# Bulletin

WORK SAFE ALBERTA

# The Effects of Unusual Work Schedules and Concurrent Exposures on Occupational Exposure Limits (OELs)

Government of Alberta
Employment and Immigration

## Introduction

Alberta’s Occupational Exposure Limits (OELs) for airborne substances (vapours, gases, fumes, dusts and fibres) are contained in Part 4 of the Occupational Health and Safety Code. Employers are required to ensure that a worker’s exposure to any substance is kept as low as reasonably achievable/practicable and does not exceed the substance’s OEL. Since many factors affect total exposure, it is important to be aware of and consider the impact of these factors to prevent overexposure.

Three of the most significant factors to consider are:
(1) the potential for absorption into the body by all routes of exposure;
(2) the duration of exposure; and
(3) the effect of simultaneous exposure to multiple agents.

Routes of absorption for specific substances are identified in the Material Safety Data Sheets (MSDSs) for those substances.

These factors are important as they determine the health outcome of exposure. This Safety Bulletin deals with the adjustment of airborne exposure limits but employers must be aware that unusual work schedules may have an impact on many other aspects of health and safety on the job. A change in the length of the workday will also affect allowable exposure levels for physical hazards such as noise. This Safety Bulletin explores the impact of several key factors and how these factors should be considered in the evaluation of workplace exposure.

## Routes of exposure

The three main routes of exposure at the work site are:
(1) dermal (through the skin);
(2) oral (through the gastrointestinal tract); and
(3) inhalation (through the respiratory system).

Routes of absorption for specific substances are identified on the Material Safety Data Sheets (MSDSs) for those substances.

# Dermal exposure

Work practices involving the handling of chemicals or close contact with chemicals during maintenance, degreasing or cleaning activities can result in significant exposure from skin absorption. Even if inhalation exposure is controlled, a dose equivalent to or greater than that from inhalation exposure alone can result from absorption through the skin. Without adequate assessment of the properties of the chemical and potential for dermal exposure, the worker may not be protected enough.

Materials with the potential for significant absorption through the skin are identified with the "1" notation in the substance interaction column of Table 2 in Schedule 1 of the Occupational Health and Safety Code.

Dermal exposure can be controlled by:

(a) substitution of a chemical that is not as easily absorbed through the skin;
(b) a process change to eliminate skin contact; or
(c) the use of appropriate personal protective equipment (PPE).

The MSDS, chemical supplier or PPE manufacturer must be consulted to ensure that material from which the PPE is made provides an adequate barrier to the chemical. Gloves are made from a variety of materials, such as polyvinyl chloride, natural rubber and neoprene, and the degree of protection provided varies with the properties of the chemical. The protection offered by different materials is rated as "fair", "good" "excellent" or "not recommended" as determined by manufacturer testing. For example, a glove made of polyvinyl chloride is not recommended for use against acetone. The use of inappropriate PPE gives workers a false sense of security.

A good reference to assist with the selection of protective clothing is *Recommendations for Chemical Protective Clothing*, published by the National Institute of Occupational Safety and Health (NIOSH). This publication and others on protective clothing are available online at:

www.cdc.gov/niosh/nppt/topics/protclothing

## Oral exposure — ingestion of chemicals

Oral exposure from chemicals in the workplace is largely accidental through the contamination and subsequent ingestion of food or materials that are brought into contact with the mouth such as tobacco products and chewing gum. Contaminants can also be ingested through hand to mouth contact such as nail biting or hand contamination of food. Exposure to metals and their oxides such as lead and lead oxide has caused occupational poisoning. There is a requirement in Part 4 of the Occupational Health and Safety Code that prohibits eating, drinking and smoking in areas contaminated by harmful substances.

## Inhalation exposure

The most common way that workers are exposed to chemicals at the work site is by inhalation. Most airborne exposure standards including Alberta's OELs, make reference to 8-hour, 15-minute or ceiling exposure limits. The value represents the time-weighted average concentration of the airborne substance over the specified exposure period. When an 8-hour exposure limit is set, the basic premise is that nearly all workers can be exposed day-after-day (8 hours per day/40 days per week) to these concentrations without suffering adverse health effects. OELs are established on the basis to protect nearly all workers so susceptible groups or those with pre-existing medical conditions may not be protected enough by the exposure limit. Factors such as age, sex, reproductive status (pregnancy), genetic factors and lifestyle factors such as smoking and alcohol use, may also play a role in the biological outcome of exposure to chemicals. It is also thought that patterns of exposure and the impact of shift work, which may be combined with extended work hours, can also affect the biological outcome. Although it is not possible to adjust the OEL for each of these parameters, they should be considered in the overall strategy to protect workers.

When accounting for unusual work schedules, adjustments are generally made to 8-hour exposure limits. Part 4 of the Occupational Health and Safety Code requires employers to adjust OELs for work shifts that are longer than 8-hours unless there is a "3" notation in the substance interaction column of Table 2 in Schedule 1.

## The impact of unusual work schedules on exposure limits

Standards can never be adjusted upwards to accommodate shorter periods of exposure.

Non-traditional work schedules are becoming more common in the workplace. There is an increasing trend toward extended work hours with more days off between shifts. Many continuous process operations such as chemical manufacturing, oil refineries, steel mills, drilling rigs and paper mills require two or three shifts in a 24-hour period to accommodate continuous production. Workers may routinely work overtime during periods of heavy demand. A second job may also result in workers being exposed to chemicals for extended periods. This prolonged exposure time can have a health impact where workers are exposed to physical and chemical hazards.

OELs are based in the assumption that exposure occurs for an 8-hour period after which the body is no longer exposed but allowed to recover for the next 16 hours. Where the worker is exposed for more than 8-hours in a day, these assumptions do not hold true. Numerous biological factors come into play when adjusting the OEL. The booklet produced each year by the American Conference of Governmental Industrial Hygienist (ACGIH), *Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs*), should be consulted to ensure it is appropriate to adjust the limit. For example, it is unnecessary to adjust limits where they are based on odour. Although limits can be adjusted downwards to accommodate longer periods of exposure, standards can never be adjusted upwards to accommodate shorter periods of exposure.

## Models to adjust exposure limits of airborne substances for unusual work schedules

The risk of an increased exposure to certain chemicals (body burden) has been recognized and several models proposed to modify the 8-hour per day, 40-hours per week standard to a “non-standard” work day. The intent of the models is to maintain the same overall body burden yet preserve the same margin of safety as the original standard.

There are three ways to adjust occupational exposure standards. Each model has its strengths and weaknesses, requiring specific types of information to be applied properly.

## Pharmacokinetic models

Pharmacokinetic models use information such as the biological half life of the substance and exposure time to predict peak body burden. Pharmacokinetic models most accurately predict body burden and therefore result in the least conservative recommendations when adjusting to unusual work schedules. The difficulty with adjusting exposure standards based on this model is that biological half lives are not available for many chemicals. These models are suitable only for chemicals with standards based on accumulated body burden. They are not suitable for chemicals with standards based on odour, irritancy, or other non-systemic health effects.

A number of pharmacokinetic models are available. The one most widely used is the Hickey and Reist model (Hickey J, Reist P, *Application of Occupational Exposure Limits to Unusual Work Schedules*, Am. Ind. Hyg. Ass. J. (38), 11/77).

## OSHA/Quebec model

This model was originally developed by the U.S. Occupational Safety and Health Administration (OSHA) in 1979 and adopted by Quebec in the late 1990s. This model is based on the assumption that the intensity of a toxic response is a function of the concentration that reaches the site of action. While this is true for many systemic toxicants (substances toxic to a particular organ or system in the body), it may not be true for substances such as sensitizers or carcinogens. As a result, the model should not be used to adjust exposure limits for these substances. The intent of the model is to restrict the dose received during an extended work period to the same total dose that would be received under standard conditions. This should provide a peak body burden no higher than would be reached under an 8-hour shift.

Chemicals are divided into six work schedule categories:

1. Ceiling standards (do not adjust)
2. Irritants or odourous substances with strong odours (do not adjust)
3. Simple asphyxiants, substances presenting a safety risk (e.g. fire) or very low health risk whose half life in the body is less than 4 hours (do not adjust)
4. Substances with acute (short-term) exposure effects (daily adjustment)
5. Substances with chronic (long-term) exposure effects (weekly adjustment)
6. Substances with both acute and chronic effects (daily or weekly adjustment, whichever is most conservative)

More information on this model and how to perform the adjustment is provided in the document "*Guide for the Adjustment of Permissible Exposure Values (PEVs) for Unusual Work Schedules*", available on the Institut de Recherche Robert-Sauvé en Santé et en Securité du Travail (IRSST) website at: http://www.irsst.qc.ca/files/documents/PubIRSST/t-22.pdf. IRSST also has an exposure limit adjustment utility available online at http://www.irsst.qc.ca/en/_outil_100011.html, however users should be aware that the utility uses the Quebec exposure limit values as input when adjusting the limits.

# Brief and Scala model

The simplest and most conservative model is that developed by Brief and Scala. It compensates for unusual work schedules by reducing the permissible concentration in proportion to both the increase in exposure time and the reduction in recovery time. Daily and weekly exposures are addressed by the following formulae:

## Daily Adjustments of Occupational Exposure Limits:

$$\textit{Daily Reduction Factor} = \left\{\frac{8}{h} x \left(\frac{24-h}{16}\right)\right\}$$

Where $h$ = hours worked per day

*Adjusted Exposure Limit = 8 hr OEL x Daily Reduction Factor*

Weekly Adjustments of Occupational Exposure Limits:

$$\text{Weekly Reduction Factor} = \left\{ \frac{40}{hw} x \left( \frac{168 - hw}{128} \right) \right\}$$

Where $hw$ = hours worked per week

Adjusted Exposure Limit = 8 hr OEL x Weekly Reduction Factor

Note: The adjusted exposure limit should be calculated using each equation and the most restrictive value adopted.

# Adjusting OELs at the work site

There are differences in the complexity of information required to apply each of the methods to adjust exposure limits. When adjustment values are compared, the Brief and Scala model is the most conservative and results in the greatest reduction of the exposure limit. The Occupational Health and Safety Code requires that the Brief and Scala model be used to adjust OELs unless the employer has received approval from a Director of Occupational Hygiene to use another method.

When adjustments to exposure limits are necessary, it is recommended that a competent person be consulted to ensure that the adjustment is appropriate and applicable as the models are theoretical and involve assumptions that may not apply to every chemical. An understanding of the chemical is required and caution must be taken where limited toxicity data is available, the toxic effect being avoided is serious, or the chemical accumulates following repeated exposure. Where unusual work schedules are common, the need to adjust exposure limits should be explored and the most appropriate model selected.

# Concurrent multiple chemical exposures

Another consideration in the evaluation of workplace exposure is the effect of concurrent chemical exposures. In fact, exposure to a single chemical in the workplace rarely occurs. Exposure to several chemicals can result from complex work processes, breakdown products, or from work performed by others in the area. However, standards are generally established based on information, testing or experience resulting from exposure to a single chemical. The resulting biological effect of exposure to several chemicals is rarely known but available data indicates that interactions between chemicals is more likely to occur under conditions of high exposure.

The combined effects of chemicals are described as independent, additive, antagonistic, synergistic or potentiating. These effects are described in Table 1. If known, information on potential health effects, both individual and interactive, are described in the MSDS. In evaluating the impact of concurrent chemical exposures, materials acting independently can be evaluated individually. Where the potential for synergistic or potentiating effects are suspected, this enhancement of toxic effect must be reflected in the allowable exposure. However, there is no model for adjustment of the exposure limit to account for synergistic or potentiating effects. The easiest solutions are to either find a substitute for one of the chemicals to avoid the potential effect or ensure exposure is maintained as low as reasonably practicable. In the occupational setting, antagonistic effects are not used as a basis for increasing exposure limits.

Where chemicals are known to have toxicological effects with similar modes of toxic action, or additive effects, Part 4 of the Occupational Health and Safety Code contains a formula which is intended to prevent overexposure:

$$\frac{C_1}{T_1} \pm \frac{C_2}{T_2} \pm \frac{C_3}{T_3} \pm \ldots \frac{C_n}{T_n} \leq 1$$

where $C_1$ $C_2$ $C_3 \ldots C_n$ = actual airborne concentration of each contaminant and

$T_1$ $T_2$ $T_3 \ldots T_n$ = respective 8 hr OEL

To prevent overexposure, the sum of the standardized exposures must not exceed 1.

The assessment of worker exposure must be comprehensive to ensure that total exposure is not underestimated. The potential for exposure from all forms of contaminants such as gases, vapours and dust, and all routes of exposure such as dermal, oral and inhalation, must be considered. In addition, the interaction of these materials and the duration of exposure must be accounted for. Only when all factors are considered and adjusted for are workers protected.

Table 1 Effects Caused by Concurrent Exposures

| Term | Definition | Model | Example |
|---|---|---|---|
| Independent | The toxicity of each compound is produced by independent mechanisms and/or act upon separate organs or systems. Independent substances exert their own toxicity without influence or interference from one another. | 2 + 3 = 2 + 3 | Silica Dust and Carbon Monoxide |
| Additive | Compounds with similar toxicity produce a response that is equal to the sum of the effects produced by each of the individual compounds acting alone. | 2 + 3 = 5 | Xylene and Toluene |
| Antagonistic | Toxicity of one chemical is reduced by exposure to another. | $2 + 3 \leq 5$ | BAL and Lead |
| Potentiating | One substance does not have a toxic effect on a certain organ but when combined with exposure to another chemical, the latter becomes much more toxic. | $0 + 3 \geq 3$ | Isopropanol and Carbon Tetrachloride (↑ liver toxicity) |
| Synergistic | Two materials act together to produce toxicity greater than that produced by either material if administered separately. | $2 + 3 \geq 5$ | Carbon Tetrachloride and Ethanol |

*Adapted from Whylie and Elias (1992)*

# Contact us:

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- **1-800-232-7215** throughout Alberta

## Web Site

www.worksafe.alberta.ca

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www.qp.gov.ab.ca

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## Occupational Health and Safety

http://employment.alberta.ca/SFW/295.html

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