Oregon OSHA
TECHNICAL MANUAL

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

SAMPLING, MEASUREMENTS METHODS and INSTRUMENTS

*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

<u>Chapter Revision Information:</u>

- *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 "<u>Personal Sampling for Air Contaminants</u>".*
- *In December 2014, Federal OSHA's February 11th,2014 Technical Manual update "<u>Personal Sampling for Air Contaminants</u>" was customized to make the document's instructions specific to Oregon OSHA's sampling equipment, Lab 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).*
- *In September 2022, the chapter was updated to reflect current Oregon OSHA operating procedures and sampling equipment.*

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 the Oregon OSHA Lab's Sampling Procedures and the Oregon OSHA Field Inspection Reference Manual (FIRM). Sampling and analytical methods that have been validated by either Federal OSHA or the National Institute for Occupational Safety and Health (NIOSH) should be used whenever possible. Sometimes the Oregon OSHA Lab (henceforth referred to as the Lab) will approve the use of procedures developed by other organizations. Only procedures approved by the Lab should be used. The use of sampling methods not approved by the Lab may require resampling with an approved sampling procedure. The Lab 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 Lab whenever questions arise.

Sampling strategies should be planned for 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 Lab 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 Lab Manager is required. Follow all chain-of-custody protocols. Apply tamper-evident seals (Lab seal Form 440-1316) to each sample as shown in Appendix G, and ensure that the chain-of-custody information is visible. Make certain that samples are properly documented in the Lab Information Management System (LIMS) and create a sample submittal form (Report – LIM8001).

II. Pre-inspection Activities

A. Review Background Information

Review and follow the inspection procedures in the Oregon OSHA Field Inspection Reference Manual (FIRM). 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 the Lab's Sampling Procedures for the required sampling media, minimum and maximum sampling volumes and flow rates, potential interferences, and handling requirements for individual chemical substances, including whether there are special handling or shipping requirements prior to sample collection. For example, some types of samples require expedited shipping and/or in a cooler with cold packs, or may need to be protected from light. Contact the Lab for further guidance if necessary.

B. Available Sampling Media, Equipment and Supplies

The Lab provides sampling media, supplies and equipment such as:

- Filter cassettes
- Sorbent tubes, such as charcoal tubes
- Ghost wipes
- Sample containers
- Whirl-Pak® sample bags
- Tube holders, tube openers, collar clips and manifolds
- Lab sample seals
- Sealing tape
- Draeger Chip Measurement System (CMS) chemical sensing chips
- Detector tubes
- Cyclones
- IOM samplers
- Tygon tubing
- Calibration gas and accessories
- Ventilation smoke tubes
- Nitrile gloves
- N95 respirators

CSHOs may place orders for expendable supplies through the Lab via email, phone, or in person. If needed supplies are not in stock or specialized media is requested, the Lab can place an order.

A wide range of specialized monitoring and other equipment is available from the Lab. The equipment includes 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 may be picked up or shipped as needed. A list of sampling equipment available may be found at Lab's Field Equipment webpage.

The Lab provides pre-weighed filter/cassette units for gravimetric sampling and analysis. Gravimetric filters are weighed at the Lab and shipped to the field assembled in cassettes to be used for sampling. The cassettes are returned to the Lab after sampling for gravimetric determinations and other analyses. See Appendix A for a discussion of pre-weighed filters and Appendix B for a list of substances for gravimetric determination.

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 Lab 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 Lab 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 pre-sampling calibration data (such as pump tag 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 (Lab Information Management System) for samples requiring analysis by the Lab.

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 Lab has diffusive samplers available to use for a select list of volatile compounds.

III. On-Site Inspection Activities

A. Develop Documentation

- Document accurate and complete sampling pump calibration records and field sampling notes using an appropriate sampling form and then enter the information into the OSHA Technical Information System (OTIS).
    - 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. An aerosol fog generator is also available for use from the Lab.

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 (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 the Lab's 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

$$Minimum\ sample\ time = \frac{minimum\ sample\ volume}{flow\ rate}$$

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

$$Maximum\ sample\ time = \frac{maximum\ sample\ volume}{flow\ rate}$$

For example, the Lab's method 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 Lab’s Sampling Procedures.

Many air contaminants in the Oregon Rules for Air Contaminants (OAR 437-002-0382) have a ceiling limit, either in addition to or instead of an 8-hour TWA PEL. In 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 a duration sufficient to meet the minimum sample volume in the sampling method in the Lab’s 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 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 sealed glass sorbent tubes, break open both ends of the tube as outlined in the manufacturer’s instructions.

    - 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, either due to adsorption of vapors or electrostatic attraction of particulates.

    - If using a respirable dust cyclone, orient the inlet (vortex finder) so that it faces away from the employee. See Appendix I for more details.

- 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 that 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 Lab's 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. Sorbent tubes have a backup section to monitor for overloading. This section is analyzed separately by the Lab and a note will be including on the report if overloading is observed.

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 the employee goes to lunch or on a break). 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 a Lab seal as soon as possible after sampling (see Appendix G regarding lab seals and sample integrity). Samples with seals that can be removed without obvious evidence of tampering will be identified as “Seal improperly applied” in the Lab reports of analytical results.

E. Extended Work Shifts

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 Lab’s 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 Lab’s Sampling Procedures.

*The lead standards for construction (1926.62) and general industry (1910.1025 and 403-002-0371) require PEL adjustments with respect to extended 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 toxic gases 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. Toxic substances 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 Lab 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. Specific types of plastic may produce the following thermal decomposition products: hydrogen chloride from polyvinyl chloride (PVC); styrene from polystyrene; fluoride compounds from polytetrafluoroethylene (PTFE/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

Employees are often exposed to a variety of chemical substances simultaneously. In many industrial 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, the health effects information in the NIOSH Pocket Guide to Chemical Hazards should be reviewed 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, such as how 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. Additional examples of chemicals which have additive effects when exposure occurs together include:

- acetonitrile + cyanides
- n-hexane + hexone (methyl isobutyl ketone [MIBK]) which produce the toxic metabolites 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 with exposure to carbon tetrachloride (a liver toxin), the liver toxicity is much greater than that due to carbon tetrachloride alone. Another example is how 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. This calculation should be used when the components in the mixture pose a combined threat to worker health and the components 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 work shift.

The mixture calculation is expressed as:

Equation 3

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

Where:

E_m = equivalent exposure for the mixture (if less than or equal to 1 then in 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 Federal OSHA's Extranet 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.

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. All such cases should be discussed with the field enforcement manager as per Chapter 7 of the Oregon OSHA Field Inspection Reference Manual (FIRM).

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 3: *Composition:*

Ingredient	***CAS No.***	***Concentration***
Methyl Alcohol	*67-56-1*	*1-1.5%*
Formaldehyde	*50-00-0*	*4%*
Water	*7732-18-5*	*~95%*

.
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 PEL

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 OSHA Occupational Chemical Database file for each chemical, or in the NIOSH Pocket Guide to Chemical Hazards, which can also be accessed from links in each chemical's OSHA file.

Excerpts from NIOSH Pocket Guide:

Methyl Alcohol:
Boiling point: 147ºF
Vapor Pressure: 96 mmHg

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

IDLH: Ca [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 OSHA Occupational Chemical Database 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:*

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

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 OSHA Occupational Chemical Database file, including the NIOSH Pocket Guide.

Excerpts from CSI and/or NIOSH Pocket Guide:

Chemical	**Boiling Point**	**Vapor Pressure**
Toluene	232ºF	21 mmHg
1,2-propanediol	370.8ºF	0.08 mmHg
m-xylene	282ºF	9 mmHg

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.

1,2-propanediol is not listed in the NIOSH Pocket Guide but is in the OSHA database and listed as propylene glycol. Due to its low vapor pressure, low concentration, and non-toxic classification, sampling for this material is unnecessary.

Note that this SDS includes references to non-OSHA occupational exposure limits, in particular, limits set by The National Institute for Occupational Safety and Health (NIOSH) and the 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:*

Ingredient	***CAS No.***	***Percent***	***Exposure Limits***	***Vapor Pressure***
Propane	*74-98-6*	*25%*	*PEL 1,000 ppm*	*760 mmHg*
VM & P Naphtha	*8032-32-4*	*12%*	*REL 350 mg/m^3*	*12 mmHg*
Toluene	*108-88-3*	*15%*	*PEL 200 ppm* *TLV 20 ppm*	*22 mmHg*
Light Aromatic Hydrocarbons	*64742-95-6*	*1%*	*Not available*	*4 mmHg*
1,2,4-Trimethylbenzene	*95-63-6*	*2%*	*TLV 10 ppm*	*2 mmHg*
Acetone	*67-64-1*	*30%*	*PEL 1,000 ppm*	*180 mmHg*
Titanium Dioxide (Total Dust)	*13463-67-7*	*0.1%*	*PEL 15 mg/m^3* *TLV 10 mg/m^3*	*n/a*

***Section 5** – Firefighting Measures:*

Flash Point of Propane: <0ºF; 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 OSHA Chemical Database 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. The exception is for asbestos fiber counts which require 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 as well as for toxicologically inert, nuisance dusts, whether mineral, inorganic, or organic. These dusts are listed in the Oregon Rules for Air Contaminates, 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.

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 Lab. Use a maximum flow rate of 2 L/min for a maximum sampling time of 480 minutes (8 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.

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, up to 10 µm aerodynamic diameter particle size. 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. Parallel particle impactors (PPIs) are an alternative option to using a cyclone and also collect the sample on a pre-weighed PVC filter. Both sampling options are available from the Lab. Appendix B lists dusts for which respirable sampling should be performed.

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 minimum sampling time of 10 minutes and a maximum time up to 480 minutes if the filter is not overloaded. Parallel particle impactors available from the lab require a flow rate of 2.0 L/min. For respirable crystalline silica sampling the minimum sampling time is 160 minutes and is discussed in further detail in the next section.

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 or a SKC 225-01-02 parallel particle impactor set to 2 L/min will meet the criteria described in Table Z-3, Mineral Dusts, in the Oregon Rules for Air Contaminates. When used at the proper flow rate, both devices will meet the OSHA and ACGIH definitions for respirable particulate (50% cut-point less than 4.0 µm aerodynamic diameter).

TABLE 1. Sampling Characteristics of a Size Selector

Aerodynamic diameter, µm	Percent passing size selector
0	100
1	97
2	91
3	74
4	50
5	30
6	17
7	9
8	5
10	1

Appendix I shows the available types of size selective devices and also contains cyclone set-up 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. Never invert the cyclone with the cassette attached because material collected in the grit pot could fall onto the filter. Note that other sampling devices are available for thoracic (50% cut-point less than 10 µm aerodynamic diameter) and inhalable dust (50% cut-point less than 100 µm aerodynamic diameter) fractions.

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 an SKC aluminum or other suitable cyclone for respirable dust samples. A silica sample collected without a cyclone would be a total dust sample and different PELs would apply. Because of analytical difficulties, CSHOs are discouraged from submitting total dust air samples for silica analysis. The Lab'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. In addition, the exposure limits for silica are not based on non-respirable samples.

In general, cristobalite and/or tridymite are produced under conditions involving the high temperature firing of quartz. Quantitative data for quartz and cristobalite is reported by the Lab. Qualitative data for tridymite can be reported if requested.

X-ray diffraction (XRD) is the preferred silica analytical method because of its sensitivity, its sample preparation, and its ability to identify polymorphs (different crystalline forms) of free silica. Quartz is initially identified by its 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. The Lab should be notified 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 Lab results for silica air samples are usually reported under one of three categories:

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

- Approximate values in units of mg/m^3 or percent are given for total dust/bulk 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 and/or cristobalite present in the sample is not greater than the detection limit of the instrument. The detection limit is approximately 5 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. Also, where the employee is exposed to combinations of silica dust (i.e., quartz and cristobalite), the additive effects of the mixture are to be considered.

L. Metals

1. Air Samples

The primary air sampling for metals is conducted in welding operations, and secondarily in sandblasting operations. 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) in 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 filters in 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.

Collect metal fumes using 0.8 µm MCEF cassettes or 5.0 µm PVC filter cassettes at a flow rate of 1 to 3 L/min with a maximum air volume of 960 L. MCEF cassettes are preferred if gravimetric analysis for total welding fume is not required. Specify the metals of greatest interest on the LIMS sample submittal form. See the Lab's Sampling Procedures for further detail and the information in the metal analysis section below. Be careful not to overload the filter which can cause issues with pump performance. Oregon OSHA Lab method 1008 (atomic absorption spectroscopy graphite furnace analysis) is available if greater analytical sensitivity is needed for instances where not much sample volume can be collected.

Note that grinding is often a part of the process in welding operations. For welding, the fumes of the metals, and for some their oxides, are reported. For grinding, the metal dust is reported. It is important to note in LIMS on the sample submittal form which processes are being done so that the correct analyte is reported. This is especially important for copper because the PEL for copper fume is ten times less than the PEL for copper dusts and mists. If the sample is a mix of welding and grinding, then the default is to report as metal dust.

2. Bulk Samples

Bulk samples are sometimes taken to document the source of the material present in the air. Paint chips to be tested for lead are also common. Always attempt to take representative samples for bulk analysis. The Lab analysts will make a reasonable attempt to homogenize samples, however, excessive sample quantities and highly non-homogenous samples complicate this process. Ideally, bulk samples should contain a minimum of approximately 200 mg and less than a gram, shipped in glass vials with PTFE-lined caps or in Whirl-Pak® bags.

3. Metal Analysis

The Lab 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 Lab method 1034 by ion chromatography. The combinations of metals from Oregon OSHA Lab method 1001 which can be sampled together and individually are listed below. Refer to the Lab's Sampling Procedures for the most up-to-date sampling info.

The following metals (a maximum of five to six) may all be sampled on the same filter or wipe:

Aluminum
Barium (insoluble)
Cadmium
Calcium
Chromium
Cobalt
Copper
Hafnium
Iron
Lead
Magnesium
Manganese
Molybdenum (insoluble)
Nickel
Silver
Tellurium
Thallium
Vanadium
Zinc
Zirconium

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

Antimony and Selenium	Hexavalent chromium
Arsenic	Water soluble metals (may all be sampled on the same filter):
Beryllium	Barium (soluble)
Mercury	Sodium (hydroxide, salts, & bisulfite)
Platinum	Molybdenum (soluble)
Tin	Potassium (hydroxide and salts)
Titanium	Zinc (soluble such as zinc chloride)
Tungsten	

M. Asbestos (Fibers)

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 with the filter facing downward. Use a flow rate of 0.5 to 2.5 L/min. 1.0 L/min is suggested for general sampling and for office environments use flow rates up to 2.5 L/min.

Calibrate the sampling 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 a lab seal as shown in Appendix G, Figure G-4, 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 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. Wrap sample cassettes in plastic bubble wrap or other appropriate packing material. Do not use expanded polystyrene packing peanuts (Styrofoam™) or other static-producing packaging material.

Asbestos air samples are analyzed by phase contrast microscopy (PCM) to determine fiber counts. PCM does not identify fiber type; non-asbestos fibers which meet the NIOSH counting rules will be included in the result. List any known fibrous interferences present during sampling in the LIMS sample submittal form, 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 Lab does not have TEM capability but can contract the samples out if additional analysis is required. For unusual sampling conditions contact the Lab 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 (Figure 2) with low-flow sampling pumps. Refer to the Lab's Sampling Procedures for required sampling media, rates, and volumes for specific chemical sampling.

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 backup section. This is known as **breakthrough**. The Lab analyzes the two sorbent sections separately to monitor for breakthrough. If greater than 25% of the compound of interest is found in the backup section, this may indicate that some of the analyte was lost through the back of the sorbent tube and result in an underestimation of employee exposure. The Lab report will note if breakthrough has occurred when greater than 25%.

Figure 2. **Charcoal Tube with flame-Sealed Ends and Caps**

Chemical **migration** may also occur, where the compound of interest bound in the primary section desorbs and passes into the backup section after sample collection is completed. The Lab cannot distinguish whether material found in the backup section is the result of break-through or migration. To avoid migration, samples should be shipped to the Lab without delay. In some cases, refrigeration of samples is recommended to reduce migration, and is good standard practice regardless. Some sampling methods, such as the Lab method for ethanol, address the problem of migration by using two sorbent tubes attached in series (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 contaminants are present in high concentrations.

Certain situations require the use of multiple sorbent tubes, either in series or in parallel (Figures 3 and 4). As described above, tubes may be used in series to avoid migration of the analyte of interest, or to prevent breakthrough by increasing the sampler capacity. Series sampling may also be used where the compound 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 sorbet tubes connected in series. The front and back tubes contain molecular sieves impregnated with triethanolamine, and the middle oxidizer tube contains an inert support impregnated with a chromate salt and inorganic acids. 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**

Figure 4. **SKC Dual Adjustable Low Flow Tube Holder for Sampling in Parallel**

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. Sorbent tubes are manifolded together using adjustable flow controllers and tube holders available through the Lab. The airflow through each tube must be adjusted separately, and the combined flow cannot exceed the flow range of the sampling pump.

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. Care should be taken with the broken tube ends. 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.

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 a Lab seal as shown in Appendix G 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. Do not ship air samples in the same package as bulk samples to avoid cross-contamination.

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 may be less accurate than active sampling due to lack of sampling data, and that the limit of detection may not be 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 Lab has diffusive samplers available to use for a select list of volatile compounds.

Figure 5. **Diffusive Sampler**

The following material outlines the use of diffusive samplers available in the Oregon OSHA Lab program. Table 2 below 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.

Temperature and pressure are needed for proper calculation of exposure results for diffusive samplers. These measurements should be recorded at the sampling worksite. Results from samples without the sampling site temperature and pressure will have significantly higher sampling and analytical error values. The National Oceanic and Atmospheric Administration's (NOAA) website may be checked 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 2. Oregon OSHA Validated Sampling and Analytical Methods for Diffusive Sampling

Analyte	**Federal OSHA Method**	**SKC Passive Sampler**
Acetone	none (full validation by SKC)	575-002
Benzene	OSHA 1005	575-002*
2-Butanone (MEK)	OSHA 1004	575-002
Butyl Acetates (n-, iso-, sec-, tert-)	OSHA 1009	575-002
Cyclohexane	OSHA 1022	575-002
Ethyl Benzene	OSHA 1002	575-002
Hexone (MIBK)	OSHA 1004	575-002
Tetrachloroethylene (Perchloroethylene)	OSHA 1001	575-002*
Styrene	OSHA 1014	575-006
Toluene	OSHA 111	575-002
Trichloroethylene	OSHA 1001	575-002*
Trimethylbenzenes (1,2,3-; 1,2,4-; 1,2,5-)	OSHA 1020	575-002
Xylenes (o, m, p isomers)	OSHA 1002	575-002

*Fully validated by SKC on 575-001 passive samplers

Additional compounds fully validated by SKC as of 2022	
Analyte	**SKC Passive Sampler**
Acrylonitrile	575-002
1-Bromopropane	575-001 or 002
tert-Butyl Methyl Ether	575-001
1,2-Dichloroethylene	575-001
Methylene Chloride	575-001
Ethyl Methacrylate	575-001 or 002
Ethylene Oxide	575-005
Halothane	575-002
Isoflurane	575-002
Methyl Acrylate	575-002
1-Methylcyclohexanol	575-001 or 002
n-Pentane	575-001
Vinyl Acetate	575-002

Note: The list of fully validated analytes will increase as additional validation data is collected.

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 the Lab’s Sampling Procedures to see if alternative methods can be used.

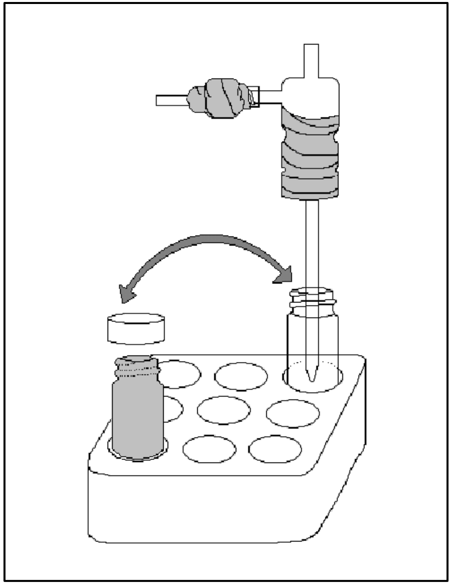
An example of a midget impinger is shown in Figure 6. The term midget refers to the volume of the sampler vial. The jet (inlet tube) of an impinger is tapered and sized to allow sufficient velocity for particles to strike the bottom of the flask and become suspended in the liquid.

Figure 6. **Impinger Vial with Filter**

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). The glass tube is fragile, care should be taken to prevent damage.
- The Lab provides impingers with the appropriate absorbing solutions in separate vials.
- 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 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 into the pump. 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 Lab’s Sampling Procedures.

Figure 7. **Impinger Storage**



4. Gas Sampling Bags and Canister Samplers

The Lab provides Tedlar® air sampling bags (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 a Lab seal over the valve(s) before shipping to the Lab. Gas sampling bags are sometimes used to collect whole air samples for forensic-type investigations. 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 section.

B. Complete Documentation

1. Complete the LIMS sample submittal form before sending samples to the Lab. CSHOs should also be diligent in completing the following items in OTIS:
    - Report number
    - Inspection number
    - Sample numbers
    - Establishment name and address
    - 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 Lab will report sample results using the air volume reported in the LIMS sample submittal form 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 Lab.
- 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 Lab 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 LIMS sample submittal form and any applicable SDSs with the samples. The Lab can print out the LIMS form if not convenient to do so at the time of shipping.

D. Receive Sample Results

Calculate the exposure severity as shown below in part 3. The exposure severity 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 Lab on the Lab Analysis Report.

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 (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 on the Lab Analysis Report. 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.

  - 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 STEL and ceiling (peak) 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 because it will reflect a higher final sample air volume. 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 Lab 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.

For particulates, the Lab reports milligrams per cubic meter (mg/m^3) of contaminant using the volume of air sampled as reported by the CSHO. The Lab 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), PEL, and SAE. The SAE can be obtained from the LIMS sample report or by contacting the Lab. Determine the exposure severity, Y, as follows:

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

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, further sampling should be considered, taking into consideration the seriousness of the hazard and pending citations. If further sampling is not conducted the CSHO may wish to explain to the employer and employee representative at the closing conference that the exposed employee(s) may be overexposed but there is insufficient data to document noncompliance. The employer should be encouraged to voluntarily reduce the exposure and/or 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 following box.

Compliance/Noncompliance Method

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:

Also obtain the SAE listed on the LIMS air sampling report.

1. Compute the TWA exposure, X.

   Equation 4

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

2. Divide the TWA exposure by the PEL to find Y, the standardized average (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 same as always:

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 $LCL_{95\%} < 1.0$ and $UCL_{95\%} > 1.0$, 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, an employee is often 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 Section III.G.2).

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

Where:

E_m = equivalent exposure for the mixture (if less than or equal to 1 then in compliance)
C = concentration of a particular substance
L = PEL

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

Exposure ratio (for each substance):

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

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

Equation 9

$$\mathrm{UCL} = 1 + R_{St}$$

Equation 10

$$\mathrm{LCL} = 1 - R_{St}$$

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

If LCL ≤ E_m ≤ 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.

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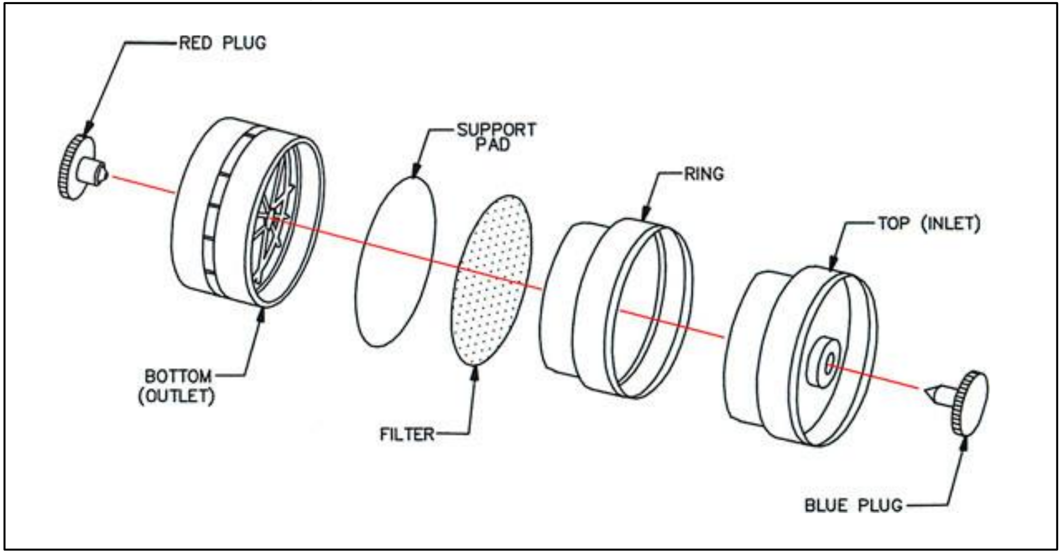
Appendix A - Pre-Weighted Filters

The Lab provides pre-weighed filters for gravimetric analysis. The filters are weighed at the Lab and the units are shipped to the field fully assembled and ready for use. The filter/cassette units are returned to the Lab for gravimetric determinations and additional analyses as needed. The primary filter medium is 5 μm pore size low-ash PVC on a cellulose support pad in either 37 mm or 25 mm diameter 2 or 3-piece polystyrene cassettes. The PVC filters should be used for silica 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. If a cyclone is being used, then a 3-piece cassette is required (Figure A-1). 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 are preferred for metals analysis when a gravimetric analysis is not required. 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 and using 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 a cyclone is used with the 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. 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 necessary to include all of the filter batches.

The red capped outlet connects to the sample pump and the blue capped inlet is open to the atmosphere (Figure A-2). The caps are to be removed prior to sampling and then put back in place after sampling is completed. 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 and on the white band. The numbering system is based on the date the filter was prepared and the number of filters in the batch (year/day/month-filter number in batch). For example, a filter labeled 220926-10, was prepared on September 26, 2022 and is the tenth filter in the batch. All pre-weighed filters expire after one year for gravimetric analyses and 5 years for chemical analyses.

Figure A-2. **Filter Cassettes:**

APPENDIX B – Substances for Gravimetric Determination

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

Substance	IMIS
Respirable Particulate, including Nuisance Dust and PNOR*	9130
Total Particulate, including Nuisance Dust and PNOR*	9135
Welding Fume	2587
Crystalline silica, respirable (quartz and cristobalite)	9000
Quartz, crystalline	9010
Cristobalite, crystalline	9015
Oil Mist (mineral)	5010
Metalworking Fluids (synthetic oil mist)	C727
Wood Dust (Inhalable or Total), all hard and soft woods except,	W103
Western Red Cedar	W102
Hardwood only (non-allergenic)	9210
Softwood only (non-allergenic)	9211
Combustible Dust	P100
Cotton Dust	0735
Grain Dust	G109
Asphalt Fume	0290
Carbon Black	0527
Coal Tar Pitch Volatiles/Benzene Solubles	0700
Diesel Exhaust (elemental carbon)	D130
Paraffin Wax Fume	2000

APPENDIX C – Analytes Using Impinger as Primary Method

Table C-1. Impinger Methods

Chemical Name	CAS Number	Impinger solution
Alkyl dimethyl benzyl ammonium chloride	139-08-2	water
Benzyl cetyl dimethyl ammonium chloride	122-18-9	water
Chlorine Dioxide	10049-04-4	0.02% KI in a buffer
Diisocyanates:		MAMA in toluene*
• HDI (Hexamethylene diisocyanate)	822-06-0	The Lab switched to sampling on ASSET EZ4-NCO dry samplers in 2020
• HDI-BT (Biruet Trimer of HDI)	4035-89-6	
• HDI-IC (Isocyanurate of HDI)	3779-63-3	
• IPDI (Isophorone diisocyante)	4098-71-9	
• MDI (Methylene diphenyl diisocyanate)	101-68-8	
• TDI (Toluene diisocyanate)	584-84-9	
Hexamethylenetetramine	100-97-0	water*
Hydrogen cyanide	57-12-5	0.1 N KOH*
MEK Peroxide	1338-23-4	dimethyl phthalate*

*alternate sampling method without impinger available

APPENDIX D – Shelf Life of Sampling Media

The Lab 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 Lab

Sampling medium	Shelf Life	Comments/OR-OSHA Lab method #
Pre-weighed PVC and silver membrane filters	1 year	May use for analyses other than gravimetric.
MCEF, Glass fiber (GFF), Quartz, and Teflon filters	5 years	
MAMA solution in impingers and treated GFF	1 month	Method 1010 discontinued as primary method in 2020
MCEF filters treated with Na_2CO_3	1 week	method 1008 – Arsenic (gaseous)
Dimethyl phthalate in impingers	5 years	method 1021 – MEK peroxide
Sodium carbonate treated cellulose filters	1 month	method 1079 – Sulfur dioxide
Nitrite impregnated glass fiber filter	45 days	method 1030 - Ozone
Pre-cleaned silver membrane filters	8 months	method 1035 – Chlorine and bromine
Potassium hydroxide solution in impingers	1 year	method 1043 - Cyanide
Pre-treated silver membrane filters	1 year	method 1004 – Diesel exhaust
Potassium iodide solution in impingers	6 months	method 1058 – Chlorine dioxide
Titanium oxysulfate treated quartz fiber filters	6 months	method 1061 – Hydrogen peroxide
Teflon filter with two treated quartz fiber filters	1 month	method 1075 – Nitrogen trichloride
Mercuric acetate treated glass fiber filter	1 month	method 1084 – Methyl mercaptan
Water in impingers	1 year	method 1102 – Quaternary amines
Sulfuric acid treated glass fiber filter	1 month	method 1105 – Xylenediamine method 1138 – MOCA and Methylenedianiline

APPENDIX E – Common Sampling Media for Most Frequently Requested Analyte Groups from the Lab

- Acids (inorganic) – SKC 226-10-03 silica gel tubes
- Aldehydes – SKC 226-119 DNPH treated silica gel tubes
- Isocyanates – ASSET EZ4-NCO dry samplers
- Metals – 5.0 µm LA-PVC filters or 0.8 µm MCEF filters in 2-piece cassettes
- Particulate/Dust – 5.0 µm LA-PVC in 2- or 3-piece cassettes
- Silica – 5.0 µm LA-PVC filters in 3-piece cassettes
- Solvents – SKC 226-01 charcoal tubes

For a detailed list, reference the Lab's 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 service interval. Record the Oregon tag number of the calibration equipment in your case file and in the OTIS air sampling information as well as the digital flow readouts of pre- and post- calibrations.

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. Expired media may be used for calibration checks.

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 and 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 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.

C. Electronic Flow Calibrators

There are two types of flow calibrators to measure the flow rates of sampling pumps, wet and dry calibrators. The flow calibrators available from the Lab are dry calibrators, piston style and hot wire. The piston style uses a near frictionless piston technology as opposed to the frictionless soap bubble tubes used in wet calibrators. The hot wire style is a mass flow meter which uses the cooling effect of air flowing across a heated wire to calculate the flow rate.

The three models of mass flow meters available from the Lab are the TSI 4140, SKC chek-mate, and Alicat MB-5SPLM (Figure F-1). These all provide instantaneous air flow readings for pump calibration. An additional low flow dry cell calibration option is the Bios Defender 520 (Figure F-2). These provide instantaneous air flow readings and cumulative averaging of multiple measurements. All of 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 choice of calibrator to be used is dependent on the flow range of the pump to be measured.

For calibration requiring flow rates above 5 L/min., the Lab has different equipment to use. Electronic bubble flow meters may also be used but are no longer readily available.

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.

Figure F-1. **Mass Flow Meters**

TSI 4140 **SKC chek-mate** **Alicat MB-5SPLM**

These are to use with medium flow pumps and a range of 0.5 – 5 liters per minute (LPM)
A low flow version of the SKC chek-mate is available at 0.02 – 0.5 LPM

Figure F-2. **Bios Defender 520 <u>low flow</u> calibrator**:

0.01 – 0.5 liters per minute (LPM)

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 Lab annually to be serviced and calibrated against a primary standard.

<u>APPENDIX G – How to Apply Chain of Custody Lab Seals (Form 440-1316) to Sampling Media</u>

Figure G-1. **Correctly and incorrectly sealed charcoal tube.**

Sample inside lab seal

End caps can be removed, allowing sample integrity to be jeopardized without disturbing the seal

Figure G-2. **Correctly and incorrectly sealed charcoal tubes.**

Note: This practice is preferred by the Lab to facilitate easier sample preparation.

Charcoal tubes inside of a Whirl-Pak® with bag opening securely closed and sealed. Other media types, such as filter cassettes and bulk solid material (e.g. paint chips), may be sealed in this manner.

Charcoal tubes in zip lock bag allow access to samples because bag opening not completely sealed.

Figure G-3. **Correctly and incorrectly sealed cassettes.**

Lab seal covers inlet/outlet ports maintaining sample integrity.

Sealed cassette allows access to inlet/outlet ports after sample has been taken.

Figure G-4. **Asbestos cassette (25mm) correctly sealed.**

APPENDIX H – Example Calculations for Mixtures

As an example, an exposure to three different substances:

Material	8-hr. Exposure (ppm)	8-hr. TWA PEL (ppm)	SAE
Substance 1	500	1,000	0.089
Substance 2	80	200	0.11
Substance 3	70	200	0.18

Using Equation 3 from Section III.G.2:

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

Where:

E_m 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

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

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 and Equation 10 UCL = 1 + R_{St} and 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:

$Y_1 = 500/1{,}000$	$Y_2 = 80/200$	$Y_3 = 70/200$
$Y_1 = 0.5$	$Y_2 = 0.4$	$Y_3 = 0.35$
$R_1 = Y_1/E_m = 0.4$	$R_2 = 0.32$	$R_3 = 0.28$

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

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

$$UCL = 1 + R_{st} = 1.071$$

$$E_m = 1.25$$

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.

APPENDIX I – Size selective samplers

A. Cyclones

Inspect the cyclone for signs of wear or damage, including the black O-ring and the red grit pot. Return the cyclone to the Lab if the parts appear to be damaged. Cyclones are inspected and leak tested annually by the Lab. **After each use** remove the grit pot from the cyclone and empty by turning it upside down and tapping gently on a solid surface. Clean the cyclone 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.

Figure I-1. **SKC aluminum 37mm cyclone (2.5 L/min)**

Figure I-2. **SKC aluminum 25mm cyclone (2.5 L/min)**

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.

Figure I-4. **Aluminum Calibration Chamber**

Figure I-5. **Exploded view of cyclone-filter cassette assembly.**

Top section of cassette is removed before securing onto cyclone.

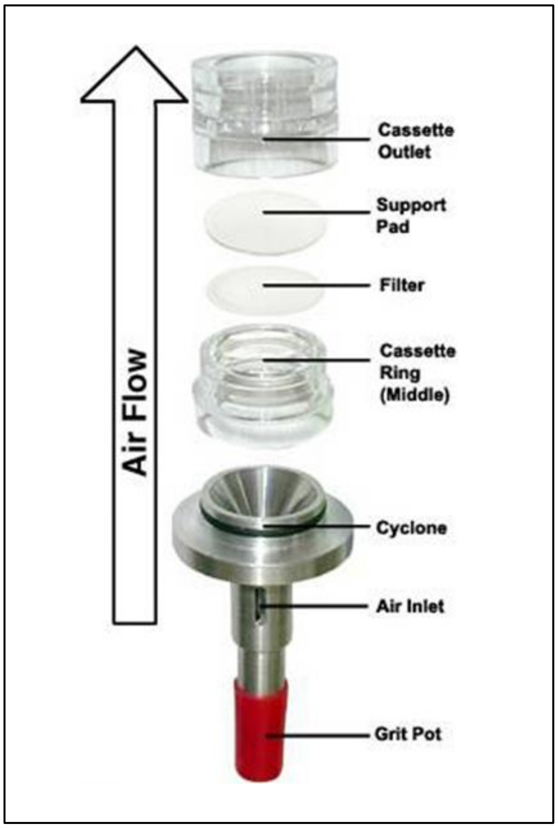


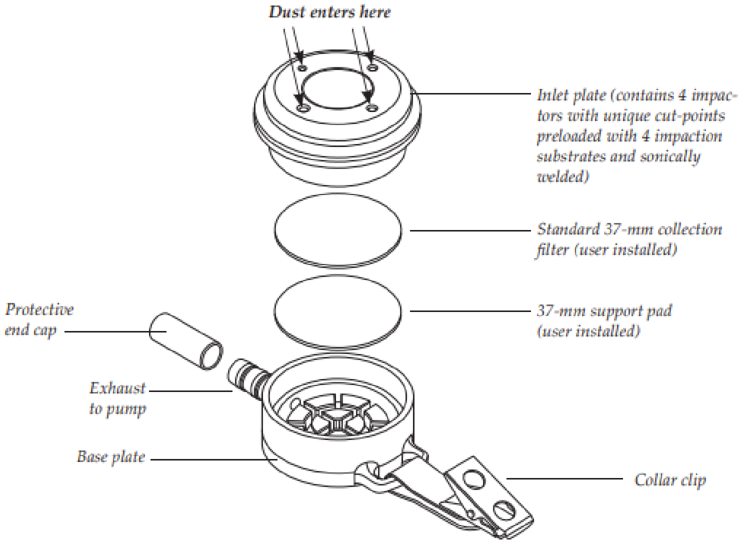
Figure I-6. **Mesa Laboratories BGI GK2.69 thoracic cyclone (1.6 L/min)**

B. Parallel Particle Impactors (PPIs)

Figure I-7. **SKC 225-385 respirable (2 L/min)**

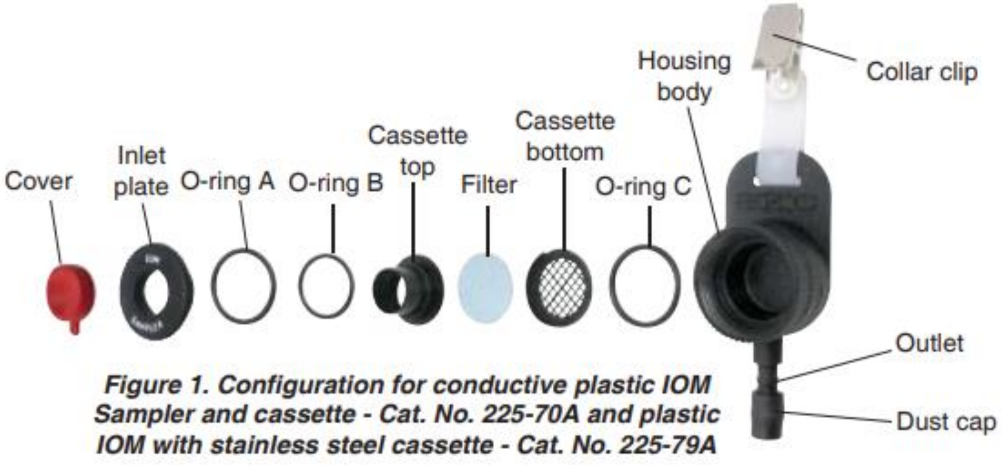
Figure I-8. **SKC PPI 225-386 thoracic (2 L/min)**

Figure I-9. **Exploded view of a Parallel Particle Impactor**



C. Inhalable Dust Sampler (IOM)

Figure I-10: **Exploded view of SKC IOM (2 L/min)**



APPENDIX J – Chain of Custody

The Lab uses established chain-of-custody procedures as outlined in the Lab's Quality Assurance Manual to track whether 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 Lab through use of the LIMS. The chain of custody includes the following dates: sample collection by the CSHO, physical sample receipt at the Lab, sample log in to the LIMS by the Lab, sample assignment to the analyst, and release of sample results 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.

APPENDIX K – Health Effects Codes

The Federal OSHA Chemical Sampling Information files contain health effects information, and may include the applicable Health Effects Codes, when available, 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 (FIRM).

Table K-1. Health Effects Codes

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

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 ppm to mg/m3 conversion calculator is available from the Lab.

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 Lab'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

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

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

NOTE: When a chemical 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 often 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 glass fiber filter and personal sampling pump were used to sample for carbaryl for an 8-hour period. The Lab reported 6.07 mg/m^3. The SAE for this method is 0.23. The PEL is 5.0 mg/m^3.

Step 1. Calculate the exposure severity:

$$Y = \frac{6.07}{5.0} = 1.21$$

Step 2. Calculate confidence limits, the $LCL_{95\%}$ and the $UCL_{95\%}$

$$LCL_{95\%} = 1.21 - 0.23 = 0.98$$

Because the $LCL_{95\%}$ does not exceed 1.0, noncompliance is not established.

$$UCL_{95\%} = 1.21 + 0.23 = 1.44$$

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:

Sample Results		
	A	**B**
Sampling rate (L/min)	2.0	2.0
Time (min)	240	240
Volume (L)	480	480
Weight (mg)	3.005	2.808
Concentration (mg/m^3)	6.26	5.85

The SAE for this method is 0.23. The PEL is 5.0 mg/m^3.

Step 1. Calculate the $UCL_{95\%}$ and the $LCL_{95\%}$ from the sampling and analytical results. Using Equation 4 from Section IV.D.4.:

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

$$Severity\ Ratio\ \ (Y = \frac{X}{PEL}) = \frac{Sample\ respirable\ dust\ concentration\ (mg/m^3)}{calculated\ PEL\ (mg/m^3)}$$

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

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

$$Assuming\ a\ continuous\ sample\colon\ LCL_{95\%} = 1.21 - 0.23 = 0.98$$

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

$$UCL_{95\%} = 1.21 + 0.23 = 1.44$$

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.

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.):

$$LCL_{95\%} = (1.21) - \frac{0.23\sqrt{(240\ min)^2(6.26\ mg/m^3)^2 + (240\ min)^2(5.85\ mg/m^3)^2}}{5.0\ mg/m^3\ \ (240\ min + 240\ min)}$$

$$= 1.21 - 0.20 = 1.01$$

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