



Labour Program: fair, safe and productive workplaces

CANADIAN

Occupational Chemical Agent Compliance

SAMPLING GUIDELINE



You can download this publication by going online
publicentre.esdc.gc.ca

This document is available on demand in multiple formats by contacting
1 800 O-Canada (1-800-622-6232), teletypewriter (TTY), 1-800-926-9105.

© Her Majesty the Queen in right of Canada, 2016

droitdauteur.copyright@HRSDC-RHDCC.gc.ca

PDF

Cat. No.: Em8-20/2016E-PDF

ISBN: 978-0-660-06196-2

ESDC

Cat. No.: LT-292-09-16E

CANADIAN

Occupational Chemical Agent Compliance

SAMPLING GUIDELINE

Prepared by

Matthew Ziembicki

ESDC Labour Program – Technical Services Unit

Eva Karpinski

ESDC Labour Program – Technical Services Unit

France de Repentigny

ESDC Labour Program – Regional Operations and Compliance Directorate Quebec Region

August 14, 2015

This Guideline is intended to help experts, such as industrial hygienists and other health and safety specialists, perform their duties related to the sampling of hazardous substances in federally regulated work places. This document supports the Labour Program's priority of keeping employers and employees safe in the work place, by helping to ensure compliance with federal labour legislation.

Table of Contents

1. Purpose	1
2. Scope	1
3. Issue	1
4. Background	1
5. Policy Intention	2
6. Definitions	3
Breathing Zone	3
Dermal Sensitization Notation (DSEN)	3
Excursion Limits (ELs)	3
Fibre per Cubic Centimetre (f/cc)	3
Geometric Mean (GM)	3
Geometric Standard Deviation (GSD)	4
Lower Confidence Limit (LCL)	4
Milligram per Cubic Metre (mg/m ³)	5
Occupational Exposure Limit (OEL)	5
Particle Size-Selective Sampling Criteria for Airborne Particulate Matter	5
Particles (insoluble or poorly soluble) not Otherwise Specified (PNOS)	6
Part per Million (ppm)	6
Respiratory Sensitization Notation (RSEN)	6
Skin Notation (Skin)	6
Threshold Limit Value – Ceiling (TLV-C)	6
Threshold Limit Value – Short-Term Exposure Limit (TLV-STEL)	6
Threshold Limit Value – Time-Weighted Average (TLV-TWA)	7
Threshold Limit Values (TLVs [®])	7
Upper Confidence Limit (UCL)	7
7. Procedures	7
7.1 Considerations for Conducting Sampling	7
Complaint or Work Refusal	7
Field Blanks	7
Lunch Break	8
Skin Notation and Sensitization Notation	8
Threshold Limit Values for Mixtures	8
Mixture Example	9

7.2 Sampling for a TWA Value Based on an 8-Hour Work Shift Exposure	9
Toluene Vapour	10
7.3 Sampling for STEL Values of a Hazardous Substance Based on 15-Minute Exposures	11
Hydrogen Sulfide (H ₂ S) gas	11
7.4 Sampling for a Ceiling Value (C) of a Hazardous Substance	12
Potassium Hydroxide (KOH) Aerosol	12
7.5 Sampling for Excursion Limits	13
Carbon Monoxide (CO) gas	13
Statistical Analysis of Hazardous Substance Air Sampling Results	14
Excursion Limits GSD Calculation Example for CO	14
7.6 Sampling for an Adjusted TLV	16
Flour Dust (inhalable) Exposure for a 12-hour Work Shift	16
IRSSST OEL-TWA Adjustment Method	18
Brief and Scala TLV-TWA adjustment method (alternate method)	18
7.7 Sampling and Analysis Quality Control Measures	18
8. References	20

1. Purpose

This guideline will help Labour Program (LP) industrial hygiene specialists, employers, and industrial hygiene consultants in interpreting the sampling requirement regulations and in taking samples for compliance with Part X of the *Canada Occupational Health and Safety Regulations (COHSR)*, “Hazardous Substances”.¹

2. Scope

This procedure should be used when measurements of airborne chemical concentrations in federally regulated work places are taken by a qualified person to verify compliance regarding worker exposure to a chemical agent as per the requirements in Part X of the COHSR “Hazardous Substances”. Following this procedure will ensure a uniform approach and yield consistent results.

3. Issue

How should personal air sampling be conducted in a work place for:

- TLV-TWA or OEL-TWA (8-hour)?*
- TLV-STEL or OEL-STEL (15-minute)?*
- TLV-C or OEL-C (peak concentration)?*

* See Section 6 for an explanation of these terms.

4. Background

Briefly, Part X of the COHSR requires:

- chemical sampling of work place air for the entire work shift;
- use of a National Institute for Occupational Safety and Health (NIOSH) method or any other scientifically proven method based on active sampling.

In addition, *Canada Labour Code*, Part II² requires an employee member of the work place health and safety committee or health and safety representative be present at least at the beginning of the compliance sampling.

5. Policy Intention

Subsection 10.19(1) of the COHSR states that:

- 10.19(1) An employee shall be kept free from exposure to a concentration of
(a) an airborne chemical agent in excess of the value for that chemical agent adopted by the American Conference of Governmental Industrial Hygienists, in its publication entitled Threshold Limit Values and Biological Exposure Indices, as amended from time to time.¹
- 10.19(3) Where there is a likelihood that the concentration of an airborne chemical agent may exceed the value referred to in subsection (1), air samples shall be taken and the concentration of the chemical agent shall be determined¹
(b) in accordance with the standards set out by the United States National Institute for Occupational Safety and Health in the NIOSH Manual of Analytical Methods, fourth edition, volumes 1 and 2, as amended from time to time;
(c) in accordance with a method that collects and analyses a representative sample of the chemical agent with accuracy and with detection levels at least equal to those which would be obtained if the standards referred to in paragraph (b) were used; or
(d) where no specific standards for the chemical agent are set out in the publications referred to in paragraph (b) and no method is available under paragraph (c), in accordance with a scientifically proven method used to collect and analyse a representative sample of the chemical agent.¹

While the following requirements are not yet contained in the regulations, it is strongly recommended that work place parties follow these guidelines:

- Where there is a likelihood that the concentration of an airborne chemical agent may exceed the value referred to in subsection 10.19(1), samples shall be taken to evaluate an employee's exposure to the airborne contaminant.
- Air samples shall be obtained from the breathing zone of the most highly exposed employees as determined by a qualified person.
- When sampling measurements are to be compared with a TLV-TWA or OEL-TWA, the airborne chemical agent shall be sampled over the full work shift.
- When sampling measurements are to be compared with a TLV-STEL or OEL-STEL, the airborne chemical agent shall be sampled for 15 minutes during the periods of maximum concentration as determined by a qualified person. A minimum of three samples shall be taken. If the airborne chemical agent is generated for a period of 45 minutes or less, consecutive 15-minute samples shall be taken for the entire duration of the work activity. The highest of all measurements shall be compared with the TLV-STEL or OEL-STEL.¹
- When sampling measurements are to be compared with a TLV-C or OEL-C, the airborne chemical agent shall be sampled instantaneously as determined by a qualified person. If instantaneous measurements are not available, sampling shall be conducted for the minimum period of time sufficient to detect exposures at or above the TLV-C or OEL-C.¹

6. Definitions

Breathing Zone

Breathing zone means a hemisphere of 300 mm radius extending in front of a person's face and measured from the midpoint of an imaginary line joining the ears.³

Dermal Sensitization Notation (DSEN)

Warns of an agent to produce dermal sensitization.⁴

Excursion Limits (ELs)

For many substances with a TLV-TWA, there is no TLV-STEL. Nevertheless, excursions above the TLV-TWA should be controlled, even where the 8-hour TLV-TWA is within recommended limits. Excursion limits apply to those TLV-TWAs that do not have TLV-STELs.⁴

Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded.⁴

It is often difficult to directly measure brief excursions that exceed 5 times the TLV-TWA. However, the geometric standard deviation (GSD) of short term exposures can be used to estimate excursion limit measurements. For example, if the true GSD of short-term exposures is three, then about 7% of all values will, in fact, exceed 5 times the geometric mean (GM). Refer to the ACGIH publications, Threshold Limit Values and Biological Exposure Indices and Modern Industrial Hygiene.⁵

Fibre per Cubic Centimetre (f/cc)

A measure of concentration of a fibrous substance in air. It describes the number of fibres per cubic centimetre (cc) of air.⁴

Geometric Mean (GM)

The measure of central tendency in a lognormal distribution is the antilog of the mean logarithm of the sample values. The distribution is skewed, and the geometric mean is always smaller than the arithmetic mean by an amount that depends on the geometric standard deviation.⁴

Geometric Standard Deviation (GSD)

A measure of the variability of the sample data. In the lognormal distribution, the GSD is the antilog of the standard deviation of the sample value logarithms, and 68.26% of all values lie between GM / GSD and $GM \times GSD$. A GSD of 1.0 occurs when the data points have no variability. GSDs of approximately 2.0 are common in workplaces. A GSD of 2.0 means that 5% of all values will exceed 3.13 times the geometric mean. A GSD greater than 2.0 is considered high variability and indicates inconsistent control of worker exposures.⁴

Lower Confidence Limit (LCL)

The LCL should be calculated when many measurements are taken at a work place for the purpose of an industrial hygiene monitoring program as part of the internal responsibility system. If a measured sampling value is slightly greater than its respective TLV or OEL, then the LCL should be calculated. If the LCL subtracted from the measured sampling value is still greater than the TLV or OEL, then there is non-compliance. Refer to the NIOSH publication, Occupational Exposure Sampling Strategy Manual for LCL formulas and example calculations.⁶

The NIOSH Occupational Exposure Sampling Strategy Manual is used to calculate the UCL and LCL of samples that are close to the TLV or OEL.⁶

When sampling for a full period, use the formulas below:⁶

X = full period sample value

STD = TWA-TLV or 8-hour OEL

x = transformed sample value

1.645 = 95% point (one-sided) of the normal distribution

(CV_T) = coefficient of variation for the sampling/analytical method as stated on the associated method

$$x = \frac{X}{STD}$$

$$UCL (95\%) = x + (1.645) \times (CV_T)$$

$$LCL (95\%) = x - (1.645) \times (CV_T)$$

If the $UCL (95\%) < 1$, then compliance exists at a 95% confidence level. This is the employer's test for compliance.

If the $LCL (95\%) < 1$ and the $UCL (95\%) > 1$, then non-compliance exists at a 95% confidence level.

If the $LCL (95\%) > 1$, then non-compliance exists at a 95% confidence level. This is the compliance officer's test for non-compliance.⁶

Example

Using alpha-chloroacetophenone (2-chloroacetophenone)⁶

$$X = 0.04 \text{ ppm}$$

$$\text{STD} = 0.05 \text{ ppm}$$

$$\text{CV}_T = 0.09$$

$$x = \frac{0.04 \text{ ppm}}{0.05 \text{ ppm}}$$

$$x = 0.8$$

Note: no LCL is required, since the value of x is below 1.0.

$$\text{UCL (95\%)} = 0.8 + (1.645) \times (0.09)$$

$$\text{UCL (95\%)} = 0.95$$

The UCL (95%) value of 0.95 is less than 1.0, so compliance exists at a 95% confidence level.⁶

Milligram per Cubic Metre (mg/m³)

A measure of concentration of a particulate substance in air. It is a mass per volume unit. The mass of the hazardous substance is measured in the metric unit of the milligram (mg), while the volume of work place air sampled is measured in the metric unit of the cubic metre (m³). 1 m³ = 1000 litres (L).³

Occupational Exposure Limit (OEL)

Labour Program regulatory limit for an airborne hazardous substance. The relevant OEL for a hazardous substance is to be used when specified instead of the corresponding ACGIH[®] TLV[®].

Particle Size-Selective Sampling Criteria for Airborne Particulate Matter

The Particle Size-Selective TLVs[®] (PSS-TLVs) are expressed in three forms:

1. Inhalable Particulate Matter TLVs[®] (IPM-TLVs) for those materials that are hazardous when deposited anywhere in the respiratory tract.
2. Thoracic Particulate Matter TLVs[®] (TPM-TLVs) for those materials that are hazardous when deposited anywhere within the lung airways and the gas-exchange region.
3. Respirable Particulate Matter TLVs[®] (RPM-TLVs) for those materials that are hazardous when deposited in the gas-exchange region.⁴

Particles (insoluble or poorly soluble) not Otherwise Specified (PNOS)

Particles that: Do not have an applicable TLV; are insoluble or poorly soluble in water (or, preferably, in aqueous lung fluid if data are available); and have low toxicity (i.e. are not cytotoxic, genotoxic, or otherwise chemically reactive with lung tissue, and do not emit ionizing radiation, cause immune sensitization, or cause toxic effects other than by inflammation or the mechanisms of “lung overload”).⁴

ACGIH® believes that even biologically inert, insoluble, or poorly soluble particles may have adverse effects and recommends that airborne concentrations should be kept below 3 mg/m³, respirable particles; and 10 mg/m³, inhalable particles, until such time as a TLV® is set for a particular substance.⁴

Part per Million (ppm)

A measure of concentration of a vapour or gas in air. It is a volume per volume unit. The unit ppm is an abbreviation of the term part per million.³

Respiratory Sensitization Notation (RSEN)

Warns of an agent to produce respiratory sensitization.⁴

Skin Notation (Skin)

The designation “Skin” in the “Notations” column refers to the potential significant contribution to the overall exposure by the cutaneous route, including mucous membranes and the eyes, by contact with vapors, liquids, and solids.⁴

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.⁴

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 8-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 will not necessarily protect against these effects if the daily TLV-TWA is exceeded.⁴

Threshold Limit Value – Time-Weighted Average (TLV-TWA)

The TWA concentration for a conventional 8-hour workday and 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.⁴

Threshold Limit Values (TLVs®)

A threshold limit value refers to an airborne concentration of a chemical substance 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. It is a health-based value. TLVs are determined at normal temperature and pressure (NTP).

Note: A correction factor shall be applied to sampled values taken at work place conditions that differ from NTP. Refer to the ACGIH publication, Threshold Limit Values and Biological Exposure Indices.⁴

Upper Confidence Limit (UCL)

The UCL should be calculated when many measurements are taken at a work place for the purpose of an industrial hygiene monitoring program as part of the internal responsibility system. If a measured sampling value is less than, but close to its respective TLV or OEL, then the UCL should be calculated. If the UCL added to the measured sampling value is still less than the TLV or OEL, then there is compliance. Refer to the NIOSH publication, Occupational Exposure Sampling Strategy Manual for UCL formulas and example calculations.⁶

7. Procedures

7.1 Considerations for Conducting Sampling

Complaint or Work Refusal

In the event of an occupational health and safety complaint from an employee or a work refusal from an employee, refer to the Labour publications:

- 3 – Internal complaint resolution process; and
- 4 – Right to refuse dangerous work.^{7,8}

Field Blanks

Follow the requirements and recommendations of the sampling method being used with regard to the number of field blanks. The field blanks must be the same in every way as the actual sampling media. The field blanks must also be handled in the same manner as the actual sampling media, but are not connected to a pump.

Lunch Break

The pump should be stopped during the lunch break and placed in a non-contaminated area and it must be assumed that the worker had no exposure to the substance being sampled for that time period.

Depending on the circumstances, a qualified person may decide to let the sampling pump continue to operate during the lunch break at the workstation of the worker being sampled. The worker shall then resume wearing the sampling pump after the lunch break.

Note: The status and location of the sampling pump during the lunch break must be recorded in the sampling report. An explanation of the circumstances of not sampling or sampling during the lunch break should be included in the interpretation of the sampling results.

Skin Notation and Sensitization Notation

When sampling for a hazardous substance that has a skin notation (Skin) as part of its TLV entry, extra consideration should be given to the dermal and ingestion routes of exposure.

When sampling for a hazardous substance that has a dermal sensitization notation (DSEN) or respiratory sensitization notation (RSEN) as part of its TLV entry, extra consideration should be given to further reducing worker exposures through control measures.⁴

Threshold Limit Values for Mixtures

Most threshold limit values are developed for a single chemical substance. However, the work environment is often composed of multiple chemical exposures both simultaneously and sequentially. It is recommended that multiple exposures that comprise such work environments be examined to assure that workers do not experience harmful effects.

There are several possible modes of chemical mixture interaction. Additivity occurs when the combined biologic effect of the components is equal to the sum of each of the agents given alone. Synergy occurs where the combined effect is greater than the sum of each agent. Antagonism occurs when the combined effect is less.⁴

The general ACGIH[®] mixture formula applies to the additive model. It is utilized when additional protection is needed to account for this combined effect. This guidance does not apply to substances in mixed phases.

The “TLV[®] Basis” column found in the table of Adopted Values lists the adverse effect(s) upon which the TLV[®] is based. This column is a resource that may help alert the reader to the additive possibilities in a chemical mixture and the need to reduce the combined TLV[®] of the individual components. Note that the column does not list the deleterious effects of the agent, but rather, lists only the adverse effect(s) upon which the threshold limit was based. The current Documentation of the TLVs[®] and BEIs[®] should be consulted for toxic effects information, which may be of use when assessing mixture exposures.⁴

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 is the same.

If the below inequality is true for a mixture of two or more hazardous substances with additive effects, then a worker overexposure has not occurred. In the below inequality, C is a measured concentration of a hazardous substance and T is the corresponding TLV or OEL.⁴

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n} < 1$$

Mixture Example

A mixture of two chemicals are presented below that both affect the central nervous system (CNS), since both chemicals have a “CNS impair” TLV Basis.⁴ The first chemical in this example is tetrachloroethylene and the second chemical is n-hexane. The average TWA measurement in an example work place and corresponding TLV-TWA are used for each chemical in the below inequality.

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n} < 1$$

$$\frac{16 \text{ ppm}}{25 \text{ ppm}} + \frac{24 \text{ ppm}}{50 \text{ ppm}} < 1$$

$$0.64 + 0.48 > 1$$

$$1.12 > 1$$

Even though the individual worker exposures to tetrachloroethylene and n-hexane are below their respective TLV-TWAs, they combine to cause an overexposure to the CNS. Efforts should be made to reduce worker exposure to these two chemicals through engineering controls.

7.2 Sampling for a TWA Value Based on an 8-Hour Work Shift Exposure

The entire 8-hour work day must be sampled. To verify compliance, the worst case exposed workers should be sampled. The obtained results must be compared to the corresponding TLV-TWA or OEL-TWA.

Note: To conduct industrial hygiene sampling for other purposes such as identifying trends, estimating the size of an exposure problem, identifying specific targets for exposure prevention strategies, work place prevention programs, occupational disease surveillance programs, or research, refer to the NIOSH publication, Occupational Exposure Sampling Strategy Manual.⁶

Examples

Toluene Vapour

2015 ACGIH TLV-TWA: 20 ppm

NIOSH method 1501 was used¹⁰

Equipment: glass tube (7 cm long, 6-mm OD, 4-mm ID, flame-sealed ends, containing two sections of activated coconut shell charcoal (front = 100 mg, back = 50 mg) separated by a 2-mm urethane foam plug. A silylated glass wool plug precedes the front section and a 3-mm urethane foam plug follows the back section. Tubes are commercially available).

Personal air sampling pump with flexible connecting tubing.¹⁰

Three consecutive 160-minute samples were taken over the entire 8-hour work shift of 9:00 to 17:00 (9 am to 5 pm). All three samples used a flow rate of 0.04 L/min in order to remain within the required volume range of the method for toluene sampling. 6.4 L of air were passed through each sample media, which is within the 1 L to 8 L volume range.

All the samples were sent to a laboratory for analysis. The results obtained are as follows:

- **Sample 1** (9:00–11:40):
20 ppm average toluene concentration sampled in 6.4 L (0.0064 m³) of air
- **Sample 2** (11:40–14:20):
10 ppm average toluene concentration sampled in 6.4 L (0.0064 m³) of air
- **Sample 3** (14:20–17:00):
37 ppm average toluene concentration sampled in 6.4 L (0.0064 m³) of air

In order to calculate worker exposure to toluene vapour during the entire work shift, the following equation must be used:

$$TWA = \frac{\sum c_i t_i}{\sum t_i}$$

Calculation of TWA based on the lab results:

$$TWA_8 = \frac{(20 \text{ ppm} \times 160 \text{ min}) + (10 \times 160) + (37 \times 160)}{480 \text{ min}}$$

$$TWA_8 = \frac{(3200 + 1600 + 5920) \text{ ppm} \times \text{min}}{480 \text{ min}}$$

$$TWA_8 = 22.3 \text{ ppm}$$

The measured TWA of 22.3 ppm is greater than the TLV-TWA_{toluene} of 20 ppm. Therefore, the sampling results indicate a worker overexposure and non-compliance in this case.

7.3 Sampling for STEL Values of a Hazardous Substance Based on 15-Minute Exposures

Some substances that have a TLV-TWA also have a TLV-STEL, which is a 15-minute TWA exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the TLV-TWA. It is possible for the TLV-TWA of a chemical to not be exceeded, but the corresponding TLV-STEL may be exceeded during the same time as the TWA measurements. A minimum of 3 samples of 15 minutes in duration must be sampled at the peak exposure of the chemical of interest. The worst case exposed workers shall be sampled. The measured values shall be directly compared to the corresponding TLV-STEL or OEL-STEL.⁴

Example

Hydrogen Sulfide (H₂S) gas

2015 ACGIH TLV-STEL: 5 ppm

NIOSH method 6013 was used¹¹

Equipment: Sampler: glass tube, 10 cm long, 8-mm OD, 6-mm ID, flame-sealed ends with plastic caps, containing 20/40 mesh activated (600°C) coconut shell charcoal (front = 400 mg, back = 200 mg) separated by a 6-mm urethane foam plug. A silyated glass wool plug precedes the front section and a 6-mm urethane foam plug follows the back section. Pressure drop across the tube at 1 L/min airflow must be less than 3.4 kPa. Tubes are commercially available. Zefluor PTFE pre-filter, 0.45-µm, 25-mm, with porous plastic support pad in 25-mm cassette.

Note: Some lots of charcoal have excessively high sulfur backgrounds, and/or desorption efficiencies. Screen each lot before field use.

Personal air sampling pump with flexible connecting tubing.¹¹

Four 15-minute samples were taken during the work shift.

A STEL sampling procedure was conducted. According to NIOSH method 6013, a pump flow rate of 1 L/min should be used for 15-minute samples. The STEL samples should be taken at the breathing zone of the worst case exposed worker during a task when excessive hydrogen sulfide is released into the work place air.

The following lab results were obtained:

- **Sample 1:**
4.3 ppm average hydrogen sulfide concentration sampled in 15 L (0.015 m³)
- **Sample 2:**
4.6 ppm average hydrogen sulfide concentration sampled in 15 L (0.015 m³)
- **Sample 3:**
2.4 ppm average hydrogen sulfide concentration sampled in 15 L (0.015 m³)
- **Sample 4:**
1.4 ppm average hydrogen sulfide concentration sampled in 15 L (0.015 m³)

Do not average the STEL measurements. Compare each STEL measurement to the TLV-STEL for compliance.

The greatest measured 15-minute STEL of 4.6 ppm is less than the TLV-STEL_{hydrogen sulfide} of 5 ppm. Therefore, the sampling results do not indicate a worker overexposure and compliance exists in this case. Since the value exceeds the action level (50% of the TLV), it is recommended to lower worker exposures to H₂S through engineering control measures over 15-minute intervals.

7.4 Sampling for a Ceiling Value (C) of a Hazardous Substance

A ceiling value is the concentration that should not be exceeded during any part of the workday. Substances that have a C value, do not have a TLV-TWA or TLV-STEL.⁴ A direct reading instrument (DRI) with data logging capabilities should be used if reasonably practicable. The worst case exposed worker will be sampled. 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.

Example

Potassium Hydroxide (KOH) Aerosol

2015 ACGIH TLV-C: 2 mg/m³

NIOSH method 7401 was used¹²

Equipment: 37-mm diameter PTFE membrane filter (Millipore, Fluoropore or equivalent), 1.0- μ m pore size, supported by a cellulose backup pad in a 37 mm closed face cassette (CFC) filter holder.

Personal air sampling pump with flexible connecting tubing.¹²

Four 20-minute samples were taken during the work shift because a direct reading instrument (DRI) measuring KOH is not available. A C sampling procedure was conducted. According to NIOSH method 7401, a pump flow rate of 4 L/min should be used for 20-minute samples. The maximum flow rate of 4 L/min for 20 minutes is necessary to exceed the minimum required sampling volume of 70 L. The C value samples should be taken at the breathing zone of the worst case exposed worker during a task when excessive potassium hydroxide is released into the work place air.

The following lab results were obtained:

- **Sample 1:**
0.09 mg potassium hydroxide in 80 L (0.08 m³) of air
 $0.09 \text{ mg} / 0.08 \text{ m}^3 = 1.125 \text{ mg/m}^3$
- **Sample 2:**
0.1 mg potassium hydroxide in 80 L (0.08 m³) of air
 $0.1 \text{ mg} / 0.08 \text{ m}^3 = 1.25 \text{ mg/m}^3$

- **Sample 3:**
0.03 mg potassium hydroxide in 80 L (0.08 m³) of air
 $0.03 \text{ mg} / 0.08 \text{ m}^3 = 0.375 \text{ mg/m}^3$
- **Sample 4:**
0.04 mg potassium hydroxide in 80 L (0.08 m³) of air
 $0.04 \text{ mg} / 0.08 \text{ m}^3 = 0.5 \text{ mg/m}^3$

Do not average the C measurements. Compare each C measurement to the TLV-C for compliance.

The greatest measured C of 1.25 mg/m³ is less than the TLV-C_{potassium hydroxide} of 2 mg/m³. Therefore, the sampling results do not indicate a worker overexposure and compliance exists in this case.

7.5 Sampling for Excursion Limits

The worst case exposed workers are to be sampled. Sample for excursion limits when the measured TWA value is not exceeded and a TLV-STEL does not exist.

Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded.⁴

Example

Carbon Monoxide (CO) gas

2015 ACGIH TLV-TWA: 25 ppm

NIOSH method 6604 was used¹³

Equipment: Carbon monoxide monitor: Envirocheck I single sensor CO Monitor (Quest Technologies); CO262 or STX70 (Industrial Scientific); MiniCO (MSA); or other electrochemical CO monitor with equivalent performance specifications.

Replacement batteries or battery recharger, as appropriate for monitor.¹³

Four 15-minute samples were taken during the work shift.

A short term exposure sampling procedure was conducted. According to NIOSH method 6604, a portable direct reading carbon monoxide monitor should be used for 15-minute samples. The 15-minute samples should be taken at the breathing zone of the worst case exposed worker during a task when excessive carbon monoxide is released into the work place air.

The following lab results were obtained:

- **Sample 1:**
19 ppm average carbon monoxide concentration sampled over 15 minutes
- **Sample 2:**
138 ppm average carbon monoxide concentration sampled over 15 minutes
- **Sample 3:**
104 ppm average carbon monoxide concentration sampled over 15 minutes
- **Sample 4:**
80 ppm average carbon monoxide concentration sampled over 15 minutes

Excursion limit analysis:

- The greatest measured STEL value is 138 ppm, which is more than 5 times the TLV-TWA of 25 ppm. Three of the measured STEL values exceed the excursion limit of 3 times the TLV-TWA for 30 minutes. Therefore, it appears that the sampling results indicate a worker overexposure and non-compliance in this case.

Statistical Analysis of Hazardous Substance Air Sampling Results

Excursion Limits GSD Calculation Example for CO

Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded.⁴

- **Sample 1:**
19 ppm average carbon monoxide concentration sampled over 15 minutes
- **Sample 2:**
138 ppm average carbon monoxide concentration sampled over 15 minutes
- **Sample 3:**
104 ppm average carbon monoxide concentration sampled over 15 minutes
- **Sample 4:**
80 ppm average carbon monoxide concentration sampled over 15 minutes

It is necessary to calculate the GSD of measured 15-minute sample values from similarly exposed workers to gain a better understanding of the variations of worker exposure to hazardous substances. The Microsoft® Excel-based software program [New IHSTAT](#) developed by the American Industrial Hygiene Association (AIHA) was used to calculate the GM, GSD, and other descriptive statistics of the above CO excursion limit data, which can be seen in Figure 1 and Figure 2.¹⁴

Figure 1
CO STEL Measurements Analyzed with New IHSTAT¹⁴

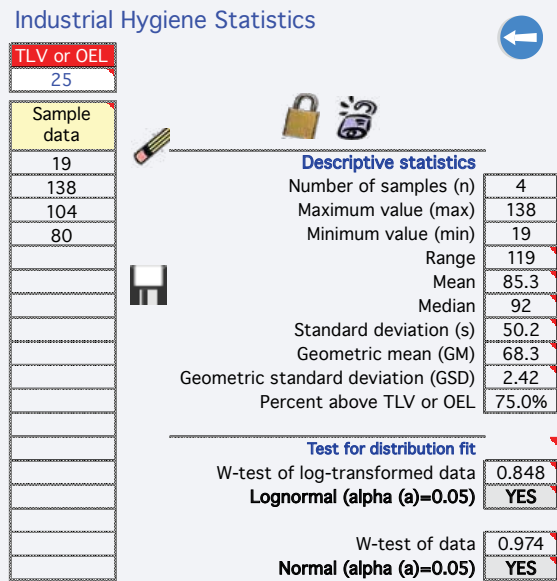
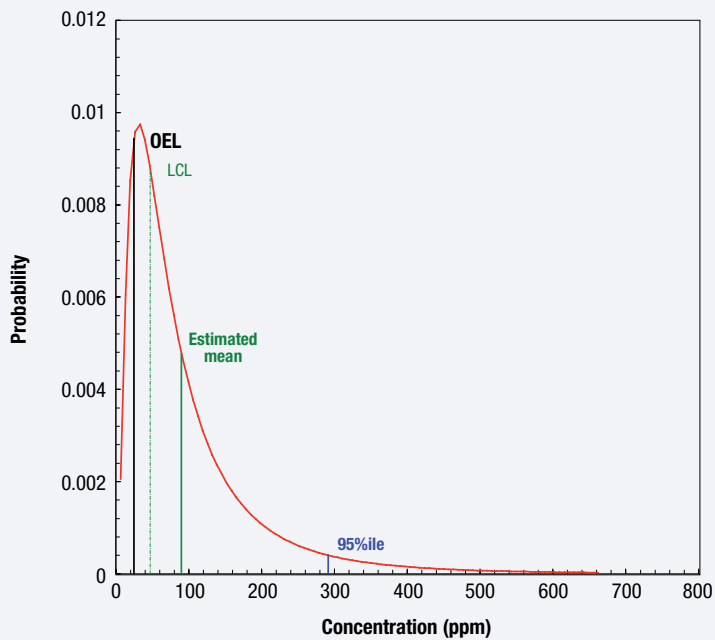


Figure 2
Idealized Lognormal Distribution of CO STEL Measurements from New IHSTAT¹⁴



The CO excursion limit data points are normally distributed because the value of the *W*-test of the data is greater than the *W*-test of the log-transformed data. The GSD is greater than 2.0, thus the relatively high CO variability indicates that the work process emitting CO is not under good control and efforts should be made to restore control. Improving engineering control measures will reduce the worker exposure and exposure variability, and thus reduce the GSD. However, it is recognized that the geometric standard deviations of some common workplace exposures may exceed 2.0. If such distributions are known and workers are not at increased risk of adverse health effects, recommended excursion limits should be modified based upon workplace-specific data. When the toxicological data for a specific substance are available to establish a TLV-STEL or TLV-C, these values take precedence over the excursion limit.⁴

7.6 Sampling for an Adjusted TLV

The entire work day must be sampled. The worst case exposed worker is sampled.

Example

The TLV-TWA or OEL-TWA must be adjusted so that the measured air concentration can be properly compared to the limit. Use the Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) method to adjust the TLV-TWA or OEL-TWA.

Flour Dust (inhalable) Exposure for a 12-hour Work Shift

2015 ACGIH TLV-TWA: 0.5 mg/m³

OEL-TWA: 3.0 mg/m³

IRSST method No. 373 was used¹⁵

Equipment: 25-mm 5 µm pore size PVC filter supported by an Institute of Occupational Medicine (IOM) inhalable dust sampler or equivalent.

Personal air sampling pump with flexible tubing.^{15,16}

Note: The same method and example apply to the TLV-TWA of 0.5 mg/m³.

Four consecutive 180-minute samples were taken over the entire 12-hour work shift of 7:00 to 19:00 (7 am to 7 pm). All four samples used a flow rate of 2 L/min as required in the method. 360 L of air were passed through each sample media, which is below the 400 L sampled volume stated in the method.

All the samples were sent to a laboratory for analysis. The results obtained are as follows:

- **Sample 1** (7:00–10:00):
0.9 mg flour dust in 360 L (0.36 m³) of air
0.9 mg / 0.36 m³ = 2.5 mg/m³
- **Sample 2** (10:00–13:00):
0.8 mg flour dust in 360 L (0.36 m³) of air
0.8 mg / 0.36 m³ = 2.22 mg/m³
- **Sample 3** (13:00–16:00):
1.2 mg flour dust in 360 L (0.36 m³) of air
1.2 mg / 0.36 m³ = 3.33 mg/m³
- **Sample 4** (16:00–19:00):
1.1 mg flour dust in 360 L (0.36 m³) of air
1.1 mg / 0.36 m³ = 3.06 mg/m³

In order to calculate 12-hour worker exposure to flour dust (inhalable) during the entire work shift, the following equation must be used:

$$TWA = \frac{\sum c_i t_i}{\sum t_i}$$

Calculation of TWA_{12h} based on the lab results:

$$TWA_{12} = \frac{(2.5 \text{ mg/m}^3 \times 180 \text{ min}) + (2.2 \times 180) + (3.33 \times 180) + (3.06 \times 180)}{720 \text{ min}}$$

$$TWA_{12} = \frac{(450 + 396 + 599.4 + 550.8) \text{ mg/m}^3 \times \text{min}}{720 \text{ min}}$$

$$TWA_{12} = 2.77 \text{ mg/m}^3$$

The measured TWA₁₂ of 2.77 mg/m³ is less than the unadjusted 8-hour OEL-TWA_{flour dust} of 3.0 mg/m³. Therefore, it appears that the samples do not indicate a worker overexposure and compliance exists; however the flour dust OEL-TWA must be adjusted to be properly compared to the data acquired from the 12-hour shift. As well, the measured TWA₁₂ of 2.77 mg/m³ is greater than the unadjusted TLV-TWA_{flour dust} of 0.5 mg/m³. Using this limit, a worker overexposure and non-compliance exists. An adjustment of the TLV-TWA_{flour dust} is not needed, since an overexposure is already demonstrated.

IRSST OEL-TWA Adjustment Method

Flour dust is a category III substance due to its long-term ill effects on health. Category III substances require a weekly adjustment to the OEL-TWA based on the average exposure duration in hours per week based on a repetitive work cycle.¹⁷

In this case, the work schedule for the sampled employee is 12h/day for 5 days per week. This gives 60h/week and an adjustment factor of 40/60 or 0.67.

The OEL-TWA_{flour dust} of 3.0 mg/m³ multiplied by the adjustment factor of 0.67 gives an adjusted 12-hour OEL-TWA_{flour dust} of 2.0 mg/m³.

Brief and Scala TLV-TWA adjustment method³ (alternate method)

$$\text{OEL-TWA}_h = \text{OEL-TWA}_8 \times (8/h) \times (24-h)/16$$

Where h = length of unusual shift in hours

$$\text{OEL-TWA}_{12} = 3 \text{ mg/m}^3 \times (8/12) \times [(24-12)/16]$$

$$\text{OEL-TWA}_{12} = 3 \text{ mg/m}^3 \times 0.67 \times 0.75$$

$$\text{OEL-TWA}_{12} = 1.5 \text{ mg/m}^3$$

The measured OEL-TWA₁₂ of 2.77 mg/m³ is greater than the IRSST 12-hour adjusted OEL-TWA_{flour dust} of 2.0 mg/m³ and the Brief and Scala 12-hour adjusted OEL-TWA_{flour dust} of 1.5 mg/m³. Therefore, the sampling results indicate a worker overexposure and non-compliance in this case.

7.7 Sampling and Analysis Quality Control Measures

The IRSST or any other lab accredited by the AIHA Laboratory Accreditation Programs (LAP), LLC should be used to analyze the collected sample media. The lab should be accredited for the chemical that they will analyze. The most recent version of the NIOSH method or other sampling and analysis method for the chemical of interest should be used.

The sampling strategy used and conditions in the workplace should be consistent with the sampling strategy used and conditions in the past and with sampling strategies used in the future. This consistency is needed so that the air sampling data collected at a certain work place can be legitimately compared to past and future air sampling data.

Required compliance sampling strategy:

- Sample the breathing zone of the most highly exposed worker(s)

Work place conditions that shall be considered during compliance sampling:

- Day of week
- Month of year (due to the effect of different seasons on work conditions)
- Temperature and pressure
- Workload
- Type of shift (day or night)

8. References

- 1 *Canada Occupational Health and Safety Regulations*. 2014. SOR/86-304.
- 2 *Canada Labour Code*. 2015. RCS/85-L2.
- 3 Dumschat CJ, Whiting RF, Callaghan JM. "The material safety data sheet: An explanation of common terms." 1988. CCOHS. CCOHS Number P88-9E.
- 4 ACGIH. "Threshold Limit Values and Biological Exposure Indices." 2015. ACGIH.
- 5 Perkins JL. *Modern Industrial Hygiene: Recognition and Evaluation of Chemical Agents*. 2008. ACGIH: Volume 1, 2nd Edition.
- 6 Leidel NA, Busch KA, Lynch JR. "Occupational exposure sampling strategy manual." 1977. NIOSH. DHEW (NIOSH) Publication Number 77-173.
- 7 Labour Program. "Information on occupational health and safety: 3 – Internal complaint resolution process" 2010. http://www.labour.gc.ca/eng/health_safety/pubs_hs/resolution.shtml. 30 June 2015.
- 8 Labour Program. "Information on occupational health and safety: 4 – Right to refuse dangerous work." 2014. http://www.labour.gc.ca/eng/health_safety/pubs_hs/refuse.shtml. 8 June 2015.
- 9 Clere J, Hearl F. "Method 0500: particulates not otherwise regulated, total." NIOSH Manual of Analytical Methods. 1994. 4th edition. Issue 2.
- 10 Pendergrass SM. "Method 1501: hydrocarbons, aromatic." NIOSH Manual of Analytical Methods. 2003. 4th edition. Issue 3.
- 11 Cassinelli ME. "Method 6013: hydrogen sulfide." NIOSH Manual of Analytical Methods. 1994. 4th edition. Issue 1.
- 12 Cassinelli ME. "Method 7401: alkaline dusts." NIOSH Manual of Analytical Methods. 1994. 4th edition. Issue 2.
- 13 Woodfin WJ. "Method 6604: carbon monoxide." NIOSH Manual of Analytical Methods. 1996. 4th edition. Issue 1.
- 14 AIHA Exposure Assessment Strategies Committee. "Exposure Assessment Strategies Committee." New IHSTAT (EASC-IHSTAT-V235). <https://www.aiha.org/get-involved/VolunteerGroups/Pages/Exposure-Assessment-Strategies-Committee.aspx/>. 28 May 2015.
- 15 Drolet D, Beauchamp G. "T-15: Sampling guide for air contaminants in the workplace." 2013. 8th edition. Version 8.1. IRSST: 1-152.
- 16 Karpinski EA. "Exposure to inhalable flour dust in Canadian flour mills." 2003. *App. Occ. Env. Hygiene* 18: 1022-1030.
- 17 Drolet D. "Guide for the adjustment of permissible exposure values (PEVs) for unusual work schedules." 2008. 3rd edition IRSST: 1-17.