SAFE WORK

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Guideline for Chemical and Biological Substances in the Workplace

December 2009

Manitoba

Guideline

For Chemical and Biological Substances in the Workplace

Workplace Safety & Health
Division
200 – 401 York Avenue
Winnipeg, Manitoba
R3C 0P8

December 2009

Manitoba

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INTRODUCTION

Introduction

Exposure to chemical or biological substances in the workplace may be harmful to worker safety and health.

This guideline provides information and minimum requirements to help protect workers from exposure to these substances in the workplace.

Workplace Safety and Health Regulation Requirements

Under Part 36 of *Workplace Safety and Health Regulation 217/2006*, employers must ensure the safety and health of their workers who use, produce, store, handle and dispose of chemical or biological substances in the workplace.

Some workplaces have only a few chemical or biological substances to consider and others have hundreds. This guide presents steps and actions that must be taken to meet legal requirements and protect workers from exposure to these substances.

Steps listed briefly here are fully explained in this guide:

1. Determine which chemical or biological substances in the workplace present a risk to workers.
2. Use safe work procedures for each chemical or biological substance that presents a risk.
3. Determine if the risk is from a non-airborne (ex: skin, eyes, mucous membranes) or airborne (inhalation) exposure.
4. If exposure is not airborne, immediately apply control measures to eliminate the risk.
5. If the exposure is airborne, establish an appropriate occupational exposure limit (OEL).
6. Monitor airborne exposures to chemical or biological substances.
7. If the workplace assessment or monitoring indicates that workers are exposed to a chemical or biological substance in excess of the OEL, apply control measures to reduce exposure and meet the OEL.
8. Make sure control measures ensure worker exposures do not exceed the OEL.
9. Reassess risk of exposure to workers when there is new information on the toxicity of a chemical or biological substance, or when workplace conditions change.

A flow chart, attached as Appendix 1, shows options available and refers to the appropriate sections of *Workplace Safety and Health Regulation 217/2006*.

ASSESSMENT OF CHEMICAL AND BIOLOGICAL SUBSTANCES

Introduction

In every workplace where chemical or biological substances are present (used, produced, stored, handled or disposed of), it is necessary to assess whether those substances are a risk to the safety or health of workers. The definition of a chemical or biological substance is so broad that substances not intended to be regulated could be included. The definitions in the regulation, state:

- "biological substance" means a substance containing living organisms or parts of living organisms in their natural or modified forms.
- "chemical substance" means any natural or artificial substance, whether in the form of a solid, liquid, gas or vapour, other than a biological substance.

The intent of Part 36 of Workplace Safety and Health Regulation 217/2006 is to control only those substances are a risk to the safety or health of workers. For example, vinegar is dilute acetic acid and therefore would be included in the list of chemicals present at the workplace. But vinegar used in a lunchroom is not a risk to worker safety or health and does not need further risk assessment. On the other hand, glacial acetic acid in a laboratory is a risk to safety and health, and must be addressed.

The risk presented by a chemical or biological substance in the workplace is directly related to the hazards associated with the substance and how it is used in the workplace. If a substance is only received and re-shipped at the workplace, risk would be limited to workers who handle the product. Risks would include the potential for harm in case of spills or leaks. When a chemical or biological substance is used, produced, handled or disposed of in a manufacturing process, the risk to workers of harmful exposure must be assessed for each step of the process. An accurate initial assessment of the risk presented by the substance is required for the steps that follow in this guideline.

Which chemical and biological substances must be assessed?

The best way to answer this question is by first creating a list of all chemical and biological substances in your workplace. When creating this list, you may want to consider a number of things, including:

- All controlled products falling under the Workplace Hazardous Materials Information System (WHMIS) will be on this list.
- Production flow charts should be reviewed for any substances that are added as part of the process or substances that are produced during the process.
- Cross reference lists of products purchased.
- An accurate list of all products can be further assessed during a workplace inspection.

Creating an inventory of chemical or biological substances is one way to ensure that all substances in the workplace are identified. An effective inventory will include substances that are produced as fugitive emissions from any industrial processes at the workplace. It will also include all hazardous chemical and biological substances in products, such as consumer products, that may be exempt from supplier label and material safety data sheet (MSDS) requirements.

The Risk Assessment Process

Once you know what chemical or biological substances are present in the workplace, the next step is to evaluate all hazard information on each substance. Next, review work processes that use the substances to determine if they could cause harm. Most of the hazard information that you need to review will be in the MSDS. The MSDS will clarify what hazard classes the product falls into. While more specific information on these hazard classes is contained in the Workplace Safety and Health Division's *WHMIS Guideline*, the hazard classes include:

- Class A Compressed Gas
- Class B Flammable and Combustible Material
- Class C Oxidizing Material
- Class D Poisonous and Infectious Material
- Class E Corrosive Material
- Class F Dangerously Reactive Material

Review all MSDS information to determine what hazards the substance presents in any of the applicable classes. Information can be determined for health issues, fire and explosive hazards or corrosive hazards to eyes or skin. If a controlled product is a poisonous or infectious material, pay particular attention to toxicological properties listed in the MSDS. Toxicological properties for some substances can be complicated and support from outside consultants may help decision-making. MSDS information covers both acute and chronic exposures to substances.

Be aware that the MSDS points out hazards relating to a product's intended use. If a product is used differently than intended, additional information should be requested from the supplier or an independent expert. If a MSDS has not been obtained for an identified controlled product because of a supplier exemption, the employer should refer to the label on the product and any other hazard information that has been obtained about the product.

Carefully consider the use of the product in the workplace. Where exposures to workers are expected to be the same as for users outside the workplace, no further information should be necessary for that product. Be aware that not all information systems (ex: Consumer Chemical Container Regulation) provide information on the consequences of chronic exposure to a product.

Evaluation of the Hazards

In this step, look at each substance in terms of its potential effects on humans. It is also important to consider where the product is located, how it is used, stored and disposed of, and what types of exposures may occur during these activities. Compare your measures for controlling exposure to substances under normal and emergency circumstances with those recommended in the information you have gathered.

Determining Product Use

When looking at how a substance is used, both expected and non-expected uses must be considered. For example, toluene may be brushed onto surfaces to dissolve organic material such as grease or paint. It presents a certain risk when used in this manner. Toluene can also be sprayed onto surfaces for the same purpose. Applying toluene in a different way may present different risks. Each exposure must be assessed separately. It is also important to consider how much of the product is used for a particular activity and how often that activity takes place.

Chemical process sheets and inventories are a good source of information. It is also important to talk to the workers who use the products. They are among the best sources of information on how a product is actually used, including uses that may not be documented in standard operation procedures. For example, it would be unsafe for workers to use toluene to clean their hands because it could lead to skin injury and organ damage.

Determining Potential Risk

In this step, you will need to ask the following questions about the use of each chemical or biological substance:

- What are the substances that workers are exposed to?
- What is their toxicity (hazard information)?
- How is the substance entering the worker's body (what is the route of exposure)?
- How many workers may be exposed?
- What areas of the workplace are affected?
- Are any workers complaining or experiencing ill health effects?
- What are the ill health effects at different exposures?

To determine if a risk is created, or may be created, first look at how the chemical or biological substance is used:

- Is it a liquid, solid or gas?
    - The physical state of the substance (look on the MSDS for this information) may determine how widely it may spread in the workplace if it is released from the industrial process.
    - The greater the spread in the workplace, the more workers that may be exposed to the hazard.
- Does the industrial process create new substances that are different from those that are originally used?
    - Additional information will need to be found on these new substances.
    - These may be employer produced controlled products (for further information see the WHMIS Guideline).
- Does the industrial process create any emissions (a dust, mist, fume or gas)?
- Are workers exposed to these emissions?
- Is there any possibility of contact with the skin or the eyes?
- Are there any exposures if there is a spill or an unintentional release?

One of the best ways to determine how exposure occurs is to watch how the product is used and talk with workers who normally use it.

The next step is to consider the toxicology of the controlled product, and the ways the chemical or biological substance can enter the body and cause harm:

- Can it be inhaled?
- Can it be absorbed through the skin?
- Can it be swallowed?

If the answer is “YES” to any of the above questions, you need to look at the specific health effects for each possible route of exposure.

- What are the short-term health effects (refer to the MSDS)?
- What are the long-term health effects (refer to the MSDS)?

If there are only a few chemical or biological substances in the workplace, it may not be hard to determine which one to assess first. If there are a large number of substances, you may need to develop a system to help determine in what order to assess them. You must eventually assess all substances for their risk to workers.

To help you decide which substances to assess first, consider the following:

- amount of the substance used or purchased
- number of workers exposed in a particular area or work process
- hazard information (toxicity) for each substance (usually provided in the MSDS).

After answering these questions, you should be able to determine if a chemical or biological substance present in the workplace creates, or may create, a risk to the safety or health of a worker.

The assessment process is not a one-time activity. It must be repeated if specific conditions at the workplace change:

- if there is a change in the condition in the workplace (ex: any change in the production process or chemicals used)
- if the employer becomes aware of a change in the health or physical condition of a worker
- if there is a change in the hazard information for a chemical or biological substance

The workplace safety and health regulation requires employers to share worker safety and health information with affected parties in the workplace. Results of assessments performed to determine if chemical or biological substances present risks must be shared with a workplace safety and health committee, a representative or where they are non-existing, directly with workers.

From this point on, the requirements under Part 36 of the regulation apply only to chemical or biological substances identified as a safety or health risk, or those that may become a risk.

SAFE WORK PROCEDURES

Introduction

Employers must put safe work procedures in place for the use, production, storage, handling and disposal of any chemical or biological substance that is a worker safety or health risk.

Safe work procedures must be specific for each substance and each workplace activity. They depend directly on how the product is used in the workplace. Employers must train workers in safe work procedures and ensure they use them.

If the workplace is only shipping and receiving controlled products, a simple safe work procedure may be all that is required. Such a procedure may focus on how the products are safely distributed throughout the workplace and what to do in the event of an accidental spill or leak. If a highly hazardous chemical or biological substance is used, produced, stored, handled or disposed of in a workplace, employers must provide workers with appropriate safety training.

CONTROL OF NON-AIRBORNE HAZARDS

Introduction

Non-airborne hazards generally refer to the risk associated with direct body contact (ex: skin/eye, mucous membranes) with the chemical or biological substance. For example, direct contact with a corrosive chemical substance (ex: strong caustic or acid) can result in a burning sensation on the skin's surface. In this example, the exposure might be limited to the skin's surface or affect deeper layers of living tissue. The effect of this exposure can range from irritation, to first and second degree burns, to necrosis (killing) of the tissues.

In comparison, long-term contact with an organic solvent often results in the removal of natural oil from the skin, causing drying and cracking visible on the skin's surface. These cracks on the skin's surface may lead to primary and in some cases secondary infections, or a condition known as dermatitis. Organic solvents may also pass through the skin and be distributed systemically throughout the body by the blood system. In this case, the target organ (an organ affected by the exposure) may be the liver.

If the risk assessment identifies that a non-airborne exposure to a chemical or biological substance creates, or may create, a risk to the safety or health of a worker, employers must immediately put control measures in place to eliminate that risk. Non-airborne exposures are dealt with differently from airborne exposures for these reasons:

- Though through the skin has been identified as a significant exposure route for many substances, those substances are not normally considered safe for skin contact.
- Monitoring the actual amount that passes through skin is not practical or possible for most substances.

How Do You Eliminate Non-Airborne Health Risks?

The safest and most effective way to eliminate non-airborne exposures is to substitute the hazardous chemical or biological substance with a non-hazardous substance, or change the work process so workers avoid the substance. Other control measures may include personal protective equipment like chemical resistant gloves, aprons, barrier creams and safety eyewear. The control measure must match the product the worker is exposed to and provide proper protection.

Be sure to consult with the MSDS or suppliers of protective equipment for specific products required.

AIRBORNE HEALTH RISK

Note: The remainder of this document refers to airborne health hazards.

It is possible for many substances in the workplace to be considered a risk to the health or safety of workers. Although employers must eventually address all such substances in the workplace, it may be necessary to develop a system to determine which substances to address first. The following is just one way employers can manage a large number of substances.
Substances can be addressed based on risk and possible consequences of exposure. For example, a substance can be flammable, but not a risk because there is no contact with an ignition source during the work process.

For each substance in the workplace that presents a risk to the safety or health of workers, employers must perform the following steps:

- Select the appropriate frequency of risk category from Table 1.
- Select the appropriate severity of risk category from Table 2.
- Based on the frequency and severity categories that you have selected, locate the risk level in Table 3.

Table 1 - Frequency of Risk Categories

Category	**Frequency**	
A	**Highly Likely**	The hazard is very probable (100% chance)
B	**Likely**	The hazard is probable (10%-100%)
C	**Possible**	The hazard is possible (1%-10%)
D	**Unlikely**	The hazard is unlikely to ever occur

Table 2 - Severity of Risk Categories

Category/ Impact	**a Catastrophic**	**b Critical**	**c Marginal**	**d Negligible**
	Death or fatal injury	Permanent disability, severe injury or illness	Injury or illness not resulting in disability, major quality of life loss or perceived illness	Treatable first aid injury

When evaluating each substance, select the highest category (most serious impact) the substance meets even if it fits more than one criteria (ex: select death or fatal injury even if permanent disability is also possible). Based on the answers from Table 1 and Table 2, select the overall risk level that matches.

Table 3 – Overall Risk Level

Frequency **Severity**	**A Highly Likely**	**B Likely**	**C Possible**	**D Unlikely**
a Catastrophic	**aA**	**aB**	**aC**	**aD**
b Critical	**bA**	**bB**	**bC**	**bD**
c Marginal	**cA**	**cB**	**cC**	**cD**
d Negligible	**dA**	**dB**	**dC**	**dD**

The following priorities are suggested based on the overall risk level above.

	High
	Medium
	Low
	Very Low

Given that the employer must address all substances that present a risk, the definitions used to categorize the frequency and severity can be set by the employer. The employer must consistently apply whatever definitions are developed until all risks are categorized.

SETTING OCCUPATIONAL EXPOSURE LIMITS FOR AIRBORNE HAZARDOUS SUBSTANCES

Introduction

Airborne contaminants form part of the air that workers breathe in the workplace. Chemical or biological contaminants include gases, liquids, solids, vapours, fumes, mists, fogs or dusts. By law, the amount of any contaminant that a worker may be exposed to in a workday depends on how toxic the contaminant is and its specific toxic effect. As a rule, the more toxic a substance is, the lower the allowable exposure.

The first step in addressing airborne hazardous substances (remember we are referring only to those substances that were determined to be potential risks to a worker's safety or health) is to establish an airborne occupational exposure limit (OEL). An OEL is defined in the regulation as "the limit of exposure of a worker to an airborne chemical or biological substance established under Part 36."

There are three ways that an OEL can be established:

- an airborne substance for which the American Conference of Governmental Industrial Hygienists[1] (ACGIH) has established an exposure guideline
- an airborne designated substance (a chemical substance which meets the criteria as a cause of cancer, respiratory illness, reproductive problems and birth defects under the *Controlled Products Regulations)*
- airborne substance for which the ACGIH has not established an exposure guideline

ACGIH Has Established an Exposure Guideline

The ACGIH refers to their exposure guidelines as threshold limit values (TLVs®). The term refers to airborne concentrations of chemical substances and represents conditions under which it is believed that *nearly all* workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects.

In Manitoba, the Workplace Safety and Health Regulation adopts the current ACGIH TLVs® as the allowable occupational exposure limits (OEL) for those chemical and biological substances where a TLV® exists.

The following information is derived from the ACGIH document, *Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices*, and explains the type of TLVs®.

Three categories of TLVs® are specified: time weighted average (TWA), short-term exposure limit (STEL), and a ceiling (C). For most substances, a TWA alone or with a STEL is relevant. For some substances (ex: irritant gases), only the TLV® – Ceiling is applicable. If any of these TLV® types are exceeded, a potential hazard from that substance is presumed to exist.

- **Threshold Limit Value – Time-Weighted Average (TLV® – TWA):** The TWA concentration for a conventional eight-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect.
- **Threshold Limit Value – Short-Term Exposure Limit (TLV® – STEL):** A 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the eight-hour TWA is within the TLV® – TWA. The TLV® – STEL is the concentration

to which it is believed that workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, 3) dose-rate-dependent toxic effects, or 4) narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self-rescue, or materially reduced work efficiency. The TLV® – STEL is not a separate, independent exposure guideline; rather, it supplements the TLVS® – TWA where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. Exposures above the TLV® – TWA up to the TLV® – STEL should be less than 15 minutes, should occur less than four times per day, and there should be at least 60 minutes between successive exposures in this range. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

- **Threshold Limit Value – Ceiling (TLV® – C):** The concentration that should not be exceeded during any part of the working exposure. If instantaneous measurements are not available, sampling should be conducted for the minimum period of time sufficient to detect exposures at or above the ceiling value.

ACGIH further recognizes that there should be limits as to how large an exposure should be allowed for those chemical substances where there is no TLV® – STEL. In these cases ACGIH has recommended allowable excursion limits. ACGIH defines excursion limits as the following:

> "Excursions in worker exposure levels may exceed 3 times the TLV® – TWA for no more than a total of 30 minutes during a work - day, and under no circumstances should they exceed 5 times the TLV® –TWA, provided that the TLV® – TWA is not exceeded."

Airborne Designated Substance

The second category of OEL is specific for designated substances, defined as a chemical substance that meets the criteria as a carcinogen, mutagen, respiratory sensitizer, reproductive toxin, fetotoxin or teratogen under the *Controlled Products Regulations.* These chemical substances will be specifically identified on a MSDS received from a manufacturer under the Workplace Hazardous Materials Information System (WHMIS). All worker exposures to these substances must be kept as low as possible. The regulation defines this as follows: "… as close to zero as is possible and does not exceed the threshold limit value established by the ACGIH, where one exists."

Operationally, this means the allowable exposure must be as close to zero as possible. Please note – the regulation does not use the phrase reasonably practicable for this situation. The employer is required set the effective OEL at zero. Where the ACGIH has established a TLV® for a substance that takes into account the carcinogenic, mutagenic, respiratory sensitization, reproductive toxic, fetotoxic or teratogenic effect, and a zero exposure is not possible, then the OEL shall not exceed the TLV®.

ACGIH Has Not Established an Exposure Guideline

The ACGIH has not established a TLV® for many chemical and biological substances used in industrial processes. In these cases, employers must use one of the following two options:

- Use control measures that will eliminate any risk to a worker's safety or health resulting from exposure to the substance (see the discussion later in this document on acceptable control measures).

- Establish an OEL for the chemical or biological substance that will prevent any risk to a worker's safety or health resulting from exposure.

If the option to establish an OEL for a chemical or biological substance is chosen, employers must ensure this is done by a competent person. The regulation defines a competent person as one "possessing knowledge, experience and training to perform a specific duty." Therefore, the task of establishing an OEL must only be performed by a person who knows the toxicological effects of the substance in question and other factors to be considered in protecting workers from risks to their safety or health.

The regulation does not put restrictions on who this competent person is. In a larger company, there may already be internal resources to perform this activity (occupational hygiene or medical expertise). However, a smaller company may need to ask for the help of an outside expert.

Adjustment to OELs

The final step in setting an OEL for a specific substance in a workplace is to consider if there are other conditions in the workplace (including a worker's health or physical condition that is known to the employer) requiring that the TLV® or the OEL set by the employer needs to be changed. Section 36(5) of the regulation lists several conditions that may affect (increase) the toxicity that a chemical or biological substance may have on the body. The two most common workplace factors include a workday that is longer than eight hours and multiple chemical exposures that have an additive effect on the body.

Extended Work Shift

The ACGIH TLV® is based on the assumption that a worker is exposed for no more than an eight-hour workday and has a standard five-day (40-hour) workweek. The TLV® must be changed if this is not the case.

ACGIH recognizes that there are a variety of different models available for use when adjusting an OEL for unusual shift lengths. ACGIH identifies that a comprehensive review is available in *Patty's Industrial Hygiene* (Paustenbauch, 2000). Two of these methods, Brief and Scala and OSHA models will be discussed here.

Pharmacokinetics and Unusual Work Schedules
Dennis J. Paustenbach, Ph.D., CIH, DABT

Robert L. Harris (ed.), *Patty's Industrial Hygiene*
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DOI: 10.1002/0471435139.hyg040
Article Online Posting Date: April 16, 2001.

Brief and Scala Model

Brief and Scala's approach was simple but important since it emphasized that, unless worker exposure to some systemic toxicants was lowered, the daily dose would be greater, and due to the lesser time for recovery between exposures peak tissue levels might be higher during unusual shifts than during normal shifts.

This model adjusts the TLV® by the ratio of the increased workday and the decreased time away from the workplace and is described by the following formulas:

$$\textbf{TLV® reduction factor (RF)} = \frac{8}{h} \times \frac{24h}{16}$$

where *h* is hours worked per day.

or:

$$\textbf{TLV® reduction factor (RF)} = \frac{40}{h} \times \frac{168h}{128}$$

where *h* = hours exposed per week.

The Brief and Scala model should be considered in the following situations:

- where the ACGIH establishes the TLV® based on systemic effect (acute or chronic), for extended three or four-day workweek,
- for seven-day workweek, and not
- for work schedules less than seven to eight hours per day or ≤40 hours per week.

The following are examples of the Brief and Scala model cited in *Patty's Industrial Hygiene*:

1. Refinery operators often work a six-week schedule of three 12-hour workdays for three weeks, followed by four 12-hour workdays for three weeks. What is the adjusted TLV® for methanol (assume TLV® = 200 ppm) for these workers? Note that the weekly average exposure is only slightly greater than that of a normal work schedule.

   Solution

$$RF = \frac{8}{12} \times \frac{24 - 12}{16} = 0.5$$

$$\begin{aligned} \text{Adjusted } TLV &= RF \times TLV \\ &= 0.5 \times 200 \text{ ppm} \\ &= 100 \text{ ppm} \end{aligned}$$

   Note: The TLV® reduction factor of 0.5 applies to the 12-hour workday, whether exposure is for three, four or five days per week.

2. In an eight-hour day, seven-day workweek situation, such as the 56/21 schedule, persons work 56 continuous days followed by 21 days off. What is the recommended TLV® for H_2S (assume TLV® = 10 ppm) for this special case of a seven-day workweek? Assume that the biologic half-life in humans for H_2S is about two hours and the rationale for the limit is the prevention of irritation and systemic effects.

Solution

Exposure hours per week = 8 × 7 = 56 hours

Exposure-free hours per week = (24 × 7) – 56 = 112 hours

$$RF = \frac{40}{56} \times \frac{112}{128} = 0.625$$

$$\text{Adjusted } TLV = RF \times 10 \text{ ppm} = 6 \text{ ppm.}$$

3. Ammonia has a TLV® of 25 ppm and is an upper respiratory tract irritant. What is the modified TLV® for this chemical for a work schedule of 14 hours per day for three days per week?

   Solution

   Since the rationale for the limit for ammonia is the prevention of irritation, **no** adjustment (lowering) of the limit is needed.

OSHA Model

Most toxicologists believe that, in general, the intensity of a toxic response is a function of the concentration that reaches the site of action. This principle is simplistic and, while it may not apply to irritants, sensitizers, or carcinogens, it is clearly true for the systemic toxics.

The originators of the model assumed that for chemicals that cause an acute response, if the daily uptake (concentration × time) during a long workday was limited to the amount that would be absorbed during a standard workday, then the same degree of protection would be given to workers on the longer shifts. For chemicals with cumulative effects (ex: those with a long half-life), the adjustment model was based on the dose imparted through exposure during the normal workweek (40 hours) rather than the normal workday (eight hours).

The rationale that OSHA and its expert consultants used when categorizing the various chemicals was based on the primary type of health effect to be prevented, biologic half-life (if known), and the rationale for the limit. The categories include:
(a) ceiling limit,
(b) prevention of irritation,
(c) technological feasibility limitations,
(d) acute toxicity,
(e) cumulative toxicity, as well as
(f) acute and cumulative toxicity.

OSHA has recommended that the criteria shown in the following table be used to adjusted unusual work shifts.

Category	Classification	Adjustment Criteria
1A	Ceiling standard	None
1B	Irritants	None
1C	Technologic limitations	None
2	Acute toxicants	Exposed—8 hr/day
3	Cumulative toxicants	Exposed—40 hr/week
4	Both acute and cumulative	Exposed—8 hr/day and/or Exposed—40 hr/week

This model adjusts the OSHA Permissible Exposure Limit by adjusting the allowable daily exposure limit for chemicals with acute affect and the allowable weekly exposure limit for chemicals with cumulative toxic effects and is described by the following formulas:

$$\textbf{Equivalent PEL} = \textbf{8-hr PEL} \times \frac{\textbf{8 hr}}{\textbf{hours of exposure per day}}$$

$$\textbf{Equivalent PEL} = \textbf{8-hr PEL} \times \frac{\textbf{40 hr}}{\textbf{hours of exposure in one week}}$$

The following are examples of the OSHA model cited in *Patty's Industrial Hygiene*:

1. An occupational exposure limit of 1 $\mu g/m^3$ has been suggested by NIOSH for polychlorinated biphenyls (PCBs). Studies of exposed workers indicate that the biologic half-life of PCBs is as long as several years. What adjustment to the occupational exposure limit might be suggested by NIOSH for workers on the standard 12-hour work shift involving four days of work per week if they adopted the simple OSHA formulas?

   Solution

   $$\textbf{Recommended limit} = \textbf{8 hr PEL} \times \frac{\textbf{8 hr}}{\textbf{12 hr}}$$

   $$\textbf{Recommended limit} = 1\ \mu g/m^3 \times 0.667 = 0.667\ \mu g/m^3$$

   Note: Since PCBs (chlorodiphenyl) are listed as both cumulative and acute toxicants, the daily adjusting formula rather than weekly adjusting formula should be used since it yields the more conservative results.

2. Many industries such as boat manufacturing are seasonal in their workload. During the months of January, February, March, and April, the builders of boats work five days per week, 14 hours per day and could be exposed to concentrations of toluene diisocyanate (TDI) at the TLV® of 0.005 ppm. What occupational exposure limit is

recommended for TDI for a person who works 14 hours per day for five days per week but only works eight weeks per year?

Solution. No adjustment is made.

Note: TDI is categorized as a Category 1A chemical (ex: one that has a ceiling limit). Substances in this category have limits that should never be exceeded and consequently the limits are independent of the length or frequency of exposure. Exposure limits for chemical irritants such as these are currently thought not to require adjustment. Until more is known about human response to irritants during unusually long durations of exposure, the physician, nurse and hygienist should make note of the employee tolerance to the presence of irritants at levels at or near the TLV®. Eventually, human experience will tell us whether irritation is a time-dependent phenomenon and whether the response varies with the different chemicals.

3. Assume the permissible exposure limit for elemental mercury is 50 µg/m^3. It has a half-life in humans in excess of several days. What adjustment to the limit would be recommended by OSHA for workers on a shift involving four days at 12 hours a day followed by three days of vacation, then three days of 12 hours a day followed by four days off?

   Solution

$$\text{Equivalent PEL} = 8\text{ hr PEL} \times \frac{40\text{ hr}}{48\text{ hr}}$$

$$= 50\ \mu\text{g/m}^3 \times 0.833 = 40\ \mu\text{g/m}^3$$

   Note: Since elemental mercury is classified as a cumulative toxin, the weekly adjusting formula should be used. The 48-hour workweek was used in this example since it yields a more conservative adjustment than the 36-hour workweek. It could be argued that a smaller adjustment factor based on the average number of hours worked every two weeks more accurately reflects the exposure [ex: (48 + 36)/2 = 42] since the chronic effects of mercury are due to many weeks or years of excess exposure.

   An online interactive tool to calculate the adjusted TWA based on the OSHA model is available from Institut de recherche Robert-Sauvé en santé et en sécurité du travail at http://www.irsst.qc.ca/en/utVema.htm. This tool can be used to calculate the reduction factor for an extended daily or weekly exposure.

Multiple Exposures

The second most common reason for adjusting a TLV® is because of multiple additive or synergistic chemical substance exposures. A TLV® established for individual chemical agents must be adjusted if the available toxicological information indicates that two or more chemical agents have the same effect on the same organ in the body (ex: kidney). ACGIH provides the following explanation on how to adjust the TLV®:
"When two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, different substances should be considered as additive where the health effect and target organ or system are the same."

The following formula is used to determine if an additive exposure exceeds the OEL for the mixture:

$$\frac{C[1]}{T[1]} + \frac{C[2]}{T[2]} + \frac{C[3]}{T[3]} + \ldots \frac{C[n]}{T[n]}$$

Where:

C_1 C_2 C_3...C_n = actual airborne concentrations of each containment;

T_1 T_2 T_3...T_n = respective eight hour OEL for each contaminant.

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

Example:

ACGIH provides the following example to evaluate if the OEL resulting from an exposure to multiple chemicals that have an additive effect on the body is exceeded.

A worker's airborne exposure to solvents was monitored for a full shift as well as one short-term exposure. The results are presented in Table 2:

TABLE 2. Example Results

Agent	Full-Shift Results *(TLV–TWA)*	Short-Term Results *(TLV–STEL)*
1) Acetone	160 ppm *(500 ppm)*	490 ppm *(750 ppm)*
2) sec-Butyl acetate	20 ppm *(200 ppm)*	150 ppm (N/A)
3) Methyl ethyl ketone	90 ppm *(200 ppm)*	220 ppm *(300 ppm)*

According to the *Documentation of the TLVs® and BEIs®,* all three substances indicate irritation effects on the respiratory system and thus would be considered additive. Acetone and methyl ethyl ketone exhibit central nervous system effects.

Full-shift analysis would utilize the formula:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} \leq 1$$

thus, $$\frac{160}{500} + \frac{20}{200} + \frac{90}{200} = 0.32 + 0.10 + 0.45 = 0.87$$

The full-shift mixture limit is not exceeded.

Short-term analysis would utilize the formula:

$$\frac{C_1}{T_{1STEL}} + \frac{C_2}{(T_2)(5)} + \frac{C_3}{T_{3STEL}} \leq 1$$

thus, $$\frac{490}{750} + \frac{150}{1000} + \frac{220}{300} = 0.65 + 0.15 + 0.73 = 1.53$$

The short-term mixture limit is exceeded.

In the example above the exclusion rule of not exceeding five times exposure for sec-butyl acetate applies because it does not have a STEL.

There is no formula that can be used to adjust a TLV® or the OEL set by the employer when the toxicological information available for two or more chemicals indicates that a combined exposure may have a synergistic effect. A classic example of a synergistic effect is an exposure to both asbestos and cigarette smoke. While there is a specific risk of developing lung cancer from an asbestos exposure without smoking cigarettes and from smoking cigarettes without an asbestos exposure, the combined exposure multiplies the risk of lung cancer significantly. In such cases, the allowable exposure must be set low enough to protect against the synergistic effect and should only be set by a competent person.

Additional Factors

There are additional workplace factors presented in section 36.5(2)(a) of the Workplace Safety and Health regulation that must be considered, but they are less common. These factors include heat, humidity, pressure, and ultraviolet and ionizing radiation.

The second reason for adjusting a TLV® or the OEL set by the employer is a health condition of the worker that is known to the employer. It is generally understood that a TLV® is based on an average healthy worker. In some cases, where the health of the worker may be below average, the exposure may have more of a health effect on that worker than it would have on an average healthy worker. If information on specific health conditions of an employee is known to the employer, there is an obligation for the employer to take steps to protect that worker's health. One way of protecting that worker's health is to adjust the TLV® or the OEL set by the employer to a level that would protect that worker. For an example, a worker with a heart or circulatory condition, who is exposed to carbon monoxide during his work duties, may need protecting. The TLV® of 25 ppm established by the ACGIH for a normal healthy worker may not adequately protect this worker from the exposure to carbon monoxide, and therefore the TLV® must be adjusted. It is very important to remember that a worker's personal health information is **confidential** and must be held in confidence by the employer. Here again, the setting of the TLV® to a lower level because of worker health issues will require specific expertise and should only be performed by a competent person.

MONITORING

Introduction

So far, a list of chemical or biological substances that creates or may create a risk to workers' safety and health has been developed, non-airborne substances have been controlled and appropriate occupational exposure limits have been established for airborne substances. The next step is to consider whether a worker may actually be exposed to a chemical or biological substance in excess of an established OEL.

Monitoring Options

There are several ways of determining whether a worker may be overexposed, but only qualified persons should perform this activity. The consequences of a wrong decision at this point may lead to an exposure that could result in significant adverse health effects to workers.

There may be specific information contained in a MSDS related to odour, flammability or toxicological properties that can be used to estimate exposure levels. Similarly, there are a number of mathematical formulas that can be used to estimate airborne concentrations of substances. It may also be possible to assess the potential for exposure by conducting an evaluation of the effectiveness of any engineering controls already in place to remove any fugitive emissions. Furthermore, the employer may develop reasons to believe a worker may be overexposed based upon worker concerns or complaints, equipment maintenance status, the opinion of a competent individual or regulatory officer, or on the basis of new information that comes to the employer's attention. If any of these methods indicate that a worker's exposure would be statistically less than the OEL, no further action to protect a worker is required, unless changes in the exposure occur. The need to reassess exposure where there have been changes in the workplace will be discussed later in this document.

Conversely, if any of the methods above result in an estimated exposure, or a belief that a worker is likely to be over exposed, or if estimation is not possible, then the employer must do one of the following:

- Conduct monitoring of the substance on a regular basis to determine the airborne concentration of the substance.
- Use control measures in accordance with section 36.7 sufficient to ensure that no worker is exposed to the substance in excess of the occupational exposure limit for that substance.

Employers who choose conduct monitoring must ensure that:

- the concentrations of the chemical or biological substance to which a worker is exposed are determined by a competent person from analyses of air samples representative of the worker's exposure
- the air sampling and the analyses of the air samples are conducted according to the requirements of either:
  - the *National Institute for Occupational Safety and Health Manual of Analytical Methods*, published by the United States Department of Health and Human Services (http://www.cdc.gov/niosh/docs/77-173/)
  - another method established by a recognized occupational hygiene practice

In this option, the employer must undertake monitoring of the worker's exposure to determine the actual concentration of the exposure. The regulation requires that monitoring, interpretation of data and assessment of any results be conducted by a competent professional. The process of determining a worker's exposure is a task that requires specific expertise. The regulation does not specify who may perform this task, only that that person must be competent to perform it. The definition of competent presented earlier in this document as applied to establishing OEL's also applies in this case. The employer may already have the resources to perform this task, or may need to use outside services.

The preferred way to evaluate a worker's exposure to an airborne substance is to perform personal sampling. In this case, an air sample is collected from near the worker's breathing zone, generally considered to be within 30 centimetres (one foot) from the worker's face. In most cases, the sample will be collected over the duration of the worker's full shift. Here again, a competent person will be able to determine if sampling a portion of the full shift is enough to get an accurate measurement of the exposure that would be obtained from sampling the full shift. The actual selection of the time period and sampling equipment are issues that the competent person performing these duties must determine. Enough of the contaminated air must be captured by collection of air so that it meets the minimum requirements for the analytical procedure being used. Both the length of sampling and the velocity of sampling affect the amount of the contaminant that is actually captured.

The person conducting the sampling must also consider the impact of any change in job activities over the workday or workweek, or changes in the environmental conditions within the workplace (ex: doors open in the summer but closed in the winter).

Other sampling methods, such as area sampling or emission sampling, may be used, but a determination must be made by the person designing the monitoring program that these types of monitoring procedures are representative of a worker's exposure. Here again, a competent person will be able to make the determination if these other sampling protocols can be used.

Whatever sampling strategy is used, the method of sampling and analysis must be consistent with the procedures adopted by the National Institute for Occupational Safety and Health (NIOSH) as published in their *Manual of Analytical Methods*, or by another method established by a recognized occupational practice. Sampling methods could include:

- the NIOSH *Manual of Analytical Methods*, 4th Edition (August 1994), published by the United States Department of Health and Human Services, as amended up to and including the second supplement (January 15, 1998)
- *OSHA Sampling and Analytical Method*
- HSE *Methods for the Determination of Hazardous Substances, Health and Safety Laboratory*
- *EPA Test Methods*
- IRSST *Sampling Guide for Air Contaminants in the Workplace*
- ISO standards or TC 146 air quality guides

The methods listed above are laboratory methods for analyzing samples of workers' exposure.

A second option for determining worker exposure is to use direct reading equipment. Direct reading equipment includes: colorimetric devices, passive diffusion badges, electrochemical detectors, gravimetric analyzers, photo ionization detectors, infrared analyzers, spectrophotometers and gas chromatographs. Each of these types of direct reading instruments has its own advantages and disadvantages. As with the laboratory methods, a competent person should be involved in selecting appropriate direct reading equipment.

The results of the worker exposure assessments are then compared to the allowable OEL. If worker exposure is found to be less than the OEL, the employer still needs to develop safe work procedures and train the worker(s). No further action is required, unless there is a change in the workplace that may affect the potential for worker exposure. On the other hand, if monitoring shows that a worker or workers are being exposed in excess of the OEL, the employer must use control measures to ensure that worker exposure does not exceed the OEL. More information on this follows in the next part of the guide.

Specific information from the monitoring program must be retained as a record for at least 30 years from when the record was made. Employers must make a record of all monitoring, which must include the following information:

- type of monitoring
- type of equipment used
- each result of the monitoring
- the time each result was obtained
- any interpretation of the monitoring data
- names of the workers whose exposure was measured

As with other important information, the monitoring records must be shared with the workplace safety and health committee or representative, or with workers if there is no committee or representative. Employers must also provide monitoring records to a worker who has been exposed to a chemical or biological substance, if the worker requests them.

Alternatively, the employer may leave out the monitoring activity if the risk assessment shows that a worker is exposed in excess of the OEL and proceed directly to using control measures.

CONTROL MEASURES

Introduction

Controlling worker exposure to chemical and biological substances is the most important goal of Part 36 of Workplace Safety and Health Regulation 217/2006. How you go about reaching this goal will be determined by each decision you make and the steps you take to create a safe and healthy work environment. Once you identify chemical or biological substances, determine that an airborne health risk exists and confirm that worker exposure exceeds the OEL, the next step is to control that exposure.

Control measures keep worker exposure below the OEL for each substance. Control measures for non-airborne substances focus on building a barrier between workers and substances. Control measures for airborne substances are quite different.

If the risk assessment and monitoring have been performed appropriately, there is a good chance that the source of the exposure is already known, and the monitoring has simply confirmed that exposures exceed the OEL. At this point, there are several options available to eliminate or reduce exposures to below the allowable OEL. These options are generally referred to as elimination/substitution, administrative, engineering or personal protective equipment methods.

Types of Control Measures

Any control measure that is used in the workplace needs to be effective. The first consideration, when it comes to chemical and biological hazards, is whether the substance is needed at the workplace, or if a less hazardous material can be used. Often a hazardous substance is present when it is not really needed. Therefore, eliminating it is the most effective control measure. Sometimes a hazardous substance can be replaced by a less hazardous one. This control method is known as substitution. If this method is used, the risk assessment process must be repeated to ensure that you are not simply replacing one hazardous substance with another.

In situations where a hazardous substance is required and substitution is not an option, other methods of control must be considered.

The traditional hierarchy of control methods referred to in occupational hygiene can be summarized as follows:

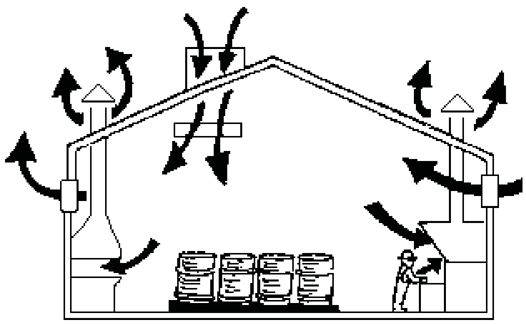
- elimination
- substitution
- engineering controls
- administrative controls
- personal protective equipment

The National Institute of Occupational Safety and Health states the following regarding the hierarchy of controls:

“The idea behind this hierarchy is that the control methods at the top of the list are potentially more effective and protective than those at the bottom. Following the hierarchy normally leads to the implementation of inherently safer systems, ones where the risk of illness or injury has been substantially reduced.

"Elimination and substitution, while most effective at reducing hazards, also tends to be the most difficult to introduce in an existing process. If the process is still at the design or development stage, elimination and substitution of hazards may be inexpensive and simple to implement. For an existing process, major changes in equipment and procedures may be required to eliminate or substitute for a hazard.

"Administrative controls and personal protective equipment are frequently used with existing processes where hazards are not particularly well controlled. Administrative controls and personal protective equipment programs may be relatively inexpensive to establish but, over the long term, can be very costly to sustain. These methods for protecting workers have also proven to be less effective than other measures, requiring significant effort by the affected workers.



"Engineering controls are used to remove a hazard or place a barrier between the worker and the hazard. Well-designed engineering controls can be highly effective in protecting workers and will typically be independent of worker interactions to provide this high level of protection. The initial cost of engineering controls can be higher than the cost of administrative controls or personal protective equipment, but over the longer term, operating costs are frequently lower, and in some instances, can provide a cost savings in other areas of the process." (http://www.cdc.gov/niosh/topics/engcontrols/)

Engineering controls normally address the generation of substances as close to the source as possible. In some cases, it may be possible to re-engineer the process creating the exposure or simply plug holes in equipment where the substance is escaping. Properly designed local exhaust ventilation can also be very effective at controlling exposures. This control method can control contaminants by removing them prior to them reaching the worker's breathing zone. This is an effective means of control, because it does not require workers to change how the work is done.

Another engineering control method, referred to as general ventilation, reduces exposures by removing large volumes of air from the workplace after the contaminant becomes airborne and mixes with air throughout the workplace. This type of control can protect workers throughout the workplace, but may be less beneficial for workers located close to the source of the emissions.

The third form of ventilation relies on increasing the amount of air pumped into an area in an attempt to dilute the concentration of the contaminant. Both general and dilution ventilation have limitations, and are used primarily when toxicity of substances is low. General and dilution ventilation methods are not normally considered as cost effective as local exhaust, since significantly larger volumes of air are required to be moved in the workplace, as compared to local exhaust strategies.

Administrative controls are defined as strategies to reduce worker exposure by means that do not control the concentration of the contaminant in the air. These methods include:

- a warning system (monitoring equipment that warns workers when a certain concentration has been reached and an area must be evacuated)
- controlling areas where workers are allowed to enter (including control room)
- limiting the amount of time that workers are allowed to be in contaminated areas

These methods certainly have application in unique situations, but the rules must be enforced if this strategy is to be effective. The reality is that workers may need to enter or re-enter areas where they are exposed to toxic chemicals. Therefore, administrative controls are usually only an add-on to other control strategies.

Half-face filter (cartridge) respirator

Using personal protective equipment to control worker exposure (ex: NIOSH approved respirators) is viewed as the last resort for controlling worker exposure. This method should be used only when other means of controls are not practical, or as a temporary method of control. While this method is quite often costly and less effective at controlling exposures, it is unfortunately the method most often chosen as the first line of defence to reduce exposures in the workplace. Personal protective equipment (PPE) is acceptable in situations where the employer is in the process of introducing other, more effective, control measures or during emergencies.

Disposable, half-face particulate respirator

Full-face filter (cartridge) respirator

After assessing worker exposure risk and putting in place control measures that reduce exposures below the OEL, employers must confirm that control measures are effective. This can be accomplished by re-monitoring worker exposure to ensure that the original contaminant is being controlled.

TRAINING AND EDUCATION

Introduction

Training all workers to **spot a hazard** before there is any risk should be a primary goal in any workplace. The training program required for chemical and biological hazards must be workplace specific. While general WHMIS education will allow everyone who may come in contact with chemical or biological substances to recognize that a hazard exists, employers are also responsible to ensure that workers who are exposed, or may be exposed, receive more specific information related to the risks associated with using the various chemical or biological substances in the workplace.

The workers need to know how to handle, use, store and dispose of the materials they are working with safely, and where emissions may be produced. They need to know what effects exposure might have so they can protect themselves and others. They also need to be able to recognize when control measures are not functioning properly.

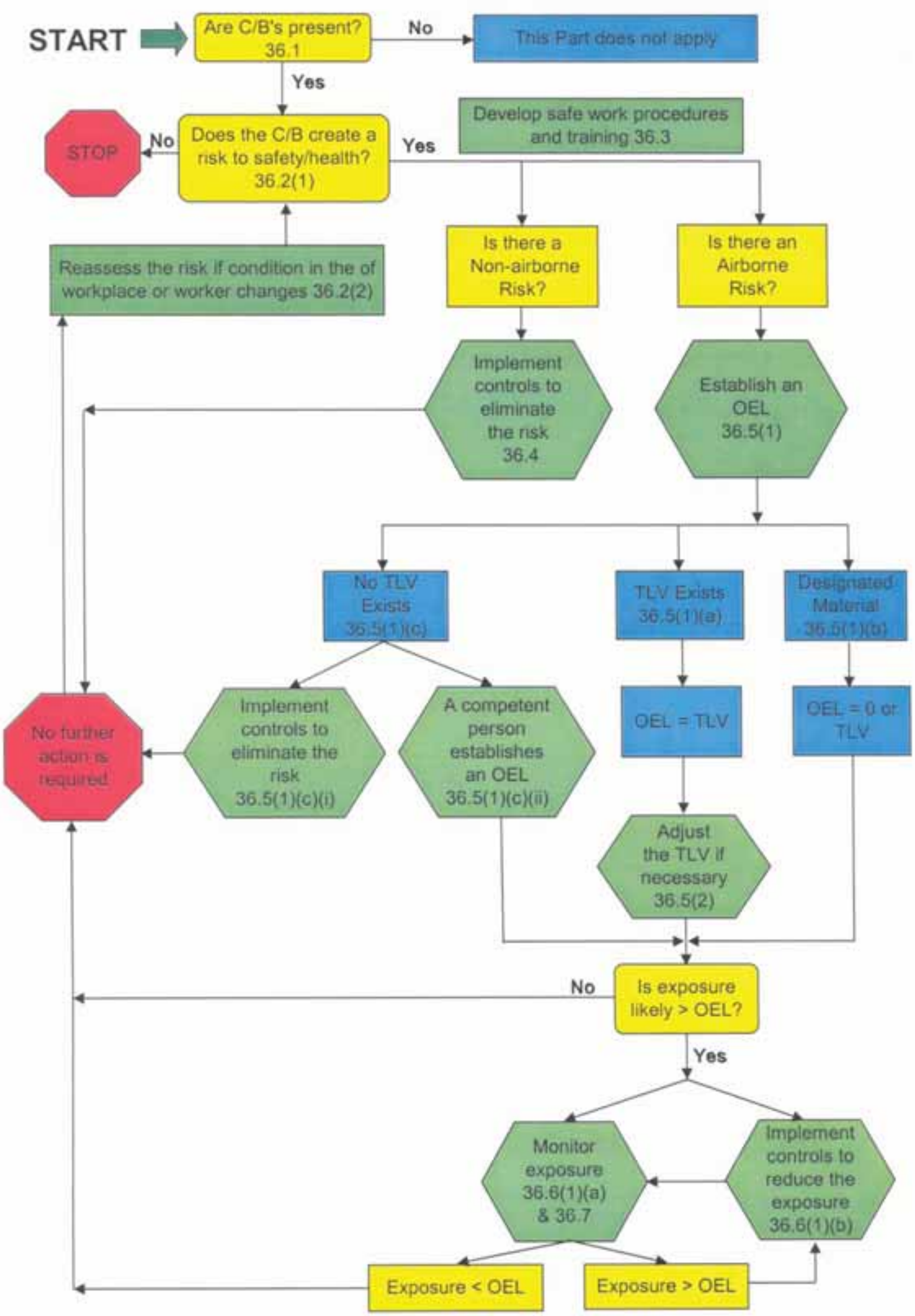
The training program must provide instruction about actions to be taken in the event of an emergency. An unexpected release or spill is one type of emergency that needs to be addressed. Training should also consider indirect emergencies and include the operation of safeguards that prevent issues from developing or worsening.

The training program in each workplace needs to be reviewed at least annually to ensure that directions given to the workers meet WHMIS specifications and all health and safety related matters regarding controlled products are included.

A worker who understands that a local exhaust system for a particular process should capture and remove fugitive emissions is in a better position to recognize and report when the system is not functioning effectively. A worker who understands the limitations of personal protective equipment is also less likely be overexposed because of ineffective equipment.

The training a worker receives from the employer must occur before that worker is placed at risk of exposure. As long as the worker is effectively trained, there is no requirement for additional training, unless there is a change in circumstances at the workplace.

Appendix 1 Flow Chart of Workplace Safety & Health Regulation – Part 36



Manitoba

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