Section II
(previously Section I of Oregon OSHA’s Technical Manual)

SAMPLING, MEASUREMENTS
METHODS and INSTRUMENTS

CHAPTER 1: PERSONAL SAMPLING FOR AIR CONTAMINANTS

CHAPTER 2: OCCUPATIONAL SKIN EXPOSURE

CHAPTER 3: TECHNICAL EQUIPMENT: ON-SITE MEASUREMENTS

CHAPTER 4: SAMPLE SHIPPING AND HANDLING

All information within this section and chapter has been reproduced from the Oregon OSHA Technical Manual (circa 1996) unless otherwise stated within the “Chapter Revision Information”, located at the beginning of each chapter.
SECTION II: CHAPTER 1

PERSONAL SAMPLING FOR AIR CONTAMINANTS

**Chapter Revision Information:**

- This chapter was previously identified as Section 1, Chapter 1 in Oregon OSHA’s circa 1996 *Technical Manual*. The Section number was modified from Section I to Section II in November 2014 to provide uniformity with the Federal OSHA Technical Manual (OTM).

- In December 2014, the original “Personal Sampling for Air Contaminants” chapter was replaced by Federal OSHA’s February 11th, 2014 update “Personal Sampling for Air Contaminants”.

- In December 2014, Federal OSHA’s February 11th, 2014 Technical Manual update “Personal Sampling for Air Contaminants” was customized to make the document’s instructions specific to Oregon OSHA’s sampling equipment, laboratory and state specific regulations.

- In December 2014, several references to Federal OSHA CPL’s, Directives, and Field Operations Manual (FOM) were revised when appropriate to reflect Oregon OSHA’s Field Inspection Reference Manual (FIRM).
SECTION II: CHAPTER 1
PERSONAL SAMPLING FOR AIR CONTAMINANTS

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I. Introduction

This chapter provides basic information related to sampling air contaminants. Other reference resources are OR-OSHA Lab Sampling Procedures and the Oregon OSHA Field Inspection Reference Manual Field Inspection Reference Manual (FIRM). Sampling and analytical methods that have been validated by either OSHA or the National Institute for Occupational Safety and Health (NIOSH) should be used whenever possible. Sometimes the Oregon OSHA Laboratory will approve the use of procedures developed by other organizations. Only procedures approved by the Oregon OSHA Laboratory should be used. The use of sampling methods not approved by the Oregon OSHA Laboratory may require resampling with an approved sampling procedure. The Oregon OSHA Laboratory is aware that unique sampling situations will arise during some inspections and it is essential that OSHA Compliance Safety and Health Officers (CSHOs) contact, and work closely with, the Oregon OSHA Laboratory whenever questions arise.

Sampling strategies should be planned for a meaningful evaluation of air contaminants and prudent use of limited resources. Screening techniques and devices, such as detector tubes and direct-reading meters, may provide valuable information when their use and their detection limits are appropriate (see Section II: Chapter 3 Technical Equipment: On-Site Measurements). Knowledge of sampling procedures, including sampling media, recommended air volumes, and sample storage precautions, are essential in planning proper sampling strategies.

Bulk samples are sometimes necessary to support analyses of air samples, to document the source of air contaminants or to identify additional hazards. For example, in conjunction with air sampling for organic dusts, it may also be useful to collect bulk samples for analysis of combustibility and explosibility to identify additional safety hazards; or when air sampling for asbestos, it may also be useful to collect one or more bulk samples of suspect building materials to identify the source(s) of airborne fibers if this is not otherwise evident at the work site. Bulk samples are sometimes used in Hazard Communication inspections (i.e., Safety Data Sheet compliance). Consult the Oregon OSHA Laboratory to determine when bulk samples are appropriate. Bulk samples often require special shipping and handling.

Ensure that appropriate sample shipping and handling requirements are followed and that the mode of shipment is appropriate for the requested analytical service. For example, “Rush Analysis” requires sample shipment with overnight delivery. If samples are for “Rush Analysis,” then concurrence by the Oregon OSHA Laboratory Manager is required. Follow all chain-of-custody protocols. Apply tamper-evident seals (Oregon OSHA Lab seal Form 440-1316) to each sample as shown in Appendix G, and ensure that the chain-of-custody information is not obstructed by the seal. Make certain that samples are properly documented using the sampling worksheet (Report – LIM8035), which is accessed through the Laboratory Information Management System (LIMS).
II. Pre-inspection Activities

A. Review Background Information


As part of the pre-inspection review, determine whether sampling may be required (and then verify during the on-site walk-around). Also during the pre-inspection review, determine whether exposure to more than one chemical may occur. Refer to OR-OSHA Lab Sampling Procedures for the required sampling media, minimum and maximum sampling volume and flow rate, potential interferences, and handling requirements for individual chemical substances. Contact the Oregon OSHA Laboratory for further guidance if necessary.

To determine whether there are special handling or shipping requirements prior to sample collection, refer to OSHA’s OR-OSHA Lab Sampling Procedures. For example, some types of samples need to be shipped back quickly and/or in a cooler with cold packs. Sampling media for isocyanates need to be stored refrigerated and protected from light until used.

B. Obtain Sampling Media, Equipment and Supplies

The Oregon OSHA Laboratory provides sampling media, supplies and equipment. The following are some of the sampling supplies that may be obtained:

- Draeger Chip Measurement System (CMS) chemical sensing chips
- Detector tubes
- Filter cassettes
- IOM samplers
- Ghost wipes
- Sorbent tubes, such as charcoal tubes
- Tube holders, tube openers, collar clips and manifolds
- Cyclones
- Tygon tubing
- Lab seals (Form 440-1316)
- Sealing tape
- Calibration gas and accessories
- Sample containers
- Whirl-Pak® sample bags
- Ventilation smoke tubes

CSHOs may place an order for expendable supplies through the Oregon OSHA Laboratory via email or phone. If needed supplies are not in stock or specialized media is requested, it can be ordered by the Oregon OSHA Laboratory.

Over 40 types of specialized monitoring and other equipment are available from the Oregon OSHA Laboratory. The equipment includes items such as air velocity meters for ventilation assessment, dust and aerosol monitors, multi-gas detectors, indoor air quality meters, air
sampling pumps and calibrators, and photoionization detectors (PID). Equipment can be shipped overnight if the need is urgent.

A list of typical sampling equipment available may be found at the following link: Oregon OSHA Sample Equipment. Orders for technical equipment may be made through the same email or phone numbers used for expendable supplies.

The Oregon OSHA Laboratory provides pre-weighed filter/cassette units for gravimetric sampling and analysis. Gravimetric filters are weighed at the Oregon OSHA Laboratory and shipped to the field assembled in special cassettes to be used for sampling. The cassette/filter units are returned to the Oregon OSHA Laboratory after sampling for gravimetric determinations and for other analyses. See Appendix A for a discussion of pre-weighed filters. Refer to OSHA's OR-OSHA Lab Sampling Procedures file or to Appendix B for a list of substances for gravimetric determination. CSHOs may order sampling media via email or phone.

C. Preparing Personal Air Sampling Equipment

1. Active Sampling

- Ensure sampling pump batteries are fully charged. Battery care is discussed in Section II: Chapter 3 (Technical Equipment: On-Site Measurements). Also, refer to the pump manual for specific battery care guidance.

- Calibrate personal sampling pumps before and after each day of sampling as described in Appendix F. Disconnect the pump from the charger before calibration. Use the same specific type of sample media in line that will be used for sampling in the field (e.g., filter, sorbent tube); but do not use the actual media used for calibration for field sampling. Where more than one pump will be used in the field, label the pumps to avoid mix-up.

- Calibrate sampling pumps at the temperature and pressure (altitude) at which samples will be collected. If site conditions are substantially above or below room temperature, calibrate the pumps in a clean area at the site, if possible. Give the pump and calibrator electronics time to equilibrate to the temperature conditions at the site. If not possible, refer to manufacturer’s guidance in the equipment manual for temperature corrections and contact the Oregon OSHA Laboratory as needed. If sampling will be performed at temperatures below 41°F, check the temperature operating range in the calibrator equipment manual before going to the site, and contact the Oregon OSHA Laboratory as needed.

- To avoid sample mix-up, each sample (i.e., cassette, sorbent tube, impinger media) must be labeled with a unique sample number. Either label each sampler before use, or prepare the lab seals beforehand by writing in the sample numbers, and then affixing a lab seal immediately after removing the sampling device from the pump after post-calibration. Lab seals are shown in Appendix G. Note that preweighed gravimetric filters have assigned lab numbers that can be used for sample identification. A blank media sample
needs to be submitted with each set of samples. It must be from the same batch/lot as was used for sampling. More than one blank media sample per set may be necessary.

- Record presampling calibration data (such as pump serial number and flow rate) and the temperature and pressure of the calibration location using the OSHA Technical Information System (OTIS) sampling worksheet. This will also serve as the source of information for data entry into the LIMS (Laboratory Information Management System) for samples requiring analysis by the Oregon OSHA Laboratory.

2. Diffusive (Passive) Sampling

- Diffusive samplers are convenient air sampling devices that sample gases and vapors and do not require the use of a sampling pump. They are discussed further in Section III.N.2, of this chapter. The Oregon OSHA Laboratory currently does not promote the use of diffusive samplers but may be able to facilitate their use if necessary.
III. On-Site Inspection Activities

A. Develop Documentation

- Document accurate and complete sampling pump calibration records and field sampling notes using the OSHA Technical Information System (OTIS) air sampling worksheet.
  
  - Ensure accurate and consistent spelling of the inspected establishment name in order to facilitate future database searches.
  
  - Refer to the Integrated Management Information System (IMIS) Enforcement Data Processing Manual for detailed sample submission instructions.

- Take photographs and/or videos (as appropriate) and detailed notes concerning sources of airborne contaminants, work practices, potential chemical interferences, movement of employees around the workplace during the performance of their duties, engineering and administrative controls, the use of personal protective equipment (PPE), and other factors to assist in evaluating employee exposures.

- Ventilation and/or smoke tube measurements may be helpful in assessing engineering controls, as described in Chapter 3: Section IV.

Be certain to observe whether the employee wore the sampling equipment properly. This is sometimes an important issue in litigation. Refer to Oregon OSHA Field Inspection Reference Manual Field Inspection Reference Manual (FIRM) for a more thorough discussion of inspection documentation procedures.

B. Sampling Strategy and Protocol

As part of the walkthrough, identify the:

- Processes/operations being run
- Tasks performed
- Materials used/materials employees are exposed to
- Work practices used
- Exposure controls in place and how effective they appear to be

Evaluate the chemicals being used. Consider the approximate quantities and utilization rates. For liquids, consider indicators of volatility (e.g., boiling point and vapor pressure). Consider whether handling practices and engineering controls are being used that would increase or decrease exposure. Determine whether exposure is likely to occur as a vapor or an aerosol.

Sample those individuals likely to have the highest workplace exposures (i.e., highest-risk employees) due to the materials and processes with which they work, the conditions in which they work (e.g., distance to exposure source and air movement), the tasks they perform, the frequency of the tasks, and the way in which they perform the tasks (e.g., work habits and
employee mobility). For example, in a welding shop, the tall welder who leans over his work may have higher exposures than a shorter welder who is not leaning into the rising plume.

Determine if employees are exposed to more than one chemical, either simultaneously or sequentially. This topic is discussed in Section III.G., Chemical Mixtures.

Determine as soon as possible after the start of the inspection whether air contaminant sampling is required by using the information collected during the walk-around (including any screening samples, such as detector tube results) and from the pre-inspection review. To eliminate errors associated with fluctuations in exposure, conduct representative full-shift sampling for air contaminants when determining compliance with an 8-hour time-weighted average (TWA) permissible exposure limit (PEL). Full-shift sampling is defined as a minimum of the total time of the work shift less one hour (e.g., seven hours of an 8-hour work shift or nine hours of a ten-hour work shift). Make every attempt to sample as much of the work shift as possible, including segments of the greatest exposure. However, no more than eight hours of sampling can be used in the 8-hour TWA calculation (for extended work shifts, refer to Section III.E.). A representative exposure sample period may be less than seven hours.

Where relatively high airborne concentrations are anticipated, it may be necessary to replace the sampler during the shift to avoid filter overloading and/or sorbent saturation (refer to Section III.D.5.). Before sampling, check OR-OSHA Lab Sampling Procedures to determine flow rate and the minimum and maximum sample volumes needed for each sample. Based on the minimum sample volume and flow rate, determine the minimum duration per sampler.

**Equation 1**

\[
\text{Minimum sample time} = \frac{\text{minimum sample volume}}{\text{flow rate}}
\]

For example, if the minimum sample volume is 240 liters, and the flow rate is 2 liters per minute (L/min), the sampler could be changed out after two hours, and full-shift sampling could be conducted using four two-hour time segments. However, if the minimum sample volume is 600 liters and the flow rate is 2 L/min, a four-hour sample would be insufficient.

And based on the maximum sample volume and flow rate, determine the maximum duration per sampler.

**Equation 2**

\[
\text{Maximum sample time} = \frac{\text{maximum sample volume}}{\text{flow rate}}
\]

For example, Oregon OSHA Lab Method 1032 for methylene chloride specifies a flow rate of 0.05 L/min and a maximum sample volume of 3 liters. For full-shift sampling it will be necessary to sample in segments of no longer than one hour to avoid exceeding the maximum sample volume (3 liters/0.05 L/min = 60 minutes, or 1 hour).
C. Short Term Exposure Limits and Ceiling Limit Values

Many of OSHA’s expanded health standards, such as formaldehyde and methylene chloride, include permissible short term exposure limits (STELs), which are generally 15-minute exposure limits. STEL sampling is conducted by taking a breathing zone air sample of 15 minutes duration in accordance with the applicable sampling method in the OR-OSHA Lab Sampling Procedures.

Many air contaminants in OAR 437-002-0382 have a ceiling limit, either in addition to or instead of an 8-hour TWA PEL. In OAR 437-002-0382, Table Z-1, these are noted by a (C), while Table Z-2 contains a separate column for acceptable ceiling concentrations. Ceiling exposures are measured by sampling for duration sufficient to meet the minimum sample volume in the sampling method in the OR-OSHA Lab Sampling Procedures.

D. Overview of the Sampling Process

1. Select the employees to be monitored and discuss with them the purpose of sampling, how the equipment will be placed, and when and where the sampling equipment will be put on and removed. Stress the importance of not removing or tampering with the sampling equipment. Instruct the employees to notify their supervisors or the CSHO if the sampler requires temporary removal.

2. Place the calibrated sampling equipment on the employee so that it does not interfere with the employee’s work performance or safety.
   - Attach the sampling pump to the employee’s belt (with the flexible tubing already attached to the pump). Use the minimum length of tubing that is necessary and secure it to the employee to prevent snagging and to avoid interfering with the employee’s work. For example, use a collar clip to attach the sampler to the employee’s lapel, and tape the tubing to the employee’s back between the shoulder blades using duct tape.
   - Attach the sampler (filter cassette, charcoal tube, etc.) to the flexible tubing after removing the outlet plug or cap. For flame-sealed sorbent tubes, break open both the ends at this time.
   - Attach the sample collection device (use a tube holder for glass sampling tubes) to the shirt collar or as close as practical to the nose and mouth in the employee’s breathing zone (i.e., in a hemisphere forward of the shoulders within a radius of approximately six to nine inches). The collection device inlet should be oriented in a downward vertical position to avoid gross contamination from airborne debris falling into the collection device. Air should not pass through any tubing before entering the collection device because otherwise the contaminant of interest may be lost to the walls of any tubing that is placed before the inlet (due to adsorption of vapors or electrostatic attraction of particulates).
   - Orient the inlet (vortex finder) to a respirable dust cyclone so that it faces away from the employee.
• For an employee wearing a respirator (including a supplied-air hood for welding or abrasive blasting), place the sampler outside of the respirator. This action is necessary to determine whether the respirator’s Assigned Protection Factor (APF) is adequate. For an employee wearing a welding helmet which is not a respirator, the collection device shall be placed under the helmet.

3. Open the inlet to the collection device: e.g., as appropriate to the sampling method, remove the inlet plug and/or face of the filter cassette or plastic end cap for sorbent tubes. Turn on the air sampling pump. After starting, observe the pump operation for a short time to make sure that it is operating correctly. For example, visually check the pump rotameter (if equipped) or digital flow readout, or touch the pump to feel for vibration.

4. Document the sampling pump start time and other required information. For diffusive samplers be sure to record the sampling site temperature and pressure.

5. Strive to sample for at least the minimum sampling time or air volume prescribed in the OR-OSHA Lab Sampling Procedures. However, this must be balanced against the need to replace the collection medium when overloading of the sampling medium is anticipated or observed during sampling. Overloading is characterized by saturation of the sampling medium. In the case of filters, overloading may be evidenced by the presence of loose material in the filter cassette, darkening of the filter and/or by a reduction in the sampling pump flow rate. For adsorbent media, overloading occurs when the ability of the sampling medium to effectively collect the analyte is compromised. In practice, overloading is difficult to detect and CSHOs should use their observations, experience, and professional judgment to avoid this adverse sampling situation. In general, overloading can be avoided by replacing the collection medium several times during the work shift (once the minimum sample volumes are achieved.)

If overloading does occur, immediately replace the sampling medium. The sample may still be analyzed, although the reported results are likely to be lower than the actual air concentration.

6. Periodically monitor the employee throughout the workday to ensure that sample integrity is maintained and cyclical activities and work practices are identified. Do not enter areas where sampling is being conducted without the appropriate PPE. Frequent pump checks may be necessary, especially when heavy filter loading is possible. For air sampling filters, verify downward orientation of the sampler inlet and symmetrical deposition of particulate on the filter. There should be no large particles on the filter, since these do not move with the airstream. Check for evidence of tampering with the sample or pump. Ensure that the sampler remains properly assembled and that the tubing does not become pinched or detached from the collection device or from the pump. Check the pump flow readout to be sure the pump is still running. Record any relevant observations. Turn off or remove sampling pumps immediately prior to an employee leaving a potentially contaminated area (such as when he/she goes to lunch or on a break in a clean area). If these areas also appear contaminated and are considered part of the
workplace, continue sampling and assess the need for surface contamination measurements (see Section II, Chapter 2, Surface Contaminants, Skin Exposure, Biological Monitoring and Other Analyses). If the pump is turned on and off during the course of the day and/or if the sampling media is changed, document subsequent start/stop times (time on/time off).

7. Before removing the pump at the end of the sampling period, check the pump flow readout (e.g., digital readout or built-in rotameter) to be sure it is still running.

8. Turn off the pump and document the stop time (time off).

9. Remove the collection device from the connecting tubing and close both the inlet and the outlet of the collection device as appropriate, for example using caps or plugs.

10. Seal the collection device with an Oregon OSHA Lab seal Form 440-1316 as soon as possible after sampling (see Appendix G regarding lab seals and sample integrity). The seal should be attached across the sampler inlet and outlet so that evidence of any tampering is visible (see Appendix G, Figures G-1, G-3, G-6 and G-7). Appendix G, Figures G-2, G-4 and G-5 are photos of incorrect applications of lab seals. Press the seal onto the cassette (or other sampler) to ensure that the adhesive adheres firmly to the cassette/ sampler. Samples with seals that can be removed without obvious evidence of tampering will be identified as “Seal improperly applied” in the Oregon OSHA Laboratory reports of analytical results.

E. Overview of the Sampling Process

CSHOs can choose one of two approaches for employees who work extended work shifts beyond eight hours. The decision will depend on the nature of the hazardous chemical and the work activity being performed.

- The first approach is to sample what the CSHO believes to be the worst continuous 8-hour work period of the entire extended work shift (e.g., two consecutive four-hour work periods separated by a lunch break).

- The second approach is to collect multiple samples over the entire work shift. Sampling is done so that multiple personal samples are collected during the first 8-hour work period and additional samples are collected for the extended work shift. Unless a CSHO is dealing with lead, the employee’s exposure in this approach is calculated based upon the worst eight hours of exposure during the entire work shift. Using this method, the worst eight hours do not have to be contiguous. Example: for a 10-hour work shift, following the established sampling protocol as per the OR-OSHA Lab Sampling Procedures, 10 one-hour samples or five two-hour samples could be taken and the eight highest one-hour samples or the four highest two-hour samples could be used to calculate the employee’s 8-hour TWA, which would be compared to the 8-hour TWA PEL. Be sure that the sample duration for each individual sample is long enough to meet the minimum sample volume described in the method.
The lead standards for construction (1926.62) and general industry (1910.1025 and 437-002-0371) require PEL adjustments with respect to extended work shifts (work shifts longer than eight hours). Similarly, under the Cotton Dust standard (1910.1043 and 437-002-1043), the PEL must be proportionately reduced for extended work shifts for the purpose of determining whether, and for how long, respirators must be worn.

**F. Combustion and Thermal Breakdown Products**

Certain contaminants are associated with combustion processes. Carbon monoxide (CO) exposures should be suspected whenever combustion-powered equipment, particularly gasoline-powered equipment, is used in areas with limited ventilation. Without a catalytic converter, gasoline-powered equipment typically produces thousands of parts per million (ppm) of tailpipe CO concentrations, as compared to a few hundred ppm produced by propane-powered equipment. The current PEL for CO is 50 ppm. Another combustion byproduct is nitrogen dioxide (NO$_2$), which has a ceiling value of 5 ppm and is a byproduct of propane-fueled equipment.

Exposures to CO and nitrogen oxides are also associated with welding activities, although such exposures are not usually a concern in open shop welding. CO and NO$_2$ sampling should be conducted when welding is performed in confined spaces. Ozone is associated with gas shielded metal arc welding. Safety data sheets (SDSs) for welding electrodes, wire and fluxes should be consulted. Contaminants commonly associated with welding include fluorides (if present in the flux-cored electrodes being used), manganese (if present in the electrodes), chromium and nickel oxide (when welding on stainless steel), and zinc (when welding on galvanized metal). “Weldable paints” may thermally degrade to aldehydes, butyric acid, bisphenol A, and numerous other organic molecules. Sampling for welding is discussed in Section III.L.

Where heated processes are present in the workplace, it may be necessary to sample for thermal decomposition products. In some cases, these are discussed in the SDSs for the products used at the establishment. In other cases, guidance is available from the Oregon OSHA Laboratory for specific industrial processes. For example, in the polymer resin and plastics industries, machining, torch or laser cutting, or overheating of molding equipment may produce toxic decomposition products such as CO or cyanide. The following thermal decomposition products are associated with specific types of plastic: hydrogen chloride from polyvinyl chloride (PVC); styrene from polystyrene; fluoride compounds from polytetrafluoroethylene (PTFE or Teflon®); cyanide compounds from urethanes; and nitrogen-containing compounds from nylon and acrylonitrile. Further information may be found in industrial hygiene references such as Patty’s Industrial Hygiene and Toxicology.

**G. Chemical Mixtures**

1. **Chemical Interactions**

Often an employee is exposed to a variety of chemical substances in the workplace simultaneously. In many construction and manufacturing processes, such exposures result in different effects than would be experienced with exposure to only one chemical. This type of exposure can also occur when impurities are present in single chemical operations. When
exposure to multiple chemicals occurs, CSHOs should review the health effects information in the federal OSHA Chemical Sampling Information (CSI) to determine whether the chemicals affect the same body organ or physiologic system.

An **additive effect** is one in which the combined health effect of the simultaneous exposures is equal to the sum of the effects of each individual substance alone. For example, the cholinesterase inhibition of two organophosphate pesticides is usually additive when exposure occurs together. Similarly, many solvents have narcotic effects that are considered additive in nature. Below are additional examples of chemicals which have additive effects when exposure occurs together:

- acetonitrile + cyanides
- n-hexane + hexone (methyl isobutyl ketone [mibk]); 2,5 hexanedione or 2,5 hexanediol (all cause peripheral neuropathy)
- carbon monoxide + methylene chloride

A **synergistic effect** is one in which the combined effect of the exposures is much greater than the sum of the individual effects. Classic examples include the synergistic effect of carbon tetrachloride and ethanol on liver toxicity and the synergistic effect on the lungs of smoking and exposure to asbestos.

**Potentiation** describes a condition in which the target organ toxicity of a particular chemical is markedly increased by exposure to another chemical which does not ordinarily have toxic effects on that organ or system. For example, isopropanol is not a liver toxin, but when combined exposure to isopropanol and carbon tetrachloride (liver toxin) occurs, the liver toxicity is much greater than that due to carbon tetrachloride alone. Ethanol potentiates the toxicity of many other chlorinated hydrocarbons.

**Antagonism** refers to the situation in which the toxic effects of two chemicals interfere with each other, or the effects of one chemical are actually reduced by exposure to another chemical. This is the basis for many antidotes. Antagonism can occur by several different mechanisms. When chemical antagonism takes place, for example with chelating agents, two chemicals react in the body to a less toxic form. Functional antagonism refers to two chemicals having opposite effects on the same system, such as central nervous system (CNS) stimulants and depressants. Competitive antagonism refers to chemicals acting on the same receptor, such as nicotine and ganglionic blocking agents. Noncompetitive antagonism refers to the toxic effect being blocked by some other means, such as atropine reducing the toxicity of cholinesterase inhibitors.

2. Mixture Formula

OSHA’s Air Contaminants standard provides a formula for assessing exposures to chemicals having additive effects (for general industry, see OAR 437-002-0382). This calculation should be used when the components in the mixture pose a combined threat to worker health and components in the mixture have an effect on the same body (target) organ or physiologic system. This formula can be used for exposures occurring simultaneously or for TWA exposures occurring consecutively within the same workshift.
The mixture calculation is expressed as:

**Equation 3**

\[ E_m = \left( \frac{C_1}{L_1} + \frac{C_2}{L_2} + \cdots + \frac{C_n}{L_n} \right) \]

Where:

- \( E_m \) = equivalent exposure for the mixture (\( E_m \) should be less than or equal to 1 for compliance)
- \( C \) = concentration of a particular substance
- \( L \) = PEL

Section IV.D describes sampling and analytical error (SAE) calculations for use of the mixture formula, and example calculations are provided in Appendix H. In addition, an online calculator is available to CSHOs on OSHA’s Intranet which will calculate a control limit for any mixture. Simply input the exposures, limits, and SAEs, and the program will calculate a control limit according to the above equation.

**Mixture Calculator**

The mixture formula may be used to assess employee exposures to chemicals having synergistic effects. However, since the health effects are generally more severe in this scenario, it may be appropriate to apply an increased penalty. As per Chapter 7 of the Oregon OSHA Field Inspection Reference Manual Field Inspection Reference Manual (FIRM), all such cases should be discussed with the field enforcement manager. Use the following resource to determine whether there is evidence for synergistic effects: Chemical Mixture Risk Calculation IRSST.

3. **Air Sampling for Mixtures (determining what to sample)**

The following three examples present portions of SDSs for products containing mixtures and illustrate the process of determining which ingredients should be evaluated for potential employee exposure.

**Sample Safety Data Sheet #1**

**Section 1: Product Name: Formalin Solution, Buffered 10%**

**Section 2: Composition:**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No.</th>
<th>Percent</th>
<th>Hazardous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl Alcohol</td>
<td>67-56-1</td>
<td>1-1.5%</td>
<td>yes</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>50-00-0</td>
<td>4%</td>
<td>yes</td>
</tr>
<tr>
<td>Water</td>
<td>7732-18-5</td>
<td>~95%</td>
<td>no</td>
</tr>
</tbody>
</table>

**Section 8: Exposure Controls / Personal Protection**
OSHA Permissible Exposure Limits:

Formaldehyde:
- 0.75 ppm TWA PEL
- 2.0 ppm STEL
- 0.5 ppm Action Level

Methyl Alcohol:
- 200 ppm TWA

Section 9: Physical and Chemical Properties:

Vapor Pressure (mmHg): Essentially the same as water
Evaporation Rate: Essentially the same as water.

Since the SDS does not report the physical properties for the individual ingredients, it is necessary to look at other reference information to determine the relative volatility of the components. Physical properties for specific chemicals may be found in either the CSI file for each chemical, or in the NIOSH Pocket Guide to Chemical Hazards, which can be accessed from links in each chemical’s CSI file.

Excerpts from NIOSH Pocket Guide:

Methyl Alcohol:
- Boiling point: 147ºF
- Vapor Pressure: 97 mmHg

Formaldehyde:
- Boiling point: -6ºF
- Vapor Pressure: > 1 atm (1 atm = 760 mmHg)

IDLH: 20 ppm

In comparing the methanol and the formaldehyde, the formaldehyde is present at four times the concentration in the mixture, is considerably more volatile, and has an Action Level which is 1/400th the PEL for methanol. Formaldehyde is a potent irritant with an Immediately Dangerous to Life or Health (IDLH) concentration which is 1/10th the PEL for methanol. Therefore, it is expected that methanol will not make a significant contribution to worker exposure as compared to formaldehyde. Sampling for formaldehyde alone would be considered sufficient. Please note that the CSI states that active sampling, rather than passive badges (diffusive samplers), must be used to sample for formaldehyde where formalin is the source of formaldehyde exposure. Also note that formaldehyde is an OSHA-regulated carcinogen with a substance-specific expanded health standard (1910.1048).
Sample Safety Data Sheet #2

Section 1 – Product Name: Gravure Ink

Section 2 – Composition:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No.</th>
<th>Percent</th>
<th>PEL (ppm)</th>
<th>Other Exposure Limits (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>108-88-3</td>
<td>29%</td>
<td>200</td>
<td>300 ceiling (OSHA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500 peak (OSHA)</td>
</tr>
<tr>
<td>1,2-propanediol</td>
<td>57-55-6</td>
<td>5%</td>
<td>none</td>
<td>not found</td>
</tr>
<tr>
<td>Xylene (mixed)</td>
<td>1330-20-7</td>
<td>31%</td>
<td>100</td>
<td>150 STEL (NIOSH and ACGIH)</td>
</tr>
</tbody>
</table>

Section 9 – Physical Properties: % Volume Volatile: 88.6

Again, the physical properties information on the SDS does not indicate the relative volatility of the components, so it is helpful to refer to the CSI file, including the NIOSH Pocket Guide.

Excerpts from CSI and/or NIOSH Pocket Guide:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Boiling Point</th>
<th>Vapor Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>232°F</td>
<td>21 mmHg</td>
</tr>
<tr>
<td>1,2-propanediol</td>
<td>188°C</td>
<td>0.05 mmHg</td>
</tr>
<tr>
<td>m-xylene</td>
<td>282°F</td>
<td>9 mmHg</td>
</tr>
</tbody>
</table>

A review of the CSI file for CAS number 57-55-6 reveals the more common name, propylene glycol. The CSI file states that this material is a Food and Drug Administration (FDA)-approved food additive which is “generally recognized as safe.” Due to its low concentration, volatility, and toxicity, sampling for this material is unnecessary.

Sampling for both toluene and the xylenes is recommended if significant quantities are used without adequate local exhaust ventilation. Additionally, toluene and xylenes have similar target organ effects, so the exposures should be evaluated as a mixture using the mixture formula. Toluene and xylenes share the following target organs: central nervous system, eyes, skin, respiratory system, liver and kidneys.

Note that this SDS includes references to non-OSHA occupational exposure limits – in particular, limits set by NIOSH and American Conference of Governmental Industrial Hygienists (ACGIH). NIOSH sets Recommended Exposure Limits (RELs), while ACGIH sets Threshold Limit Values (TLVs). Note that while there is no OSHA ceiling value for xylene, there is a NIOSH/ACGIH STEL. For substances with an 8-hour PEL, but no OSHA ceiling/STEL value, the case should be referred to the field enforcement manager if exposure exceeds an ACGIH or NIOSH STEL or ceiling value.
Sample Safety Data Sheet #3

Section 1 – Product Name: Indoor/Outdoor Spray Paint – True Blue

Section 2 – Composition:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No.</th>
<th>Percent</th>
<th>Exposure Limits</th>
<th>Vapor Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>74-98-6</td>
<td>25%</td>
<td>PEL 1,000 ppm</td>
<td>760 mmHg</td>
</tr>
<tr>
<td>VM &amp; P Naptha</td>
<td>8032-32-4</td>
<td>12%</td>
<td>TLV 300 ppm</td>
<td>12 mmHg</td>
</tr>
<tr>
<td>Toluene</td>
<td>108-88-3</td>
<td>15%</td>
<td>PEL 200 ppm TLV 20 ppm</td>
<td>22 mmHg</td>
</tr>
<tr>
<td>Light Aromatic Hydrocarbons</td>
<td>64742-95-6</td>
<td>1%</td>
<td>Not available</td>
<td>4 mmHg</td>
</tr>
<tr>
<td>1,2,4-Trimethylbenzene</td>
<td>95-63-6</td>
<td>2%</td>
<td>PEL 25 ppm</td>
<td>2 mmHg</td>
</tr>
<tr>
<td>Acetone</td>
<td>67-64-1</td>
<td>30%</td>
<td>PEL 1,000 ppm</td>
<td>180 mmHg</td>
</tr>
<tr>
<td>Titanium Dioxide (Total Dust)</td>
<td>13463-67-7</td>
<td>0.1%</td>
<td>PEL 15 mg/m³ TLV 10 mg/m³</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Section 5 – Fire Fighting Measures:

Flash Point of Propane: <0°F
LEL 0.7%
UEL 12.8%

The PEL for propane is 1,000 ppm and it constitutes 25% of the mixture. Propane is a “simple asphyxiant,” meaning it is nontoxic and acts by displacing oxygen. However, propane is flammable, so it is relevant to monitor for flammable gas.

Among the solvents, the greatest exposures will be to acetone because it is present at the highest concentration (30%) and is very volatile. Toluene should also be sampled since its PEL (200 ppm) is lower than the PEL for acetone (1,000 ppm) and its concentration in the mixture is significantly high (15%). If the spray paint is used in moderate quantities for brief periods outdoors or in a spray booth, the trimethylbenzene would likely not evaporate until after the completion of a brief spray application due to its low volatility. Under those circumstances, it is unlikely that the trimethylbenzene would contribute significantly to the worker’s exposure, since it is present at such a low percentage. However, for spray applications of long duration performed without local exhaust controls, the trimethylbenzene should be included because although its concentration in the mixture is low, its PEL is also very low warranting the need to determine the level of exposure. Since these solvents are likely to have similar narcotic effects, the CSI should be reviewed to determine whether they have the same target organs, in which case the mixture calculation should be applied.
The titanium dioxide (TiO$_2$) is present at a very low concentration, is only a nuisance dust, and would be released in a wetted form as part of an aerosol. Gravimetric sampling for the TiO$_2$ is neither necessary nor practical. The light aromatic hydrocarbons can be ignored since they are present at such a low concentration.

**H. Field Blanks**

Field blanks are used by the lab to determine if contamination has occurred before analysis or during sample handling, shipping, or storage. Field blanks (e.g., sorbet tubes, filters, wipes, absorbing solution) are clean sample media that are taken and opened in a clean area at the sampling site, but they are not used to take samples. They should be handled, stored and shipped in the same manner as other sampling media used in sampling air contaminants, with the exception that no air is drawn through them. Field blanks are required for each requested analysis and for each lot number of sampling media. Prepare field blanks during the sampling period for each type of sample collected. One field blank will usually suffice for up to 20 samples for any given analysis/sampling period. However, asbestos fiber count requires a minimum of two field blanks, even for a single asbestos sample.

**I. Total Dust**

Total dust sampling is used to evaluate exposures to a variety of dusts as shown in Appendix B. Also, use total dust sampling for toxicologically inert, nuisance dusts, whether mineral, inorganic, or organic. These dusts are listed in OAR 437-002-0382, Table Z-1 as particulates not otherwise regulated (PNOR) and Table Z-3 as nuisance dust. Please note that there are both total dust and respirable dust PELs for many PNOR (see Appendix B).

Total dust sampling uses pre-weighed PVC filters to determine the total mass of dust collected during the sampling period. Obtain pre-weighed PVC filters from the Oregon OSHA Laboratory. Use a maximum flow rate of 2 L/min for a maximum sampling time of 480 minutes or eight hours. Visually check the filter during the sampling period to avoid overloading the filter. Overloading may be evidenced by the presence of loose material in the filter cassette, by a darkening of the filter, and/or by a reduction in the sampling pump flow rate. Check for overloading by looking into the inlet of the sampling cassette, using a flashlight if needed.

**J. RESPIRABLE DUST**

Respirable dust sampling uses a cyclone to separate and capture those particles in the size range which would be deposited in the gas exchange region of the lung. Particles too large to be inhaled are collected in a grit pot in the cyclone. The respirable fraction is captured on a pre-weighed PVC filter for gravimetric analysis. Appendix B lists ducts for which respirable sampling should be performed. Obtain pre-weighed PVC filters from the Oregon OSHA Laboratory.

Collect respirable dust samples using a clean SKC aluminum cyclone and a pre-weighed PVC filter at a flow rate of 2.5 L/min for a maximum sampling time of 160 minutes but may extend sampling time up to 384 minutes if the filter is not overloaded (see Appendix I, Figures I-1, I-2, I-3 and I-4).
The particle size selective characteristics are determined by the type of cyclone used together with the sampling flow rate. A SKC aluminum cyclone set to a flow rate of 2.5 L/min can be used in order to meet the specifications described in Table Z-3 (Mineral Dusts) of OAR 437-002-0382, footnote “e.” Footnote “e” states that both concentration and percent quartz for the application of the crystalline silica and coal dust limits are to be determined from the fraction passing a size-selector with the characteristics shown in Table 1.

<table>
<thead>
<tr>
<th>Aerodynamic diameter, µm (unit density sphere)</th>
<th>Percent passing size selector</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>90</td>
</tr>
<tr>
<td>2.5</td>
<td>75</td>
</tr>
<tr>
<td>3.5</td>
<td>50</td>
</tr>
<tr>
<td>5.0</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

Although the criteria in Table 1 were written to meet the Dorr-Oliver performance specifications, any technology that meets this size selective sampling criteria can be used.

**Note:** Adjusting the flow rate of any other sampler design until a 50% cut is achieved at 3.5 µm aerodynamic diameter may not achieve comparable aerodynamic diameters to those specified at the 0, 25, 75, and 90% cut points.

Appendix I contains cyclone assembly and cleaning instructions. Be careful not to overload the filter. Make certain that the cyclone inlet (vortex finder) faces away from the person being monitored.

**K. Crystalline Silica**

1. **Air Samples**

   When employees are exposed to silica during abrasive blasting, air sampling should be done outside the abrasive blasting hood.

   Crystalline silica samples are to be collected using a SKC aluminum or other suitable cyclone as described for respirable dust samples. A silica sample collected without a cyclone would be a total dust sample and different PELs apply to respirable and total dust samples. Because of analytical difficulties, CSHOs are discouraged from submitting total dust air samples for silica analysis. The Oregon OSHA Laboratory’s silica analysis requires that the particle size distribution of the samples be matched as closely as possible to calibration standards, and this is best accomplished with a respirable sample. If the collected sample is nonrespirable, the Oregon OSHA Laboratory must be advised on the air sampling worksheet. If one feels the need to collect a Total Dust sample, first contact the Oregon OSHA Laboratory.

   In general, cristobalite and/or tridymite are produced under conditions involving the high temperature firing of quartz. Quantitative data for quartz and cristobalite are reported by the Oregon OSHA Laboratory. Qualitative data for tridymite can be reported if requested.
X-ray diffraction (XRD) is the preferred silica analytical method because of its sensitivity, its minimum requirements for sample preparation, and its ability to identify polymorphs (different crystalline forms) of free silica. Quartz is initially identified by its major (primary) x-ray diffraction peak. If significant levels of quartz are identified, its presence may be confirmed using secondary, tertiary, and/or quaternary peaks to eliminate the possibility of interfering crystalline substances. CSHOs should notify the Oregon OSHA Laboratory if any of the following substances are known to be present in the workplace:

Aluminum phosphate
Feldspars (microcline, orthoclase, plagioclase)
Graphite
Iron carbide
Lead sulfate
Micas (biotite, muscovite)
Montmorillonite
Potash
Sillimanite
Silver chloride
Talc
Zircon (zirconium silicate)

The Oregon OSHA Laboratory results for silica air samples are usually reported under one of three categories:

- Mg/m$^3$ quartz and mg/m$^3$ cristobalite present in the respirable sample. The analysis of tridymite is performed only when requested and results are qualitative only.

- Approximate values in units of mg/m$^3$ or percent are given for total dust samples. The particle size distribution in a total dust sample is unknown and creates an error in the XRD analysis which limits accuracy to an approximation.

- Less than the Limit of Quantitation (LOQ). A sample reported as less than the LOQ indicates that the quantity of quartz (or cristobalite) present in the sample is not greater than the detection limit of the instrument. The detection limit is usually 5 micrograms (µg) for quartz and 3 µg for cristobalite. If less than a full-shift sample was collected, CSHOs should evaluate a less than the LOQ result to determine whether adequate sampling was performed. If the presence of quartz (or cristobalite) is suspected, CSHOs may want to sample for a longer period of time to increase the amount of sample collected.

Other factors may have to be considered before arriving at a final exposure value. For example, the TWA calculation may require combining two or more sample results and adjusting to an 8-hour workday.

Where the employee is exposed to combinations of silica dust (i.e., quartz and cristobalite), the additive effects of the mixture will be considered.
L. Metals

1. Air Samples

Welding

When sampling for welding fumes, the filter cassette must be placed inside the welding helmet to obtain an accurate measurement of the employee’s exposure. Welding fume samples are normally taken using 37-mm mixed cellulose ester filters (MCEF) and cassettes but polyvinyl chloride (PVC) filters may be used if a gravimetric analysis for total welding fume is also required. If these cassettes will not fit inside the helmet, 25-mm MCEF or PVC and cassettes can be used. Extra care must be taken not to overload the smaller 25-mm filters when sampling.

When a welding helmet or face shield is worn, the sampler is placed on the collar or shoulder so that it is beneath the helmet when the helmet is placed down; it must be located in the breathing zone of the employee (a radius forward of the shoulders and within 6-9 inches of the mouth and nose). Studies have shown that the welding helmet alone results in a reduction in the wearer’s breathing zone exposures to welding fume. Placing the sampler under the helmet allows a determination of whether respiratory protection is needed.

Whenever respiratory protection is worn, employee exposure samples must be taken in the breathing zone, but outside the respirator, in order to determine whether the assigned protection factor of the respirator is adequate based on the measured exposures outside the respirator. Some newer styles of negative pressure respirators are designed to fit under a welding helmet. In this case, where an employee is wearing both a welding helmet and a tight-fitting negative pressure respirator, the sampler is placed under the helmet, but outside of the respirator. Where a supplied air welding hood or abrasive blasting hood is worn, the sampler is placed outside the hood, also in the defined breathing zone.

For analysis of welding fume, Oregon OSHA Laboratory method 1001 is preferred. This method allows for analysis of up to six metals on the same filter. Collect metal fumes using a 0.8-μm MCEF cassette or 5.0 μm PVC filter cassette using a maximum flow rate of 2 L/min with a maximum air volume of 960 L. MCEF cassettes are preferred if a gravimetric analysis for total welding fume is not required. Specify the metals of greatest interest in the OTIS air sampling worksheet. See OSHA’s OR-OSHA Lab Sampling Procedures for further detail. Be careful not to overload the filter.

2. Bulk Samples

Bulk samples are sometimes taken to document the source of the material present in the air. Always attempt to take representative samples for bulk analysis. The Oregon OSHA Laboratory analysts will make a reasonable attempt to homogenize samples submitted by CSHOs, however, excessive sample quantities and highly non-homogenous samples complicate this process. Ideally, bulk samples should contain a minimum of approximately 200 mg, but less than a gram, shipped in glass 20-mL vials with PTFE-lined caps or in a Whirl-Pak® bag.
3. Metal Analysis

The Oregon OSHA Laboratory is capable of analyzing a variety of metals in specific compatible combinations depending on the ability of the analytical method to simultaneously dissolve the metals of interest in a given acid matrix, and depending on the stability of the metal on the collection filter. In particular, sampling for hexavalent chromium requires use of PVC filters and a different analytical analysis, Oregon OSHA Laboratory method 1034. Some of the current analyte/matrix combinations are listed below and are defined by specific OSHA sampling and analytical methods. Refer to OR-OSHA Lab Sampling Procedures for the most up-to-date analyte/method combinations:

The following metal analytes (up to six per filter) can be analyzed on the same filter using Oregon OSHA Laboratory method 1001:

<table>
<thead>
<tr>
<th>Aluminum</th>
<th>Cobalt</th>
<th>Magnesium</th>
<th>Thallium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium (insoluble)</td>
<td>Copper</td>
<td>Manganese</td>
<td>Vanadium</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Hafnium</td>
<td>Molybdenum (insoluble)</td>
<td>Zinc</td>
</tr>
<tr>
<td>Calcium</td>
<td>Iron</td>
<td>Nickel</td>
<td>Zirconium</td>
</tr>
<tr>
<td>Chromium</td>
<td>Lead</td>
<td>Tellurium</td>
<td></td>
</tr>
</tbody>
</table>

The following metals have different analytical requirements and must be sampled separately:

<table>
<thead>
<tr>
<th>Metal</th>
<th>Oregon OSHA Lab Method #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium</td>
<td>1013</td>
</tr>
<tr>
<td>Titanium</td>
<td>1016</td>
</tr>
<tr>
<td>Antimony, Silver, &amp; Selenium</td>
<td>1017</td>
</tr>
<tr>
<td>Tin</td>
<td>1018</td>
</tr>
<tr>
<td>Arsenic</td>
<td>1020</td>
</tr>
<tr>
<td>Tungsten</td>
<td>1063</td>
</tr>
<tr>
<td>Water soluble metals:</td>
<td></td>
</tr>
<tr>
<td>Barium (soluble)</td>
<td>1014</td>
</tr>
<tr>
<td>Chromium (II and III)</td>
<td></td>
</tr>
<tr>
<td>Sodium (hydroxide, salts, &amp; bisulfite)</td>
<td></td>
</tr>
<tr>
<td>Molybdenum (soluble)</td>
<td></td>
</tr>
<tr>
<td>Potassium (hydroxide and salts)</td>
<td></td>
</tr>
<tr>
<td>Zinc (soluble such as zinc chloride)</td>
<td></td>
</tr>
</tbody>
</table>

M. Asbestos

Collect samples for asbestos using 0.8-µm, 25-mm diameter MCEF cassettes which have been specially designated by the manufacturer for asbestos analysis. The filters must be contained in an electrically conductive cassette assembly that includes a 50-mm extension cowl as shown in
Figure 1. An electrically conductive cassette is necessary to prevent loss of fibers to the walls of the cassette due to electrostatic forces. Ensure that the bottom joint (between the extension and the conical black piece) of the cassette is sealed tightly with a shrink band or electrical tape. Make certain that the cassette does not leak. Fasten the (uncapped) open-face cassette to the worker’s lapel. Orient the open face downward.

Use a flow rate in the range of 0.5 to 2.5 L/min. 1.0 L/min is suggested for general sampling. For office environments use flow rates up to 2.5 L/min.

Calibrate pump as discussed in Appendix F. Do not use nylon or metal (e.g., stainless steel or plated brass) adapters if in-line calibration is done. Do not use the same filter cassette intended to be used for field sampling for sampling pump calibration.

Figure 1. Standard Asbestos Cassette

Sample for as long a time as possible without overloading (obscuring) the filter because overloading can lead to an unreadable sample. In a dusty environment, smaller air volumes may be necessary to prevent obscuring the filter (see the discussions on filter overloading in Section III.D and Section III.I). Instruct the employee to avoid knocking the cassette and, if possible, to avoid using a compressed air source that might dislodge the collected contaminant while sampling. After sampling, replace the face cover and end caps and secure with OSHA Form 440-1316 lab seal as shown in Appendix G, Figure G-7, then post-calibrate the sampling pump.

Approximately 10% of all samples submitted should be blanks, with a minimum of two blanks in all cases.

Where possible, collect and submit a bulk sample of the material suspected to be in the air. Use a wet method for sampling and wear respiratory protection in accordance with regional policy. Submit approximately 0.5 to 1 gram of material in a 20 mL glass vial with a PTFE-lined cap or in a Whirl-Pak® bag. Be sure to collect samples from all layers and phases (visually distinct types) of the material. A knife or cork-borer may be used. If possible, make separate samples of each different phase of the material, and place each bulk sample in a separate vial or bag. Ship the bulk samples and air samples separately to avoid cross-contamination.

Secure and handle the samples so that they will not rattle during shipment or be exposed to static electricity. Do not ship samples in expanded polystyrene peanuts, vermiculite, or paper shreds. Tape sample cassettes to sheet bubbles and place in a container that will cushion the samples without rattling.
Asbestos air samples are analyzed by phase contrast microscopy (PCM) to determine fiber counts. However, PCM does not identify fiber type. List any known fibrous interferences present during sampling in the OTIS air sampling worksheet, for example, cellulose (paper, wood), fiberglass, fur, or refractory ceramic. Also, note the workplace operation(s) sampled. Bulk samples are analyzed by polarized light microscopy (PLM) to confirm fiber type. If necessary, air samples can be analyzed by Transmission Electron Microscopy (TEM) to confirm fiber type and percentage. The Oregon OSHA Laboratory does not have TEM capability but can contract the samples out if additional analysis is required.

For unusual sampling conditions contact the Oregon OSHA Laboratory for more detailed instructions.

N. Organic Vapors and Gases

1. Solid Sorbent Sampling Tubes

Organic vapors and gases can be collected using several different sampling media including charcoal and other sorbents in sampling tubes (see Figure 3) with low-flow sampling pumps. Refer to OSHA’s OR-OSHA Lab Sampling Procedures for required sampling media, rates, and volumes for specific chemicals.

Sorbent tube sampling is generally conducted at much lower flow rates than particulate sampling to allow sufficient residence time for the contaminant of interest to adsorb to the sorbent. Sorbent sampling tubes typically contain two sections of sorbent separated by a spacer, such as foam or glass wool. The larger section of sorbent is the primary, and the smaller section is the backup. Orient the back-up section toward the sampling pump. As air is drawn through the sorbent tube, the contaminant of interest will pass into the primary section and bind to the sorbent. When the sorbent in the primary section becomes saturated, contaminant will pass into the back-up section. This is known as breakthrough. The lab analyzes the two sorbent sections separately; if greater than 25% of the contaminant is found in the back-up section, this may indicate that sample was lost due to breakthrough. Breakthrough may result in an underestimation of the employee exposure. The lab should notify the CSHO if breakthrough may have occurred.

Figure 2. Charcoal Tube with flame-Sealed Ends and Caps
Contaminant migration may also occur—where contaminant bound in the primary section desorbs and passes into the back-up section after sample collection is completed. There is no way for the lab to distinguish whether material found in the back-up section is the result of breakthrough or migration. To avoid migration, ship samples to the lab without delay. In some cases refrigeration of samples is recommended to reduce migration, for example, in Oregon OSHA Laboratory method 1023 for 1,3-Butadiene. Some sampling methods, such as OSHA Laboratory method 1065 for ethanol, address the problem of migration by using two sorbent tubes attached in series (see Figure 3). The two tubes must be separated from each other and sealed (capped) immediately after sampling.

Note that other airborne contaminants, including moisture, will compete for binding sites on the sorbent. Sample volumes (flow rate and/or sample duration) may need to be decreased under conditions of high humidity (> 90%) or when competing contaminants are present in relatively high concentrations.

Certain situations require use of multiple sorbent tubes, either in series or in parallel (see Figures 3 and 4). As described above, tubes may be used in series to avoid migration of the analyte of interest from the primary to the back-up sections, or to prevent breakthrough by increasing the sampler capacity. Series sampling may also be used where the contaminant of interest must be chemically converted to a more stable form in order to be retained on the sorbent. For example, nitric oxide is sampled using three sorbent tubes connected in series. The front and back tubes contain molecular sieves impregnated with triethanolamine, and the middle or oxidizer tube contains an inert support impregnated with a chromate salt. The middle tube is not submitted to the lab for analysis, but may undergo a color change indicative of depletion of the oxidizer.

Figure 3. Two Charcoal Tubes in Series
Sampling tubes may also be used in parallel. Sampling in parallel allows simultaneous sampling for multiple chemicals using different sampling media with the same sampling pump. This would generally be done when multiple airborne contaminants are suspected to be present, and either the analytical method does not allow for analysis of more than one of the components from the same sorbent tube or the methods require the use of different sampling media. For example, in ink manufacture, tubes containing different sorbents would be used in parallel. Sorbent tubes are manifolded together using adjustable flow controllers and tube holders available through the Oregon OSHA Laboratory. The airflow through each tube must be adjusted separately, and the combined flow cannot exceed the flow range of the sampling pump. When considering sampling for multiple contaminants operating from the same sampling pump, contact the Oregon OSHA Laboratory for further guidance.

Prior to sampling, calibrate the sampling pump as per Appendix F. Do not use the same sorbent tube for pump calibration as will be used for sampling. Immediately before sampling, use a tube opener to break off the ends of the flame-sealed tube to provide an opening approximately half the internal diameter of the tube. Wear eye protection when breaking ends, and be careful not to cut yourself. Do not use the charging inlet or the exhaust outlet of the pump to break the ends of the tube. Insert the sorbent tube into the adjustable low flow controller, slide an appropriate length tube holder over the sorbent tube to shield the sampled person from the sharp ends, and secure the tube holder to the low flow controller. Tube openers (also called tube breakers), holders, and low flow controllers are available through the Oregon OSHA Laboratory.

Position the sampling tube vertically so that the opening is pointing downward during sampling. Draw air to be sampled directly into the inlet of the tube. To avoid sample loss, air is not to be passed through any hose or tubing before entering the sorbent tube (except in cases where a very short piece of tubing is used to connect two tubes together that are used in series).

Immediately after sampling, cap the tube with the supplied plastic caps, and seal the tube with an Oregon OSHA Lab seal Form 440-131 (see Appendix G, Figures G-1 and G-2). The lab seal
should cover the end caps. If the seal does not cover the end caps because the tube is too long, tape the ends of the seal, using clear plastic tape, so that it is secure and tamper-resistant.

After the samples are properly sealed, post-calibrate the sampling pumps. If the pre- and post-sampling flow rates differ by greater than 5%, note this in the air sampling worksheet. For example, if the pre-calibration flow rate is 50 milliliters per minute (mL/min), the post-calibration flow rate should be between 47.5 and 52.5 mL/min. Likewise, if the pre-calibration flow rate is 200 mL/min, the post-calibration flow rate should be between 190 and 210 mL/min.

Submit the sample for analysis. Do not ship air samples with bulk samples.

2. Diffusive (Passive) Sampling

Diffusive samplers, also known as passive monitors or badges, can be useful for compliance monitoring. The major advantage of diffusive sampling is that no air sampling pump is required. Two common disadvantages are that diffusive samplers are frequently less accurate than active sampling, and that the limit of detection is not always low enough for compliance monitoring, particularly for STEL sampling. As with active sampling, chemical interferences may also be a concern. Figure 5 shows an example of one style of diffusive sampler. The Oregon OSHA Laboratory does not currently promote the use of diffusive samplers but may be able to facilitate their use if necessary.

Figure 5. Diffusive Sampler

The following material is for reference use only and outlines the use of diffusive samplers in the Federal OSHA program. Table 2 lists the analytes for which passive diffusive sampling methods have been validated for compliance sampling. Additional airborne contaminants may be identified and quantified, but these analytical results are usually reported as “approximations” and should be used only for screening purposes.

Record the temperature and barometric pressure at the sampling site in the OTIS air sampling worksheet. Temperature and pressure are needed for proper calculation of exposure results for diffusive samplers. Results from samples without the sampling site temperature and
pressure will have significantly higher sampling and analytical error values. Check the National Oceanic and Atmospheric Administration’s (NOAA) website the same day as sampling to obtain the barometric pressure reported with the local weather forecast for that day. The barometric pressure for the time period sampled can sometimes be obtained by contacting the local weather station or airport. If air pressures are obtained by these means, it is necessary to obtain the unadjusted barometric pressure (station pressure) for compliance applications. **If the barometric pressure value cannot be found, note the time and elevation** where the samples were collected, and refer to Appendix L, Equation L-4.

Specific sampling instructions for each type of diffusive sampler are supplied with the sampler and included in the OSHA methods that permit diffusive sampling (listed below in Table 2). Diffusive samplers should not be opened until just before sampling because they begin to sample as soon as they are opened. To terminate sampling, properly seal the samplers with the manufacturer's packaging materials. Field blanks for diffusive samplers should be briefly opened in the field in an area on-site where no contamination is expected and then they should be immediately resealed with manufacturer's materials. Follow sample seal procedures for the field blanks as described in Appendix G.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Method</th>
<th>Sampler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>OSHA 1005</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>2-Butanone (MEK)</td>
<td>OSHA 1004</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Butyl acetate (n, iso, sec, tert isomers)</td>
<td>OSHA 1009</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Ethyl benzene</td>
<td>OSHA 1002</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Ethylene oxide</td>
<td>OSHA 49</td>
<td>3M 3551</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>OSHA 1007</td>
<td>AT Aldehyde Monitor 571</td>
</tr>
<tr>
<td>Hexone (MIBK)</td>
<td>OSHA 1004</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>Kem Medical Products Method</td>
<td>Kem Vapor Trak Nitrous Oxide Monitor</td>
</tr>
<tr>
<td>Radon</td>
<td>OSHA-208</td>
<td>E-Perm</td>
</tr>
<tr>
<td>Styrene</td>
<td>OSHA 1014</td>
<td>SKC 575-006</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>OSHA 1001</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>OSHA 1001</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Thoron</td>
<td>Contact Oregon OSHA Laboratory</td>
<td>E-Perm</td>
</tr>
<tr>
<td>Toluene</td>
<td>OSHA 111</td>
<td>SKC 575-002</td>
</tr>
<tr>
<td>Xylene (o, m, p isomers)</td>
<td>OSHA 1002</td>
<td>SKC 575-002</td>
</tr>
</tbody>
</table>
3. Impingers

In many cases, newer methods, such as specially treated sorbents, have been developed that can be used in place of the methods calling for use of an impinger. However, in specialized conditions, such as high humidity, methods requiring an impinger must still be used. Appendix C lists the chemicals for which the primary method is an impinger method. It is always advisable to check OR-OSHA Lab Sampling Procedures to see if alternative methods can be used.

An example of a midget impinger is shown in Figure 6. The term midget refers to the volume of the sampler flask. The jet (inlet tube) of an impinger is tapered and sized to allow sufficient velocity for particles to strike the bottom of the flask and become suspended in the liquid.

![Impinger Vial with Filter](image)

The following suggestions should be followed when using impingers:

- Numbers are written on tape on impinger vials and impinger tops with filter holders (matching numbers should be used whenever possible). Take care in using impingers so that tips are not damaged.

- The Oregon OSHA Laboratory will provide impingers with the appropriate absorbing solutions.

- Before sampling, unscrew the impinger top from the empty vial. Uncap the vial with the impinger solution and carefully place the impinger top with the tube into the solution and screw into place.

- To prevent overflow, not more than 10 mL of absorbing solution will be added to midget impingers. Care must be taken to not invert the impinger to prevent impinger liquid from being spilled onto the filter or from the outlet.
- The maximum sampling rate for midget impingers is usually 1.0 L/min, but should be double-checked with the individual sampling method.

- The impinger can either be hand-held by the CSHO or it can be attached to the employee's clothing using a holster. In either case, it is very important that the impinger does not tilt and cause the absorbing solution to flow down the side arm to the hose and into the pump. NOTE: The lab may attach a charcoal trap in-line with the pump to collect solvent vapors.

- In some instances, sampling time will need to be adjusted during the sampling period to prevent the amount of liquid from dropping below one half of the original amount.

- After sampling, unscrew the top portion from the impinger vial and place back on the empty vial and screw into place as shown in Figure 7. Tape the cap shut by wrapping the tape in the direction of cap closure to prevent it from coming loose due to vibration. Return impingers as they were received following storage instructions in the OR-OSHA Lab Sampling Procedures.

![Figure 7. Impinger Storage](image_url)

4. Gas Sampling Bags and Canister Samplers

The Oregon OSHA Lab provides Tedlar air sampling bags as shown in Figure 8 for the collection of bulk air samples. Be certain not to fill the bag to more than 75% of its rated volume, and to close the sampling valve after sampling. Place lab seal Form 440-131 over the valve(s). Gas sampling bags are sometimes used to collect whole air samples for forensic-type investigations. Call the Oregon OSHA Laboratory for guidance. Canister samplers are not available for use from the lab.
Figure 8. *Tedlar Sample Bag*
IV. Post-Inspection Activities

A. Post-Calibration

1. Post-calibrate sampling pumps as described in Appendix F.

2. Record results of post-calibration for all pumps used in the OTIS air sampling worksheet.

B. Complete Documentation

1. Complete the OTIS sampling worksheet before sending samples to the lab. CSHOs should be especially diligent in completing the following items:
   - Report number
   - Inspection number
   - Sample numbers
   - Establishment name and address (if enforcement)
   - Sampling date
   - Shipping date
   - Person performing sampling
   - CSHO ID
   - Weather conditions
   - Photo(s)
   - Pump checks and adjustments
   - Job location, operation, work location(s), ventilation, and controls
   - Pre-sampling - calibration location temperature and pressure
   - Post-sampling - calibration location temperature and pressure

2. Oregon OSHA TWA-PELs are defined as 8-hour TWA exposures. The Oregon OSHA Laboratory will report sample results using the air volume reported on the OTIS sampling worksheet unless otherwise requested by the CSHO. Reports will calculate exposures over the time sampled and extrapolated to an 8 hour TWA in both mg/m$^3$ and in ppm if applicable.

C. Package and Ship Samples

- Prepare the samples for transport to the Oregon OSHA Laboratory.
- Submit bulk samples and air samples separately to avoid cross-contamination.
- If any submitted materials could be considered hazardous, consult and follow appropriate shipping regulations to assure safe handling during shipment (See internal procedures or contact the Oregon OSHA Laboratory for instructions).
- Pack the samples securely in a box or other sturdy container to avoid any rattle or shock damage. For asbestos samples, do not use expanded polystyrene packing (Styrofoam™)
or other static-producing packaging material. Place samples in a plastic bag so that they
do not move freely. Use bubble sheeting or other material as packing. Put identifying
paperwork in every package. Do not send samples in unpadded envelopes.

- Ensure that you include a printout of the OTIS air sampling worksheet and any applicable
SDSs with the samples.

**D. Receive Sample Results**

Calculate the exposure severity, which is the ratio of the sampling results to the PEL. Add the
SAE to the severity to determine the upper confidence limit, and subtract the SAE from the
severity to determine the lower confidence limit. The SAE is reported by the Oregon OSHA
Laboratory on the OTIS air sampling Laboratory Analysis Report. If there is none listed for a
specific substance, contact the Oregon OSHA Laboratory.

For mixtures, the CSHO must determine the SAE as described below in Section IV.D.5. If the
PEL violation is confirmed, apply the health effects codes as per Appendix K.

All sampling and analytical methods have some degree of uncertainty. The total uncertainty
depends on the combined effects of the contributing uncertainties inherent in sampling and
analysis, and has historically been called sampling and analytical error or SAE by OSHA. The
SAE is used to determine the upper and lower confidence limits as described below. Correct
application of the SAE enables CSHOs to make reliable compliance assessments of sample
results. The SAE is especially important when sample results are near the PEL.

Error factors determined by statistical methods shall be incorporated into the sample results to
obtain the lowest value of the true exposure (with a stated degree of statistical confidence) and
also the highest value of the true exposure (also with a stated degree of statistical confidence).

Confidence limits are values at each end of the confidence interval, which is the probable range
of the true value. The lower value is called the lower confidence limit (LCL), and the upper
value is the upper confidence limit (UCL). The LCL and the UCL are each termed one-sided
because the main concern is with being confident that the true exposure is either less or greater
than the PEL.

OSHA applies the LCL and UCL with a 95% statistical confidence limit and they are expressed
here as LCL$_{95\%}$ and UCL$_{95\%}$. SAEs that provide a one-sided 95% confidence limit have been
developed and are reported out on the Laboratory Analysis Report.

If the UCL$_{95\%} < 1.0$, a violation does not exist.

If LCL$_{95\%} < 1.0$ and the UCL$_{95\%} > 1.0$, classify as possible overexposure.

If LCL$_{95\%} > 1.0$, a violation exists.
The LCL_{95\%} and UCL_{95\%} are calculated differently depending upon the type of sampling method used:

1. Sampling Methods

Sampling methods can be classified into one of two categories:

- Full-period, Continuous, Single Sampling. Full-period, continuous, single sampling is defined as sampling over the entire sample period with only one sample. The sampling may be for a full-shift sample or for a short period ceiling determination.

- Full-period, Consecutive Sampling. Full-period, consecutive sampling is defined as sampling using multiple consecutive samples of equal or unequal duration that, if combined, equal the total duration of the sample period. An example would be taking four two-hour charcoal tube samples. There are several advantages to this type of sampling:
  
  - If a single sample is lost during the sampling period due to pump failure, gross contamination, etc., at least some data will have been collected to evaluate the exposure.
  
  - The use of multiple samples should result in slightly lower sampling and analytical errors.
  
  - Collection of several samples allows conclusions to be reached concerning the manner in which differing segments of the workday affect overall exposure.
  
  - This practice also allows for monitoring peak and ceiling exposures for the appropriate time. Note that there is some loss of sensitivity with consecutive sampling as compared to continuous sampling.

2. Calculations

If the initial and final sampling pump calibration flow rates are different, use of the highest of the two calibration flow rates will provide the lowest analytical results for compliance purposes. Generally, sampling is conducted at approximately the same temperature and pressure as calibration, in which case no correction for temperature and pressure is required and the sample volume reported to the Oregon OSHA Laboratory is the volume actually measured. Where sampling is conducted at a substantially different temperature or pressure than calibration, consult the operating manual for the sampling pump to determine if the air volume needs to be adjusted. If possible, calibrate the equipment at the site. The air volume reported by the CSHO is used in all subsequent calculations.
For particulates, the Oregon OSHA Laboratory reports milligrams per cubic meter (mg/m$^3$) of contaminant using the actual volume of air sampled at the sampling site as reported by the CSHO.

The Oregon OSHA Laboratory normally does not measure concentrations of gases and vapors directly in ppm. Rather, most analytical methods determine the total weight of contaminant in the collection medium. Using the air volume provided by the CSHO, the lab calculates concentration in mg/m$^3$ and then converts it to ppm at 25°C and 760 mmHg using Equation L-1 in Appendix L. This ppm result is to be compared with the PEL without adjustment for temperature and pressure at the sampling site. Additional supporting equations are also found in Appendix L.

3. Calculations for Full-Period, Continuous Single Samples

Obtain the full-period sampling result (X), the PEL, and the SAE. The SAE can be obtained from the OTIS air sampling worksheet or by contacting the Oregon OSHA Laboratory. Divide the full-period sampling result X by the PEL to determine the exposure severity, Y:

$$Y = \frac{X}{PEL}$$

Compute the upper confidence level at the 95% confidence level (UCL$^{95\%}$) as follows:

$$UCL_{95\%} = Y + SAE$$

Compute the lower confidence level at the 95% confidence level (LCL$^{95\%}$) as follows:

$$LCL_{95\%} = Y - SAE$$

Classify the exposure according to the following classification system:

- If the UCL$^{95\%} < 1.0$, a violation does not exist.
- If LCL$^{95\%} < 1.0$ and the UCL$^{95\%} > 1.0$, classify as possible overexposure.
- If LCL$^{95\%} > 1.0$, a violation exists.

If the results are in the “possible overexposure” category, consider further sampling, taking into consideration the seriousness of the hazard and pending citations. If further sampling is not conducted, or if additional measured exposures still fall into the “possible overexposure” category, the CSHO may wish to carefully explain to the employer and employee representative at the closing conference that the exposed employee(s) may be overexposed, but that there is insufficient data to document noncompliance. The employer should be encouraged to voluntarily reduce the exposure and/or to conduct further sampling to ensure that exposures are not in excess of the PEL.

See Appendix M for an example calculation for a full-period, continuous single sample using the equations above.
4. Calculations for Full-Period Consecutive Samples

The use of multiple consecutive samples should result in slightly lower sampling and analytical errors than the use of one continuous sample because the inherent errors tend to partially cancel each other. The mathematical calculations, however, are somewhat more complicated. The CSHO should first determine if compliance or noncompliance can be established using a calculation method similar to that noted for a full-period, continuous, single sample measurement, following the instructions in the “Compliance/Noncompliance Method” box below.

<table>
<thead>
<tr>
<th>Compliance/Noncompliance Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain the results of consecutive samples taken during the workshift. Let $X_n$ be the concentration for a given sample, and $T_n$ be the sampling duration for that sample, and $n$ be the sample number:</td>
</tr>
<tr>
<td>Also obtain the SAE listed in the OTIS air sampling worksheet.</td>
</tr>
</tbody>
</table>

1. Compute the TWA exposure, $X$.

**Equation 4**

$$X = \frac{(X_1T_1) + (X_2T_2) \cdots + (X_nT_n)}{480 \text{ min}}$$

2. Divide the TWA exposure by the PEL to find $Y$, the standardized average ($\frac{TWA}{PEL}$).

3. Compute the $UCL_{95\%}$ as follows:

$$UCL_{95\%} = Y + SAE$$

4. Compute the $LCL_{95\%}$ as follows:

$$LCL_{95\%} = Y - SAE$$

Classify the exposure according to the following classification system:

If $UCL_{95\%} < 1.0$, a violation does not exist.

If $LCL_{95\%} < 1.0$, and the $UCL_{95\%} > 1.0$, classify as possible overexposure and recalculate using the more exact calculation found in Equation 14 below.

If $LCL_{95\%} > 1.0$, a violation exists.
When the $\text{LCL}_{95\%} < 1.0$ and $\text{UCL}_{95\%} > 1.0$, the results are in the “possible overexposure” region and the CSHO must analyze the data using the more exact calculation for full-period consecutive sampling, as follows:

**Equation 5**

$$LCL_{95\%} = Y - \frac{SAE \sqrt{(T_1X_1)^2 + (T_2X_2)^2 + \cdots + (T_nX_n)^2}}{PEL(T_1 + T_2 + \cdots + T_n)}$$

See [Appendix N](#) for an example calculation for a full-period consecutive sampling using the equations above.

### 5. SAEs for Exposure to Chemical Mixtures

As described above in Section III, often an employee is simultaneously exposed to a variety of chemical substances, which may result in additive or synergistic health effects. OAR 437-002-0382(4) specifies the computational approach for assessing exposure to a mixture.

Whether using a single PEL or the mixture calculation, the SAE of the individual constituents must be considered before arriving at a final compliance decision. These SAEs can be pooled and weighted to give a control limit for the additive mixture. To illustrate this control limit, the mixture calculation is expressed in the following equation (Equation 3 from above).

$$E_m = \left(\frac{C_1}{L_1} + \frac{C_2}{L_2} \right) + \cdots \left(\frac{C_n}{L_n}\right)$$

Where:

- $E_m$ = equivalent exposure for the mixture ($E_m$ should be less than or equal to 1 for compliance)
- $C$ = concentration of a particular substance
- $L$ = PEL

If $E_m > 1$, indicating that an overexposure has occurred, then the SAE for each substance also needs to be considered:

**Equation 6**

$$Y_n = \frac{C_n}{L_n}$$

Ratio to total exposure
Equation 7

\[ R_1 = \frac{Y_1}{E_m}, \ldots R_n = \frac{Y_n}{E_m} \]

The SAEs (95% confidence) of the substances comprising the mixture can be pooled to give the SAE of the mixture using:

Equation 8

\[ R_{st} = \sqrt{[(R_1 \times SAE_1)^2 + (R_2 \times SAE_2)^2 + \ldots (R_n \times SAE_n)^2]} \]

Equation 9

\[ UCL = 1 + R_{St} \]

Equation 10

\[ LCL = 1 - R_{St} \]

If \( E_m < LCL \) then no overexposure has occurred at the 95% confidence level.

If \( LCL \leq E_m \leq UCL \) then the exposure cannot be classified as either under or over the PEL at the 95% confidence level; further sampling may be necessary.

If \( E_m > UCL \) then an overexposure has occurred (95% confidence).

See Appendix H for an example calculation.
V. BIBLIOGRAPHY


Appendix A - Pre-Weighted Filters

The Oregon OSHA Laboratory provides pre-weighed filters for gravimetric analysis. These filter/cassette units reduce sample preparation time by CSHOs because the filters are weighed at the Oregon OSHA Laboratory and the units are shipped to the field fully assembled and ready for use. The filter/cassette units are returned to the Oregon OSHA Laboratory for gravimetric determinations and additional analyses as needed. The primary filter medium is 5-μm, 37-mm or 25-mm diameter, low-ash PVC. The PVC filters should be used for silica (quartz) analysis, metals, and other appropriate substances requiring gravimetric analysis such as total particulate, respirable dust, inhalable dust, and welding fume. The filter cassettes may be used with or without a cyclone. Other than for silica, if the gravimetric analysis yields a result less than the PEL for the requested substance(s), typically no further analysis will be provided unless specifically requested. MCEF filters may be used for metals analysis when a gravimetric analysis is not required. The filter/cassette unit is shown below in Figure A-1. Appendix B includes a partial listing of substances that should be sampled and analyzed gravimetrically using pre-weighed cassettes.

Figure A-1. Filter/Cassette Unit – 3 piece

Check the filter frequently to avoid overloading. This can be accomplished by looking into the inlet sampling port of the cassette. Use a flashlight, if necessary. Visual observation of the airborne dust in the workplace may assist in determining how frequently to check the filter for overloading. If used with a cassette, do not lift the cyclone in such a way that particles from the grit pot could be deposited on the filter.

Each of the filter assemblies is numbered for weighing purposes (Figure A). To aid in tracking the filters, it is helpful to use the number as the sample submission number when entering the sample information into the LIMS. A blank should be included with every set of samples. It is very important that the blank is from the same batch of filters as the samples. More than one blank may be included with each set.
Figure A-1. **Filter Cassettes:**

Red outlet connects to sample pump and blue inlet open to atmosphere. Cassettes for field use will be sealed with a white band around the cassette. The lab number will be written on the bottom of the support pad.

The filter/cassette assembly may be used with an aluminum cyclone or a standard cassette holder currently in field use.
## APPENDIX B – Substances for Gravimetric Determination

### Table B-1. Partial list of Substances for Gravimetric Determinations

<table>
<thead>
<tr>
<th>Substance</th>
<th>IMIS</th>
<th>Method #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respirable Particulate</td>
<td>9130</td>
<td>1003</td>
</tr>
<tr>
<td>Respirable Nuisance Dust</td>
<td>9130</td>
<td>1003</td>
</tr>
<tr>
<td>Respirable Welding Fume</td>
<td>2587</td>
<td>1003</td>
</tr>
<tr>
<td>PNOR (Particulate Not Otherwise Regulated)</td>
<td>9130</td>
<td>1003</td>
</tr>
<tr>
<td>Total Particulate</td>
<td>9135</td>
<td>1004</td>
</tr>
<tr>
<td>Oil Mist</td>
<td>5010</td>
<td>1004</td>
</tr>
<tr>
<td>Welding Fume</td>
<td>2587</td>
<td>1004</td>
</tr>
<tr>
<td>Cotton Dust</td>
<td>0735</td>
<td>1004</td>
</tr>
<tr>
<td>Grain Dust</td>
<td>G109</td>
<td>1004</td>
</tr>
<tr>
<td>Wood Dust</td>
<td>9210, 9211, or W102</td>
<td>1004</td>
</tr>
<tr>
<td>PNOR (Particulate Not Otherwise Regulated)</td>
<td>9130</td>
<td>1004</td>
</tr>
<tr>
<td>Carbon Black</td>
<td>0527</td>
<td>OSHA ID-196</td>
</tr>
<tr>
<td>Asphalt Fume</td>
<td>0290</td>
<td>1009</td>
</tr>
<tr>
<td>Benzene Solubles</td>
<td>0700</td>
<td>1009</td>
</tr>
<tr>
<td>Coal Tar Pitch Volatiles</td>
<td>0700</td>
<td>1009</td>
</tr>
<tr>
<td>Paraffin Wax Fume</td>
<td>2000</td>
<td>1040</td>
</tr>
<tr>
<td>Inhalable Dust</td>
<td>9210, 9211, or W102</td>
<td>1048</td>
</tr>
<tr>
<td>Inhalable Wood Dust</td>
<td>9210, 9211, or W102</td>
<td>1048</td>
</tr>
<tr>
<td>Diesel Exhaust</td>
<td>D130</td>
<td>1055</td>
</tr>
<tr>
<td>Combustible Dust</td>
<td>P100</td>
<td>1064</td>
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<tr>
<td>Moisture Content</td>
<td></td>
<td>1064</td>
</tr>
</tbody>
</table>
# APPENDIX C – Analytes Using Impinger as Primary Method

## Table C-1. Impinger Methods

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Chemical Abstracts Service (CAS) Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkyl dimethyl benzyl ammonium chloride</td>
<td>139-08-2</td>
</tr>
<tr>
<td>Benzyl cetyl dimethyl ammonium chloride</td>
<td>122-18-9</td>
</tr>
<tr>
<td>Chlorine Dioxide</td>
<td>10049-04-4</td>
</tr>
<tr>
<td>Cyanide</td>
<td>57-12-5</td>
</tr>
<tr>
<td>Diisocyanates:</td>
<td></td>
</tr>
<tr>
<td>• HDI (Hexamethylene diisocyanate)</td>
<td>822-06-0</td>
</tr>
<tr>
<td>• HDI-BT (Biruet Trimer of HDI)</td>
<td>4035-89-6</td>
</tr>
<tr>
<td>• HDI-IC (Isocyanurate of HDI)</td>
<td>3779-63-3</td>
</tr>
<tr>
<td>• IPDI (Isophorone diisocyanate)</td>
<td>4098-71-9</td>
</tr>
<tr>
<td>• MDI (Methylene diphenyl diisocyanate)</td>
<td>101-68-8</td>
</tr>
<tr>
<td>• TDI (Toluene diisocyanate)</td>
<td>584-84-9</td>
</tr>
<tr>
<td>Hexamethylenetetramine</td>
<td>100-97-0</td>
</tr>
<tr>
<td>Hydrogen cyanide</td>
<td>57-12-5</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>7722-84-1</td>
</tr>
<tr>
<td>MEK Peroxide</td>
<td>1338-23-4</td>
</tr>
<tr>
<td>MOCA</td>
<td>101-14-4</td>
</tr>
<tr>
<td>Rosin Core Pyrolysis Products</td>
<td></td>
</tr>
</tbody>
</table>
The Oregon OSHA Laboratory will provide an expiration date for sampling media shipped to the field. The date will be printed on its packaging. Expired media should be returned to the lab. Return liquid media to the lab in the same outer packaging in which it was received.

Table D-1. Shelf Life of Sampling Media Provided by the Oregon OSHA Laboratory

<table>
<thead>
<tr>
<th>Sampling medium</th>
<th>Shelf Life</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-weighed PVC filters</td>
<td>1 year</td>
<td></td>
</tr>
<tr>
<td>Pre-weighed silver membrane filters</td>
<td>1 year</td>
<td></td>
</tr>
<tr>
<td>MCEF filters</td>
<td>5 years</td>
<td></td>
</tr>
<tr>
<td>Glass fiber filters</td>
<td>5 years</td>
<td></td>
</tr>
<tr>
<td>Quartz fiber filters</td>
<td>5 years</td>
<td></td>
</tr>
<tr>
<td>Teflon filters</td>
<td>5 years</td>
<td></td>
</tr>
<tr>
<td>x MAMA solution in impingers and MAMA treated glass fiber filters</td>
<td>1 month</td>
<td>method 1010 - Diisocyanates</td>
</tr>
<tr>
<td>x MCEF filters treated with Na₂CO₃</td>
<td>1 week</td>
<td>method 1020 – Arsenic (gaseous)</td>
</tr>
<tr>
<td>x Dimethyl phthalate in impingers</td>
<td>5 years</td>
<td>method 1021 – MEK peroxide</td>
</tr>
<tr>
<td>x Glass fiber filters coated with HBr</td>
<td>6 months</td>
<td>method 1025 – Triglycidyl isocyanurate</td>
</tr>
<tr>
<td>x Carbonate treated Whatman filter</td>
<td>6 months</td>
<td>method 1029 – Sulfur dioxide</td>
</tr>
<tr>
<td>x Nitrite impregnated glass fiber filter</td>
<td>1 month</td>
<td>method 1030 - Ozone</td>
</tr>
<tr>
<td>x Pre-cleaned silver membrane filters</td>
<td>6 months</td>
<td>method 1035 – Chlorine and bromine</td>
</tr>
<tr>
<td>x MBTH solution in impingers</td>
<td>1 week</td>
<td>method 1037 – Rosin core pyrolysis products</td>
</tr>
<tr>
<td>x Hydrochloric acid solution in impingers</td>
<td>1 year</td>
<td>method 1042 – MOCA</td>
</tr>
<tr>
<td>x Potassium hydroxide solution in impingers</td>
<td>1 year</td>
<td>method 1043 - Cyanide</td>
</tr>
<tr>
<td>x Pre-treated silver membrane filters</td>
<td>1 year</td>
<td>method 1055 – Diesel exhaust</td>
</tr>
<tr>
<td>x Potassium iodide solution in impingers</td>
<td>6 months</td>
<td>method 1058 – Chlorine dioxide</td>
</tr>
<tr>
<td>x Titanium sulfate solution in impingers</td>
<td>1 week</td>
<td>method 1061 – Hydrogen peroxide</td>
</tr>
<tr>
<td>x Teflon filter with two treated quartz fiber filters</td>
<td>1 month</td>
<td>method 1075 – Nitrogen trichloride</td>
</tr>
<tr>
<td>x Mercuric acetate treated glass fiber filter</td>
<td>1 month</td>
<td>method 1084 – Methyl mercaptan</td>
</tr>
<tr>
<td>Water in impingers</td>
<td>1 year</td>
<td>method 1102 – Quaternary amines</td>
</tr>
<tr>
<td>x Sulfuric acid treated glass fiber filter</td>
<td>1 month</td>
<td>method 1105 – Xylenediamine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>method 1123 - Methylenedianiline</td>
</tr>
</tbody>
</table>

* Give the Oregon OSHA Laboratory at least two days notice to allow time for reagent preparation. * Hazardous materials shipment requirements.
APPENDIX E –
Common Sampling Media for Most Frequently Requested Analyte Groups from the Oregon OSHA Laboratory

- Acids (inorganic) – SKC 226-10-03 silica gel tubes
- Aldehydes – SKC 226-119 DNPH treated silica gel tubes
- Isocyanates – MAMA in toluene reagent in midget impinger followed by filter
- Metals – 5.0 µm LA-PVC filters or 0.8 µm MCEF filters in 2 piece cassettes
- Particulate/Dust – 5.0 µm LA-PVC
- Silica – 5.0 µm LA-PVC filters in 3-piece cassettes
- Solvents – SKC 226-01 charcoal tubes

For a detailed list reference the OR-OSHA Lab Sampling Procedures
APPENDIX F – Calibration

A. Sampling Pump Calibration

Calibrate personal sampling pumps before and after each day of sampling using one of the techniques described below. Assure that the calibration equipment is within its prescribed calibration interval and not overdue to be calibrated. Record the Oregon tag number of the calibration equipment in your case file and the OTIS air sampling report.

If the sampling pump is equipped with a rotameter or digital flow readout, record the reading in the OTIS air sampling report. Bear in mind that the accuracy of a pump rotameter is only approximate; it is intended primarily to facilitate setting the flow rate for calibration.

Most of the following examples in this appendix use filter cassettes as the sampling media, but the examples are generally applicable to adsorbent tubes as well.

Before pre-calibration, replace or recharge sampling pump batteries as needed.

Place the same type of sampling media in-line during sampling pump calibration that will be used to sample in the field. Do not use the actual cassette and filter intended for sampling use to perform calibration.

B. Pump Calibration for use with Cyclone

The “Jarless Cyclone Calibration” procedure is the recommended method for calibrating a cyclone. A one-liter jar should no longer be used due to technical issues such as leakage of the jar lid but an SKC aluminum calibration chamber used instead.

The purpose of the procedure is to determine whether the sampling pump will be able to maintain the required flow rate as the drop in static pressure grows due to particulates loading up on the filter. The typical pressure drop across a clean 5-µm filter is 2 inches of water pressure. The additional pressure drop from the cyclone is approximately 0.25 inches. As a filter loads up, the additional pressure drop may be as high as 20 inches of water pressure.

The SKC aluminum calibration chamber (see Figure F-1) fits over the stem of the cyclone allowing for standard ¼” tubing to be attached to the air flow controller.
Refer to additional information on cyclone use in Appendix I.

Figure F-1. Calibration Chamber

Figure F-2. TSI Mass Flow Meter

Figure F-3. Gillian Gilibrator Pump Calibrator
C. Electronic Flow Calibrators

The TSI 4140 mass flow meter (see Figure F-2) provides instantaneous air flow readings for pump calibration. These calibrators measure the flow rate and display the results as volume per unit of time and can be used to calibrate most air sampling pumps. The TSI 4140 unit has a range of 0.01-20L/min.

For calibration requiring higher flow rates, contact the Oregon OSHA Lab for different equipment.

Electronic bubble flow meters may also be used but are not as widespread.

The Gilian Gilibrator® I and II by Sensidyne® (see Figure F-3) are electronic bubble flow meters, used to calibrate sampling pumps that provide instantaneous air-flow readings and cumulative averaging of multiple measurements. Different flow cells are used to accommodate different flow ranges. The middle-sized flow cell is typically used for personal sampling for particulates, while the largest cell is used for high volume area sampling and the smallest cell may be needed for certain low flow sorbent tube methods. The total range with the different flow cells is from 1 mL/min to 30 L/min. Gilibrators should not be left plugged into the charger for extended time periods because doing so will decrease the service life of the battery.

Another wet-cell calibrator available in some OSHA field offices is the mini-Buck™ (see Figure F-4). Its operation is similar to the Gilibrator.

It is recommended that the flow rates obtained from these devices be reported to three significant figures. For example, a flow rate shown as 1.006 L/min should be reported as 1.01 L/min.

D. Maintenance and Care of Electronic Calibrators

Consult the manufacturer's instruction manuals for complete details. Periodically, compare the calibrator to another unit to make sure that it is functioning properly. Return the calibrator to the Oregon OSHA Laboratory annually to be calibrated and serviced.
APPENDIX G – How to Apply Lab Seals (Form 440-1316) to Sampling Media

FIGURE G-1. Correctly sealed charcoal tube. (Sample inside lab seal.)

FIGURE G-2. Incorrectly sealed charcoal tube. (End caps can be removed, allowing sample integrity to be jeopardized without disturbing the seal.)

FIGURE G-3. Correctly sealed charcoal tubes. (Samples inside of a Whirl-Pak® with bag opening securely closed and sealed. Other media types, such as filter cassettes and bulk solid material, may be sealed in this manner.)
FIGURE G-4. Incorrectly sealed charcoal tubes in zip lock bag allow access to samples because bag opening not completely sealed.

FIGURE G-5. Incorrectly sealed cassette allows access to inlet/outlet ports after sample has been taken.

FIGURE G-6. Correctly sealed cassette with lab seal covering inlet/outlet ports maintaining sample integrity.

FIGURE G-7. Standard asbestos cassette (25mm) correctly sealed.
APPENDIX H – Example Calculations for Mixtures

As an example, an exposure to three different substances:

<table>
<thead>
<tr>
<th>Material</th>
<th>8-hr. Exposure (ppm)</th>
<th>8-hr. TWA PEL (ppm)</th>
<th>SAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance 1</td>
<td>500</td>
<td>1,000</td>
<td>0.089</td>
</tr>
<tr>
<td>Substance 2</td>
<td>80</td>
<td>200</td>
<td>0.11</td>
</tr>
<tr>
<td>Substance 3</td>
<td>70</td>
<td>200</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Using Equation 3 (from Section III.G.2.):

\[ E_m = \left( \frac{C_1}{L_1} + \frac{C_2}{L_2} + \cdots \frac{C_n}{L_n} \right) \]

Where:
- \( E_m \) is the equivalent exposure severity for the mixture
- \( E_m \) should be < 1 for compliance
- \( C \) is the concentration of a particular contaminant
- \( L \) is the OSHA exposure limit for that substance.

\[ E_m = \frac{500}{1000} + \frac{80}{200} + \frac{70}{200} = 1.25 \]

Since \( E_m > 1 \) an overexposure appears to have occurred; however, the SAE for each substance also needs to be considered:

Exposure severity ratio (for each substance) (from Equation 6 from Section IV.D.5. above)

\[ Y_n = \frac{C_n}{L_n} \]

Ratio each to total exposure (using Equation 7 from Section IV.D.5.)

\[ R_1 = \frac{Y_1}{E_m}, \ldots, R_n = \frac{Y_n}{E_m} \]

The SAEs (95% confidence) of the substances comprising the mixture can be pooled by:

Equation H-1

\[ R_{st} = \sqrt{\left[ (R_1)^2 \times (SAE_1)^2 + (R_2)^2 \times (SAE_2)^2 + \cdots (R_n)^2 \times (SAE_n)^2 \right]} \]

which is also equivalent to (using Equation 8 from Section IV.D.5.):
\[ R_{st} = \sqrt{[(R_1 \times SAE_1)^2 + (R_2 \times SAE_2)^2 + \cdots + (R_n \times SAE_n)^2]} \]

From **Equation 9**

UCL = 1 + R_{st}

From **Equation 10**

LCL = 1 - R_{st}

If \( E_m < LCL \) then no overexposure has occurred at the 95% confidence level.

If \( LCL \leq E_m \leq UCL \) then the exposure cannot be classified as either under or over the PEL at the 95% confidence level; further sampling may be necessary.

If \( E_m > UCL \) then an overexposure has occurred (95% confidence).

Using the mixture data above:

<table>
<thead>
<tr>
<th>Y_1 = 500/1,000</th>
<th>Y_2 = 80/200</th>
<th>Y_3 = 70/200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y_1 = 0.5</td>
<td>Y_2 = 0.4</td>
<td>Y_3 = 0.35</td>
</tr>
<tr>
<td>R_1 = Y_1/E_m = 0.4</td>
<td>R_2 = 0.32</td>
<td>R_3 = 0.28</td>
</tr>
</tbody>
</table>

\[(R_{st})^2 = (0.4 \times 0.089)^2 + (0.32 \times 0.11)^2 + (0.28 \times 0.18)^2\]

\[ R_{st} = \sqrt{(R_{st})^2} = 0.071 \]

\[ UCL = 1 + R_{st} = 1.071 \]

\[ E_m = 1.25 \]

Therefore \( E_m > UCL \) and an overexposure has occurred within 95 percent confidence limit.

An executable computer program is available which will calculate a control limit for any mixture. Simply input the exposures, limits, and SAEs and the program will calculate a control limit according to the above equation. Access to federal OSHA’s Extra Net may be possible through your Health or Safety Manager.

**Mixture Calculator**
APPENDIX I – Cyclone Assembly and Cleaning Instructions

A. Cyclone Assembly

Inspect the cyclone for signs of wear or damage. Inspect the O-ring and the grit pot. Return the cyclone to the Oregon OSHA Lab if the parts appear to be damaged. Cyclones are inspected and leak tested annually by the Oregon OSHA Lab.

Figure I-1. SKC aluminum 37mm cyclone

Figure I-2. SKC aluminum 25mm cyclone

Figure I-3. Cyclone holder apparatus.
(Cyclone should always remain upright during sampling and cassette removal to ensure grit pot does not empty onto the filter.)
B. Cyclone Cleaning – **After each use**

Unscrew the grit pot from the cyclone. Empty the grit pot by turning it upside down and tapping it gently on a solid surface. Clean the cyclone thoroughly and gently after each use in warm soapy water. Rinse it thoroughly in clean water, shake off excess water, and set aside to dry before reassembly. Never insert anything into the cyclone during cleaning.
APPENDIX J – Chain of Custody

The Oregon OSHA Laboratory uses established chain-of-custody procedures as outlined in the Quality Assurance Manual to track whether official Form 440-1316 lab seals were properly used (see Appendix G) to ensure the integrity of samples collected by OSHA CSHOs. The procedure also tracks the history and control of samples received at the Oregon OSHA Laboratory through use of the LIMS. The chain of custody includes the following dates: the date the sample was collected, the date the sample was received at the Oregon OSHA Laboratory, the date the sample was logged into the LIMS at the Oregon OSHA Laboratory, the date the sample was assigned to the analyst, and the date the sample results were released by the lab manager or his/her representative. It is important to follow chain-of-custody requirements because it documents the proper handling of OSHA samples for litigation purposes.
When available, the Federal OSHA [Chemical Sampling Information](#) files contain health effects information, including the applicable Health Effects Codes, for each chemical. The complete list of Health Effects Codes is shown below in Table K-1. The Health Effects Codes indicate the principal health effects of exposure to each substance, and are used to determine the seriousness of a violation and severity of the penalty, based on the guidelines contained in Chapter 7 of the Oregon OSHA Field Inspection Reference Manual [Field Inspection Reference Manual](#) (FIRM).

### Table K-1. HEALTH EFFECTS CODES

<table>
<thead>
<tr>
<th>Code</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE1</td>
<td>Cancer---Currently regulated by OSHA as carcinogen</td>
</tr>
<tr>
<td>HE2</td>
<td>Chronic (Cumulative) Toxicity---Known or Suspected animal or human carcinogen, mutagen (except Code HE1 chemicals)</td>
</tr>
<tr>
<td>HE3</td>
<td>Chronic (Cumulative) Toxicity---Long-term organ toxicity other than nervous, respiratory, hematologic or reproductive</td>
</tr>
<tr>
<td>HE4</td>
<td>Acute Toxicity---Short-term high risk effects</td>
</tr>
<tr>
<td>HE5</td>
<td>Reproductive Hazards---Teratogenesis or other reproductive impairment</td>
</tr>
<tr>
<td>HE6</td>
<td>Nervous System Disturbances---Cholinesterase inhibition</td>
</tr>
<tr>
<td>HE7</td>
<td>Nervous System Disturbances---Nervous system effects other than narcosis</td>
</tr>
<tr>
<td>HE8</td>
<td>Nervous System Disturbances---Narcosis</td>
</tr>
<tr>
<td>HE9</td>
<td>Respiratory Effects Other Than Irritation---Respiratory sensitization (asthma or other)</td>
</tr>
<tr>
<td>HE10</td>
<td>Respiratory Effects Other Than Irritation---Cumulative lung damage</td>
</tr>
<tr>
<td>HE11</td>
<td>Respiratory Effects---Acute lung damage/edema or other</td>
</tr>
<tr>
<td>HE12</td>
<td>Hematologic (Blood) Disturbances---Anemias</td>
</tr>
<tr>
<td>HE13</td>
<td>Hematologic (Blood) Disturbances---Methemoglobinemia</td>
</tr>
<tr>
<td>HE14</td>
<td>Irritation-Eyes, Nose, Throat, Skin---Marked</td>
</tr>
<tr>
<td>HE15</td>
<td>Irritation-Eyes, Nose, Throat, Skin---Moderate</td>
</tr>
<tr>
<td>HE16</td>
<td>Irritation-Eyes, Nose, Throat, Skin---Mild</td>
</tr>
<tr>
<td>HE17</td>
<td>Asphyxiants, Anoxiants</td>
</tr>
<tr>
<td>HE18</td>
<td>Explosive, Flammable, Safety (No adverse effects encountered when good housekeeping practices are followed)</td>
</tr>
<tr>
<td>HE19</td>
<td>Generally Low Risk Health Effects---Nuisance particulates, vapors or gases</td>
</tr>
<tr>
<td>HE20</td>
<td>Generally Low Risk Health Effects---Odor</td>
</tr>
</tbody>
</table>
APPENDIX L – Conversion Equations (mg/m$^3$ to ppm)

Equation L-1

$$ ppm_{NTP} = \frac{(mg/m^3)(24.45)}{MW} $$

Where:
- 24.45 = molar volume at 25°C (298K) and 760 mmHg
- MW = molecular weight
- NTP = Normal Temperature and Pressure (25°C and 760 mmHg)
- mmHg = millimeters of mercury

A conversion calculator is available from SKC at: [SKC pm to mg/m3 Conversion Calculator](#)

CSHOs will not usually need to calculate the exposure concentration in ppm at the sampling site (ppm$_{PT}$) but, if necessary, it can be calculated from the Oregon OSHA Laboratory’s results reported in ppm$_{NTP}$ by using the following equation:

**Equation L-2**

$$ ppm_{PT} = (ppm_{NTP}) \left(\frac{760}{P}\right) \left(\frac{T}{298}\right) $$

Where:
- P = sampling site pressure (mmHg)
- T = sampling site temperature (K)
- 298 = normal temperature in degrees Kelvin (273 + 25)
- 760 = normal atmospheric pressure in mmHg

**Equation L-3**

Because $ppm_{NTP} = \frac{(mg/m^3)(24.45)}{MW}$

$$ ppm_{PT} = (mg/m^3) \left(\frac{24.45}{MW}\right) \left(\frac{760}{P}\right) \left(\frac{T}{298}\right) $$

NOTE: When a contaminant concentration is converted from mg/m$^3$ and expressed as ppm$_{PT}$, that value cannot be compared directly to the PEL table without first converting it to its corresponding ppm$_{NTP}$ value.

NOTE: The [barometric pressure](#) for the time period sampled can sometimes be obtained from the [NOAA website](#) or by calling the local weather station or airport. If air pressures are obtained by this route, it is necessary to obtain the unadjusted barometric pressure (station pressure) for
compliance applications. The barometric pressure information most readily available from weather and aviation sources is the sea-level adjusted barometric pressure which tends to average about 760 mmHg and does not represent the actual air pressure of worksites much removed from sea level.

If the sources above are not readily available or cannot provide the actual station pressure, then the elevation (Elev) in feet of the worksite can be used to calculate the typical barometric pressure (P) in mmHg using the following equation:

**Equation L-4**

\[
P = 760 \times \left[1 - \frac{Elev \times 1.6470 \times 10^{-3}}{295.20 \times (1 + Elev \times 4.9787 \times 10^{-8})}\right]^{6.3222}
\]

Equation L-4 is an adaptation of the atmospheric model equation used in the *U.S. Standard Atmosphere* (1976) using a higher average effective sea-level screen temperature (295.2K) and lower temperature lapse rate (5.4K/km) typically observed over land surfaces within the northern latitudes of the U.S. (19ºN to 61ºN). For most of the U.S., the barometric pressures obtained with this equation are better estimates of observed station pressures than the 1976 model, and deviate from mean annual station pressures by about 0.24% RSD (percent relative standard deviation) for elevations below 4,300 feet and 0.52% RSD for elevations below 30,000 feet. These deviations are insignificant compared to the estimated 1.6% RSD for combined normal seasonal, storm, and diurnal station pressure variations observed at any elevation within the year. The 1.6% RSD may be assumed if the worksite elevation can be estimated to within 100 feet. A global positioning system (GPS) elevation measurement is typically within 100 feet of the actual elevation. GPS elevation measurements should be made outdoors and away from tall structures. Example calculations using the equation give 723.2 mmHg for an elevation of 1,400 feet above mean sea level and 569.5 mmHg for an elevation of 8,000 feet above mean sea level.
APPENDIX M – Example Calculations for Full-Period, Continuous Single Sample

A single glass-fiber filter and personal sampling pump were used to sample for carbaryl for an 8-hour period. The Oregon OSHA Laboratory reported 6.07 mg/m³. The SAE for this method is 0.23. The PEL is 5.0 mg/m³.

Step 1. Calculate the exposure severity:

\[ Y = \frac{6.07}{5.0} = 1.21 \]

Step 2. Calculate confidence limits

Calculate the LCL\(_{95\%}\):

\[ LCL_{95\%} = 1.21 - 0.23 = 0.98 \]

Because the LCL\(_{95\%}\) does not exceed 1.0, noncompliance is not established.

Calculate the UCL\(_{95\%}\):

\[ UCL_{95\%} = 1.21 + 0.23 = 1.44 \]

Step 3. Classify the exposure.

Because the LCL\(_{95\%}\) < 1.0 and the UCL\(_{95\%}\) > 1.0, classify as possible overexposure.
APPENDIX N – Example Calculations for Full-Period Consecutive Sampling

If two consecutive samples had been taken for carbaryl instead of one continuous sample, and the following results were obtained:

<table>
<thead>
<tr>
<th>Sample Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>Sampling rate (L/min)</td>
</tr>
<tr>
<td>Time (min)</td>
</tr>
<tr>
<td>Volume (L)</td>
</tr>
<tr>
<td>Weight (mg)</td>
</tr>
<tr>
<td>Concentration (mg/m³)</td>
</tr>
</tbody>
</table>

The SAE for carbaryl is 0.23

**Step 1.** Calculate the UCL₉₅% and the LCL₉₅% from the sampling and analytical results. Using Equation 4 from Section IV.D.4.:

\[
TWA = \frac{(6.26 \text{ mg/m}^3)(240 \text{ min}) + (5.85 \text{ mg/m}^3)(240 \text{ min})}{480 \text{ min}} = 6.055 \text{ mg/m}^3
\]

\[
\text{Severity Ratio} = \frac{\text{Sample respirable dust concentration (mg/m}^3\text{)}}{\text{calculated PEL (mg/m}^3\text{)}}
\]

The equation above is the same as: \( Y = \frac{X}{\text{PEL}} \)

\[
\text{Exposure severity (Y)} = \frac{6.055 \text{ mg/m}^3}{\text{PEL}} = \frac{6.055}{5.0} = 1.21
\]

Calculate the Lower Confidence Limit (LCL) by subtracting the SAE from the severity:

\[
LCL = \text{Severity} - \text{SAE}
\]

**Assuming a continuous sample:** \( LCL_{95\%} = 1.21 - 0.23 = 0.98 \)

Calculate the Upper Confidence Limit (UCL) by adding the SAE to the severity:

\[
UCL = \text{Severity} + \text{SAE}
\]

If the UCL is less than 1, there is a greater than 95% confidence that the sampled employee’s exposure did not exceed the PEL.
\[ UCL_{95\%} = 1.21 + 0.23 = 1.44 \]

Step 2. Because the LCL_{95\%} < 1.0 and UCL_{95\%} > 1.0, the results are in the possible overexposure region. To document an overexposure, the CSHO must reanalyze the data using the more exact calculation for full-period consecutive sampling (Using Equation 5 from Section IV.D.4.):

\[
\begin{align*}
LCL_{95\%} &= (1.21) - \frac{0.23 \sqrt{(240 \text{ min})^2(6.26 \text{ mg/m}^3)^2 + (240 \text{ min})^2(5.85 \text{ mg/m}^3)^2}}{5.0 \text{ mg/m}^3 (240 \text{ min} + 240 \text{ min})} \\
&= 1.21 - 0.20 = 1.01
\end{align*}
\]

Since the LCL_{95\%} > 1.0, a violation is established.