

Development of a Tool for the Adjustment of Workplace Exposure Standards for Atmospheric Contaminants Due to Extended Work Shifts

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Abstract

An Australian Institute of Occupational Hygienists (AIOH) position paper “Adjustment of Workplace Exposure Standards for Extended Work Shifts” provided an overview of the workplace exposure standard (WES) adjustment methods for atmospheric contaminants. It concluded that the current guidelines provided by Safe Work Australia (SWA) were inadequate in that they did not consider or accommodate the varying range of health effects of different agents and their time frame for adverse effect and could lead to inconsistent advice for affected workers. The AIOH recommended moving to a model similar to that of the Québec model and developed a tool that provides an appropriate and accessible methodology to adjust exposure standards for extended work shifts and thus more consistent and informed advice for affected workers.

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Introduction

The American Conference of Governmental Industrial Hygienists (ACGIH®) and Safe Work Australia (SWA) have in the past recommended the use of the Brief & Scala (1975) correction model for adjusting Workplace Exposure Standards (WES) for extended work schedules. Since 2004 however, the ACGIH® has also referred to the Quebec Model jointly developed by the University of Montréal and the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), emphasising that it generates results closer to the physiologically-based toxicokinetic models (PBPK) than the Brief & Scala model.

In a position paper “Adjustment of Workplace Exposure Standards for Extended Work Shifts” (AIOH 2013), first published in 2010, the Australian Institute of Occupational Hygienists (AIOH) recommended a move to a model similar to that of the Québec model. This model is computer-based and utilises current toxicological information and can provide consistent guidance. It initially led to the development of an Excel tool based on that of the IRSST (Drolet, 2008) using Safe Work Australia workplace exposure standards tables that had been

assigned adjustment factors by the AIOH Exposure Standards Committee.

This paper provides a brief overview of discussions with SWA and reports the work of the AIOH Exposure Standards Committee on the development of a Microsoft Excel tool that facilitates the adjustment of SWA WESs for extended shifts, providing a choice of either the Québec model or the Brief and Scala model according to a specific logic tree.

Safe Work Australia Documentation

Sections 17 and 19 of the model Work Health and Safety (WHS) Act (SWA, 2011) together require that exposure to substances in the workplace is kept as low as is reasonably practicable. Under the WHS Regulations (SWA, 2014), a person who conducts a business or undertaking (PCBU) must:

- manage risks under the WHS Regulations, including those associated with using, handling and storing hazardous chemicals safely, airborne contaminants and asbestos;
- ensure that no person at the workplace is exposed to a substance or mixture in an airborne concentration that exceeds the exposure standard for the substance or mixture (r 49); and
- ensure that air monitoring is carried out to determine the airborne concentration of a substance or mixture at the workplace to which an exposure standard applies if:
 - the person is not certain on reasonable grounds whether or not the airborne concentration of the substance or mixture at the workplace exceeds the relevant exposure standard, or
 - monitoring is necessary to determine whether there is a risk to health (r 50).

Safe Work Australia has produced the document “Workplace Exposure Standards for Airborne Contaminants” (SWA, 2013b), containing a list of workplace exposure standards (WES) for airborne contaminants and how to meet PCBU duties under the WHS Act and the WHS Regulations. It is a supplement to the Hazardous Substances Information System (HSIS; SWA, 2013a), which is available on the SWA website.

SWA has also produced the document “Guidance on the interpretation of workplace exposure standards for airborne contaminants” (SWA, 2013c), which provides more detailed information about the application of exposure standards.

A WES, the airborne concentration of a particular substance or mixture that must not be exceeded, can be a; 8-hour time-weighted average (TWA); peak limitation (similar to a ceiling value); and / or short term exposure limit (STEL).

SWA (2013b) clearly states,

“Where workers have a working day longer than eight hours or work more than 40 hours a week, the person conducting the business or undertaking must determine whether the TWA exposure standard needs to be adjusted to compensate for the greater exposure during the longer work shift, and decreased recovery time between shifts. Peak limitation or Short Term Exposure Limit exposure standards must not be adjusted. 8-Hour TWA exposure standards must not be adjusted (increased) for shorter work shifts.”

SWA (2013c) currently mentions several different methods for adjusting WES, but recommends use of the Brief & Scala method for its simplicity of use and conservatism. However, there is currently a recommendation to update the “Guidance on the interpretation of workplace exposure standards for airborne contaminants” document such that it recommends use of either the Québec or the Brief & Scala models, supported by an on-line / computer-based tool, the Australianised Québec model.

Québec Model

The Québec model is based on the guiding principle of “...ensuring an equivalent degree of protection to workers with a conventional schedule of 8 hours a day, 5 days a week, and to workers with unusual work schedules” and uses the logic of the Occupational Safety and Health Administration (OSHA) (Paustenbach, 1994) (the OSHA model). IRSST and University of Montréal toxicologists

proposed adjustment categories (Table 1) for each of the substances found in Schedule I of the Quebec Regulation respecting occupational health and safety (ROHS), as well as a method for calculating adjustment factors supported by toxicokinetic modeling. This group of experts also defined the conditions and limitations of application of the adjustment procedure (Drolet, 2008).

TABLE 1
List of adjustment categories for the Quebec model (as also proposed by OSHA)

Adj	Adjustment classification	Type of adjustment
1A	Substances regulated by a ceiling value	No adjustment
1B	Irritating or malodorous substances	
1C	Simple asphyxiants, substances presenting a safety risk or a very low health risk, whose half-life is less than 4 hours. Technological limitations	
2	Substances that produce effects following <i>short-term</i> exposure	Daily adjustment
3	Substances that produce effects following <i>long-term</i> exposure	Weekly adjustment
4	Substances that produce effects following <i>short- or long-term</i> exposure	Daily or weekly adjustment the most conservative of the two

In the case of **Category 1** substances, the time-weighted average exposure standard (TWAES) does not have to be adjusted, regardless of the type of work schedule. Values for short term exposure limits (STELs) and ceiling or peak limits are not subject to the adjustment principle; only the TWAESs are subject to the adjustment principle. For substances belonging to the other categories, the TWAES is adjusted by applying one of the following equations:

$F_a = 8/H_d$ **Category 2** substances, requiring a *daily* adjustment,

$F_a = 40/H_{wk}$ **Category 3** substances, requiring a *weekly* adjustment,

Where: F_a = adjustment factor
 H_d = exposure duration in hours per shift
 H_{wk} = average duration of work shifts per week *based on a repetitive work cycle*.

In the case of **Category 4** substances, the F_a must be calculated for each of the two equations for Categories 2 and 3, and the lowest F_a must be applied. It should be noted that the above-mentioned computer-based tool automatically calculates the adjusted average exposure value (AAEV) from the most conservative F_a .

The TWAES adjustment process applies only to nominal schedules with shifts of no less than 4 hours and no more than 16 hours and in no case can the AAEV be greater than the TWAES. It should also be noted that OEL adjustment is based on the toxicological knowledge available in the scientific and technical literature.

The IRSST guidance document (Drolet, 2008) should be referred to for relevant definitions and other documentation of the Québec model.

Australian Workplace Exposure Standards

There are currently 673 WES for a range of substances (and mixtures) in the document “Workplace Exposure Standards for Airborne Contaminants” (SWA, 2013b) and in the HSIS (SWA, 2013a). The great majority of these were adopted from the ACGIH®, updated to reflect the values published by the ACGIH® in 1994. Between 1998 and 2005, eighty WES reviews were undertaken. The vast majority of these involved the adoption of British Health and Safety Executive (HSE) exposure standards or the National Industrial Chemical Notification and Assessment Scheme (NICNAS) Priority Existing Chemical (PEC) Report recommendations. The last update of the WESs was in August 2005, when 31 substances were amended using the fourth batch of Source A updates adopted from the British HSE and the first batch of Source A updates adopted from the NICNAS PEC report recommendations (SWA, 2013a).

There are a number of WESs that are higher than the exposure standards for other countries (eg. the arsenic and

1,3-butadiene WESs are five times higher than their respective ACGIH® Threshold Limit Value (TLV®), as well as a number that are lower (eg. the chloroform WES is five times lower than the TLV®), and there are many international exposure standards not represented in the WESs. There are also some WESs that are not represented in Schedule I of the Québec Regulations that were compared for determination of an appropriate adjustment category (AC).

A key point to note then is that a number of the Australian WESs have not been reviewed for a number of years, hence may not reflect the most recent research on health effects due to exposures in the workplace. In assigning an appropriate adjustment category (AC) to each of the Australian WESs during the work reported herein, there was no intent to also update the WES itself. Current documentation was reviewed in order to assign the most appropriate AC with regard to health effects, as detailed in the next section.

The Australianised Québec Model

The starting point for developing the Australianised Québec model was to take the assigned adjustment category (AC) for each of the substances in Schedule I of the Québec Regulation (Drolet, 2008) and match these to corresponding substances in the list of Australian WESs from “Workplace Exposure Standards for Airborne Contaminants” (SWA, 2013b). This was thought to be the best approach as this was the most recent such assignment of ACs. Where there was no matching substance, end point health effects and toxicology were used to derive the adjustment category assignment.

Once ACs were thus assigned, the following processes were undertaken to determine the need for modification of the “Québec model” IRSST ACs:

A.WESs with a peak limitation (43 substances) were identified and assigned an AC = 1A. Not all ROHS listed substances with a peak limitation (ceiling limit) had a corresponding WES with such a limit, and *vice versa*.

B.WESs with a carcinogen designation

(Carc. 1A - known to have carcinogenic potential for humans; and Carc. 1B - presumed to have carcinogenic potential for humans) were identified and assigned an AC = 3 or 4, except for LPG, which retained its AC = 1C. A Carc.2 (suspected human carcinogen) designation did not usually elicit a change to the existing AC.

C.WESs with a sensitiser designation were identified and assigned an AC = 2, 3 or 4, except for Benzoyl peroxide, which retained its AC = 1B.

D.Selected WESs were reviewed by the Exposure Standards committee members and adjusted if the more recent documented health effects (ACGIH, 2011 & 2013) suggested a different AC.

Recent ACGIH® documentation (ACGIH, 2011), and health effects as listed in the 2013 ACGIH® TLV® booklet (ACGIH, 2013), were used to help validate proposed AC changes to those published by the IRSST (Drolet, 2008). Another list of assigned ACs based on the OSHA model, developed from the “Desktop Guide to Adjusting TLVs”, which was based on a review of the Documentation for the chemicals in the 6th Edition of *Documentation of the Threshold Limit Values and Biological Exposure Indices* published by the ACGIH® (Wylie, 2008), was also used to help validate any proposed changes.

There were a number of substances where the ACGIH® TLV® and the WES were so disparate, largely due to the WES being old, that it was difficult to discern whether the TLV® gave useful information on the sentinel effect used for developing the WES. In addition, the ‘TLV® basis’ in the booklet (ACGIH, 2013) did not always accurately reflect the documentation detail (ACGIH, 2011).

For several substances it was difficult to understand the conclusions drawn from the documentation. For a number of substances, there was limited documentation, often based solely on animal studies (e.g. the various pesticides). As an example cyclohexene, with an AC = 1B, has a TLV® of 300 ppm based on upper respiratory tract (URT) and eye irritation. The introductory

paragraph reads: “A TLV–TWA® of 300 ppm (1010 mg/m³) is recommended for occupational exposure to cyclohexene, in part by analogy with cyclohexane (see TLV® Documentation for Cyclohexane). This value is intended to minimize the potential for eye and mucous membrane irritation, based on limited data.” The cyclohexane TLV® documentation barely mentions irritation and at least two of the half dozen or so times that irritation is mentioned make the point that it does NOT happen at levels of interest. In these cases professional opinion was used to decide the AC.

A working sheet that documents AC decisions is maintained in an Excel spreadsheet kept by the AIOH Exposure Standards committee.

Brief and Scala Model

Brief & Scala (1975) proposed a “simple system” for adjusting the TLVs® for “novel work schedules”. A reduction factor (adjustment factor - F_a) for reducing the TLV® for a novel work schedule is to be calculated using the following equation:

$$\text{Daily adjustment: } F_a = (8 / H_d) \times (24 - H_d / 16)$$

Where:

F_a = adjustment factor

H_d = exposure duration in hours per shift

They suggest that the F_a value should be applied to; TLVs® expressed as a TWAES with respect to the mean and permissible excursion; and TLVs® that have a ceiling (peak) value, except where the peak limitation is based solely on sensory irritation. They suggest that in this case the irritation response threshold is not likely to be altered downward by an increase in number of hours worked and modification of the TLV® is not needed.

They then state that the F_a value should be applied to TLVs® that are based on systemic effect (acute or chronic). Acute effects are viewed as falling into two categories: (a) rapid with immediate onset and (b) manifest with time during a single exposure. They suggest that “the former are guarded by the C notation and the latter are presumed

time and concentration dependent and hence, are amenable to the modifications proposed.” STELs are not mentioned, but are presumed to be thus included in the adjustment process.

The number of days worked per week is not considered, except in the special case of a 7-day workweek. In this case the

F_a value is calculated as follows:

Weekly adjustment:

$$F_a = (40 / H_{wk}) \times (168 - H_{wk} / 128)$$

Where:
 F_a = adjustment factor

H_{wk} = average duration of work shifts per week based on a repetitive work cycle.

The Exposure Standards committee decided to only apply an adjustment factor to OELs for those substances that have a long-term chronic effect, in alignment with good occupational hygiene practice (Paustenbach, 1994) and SWA suggested practice. That is, no adjustment was made to peak and STEL values.

The AIOH / SWA TWAES Adjustment Tool

The Exposure Standards committee re-developed the Excel spreadsheet tool, which incorporated the Australianised Québec model, to include the Brief and Scale model as a choice of TWAES adjustment method. The structure of the AIOH / SWA tool is presented in figure 1 and a schematic depicting the decision logic (logic tree) embedded in the Excel tool for adjusting TWAESs is presented in figure 2. A screenshot of pages within the tool are presented in figure 3.

The tool has had many steps in its evolution and is likely to continue to evolve as we refine it and as the WESs are updated. The Exposure Standards committee will maintain a watching brief on the updating of the WESs so as to ensure that the ACs reflect the relevant known health effects.

It should be noted that OEL adjustment is based on the toxicological knowledge available in the scientific and technical

literature. However, the limits of our knowledge have to be recognized regarding dose-response relationships applicable to humans, dose-absorption kinetics relating to saturation of defence mechanisms, animal-human extrapolation of toxicological data, the

distribution of contaminants and their metabolites at the point of action of target organs, etc. Use of these models assumes a good knowledge of the work environment and application by a competent person.

The tool is available from the AIOH website at <http://www.aioh.org.au>

FIGURE 1
Structure of AIOH / SWA tool

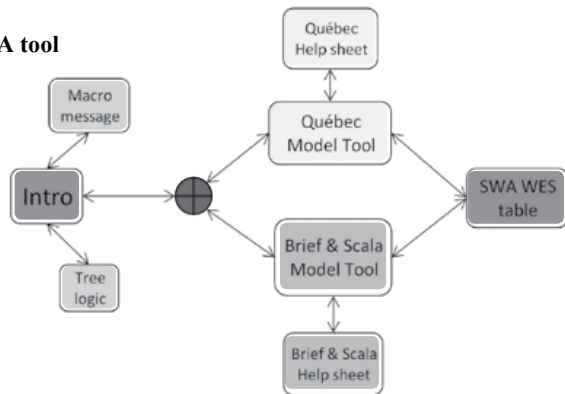


FIGURE 2
OEL adjustment process (logic tree) for unusual work schedules

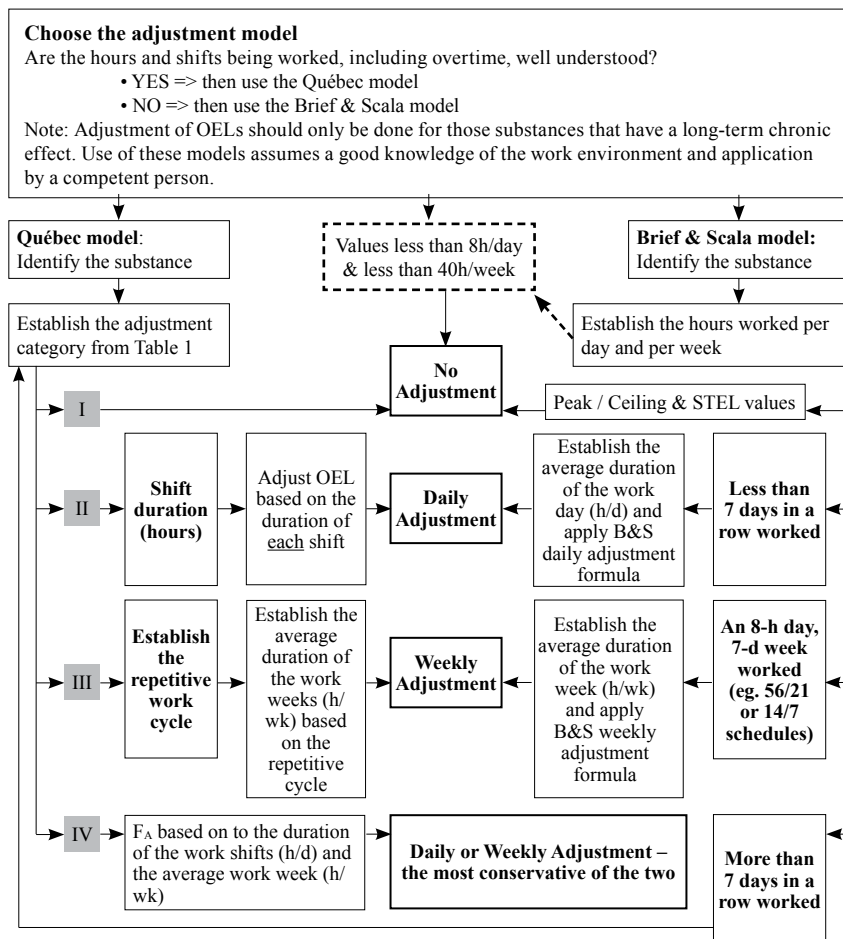


FIGURE 3
Working pages to the AIOH / SWA tool

Concluding Comments

The AIOH Exposure Standards Committee considers that the Excel-based tool will provide an appropriate and accessible methodology to adjust exposure standards for extended work shifts. Its use should therefore provide more consistent and informed advice for affected workers. The tool is freely available on the AIOH web site, however it is recommended that the workplace monitoring strategy should at least have been reviewed by appropriately qualified and experienced persons (e.g. a certified occupational hygienist).

The Committee also regards updating of the WESs to be of vital importance for protecting the health of the Australian workforce.

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papers, and review of SWA as well as State legislative hazardous substances documents. The committee also especially thanks Daniel Drolet for his voluntary prodigious efforts in re-developing the computer-based AIOH / SWA tool.

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