standard Adjustment Models 10
- Current Applicable Legislation and Standards 10
- Other Considerations 13
- Conclusions 14
- AIOH Recommendations 14
- AIOH Position 14
- References and Sources of Additional Information 15
- Attachment: A Worked Example 16

AUSTRALIAN INSTITUTE OF OCCUPATIONAL HYGIENISTS INC (AIOH)

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

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

Therefore the AIOH has a keen interest in the assessment of potential for harm due to workplace exposures to various agents relative to known workplace exposure standards or occupational exposure limits (OELs), as its members are the professionals most likely to be asked to assess exposure risks to identified workplace hazards.

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

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

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

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

CONSULTATION WITH AIOH MEMBERS

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

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LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AIOH	Australian Institute of Occupational Hygienists
ALARP	As low as reasonably practical
EU	European Union
F/mL	Fibres per millilitre
HSIS	Hazardous Substances Information System
IOHA	International Occupational Hygiene Association
mg/m^3	milligrams (10^{-3} gm) per cubic metre
NOHSC	National Occupational Health and Safety Commission
OEL	Occupational Exposure Limit
OSHA	Occupational Safety & Health Administration
PEL	Permissible exposure limit
ppm	parts per million (1 in 10^{-6})
RF	Reduction factor
STEL	short term exposure limit
TLV	threshold limit value
TWA	time weighted average
US	United States

AIOH POSITION ON ADJUSTMENT OF WORKPLACE EXPOSURE STANDARDS FOR ATMOSPHERIC CONTAMINANTS FOR EXTENDED WORK SHIFTS

Summary

Most mining and many other industries now work extended work shifts. The standard eight hour day, the epidemiological basis of almost all current exposure standards for atmospheric contaminants, no longer exists in many workplaces. For this reason, exposure standard adjustments have now become an essential component in workplace health assessment.

This is a significant change as exposure standard adjustments have generally been considered as applying to 'unusual' work shifts. These are now no longer unusual, but normal in many industries.

A major problem is that there are significant differences in the adjustment methods available, some mandated or implied in various jurisdictions across Australia; resulting in significant differences in adjusted exposure standards.

This is potentially confusing and inequitable to those who are potentially exposed to health affecting agents in the workplace.

This paper provides an overview of the exposure standard adjustment methods for atmospheric contaminants, a selection of legislative approaches in Australia and other countries and examples of the varying outcomes. It then proposes a potential way forward based on national and international consistency to provide those exposed in the workplace to consistent and appropriate information. The paper is not intended to provide a definitive methodology for adjusting atmospheric exposure standards, nor is its intent to review the underlying principles and mechanics of the adjustment models, as these are well documented in the referenced publications.

This paper does not address the adjustment of personal noise exposures as this is clearly defined in Australian/New Zealand Standard AS/NZS 1269.1.

The paper does not address exposure assessment methodologies. The AIOH recognises that appropriate exposure assessment methodologies are required to get meaningful exposure data prior to assessment against time weighted exposures.

The AIOH position is that the current guidelines provided by Safe Work Australia are inadequate in that they don't consider or accommodate the varying range of health effects of different agents and their time frame for adverse effect. The current guidelines and legislative framework across Australia can also lead to inconsistent advice for affected workers. The AIOH recommends moving to a model similar to that of the 'Quebec model' that is computer-based and utilises current toxicological information and can provide consistent guidance.

What are Workplace Exposure Standards for Atmospheric Contaminants?

National Exposure Standards are set by Safe Work Australia.

The term 'exposure standard' means an airborne concentration of individual chemical substances in the worker's breathing zone 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 limitation, or short term exposure limit (STEL). Additionally, the exposure standards are believed to guard against narcosis or irritant effects which could precipitate industrial incidents.

Time-weighted average (TWA) exposure standards apply to long term exposure to a substance over an eight-hour work shift (with a consequent 16 hour break between successive shifts), for a five-day working week, over an entire working life. It is these work patterns for which most epidemiological studies are available and upon which the exposure standards are determined.

A critical feature of exposure standards is that they are not fine dividing lines between safe and dangerous concentrations of chemicals, or 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.

What is an Extended Work Shift?

As stated above, published TWA exposure standards in Australia and other jurisdictions apply to long term exposure to a substance over an eight-hour day, five-day working week, over an entire working life.

The use of extended work shifts is now commonplace in a range of industries, including mining, service industries such as healthcare, oil and gas, processing, and manufacturing. Extended work shifts can take many forms, but they generally involve the employee working shifts of greater than 8 hours in length, or a working week of greater than 40 hours.

Common Adjustment Methods

There are numerous models that use varying approaches to adjust exposure limits, which have been published and discussed in the literature. Some are based on simple mathematical equations that consider the extended hours of work, while others use more complicated formulae that take into account rates of uptake and excretion, biological half-lives, and health effects.

There are numerous reviews of the various methods that have been documented, and those most commonly discussed are:

- The Brief and Scala Model;
- The OSHA Model;
- Pharmacokinetic Models – specifically that of Hickey and Reist;
- Quebec Model.

<u>*Brief and Scala*</u>

The Brief and Scala (1975) method is regarded as the most conservative model and considers the impact of the number of increased hours worked and the recovery time between exposure periods. No consideration of the agent's activity in the body is made. Using either the daily or weekly equation detailed below, a reduction factor is determined, and then applied to the TWA exposure standard.

Daily exposure:

$$RF = \frac{8}{h} * \frac{24-h}{16}$$

Where: RF = reduction factor

h= hours worked per shift

Note that 24-h represents the exposure free hours per day

Weekly exposure for the special case of a seven day work week:

$$RF = \frac{40}{h} * \frac{168 - h}{128}$$

Where: RF = reduction factor

h= average hours per week over full roster cycle

Note that 168 - h represents the exposure free hours per week

OSHA

The OSHA model detailed by Paustenbach (2000) is based on the assumption that the magnitude of the toxic response of an agent is a function of the concentration that reaches the site of action for that agent. The model was designed to be applied to most systemic toxic substances, but not irritants, sensitisers or carcinogens.

Each agent with an exposure limit was categorised based on its toxic effect. The assigned category is then used to determine if any adjustment is required, and if so, what equation is to be used.

The categories used are as follows:

Adjustment Category	**Classification**	**Adjustment Criteria**	**Reduction factor RF**
1A	Ceiling standard *Ceiling standard never intended to be exceeded at any time-independent of length or frequency of work shifts*	None	No adjustment
1B	Mild irritants *Standard designed to prevent acute irritation or discomfort. Essentially no cumulative effects known.*	None	No adjustment
1C	Standards set by technological feasibility or good hygiene practices - *independent of shift length or frequency.*	None	No adjustment
2	Acute Toxicants *Can accumulate during an 8 hour or longer exposure time.*	Hours/Day	$RFdaily = \frac{8}{daily\ exposure\ hours}$
3	Cumulative Toxicants *Cumulative exposure could occur over days to even years of exposure.*	Hours/Week	$RFweekly = \frac{40}{weekly\ exposure\ hours}$
4	Both Acute and Cumulative	Hours/Day and Hours/Week	RF daily or weekly whichever is lowest.

The adjusted exposure standard is determined by multiplying the 8 hour exposure standard by the Reduction Factor, RF.

It is interesting to note that the latest version of the OSHA Field Operations Manual (CPL 02-00-148 dated November 9, 2009) no longer refers to extended shift adjustment.

Pharmacokinetic Models

Pharmacokinetic adjustment models are based around the concept of 'body burden' and how the biological half-life of a substance can have a significant impact on the maximum body burden for a given work schedule. Most commonly the models use a 'one-compartment' approach, assuming that the effect of exposure is isolated to a single site within the body. These models aim to ensure that the maximum body burden accrued for the 'unusual' work routine does not exceed that accrued for a normal work shift. Although not without their limitations, pharmacokinetic models are generally considered more accurate than other models, but can involve complicated calculations that involve knowledge of the biological half-lives of substances – information that is not always easy to find.

Hickey and Reist (1977) published a formula that described a method of adjusting exposure limits based on the number of hours worked each day, the number of hours worked each week and the biological half-life of the agent.

The equation used by Hickey and Reist is as follows:

$$Fp = \frac{\left(1-e^{-kt_{1n}}\right)\left(1-e^{-k(t_{1n}+t_{2n})n}\right)\left(1-e^{-kT_s}\right)\left(1-e^{-k(t_{1s}+t_{2s})}\right)}{\left(1-e^{-kt_{1s}}\right)\left(1-e^{-k(t_{ls}+t_{2s})m}\right)\left(1-e^{-kT_n}\right)\left(1-e^{-k(t_{ln}+t_{2n})}\right)}$$

Where: RF = reduction factor

Fp = the pharmacokinetic reduction factor

k = the biologic elimination rate = (ln 2)/$T_{1/2}$, where $T_{1/2}$ = the biologic half-life

t_{1n} = the length of the standard workday (8 hours)

t_{2n} = the length of the standard recovery period (16 hours)

t_{1n}+t_{2n} = the length of the standard day (24 hours)

T_n = the length of the standard week (seven days or 168 hours)

n = number of days in standard workweek (5)

t_{1s} = length of the extended shift workday (in hours)

t_{2s} = length of the rest period between extended shift workdays (in hours)

t_{1s} + t_{2s} = length of the extended shift "day" (usually, but not always 24 hours)

T_s = total length of the periodic work cycle (the number of days worked and days in the rest period [in hours])

A number of graphs were also published that demonstrated the application of the formula to a range of exposure schedules, and identified that for an agent with a short biological half-life (less than 3 hours, eg benzene, hydrogen sulphide), no adjustment is necessary. In the case of agents with a long half-life (greater than 40 hours, eg mineral dust); the adjustment factor is approximately proportional to the ratio of the number of hours exposed in the work cycle compared to a normal 40 hour week (Paustenbach, 2000).

McMaster University, Canada (Armstrong *et al*, 2005) have further developed the concept to enable calculation of the RF for various shift rosters where the biological half-life is known as well as calculating the most conservative RF where the half-life is unknown. This spreadsheet is freely available on the McMaster University Occupational Health Laboratory website http://oehl.mcmaster.ca/. Where rosters vary within the overall cycle, the worst case portion of the cycle is used.

Quebec

The Quebec model (Drolet, 2008) is essentially based on the OSHA model and uses a recently updated category list for each of the 703 substances listed in their Regulation Respecting Occupational Health and Safety (RROHS). In assigning an agent to a particular adjustment category, the most recent toxicological information was reviewed including sensitisation, irritation, organ toxicity, reproductive system toxicity and teratogenicity (Verma, 2000).

The adjustment of the exposure standards using this model was made much easier by the development of a downloadable tool, freely available on the IRSST web site http://www.irsst.qc.ca/en/_outil_100011.html. This Excel spreadsheet has a drop down list of assessed substances that provides the Adjustment Category or Code and computes the RF (called Adjustment Factor in the spreadsheet) based on the daily and weekly average working hours.

As this system is governed by Regulation in Quebec the adjusted exposure standards are unambiguous for the listed substances, although caution must be exercised in that only the RF factor is to be used and not the exposure standards which may differ from those used in Australia.

Rules for the Application of Exposure Standard Adjustment Models

While there is no universal consensus on the best adjustment model to use, there are of course special considerations that should be made when applying any of the various adjustment models. Paustenbach (2000) identified several 'rules of thumb' for adjusting exposure limits for persons working unusual shifts. These are detailed below:

Where the goal of the occupational exposure limit is to minimise the likelihood of a systemic effect, the concentration of toxicant to which persons can be exposed should be less than the TLV if they work more than 8 hr/day or more than 40 hr/week and the chemical has a half-life between 4 and 400 hours.
Exposure limits whose goals are to avoid excessive irritation or odour will, in general, not require modification to protect persons working unusual work shifts (this suggests that no adjustment is necessary for 'Peak Limitation' and 'Short Term Exposure Limit' (STEL) values);
Adjustments to TLV or PEL values are not generally necessary for unusual work shifts if the biological half-life of the toxicant is less than 4 hours or greater than 400 hours.
The biological half-life of a chemical in humans can often be estimated by extrapolation from animal data.
The four most widely accepted approaches to modifying exposure limits will recommend adjustment factors that will vary. In order of conservatism, the Brief and Scala model will recommend the lowest limit and the (pharmaco)kinetic models will recommend the highest.
Whenever the biological half-life is unknown, a "safe" level can be estimated by assuming that the chemical has a biological half-life of about 20 hr. (Note: this will generally yield the most conservative adjustment factor for typical 8-, 10-, 12- and 14-hr workdays).

In addition to the above, there are a number of other important points that should be made:

- Some degree of conservatism is recommended to account for overtime work.
- Where shorter exposure periods or shifts exist, exposure adjustment models should not be used to justify higher exposures or exposure limits (ACGIH, 2010).

Current Applicable Legislation and Standards

In Australia, the various legislative frameworks do not specifically regulate the method of exposure standard adjustment, but in many instances provide guidance documents that identify recommended methods. In addition, at a corporate level it is often the case that within the safety and health management system framework of many large multi-national companies, advice is also provided on the recommended method of adjusting exposure standards for extended shifts or unusual work schedules.

Safe Work Australia (1996) in their Amendment (part 5A) to the *Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment,* identified that "*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*". Safe Work Australia recommend the use of the Brief and Scala (1975) method, based on its simplicity of use, more conservative approach, and suitability for the national exposure standards published in Australia.

At a state level, only regulators of certain jurisdictions in New South Wales, Queensland and Western Australia make specific reference and recommendations for the adjustment of exposure standards for extended work shifts. These references primarily exist in mining legislation and are discussed briefly in later sections of this paper.

It should be noted however, that most, if not all state based legislation calls up the national exposure standards published by Safe Work Australia, and by default the accompanying guidance note, NOHSC document 3008. Part 5A of this document clearly states that where the work environment meets the definition of an 'Altered Workshift', *"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 process"*

Exposure Standard Adjustment in Queensland Mining Legislation

The adjustment process recommended by the Queensland Mines Inspectorate and published by Simtars, uses the work schedule listing of the OSHA model to select the appropriate equation to be used for adjustment. The equations used however, are those for the daily and weekly adjustment of exposure limits, produced by Brief and Scala. In the application of this method, consideration is made of the additional hours of exposure and decreased time for recovery, and, the nature of the potential health effects associated with exposure to an agent.

Exposure Standard Adjustment in NSW Mining Legislation

In addition to the requirements of the Occupational Health and Safety legislation applying to all workplaces, the NSW mining regulation requires risk assessment of atmospheric contamination, including the requirement to minimise pollutants from diesel plant in underground mines as far as is reasonably practicable. The MDG29 Guideline for the management of diesel engine pollutants in underground environments (2008) provides general guidance for the setting of safety standards including gaseous and particulate contaminants among other things.

In this guideline section 2.7 *Adjusting Exposure Standards for Altered Work Shifts* specifically states that adjustment should be done in accordance with the TWA exposures listed in Table 2 or if there is uncertainty about the nature of the health effects then use Brief and Scala models. Table 2 is referenced as a partial extract from the model developed by the Western Australian Department of Minerals and Energy (March 1999) and discussed below.

Exposure Standard Adjustment in Western Australian Mining Legislation

The model recommended by the Western Australia Department of Minerals and Energy (1999), uses a matrix based on the health effect type.

Where a substance is considered to have medium term health effects (eg respiratory irritation, narcosis), or there is uncertainty about the health effects, the Brief and Scala adjustment model is to be used.

For agents with a potential for "cumulative poisoning, respiratory disease or cancer, it is suggested that where the hours worked per month are less than 170, that an exposure reduction factor of 1 should be used. Where more than 170 hours are worked per month, then the exposure reduction factor should be calculated as 170/x, where x is the average number of hours worked per month.

This matrix is reproduced below:

RECOMMENDED EXPOSURE REDUCTION FACTORS FOR THE WESTERN AUSTRALIAN MINING INDUSTRY

EXPOSURE STANDARD	TIME FRAME FOR ACTION	HEALTH EFFECT	TYPICAL SUBSTANCES	SHIFT ROSTER	EXPOSURE REDUCTION FACTOR
Peak	Fast - immediate	Acute poisoning	Cyanide, Caustic, Acid mists	n/a	**1**
STEL	Fast - immediate	Acute irritation	Nitrogen dioxide Sulphur dioxide, Hydrogen sulphide, Ammonia	n/a	**1**
TWA	Medium – within shift or over a few shifts	Respiratory irritation, narcosis	Solvents, Nitrogen dioxide, Sulphur dioxide, Hydrogen sulphide, Carbon monoxide	10 h/day	**0.7**
				12 h/day	**0.5**
TWA	Long – over many shifts or years	Cumulative poisoning, respiratory disease (silicosis, asbestosis) , cancer	Silica, Asbestos, Nickel, Lead, Welding fumes, Talc, Inspirable dust, Respirable dust, Diesel fume	<170 h/mth	**1**
				>170 h/mth	**170/x***
TWA	Unknown or unsure			10 h/day	**0.7**
				12h/day	**0.5**

LEGEND

x*	Average number of hours worked in the month; 170 is the typical hours worked in a month for a normal 8 h/day, 5 day/week work cycle
STEL	Short Term Exposure Limit
TWA	Time Weighted Average Exposure Standard
n/a	Not Applicable
h	Hours
mth	Calendar month

As can be seen above, there is significant variation in the approaches that are recommended in each state and/or territory. For national organisations this can prove to be a confusing and complicated arrangement, where various elements of their business fall under different, or even multiple, legislative jurisdictions. This can be further complicated where they are also operating internationally.

Other Considerations

Exposure Standard Variations

A further complication in the exposure standard area, not covered by this paper, is that exposure standards vary across Australia and internationally. For example NSW in Official Notice 9503 on 17 December 2004 set a respirable coal dust level of 2.5 mg/m^3 following the sample flow rate changes, firstly in the then revised version of AS 2985:2004, now 2009, whereas the other states and Safe Work Australia have left it unchanged. New South Wales is also the only state that has provided a guideline for diesel particulate matter. There are numerous examples of differing exposure standards internationally including respirable crystalline silica (quartz & cristobalite), hydrogen cyanide and hydrogen sulphide.

National Harmonisation of Legislation

The current move towards a nationally harmonised approach to legislation provides a further incentive for reaching a standard approach to the adjustment of the national exposure standards for all jurisdictions. It is therefore important that consideration be given to the optimal methods of exposure adjustment.

Mixtures

This paper does not consider adjustments for exposure standard adjustments for mixtures. This is well covered by Armstrong *et al* (2005) who advocated an approach based on the ACGIH additive mixture formula integrated into the McMaster University spreadsheet.

Annual leave / long service leave implications

The adjustment formulae are generally based on US experience where annual leave is two or three weeks duration compared to Australia and some EU countries where annual leave is much longer – particularly for shift workers. In addition Australia has more public holidays and long service leave. This will mean that Australian conversion factors will generally be conservative which is considered by the AIOH to be beneficial to workers.

Reporting Monitoring Results

A key factor here is how monitoring results are communicated to the workforce. Traditionally the TWA exposure standards requiring adjustment have been changed rather than the monitoring results. This approach works well where there are few variations in working hours across the workforce; however some sites have a number of variations in shift lengths and configurations resulting in an array of exposure standards.

An alternative is to correct the TWA exposures back to an eight hour basis (in the same way that AS/NZS 1269.1 (sect 9.4) recommends that we do for noise exposure). If used, this would need to be clearly communicated and explained as employees may consider that they are not being given the actual data, resulting in mistrust. If statistical analysis is carried out on data that is below the detection limit (eg quartz less than 0.01 or 0.02 mg/m^3), the data may need to be corrected up to the next significant figure inflating the calculated exposures. A further issue is that the exposure adjustment formula would need to be very clearly documented as there is a potential for the original data to be lost.

Legal Implications

The lack of consistency arising from the models may have legal implications, for example with companies that do not have a consistent approach across their operations or companies in the same industry who use different adjustment formulae. State-based differences will already be causing such issues.

In any event, the principles that exposure standards do not represent fine lines between safe and unsafe in concert with reducing exposures to as low as is reasonably practical (ALARP) should apply.

Conclusions

- The lack of consistent adjusted exposure standards for extended shift arrangements that are now becoming the norm rather than being `unusual', causes unnecessary complexity and confusion in determining 'harmful' exposure to airborne hazardous substances.
- There is therefore a need for clear and concise direction from regulators on the method considered best for Australian conditions.
- The recommendation within the current *National Guideline for the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment,* to use the Brief and Scala method for the adjustment of exposure standards for unusual work shifts is too conservative in many instances.
- Pharmacokinetic models are more scientific in their determination of a suitable exposure standard reduction factor but can be complicated to apply.
- The Quebec model uses a simple spreadsheet approach and has the advantage of being up to date, having only been recently reviewed (2008). It is recognised that there are some limitations in adopting this model in its current form and that some consideration of the applicability of its application to our national exposure standards is required.

AIOH Recommendations

- Safe Work Australia, in conjunction with State jurisdictions and expert bodies such as the AIOH should develop standardised and updated exposure standard adjustment guidelines that clearly identify workplace scenarios where adjustment is required.
- The guidelines should be computer based, available on the Web and regularly updated by appropriate experts using the Quebec model as a guide.
- Safe Work Australia should consider liaising with overseas jurisdictions on this matter.

AIOH Position

The AIOH position is that the current guidelines provided by Safe Work Australia are inadequate in that they don't consider or accommodate the varying range of health effects of different agents and their time frame for adverse effect. The current guidelines and legislative framework across Australia can also lead to inconsistent advice for affected workers. Without dismissing an individual's or organisation's legal obligation to comply with shift adjustment criteria as detailed in legislation applying to their local jurisdiction, the AIOH recommends moving to a model similar to that of the `Quebec model' that is computer-based, based on current toxicological information and can provide consistent guidance.

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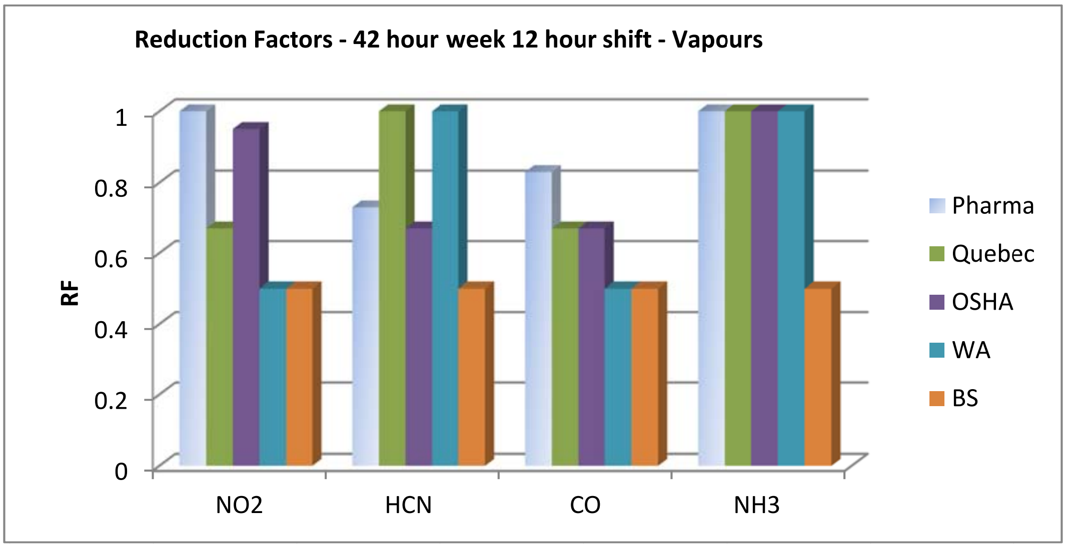
Attachment: A Worked Example

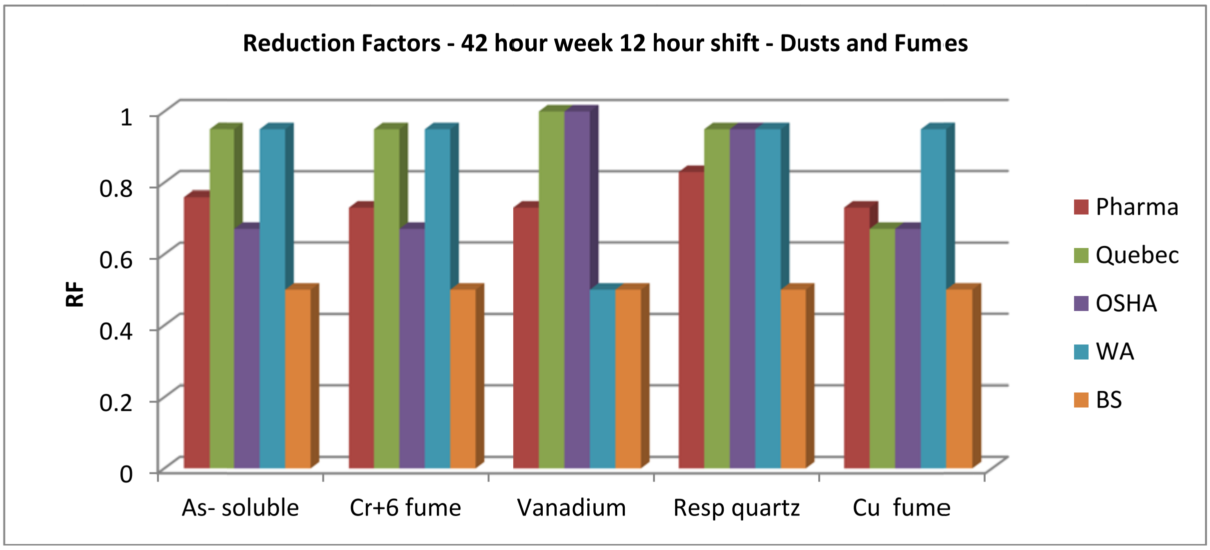
The following example sets out calculations for exposure standard adjustments using the four major calculation methods for a range of substances for a site with twelve hour shifts with a roster of days on and off as follows: 4:7, 4:3, 3:1, 3:3. This equates to an average of 14 days worked as 12 hour shifts over 28 days with a worst case of 4 days on 3 off within the cycle. The graphed and tabulated results follow below. It is important to note that these examples are not intended a a `how to' for calculating exposure standard adjustments, rather to demonstrate the different outcomes resulting from using different methodologies

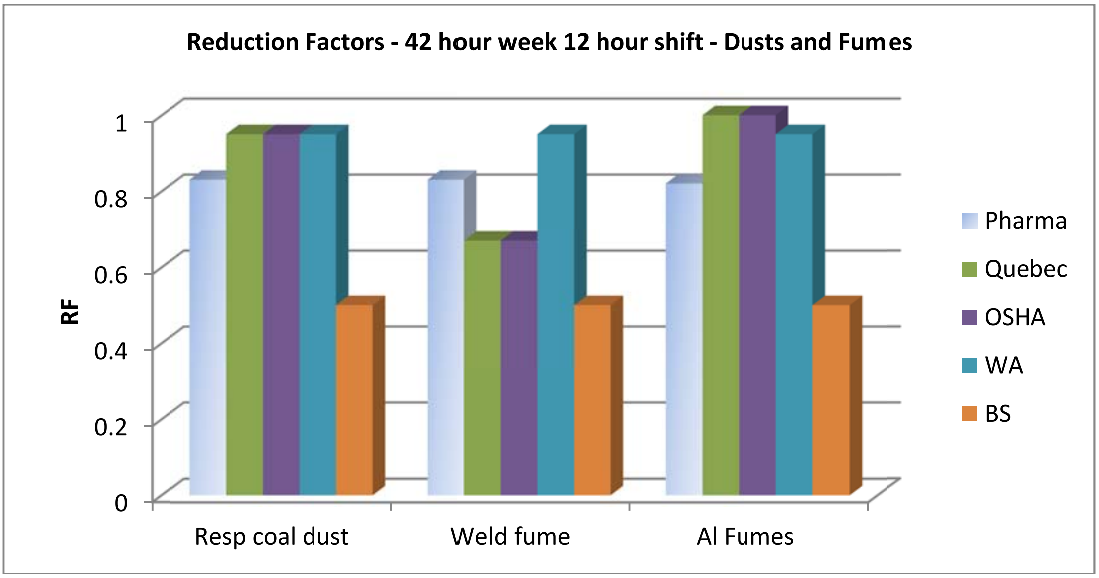
Adjusted Exposure Standards for Dust or Fume Components

			Brief and Scala		WA DOCEP		OSHA			Quebec			Pharmacokinetic	
Potential Fume / dust component	**8 hr OEL**	**Units**	**RF**	**Adjusted OEL**	**RF***	**Adjusted OEL**	**RF**	**Category OSHA**	**Adjusted OEL**	**RF**	**Category Quebec**	**Adjusted OEL**	**RF**	**Adjusted OEL**
Aluminium Fumes	5	mg/m^3	0.5	2.5	0.95*	4.75	1	1C assumed	5	1	1C	5	0.82	4.1
Arsenic- soluble compds	0.05	mg/m^3	0.5	0.025	0.95*	0.05	0.67	4	0.03	0.95	3	0.0475	0.76	0.04
Asbestos f/ml	0.1	F/ml	0.5	0.05	0.95	0.095	0.95	3	0.095	0.95	3	0.095	0.83	0.08
Chromium +6 fume	0.05	mg/m^3	0.5	0.025	0.95*	0.05	0.67	4	0.03	0.95	3	0.0475	0.73	0.04
Copper fume	0.2	mg/m^3	0.5	0.1	0.95*	0.19	0.67	4	0.134	0.67	2	0.134	0.73	0.15
Silica, Respirable crystalline quartz	0.1	mg/m^3	0.5	0.05	0.95	0.095	0.95	3	0.095	0.95	3	0.095	0.83	0.083
Respirable coal dust <5% quartz	3	mg/m^3	0.5	1.5	0.95	2.85	0.95	3	2.85	0.95	3	2.85	0.83	2.49
Welding fume not otherwise classified	5	mg/m^3	0.5	2.5	0.95	4.75	0.67	4	3.35	0.67	2	3.35	0.83	4.15
Vanadium dust & fume	0.05	mg/m^3	0.5	0.025	0.5*	0.03	1	1A	0.05	1	1B	0.05	0.73	0.04
Carbon monoxide TWA	30	ppm	0.5	15	0.5	15	0.67	2	20.1	0.67	4	20.1	0.83	24.9
Nitrogen dioxide TWA	3	ppm	0.5	1.5	0.5	1.5	0.95	3	2.85	0.67	4	2.01	1	3
Ammonia TWA	25	ppm	0.5	12.5	1	25	1	1B	25	1	1B	25	1	25
Hydrogen Cyanide, HCN TWA (peak or ceiling)	10	ppm	0.5	5	1	10	0.67	4	6.7	1	1A	10	0.73	7.3

Note: RF = Reduction Factor


Reduction Factors - 42 hour week 12 hour shift - Vapours
RF
1
0.8
0.6
0.4
0.2
0
NO2
HCN
CO
NH3
Pharma
Quebec
OSHA
WA
BS


Reduction Factors - 42 hour week 12 hour shift - Dusts and Fumes
RF
1
0.8
0.6
0.4
0.2
0
As- soluble
Cr+6 fume
Vanadium
Resp quartz
Cu fume
Pharma
Quebec
OSHA
WA
BS


Reduction Factors - 42 hour week 12 hour shift - Dusts and Fumes
RF
1
0.8
0.6
0.4
0.2
0
Resp coal dust
Weld fume
Al Fumes
Pharma
Quebec
OSHA
WA
BS

Notes:

As can be seen from the graphs and the Table there are some dramatic differences in adjusted exposure standards dependent on the adjustment methods used.

- The Brief and Scala adjustment is the most conservative, often one half of the other adjusted standards;
- The Quebec, OSHA and WA adjusted exposure standards are generally similar as they follow similar principles. One area of difference is welding fume where WA treat it as a chronic contaminant (and imply that copper is as well), Quebec treat it as acute and OSHA as acute and cumulative;
- Pharmacokinetic are generally less conservative than the other methods, however the method is more conservative in general for Category one compounds such as HCN and aluminium fume and some category 3 compounds such as coal dust compared to OSHA / Quebec and WA;
- The differences in OSHA and Quebec probably relate to the fact that the OSHA determinations in this review were made in 1985 whereas the Quebec assessments are much more recent. The latest versions of Patty's have considerably less compounds assessed compared to the earlier versions decreasing its usefulness. In general the Quebec determinations are less conservative than the old OSHA determinations.