# Chapter 3 – Sampling Procedures

## 1. General

The purpose of conducting sampling is to quantify occupational exposures to workplace stressors. In most cases, when a qualitative positive determination is made, sampling is necessary to determine the extent of the exposure, adequacy of control methods in use, or additional controls required to eliminate or minimize the hazard. The exposure monitoring plan should be developed and implemented for those operations/processes needing further evaluation and those stressors for which periodic sampling is required by regulation or directive. Additionally, all sampling data of any type should be entered into the Defense Occupational Environmental Health Readiness System – Industrial Hygiene (DOEHRS-IH). For more information on DOEHRS-IH consult the Navy and Marine Corps Public Health Center DOEHRS-IH webpage.

## 2. Definitions

a. 8-hour Time-Weighted Average (TWA)/8-hour TWA-OEL. The TWA concentration for a normal 8-hour workday and a 40-hour workweek which cannot be exceeded. It is accepted to be a concentration to which nearly all workers may be repeatedly exposed, day after day, without adverse effects. The average level of a stressor over a specified time period, weighted for the length of time at each measured level. The measurement is usually a concentration of a chemical contaminant or a level of a physical agent (e.g., noise). The duration of the TWA must be specified. The most common industrial hygiene (IH) TWA duration is 8 hours which is the length of the most common workday. A TWA may be determined by a single sample (i.e., the averaging is done by the sampling device throughout the sampled period) or by mathematical combination of one or more consecutive samples.

b. Action Level (AL). One-half the 8-hour TWA value designated as the Occupational Exposure Limit (OEL) unless a specific AL is established in an Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) adopted by the Navy (e.g., 60% of the OSHA standard for inorganic lead). The AL may initiate the implementation of specific actions such as periodic monitoring, training or medical surveillance if specified by a Navy Safety and Occupational Health (SOH) or OSHA standard.

   The necessity for an employee exposure AL is based on variations in the occupational environment (i.e., variations in the employee's daily exposures). As such, the employer should attempt to prove with 95% certainty that no employee's true daily average exposure (i.e., 8-hour TWA) exceeds the standard. (References 3-1 and 3-2).

c. Ceiling (C)-OEL. A contaminant concentration that should not be exceeded during any part of the working exposure. If instantaneous monitoring is not feasible, samples are collected and assessed as a 15-minute TWA exposure, except for those substances that may cause immediate irritation when exposures are short. (Reference 3-3).

d. Excursion Limit (EL)-OEL. Only one stressor, asbestos, currently has an Excursion Limit. The Excursion Limit for asbestos was set as a TWA over a 30-minute period, distinguishing it from a Short-Term Exposure Limit (STEL) which has a shorter averaging period. For substances that have an 8-hour TWA-OEL but no STELs, excursions in worker exposure levels may exceed 3 times the 8-hour TWA-OEL for no more than a total of 30 minutes during a work day, and under no circumstances should exceed 5 times the 8-hour TWA-OEL, provided the 8-hour TWA does not exceed the 8-hour TWA-OEL. (Reference 3-3).

e. Inspirability. Particulate or aerosol size fraction (i.e., respirable, thoracic or inhalable) or the nominal total particulate or aerosol. Each particulate or aerosol inspirable fraction requires a different sampling device. Care should be taken to determine which fraction an OEL refers to and to ensure that the correct sampling device is used.

f. Occupational Exposure Limit (OEL). Limits established to protect workers from workplace exposure to certain chemical substances or physical agents. An exposure assessment cannot be made without an OEL.

g. Occupational Exposure Limits for Chemical Contaminants. It is recognized that OSHA PELs may be less protective than exposure standards that reflect more recent medical evidence and promulgated by reputable organizations devoted to occupational health. Industrial hygienists are ethically bound to evaluate all recognized occupational health risks and provide professional recommendations to minimize or eliminate those risks. The Navy shall use the following hierarchy of OELs:
   (1) OSHA PELs
   (2) Navy developed or adopted OELs. When both the Navy and OSHA have standards applicable to a given situation, commands, activities, and units will use the more stringent of the two.
   (3) American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values® (TLVs) where OSHA PELs or Navy OELs do not exist. Use of TLVs represent best practices, i.e., risk management goals to achieve using risk management practices. When the OSHA PEL is less stringent, the ACGIH TLVs will be included in reports of data to supplement the OSHA PEL and provide additional context to aid the risk management process. However, the OSHA PEL remains the legally binding standard.
   (4) Nationally recognized industrial hygiene best practices shall be used to supplement the OEL hierarchy. The industrial hygienist will use professional judgement to

recommend appropriate OEL guidelines, when appropriate, to aid the risk management process in a given situation. Sources include but are not limited to:
(a) California Occupational Safety and Health Administration (Cal/OSHA) PELs
(b) National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits (RELs) or risk management limits for carcinogens (RMLs-CA)
(c) Occupational Alliance for Risk Science (OARS) Workplace Environmental Exposure Levels (WEELs)

For further guidance on the appropriate applications of OEL, IHPO should contact their respective regional command or Navy and Marine Corps Public Health Center (NMCPHC) for assistance.

h. Operations/Operation Codes (OPCODES)/Processes. For years, Navy IH OPCODEs have been used to denote work operations and have been documented on IH sampling forms. These OPCODEs were provided in tabular format as the Navy IH Operation Codes Dictionary. With the advent and use of DOEHRS-IH, processes now need to be defined in two basic ways: a user defined Process Name and the DOEHRS-IH Process Category/Common Process/Process Method pick lists. DOEHRS-IH requires the choice of a Process Name for each work operation. The Process Name is user defined and is what the user typically sees. Since Process Name is user defined, care must be taken to use a business practice that ensures accurate and consistent Process Names are created. The DOEHRS-IH Process Category/Common Process/Process Method pick lists are in the form of a three-tiered process pull down pick list. The DOEHRS-IH Process Methods from the pick list are the equivalent of the old OPCODEs. It is very important that proper selections are made from these DOEHRS-IH pick lists and that they are accurate and consistent for the process under consideration in order to facilitate future data mining. A spreadsheet of the entire DOEHRS-IH Process pick list is available on the NMCPHC DOEHRS-IH webpage. While the old OPCODEs can be used in house by IH groups, the applicable DOEHRS-IH Process Name and the Process Method picklist choice should be included on any sampling forms in the Operation field.

i. Permissible Exposure Limit (PEL). A legally enforceable (in the U.S.) occupational exposure standard established by federal OSHA or by a state-run program accepted by OSHA. Most PELs are TWA concentrations for a normal 8-hour workday and a 40-hour work week, which shall not be exceeded. However, PELs may also be “Ceiling” values or “Excursion Limits”. PELs are accepted to be a concentration to which nearly all workers may be repeatedly exposed, day after day, over a working lifetime without adverse effects.

j. Short-Term Exposure Limit (STEL)-OEL. A 15-minute TWA exposure that should not be exceeded at any time during the workday. The STEL is often associated with an 8-hour TWA-OEL in cases where there are recognized acute effects from a substance whose toxic effects are primarily chronic. The STEL may also be a separate independent OEL. Exposures above the 8-hour TWA-OEL up to the STEL should not be longer than 15

minutes and should not occur more than four times per day. In addition, there should be at least 60 minutes between successive exposures in this range. (Reference 3-3).

## 3. Types of Air Samples

The following are the two major types of air samples used to determine the airborne concentration of contaminants:

a. Personal Samples. For stressors having OELs, for which a decision to sample has been made, personal exposure is determined by collecting breathing zone (a.k.a. - BZ) samples. In rare instances, breathing zone sampling may not be feasible due to the lack of a personal sampling method or other considerations of the workplace environment. To obtain the sample, air is collected from within the breathing zone of the employee, a hemisphere forward of the shoulders and centered at the nose with a radius of approximately 6 to 9 inches. Breathing zone samples may be collected in the following two ways:
   (1) The sampling device is attached to the employee and worn continuously during the work shift or operation. This is the preferred method.
   (2) The sampling device is held by a second individual within the breathing zone of the employee. For example, the industrial hygienist may use a detector tube hand pump or direct reading instrument to collect one or a series of samples from within the breathing zone of the employee.

   **NOTE**: For stressors where there is no acceptable level of exposure, such as those regulated under 29 CFR 1910.1003, 1910.1004 and 1910.1006 through 1910.1016, personal sampling may not be necessary to document personnel exposures. These standards rely on work practice requirements and appropriate feasible control technology to eliminate exposures.

b. General Area (GA) Samples. The sampling equipment is placed in a fixed location in the work area. General area samples are not be used to evaluate employee exposure. They may be used to determine whether re-entry is warranted into a contaminated area, if there is potential contamination of adjacent work areas, or to verify the integrity of a negative pressure enclosure during asbestos rip out operations. They may not be used for OEL compliance determinations except in the rare instances where no feasible personal sampling method exists.

## 4. Sample Duration

Sample duration may vary from a few seconds to eight hours or more. The time period for sample collection depends on a variety of factors including: the sampling and analytical method, the expected concentration of the contaminant being measured, the type of OEL

to which the sample will be compared, the number of consecutive samples to be collected on a single employee during a single work shift and whether the work shift is longer than eight hours. Consider the following factors in determining the appropriate sample duration.

a. Sampling Method. The sampling method is one factor in determining the duration of each sample. A single grab sample collected with short-term detector tubes is collected over a period of seconds to minutes. Low flow and high flow sampling pumps, combined with filter, impingers and/or solid sorbent media are used to collect longer duration samples generally 15 minutes to 8 hours. Direct reading instruments provide almost instantaneous or real-time results.

b. Contaminant Concentration and Analytical Method. The concentration of a contaminant in the sampled air has a large effect on the sample duration. All other things being equal, the higher the concentration the shorter the duration of a single sample and vice versa. Minimum sampling times aim to collect enough mass of contaminant to be above the analytical method's reliable limit of quantification (LOQ). Maximum sampling times aim not to collect too much mass of contaminant to avoid sorbent breakthrough or filter overloading. For example, charcoal tubes may need to be changed frequently to prevent breakthrough. The breakthrough time of a charcoal tube is a function of the air concentration of the contaminant being sampled, the sample flow rate and the humidity of the environment being sampled. Breakthrough time is also a function of the type, amount, size and packing configuration of the charcoal in the tube and competition for sorbent sites by other contaminants present in the air. Similar limits on sampling time apply to filters and impingers to prevent overloading. Judgment should be exercised in changing sampling media of any type often enough to sample a sufficient volume of air to quantify the sample without the occurrence of breakthrough.

c. Type of OEL to Which the Sampling Results Will Be Compared. Samples collected for as close as possible to 100% of the time period for which the OEL is defined provide the best estimate of the TWA employee exposure. Each type of OEL imposes different sample duration requirements as follows:
   (1) Ceiling (C). Samples collected to determine compliance with ceiling limits are usually taken as a series of 15-minute samples during periods of maximum expected exposures. An exception would be if a real-time instrument (e.g., a data logging dosimeter) were available to provide instantaneous and continuous measurements. According to Reference 3-2, samples taken for comparison with ceiling limit OELs are best taken in a non-random fashion, during periods of maximum expected concentrations. A minimum of three measurements should be taken during each work shift sampled. The highest of all the measurement results is the best estimate of the employee's upper exposure for that shift.
   (2) Short-Term Exposure Limit (STEL). STEL samples should be taken over a 15 minute period. STEL samples should also be taken in a non-random fashion during periods of maximum expected concentration.

(3) 8-hour Time-Weighted Average (TWA). Evaluate the potential for employee overexposure through observation and, if appropriate, collection of screening samples before any partial- or full-shift air sampling is conducted.

(a) Full-shift samples should be taken to evaluate TWA exposures whenever possible. However, due to the realities of field sampling (e.g., time lost due to placing and removing multiple sampling devices at the beginning and end of the work shift and lunch breaks), it is unusual that a sample or series of consecutive samples spans the entire work shift. In practical terms, a full-shift sample should omit no more than one hour of the full work shift (e.g., sample at least 7 hours of an 8-hour work shift or 11 hours of a 12-hour work shift).

(b) If full-shift sampling is not possible, it is essential to sample the entire duration of the task producing the exposure of interest. Every attempt should be made to sample the period of greatest exposure during the operation. Such exposure may occur during routine set-up, take-down and end-of-shift clean-up operations. If an operation lasts less than a full shift, then sampling is to be conducted for the entire operation or as long as personnel are potentially exposed to the contaminant (e.g., personnel may remain in a potentially contaminated work area after the operation ceases), whichever is longer.

(c) If the employee is leaving the general area of the work (e.g., going off-base or to an on-base fast food vendor) for lunch the sampler and media should be removed during the lunch period. If the employee will be eating lunch in a lunch room at the work site it is permissible to leave the sampler and media on the employee but any sampling pump should be turned off and the sample inlet should be capped. Be sure that the lunch break "on" and "off" times are recorded on the sampling data sheet and cap/seal and identify all cassettes/tubes if they are removed from the employee. One exception to removing and capping sampling devices during lunch are certain passive monitors which would require removal of the diffusion membrane to be capped. In such cases the monitor may be left in place during the lunch break with documentation to that effect or the monitor may be removed and placed in a sealed container at a clean air location. Shut-down and removal of the sampling train during lunch is preferred.

(d) If technology has not been developed to allow full-shift sampling for an 8-hour TWA, a series of "grab" or "spot" samples taken randomly throughout the work shift is acceptable. A sound statistical approach should be used to design the sampling strategy. See Reference 3-1 for a complete discussion.

d. Number of Consecutive Samples to be Collected per Employee. The number of consecutive samples that should be taken during a work shift depends on the desired error of measurement as discussed in References 3-2, 3-4 and 3-5 and in Chapter 4 of this manual. Two 4-hour consecutive samples provide more statistical power than one 8-hour sample when documenting the exposure for an 8-hour work shift. Up to a point,

a larger number of shorter duration consecutive samples provide more statistical power. However, the need to collect sufficient mass of contaminant for accurate analysis limits how many consecutive samples may be used to cover a specific work shift.

e. Work Shifts Longer than 8 Hours. In general, a single sample or multiple samples are to be taken to determine the initial 8 hours of exposure for comparison with the standard. This allows direct comparison to the 8-hour OEL. A separate sample is used to determine any additional exposure beyond the initial 8 hours.

## 5. Calculating the TWA from the Sample Results

a. TWA Calculation and Unsampled Work Periods. To properly calculate an employee's TWA exposure, professional judgment is necessary to decide what assumption should be made regarding the exposure during unsampled work periods. For example, if the work shift is 8 hours and sampling was conducted for 7 hours and 15 minutes, the industrial hygienist can either assume a zero exposure for the unsampled period or assume that exposure is equal to the TWA over the sampled period. If a zero exposure is assumed for all unsampled periods, the resulting TWA is calculated per Equation 3-1a below and the industrial hygienist should document on the sampling data sheet reasons/circumstances that explain the employee's time of non-exposure (e.g., lunch break, operation completed, etc.). Where equal exposure is assumed, the resulting TWA is calculated per Equation 3-1b below and the industrial hygienist also should document the rationale on the sampling data sheet. TWA's should be calculated and entered in DOEHRS-IH. For more information on DOEHRS-IH consult NMCPHC DOEHRS-IH webpage.

$$\text{TWA } (8-\text{hours}) = \frac{C_1T_1 + C_2T_2 + \cdots + C_nT_n}{480 \text{ Minutes}}$$

**Equation 3-1a**

**NOTE:** Equation 3-1a, above, assumes that the average contaminant concentration during any unsampled portion(s) of the work shift is zero (0) and that the length of the work shift is 8 hours (i.e., 480 minutes). Field observations by the person conducting the sampling should determine if the zero exposure assumption is supportable. The denominator in Equation 3-1a must be the changed to the total minutes in the actual work shift if the work shift is other than 8 hours.

$$TWA = \frac{C_1T_1 + C_2T_2 + \cdots + C_nT_n}{T_1 + T_2 + \cdots + T_n}$$

**Equation 3-1b**

Where:
TWA = Time-weighted average contaminant concentration
$C_i$ = the contaminant concentration in Sample i
$T_i$ = the duration (minutes) of Sample i

**NOTE**: Equation 3-1b, above, assumes that the contaminant concentration during any unsampled portion(s) of the work shift is equal to the average exposure for all sampled portions of the work shift. This is a conservative estimate of exposure which is biased in favor of the worker. Field observations by the person conducting the sampling should determine if this assumption is supportable.

b. Non-Traditional Work Schedules. Standards based on 8-hour exposures may not provide appropriate protection when non-traditional work schedules are used, e.g., four 10-hour days per week. Comparison of the full-shift exposure measured during a non-traditional work schedule requires that the 8-hour OEL be adjusted to account for differences in the number of exposure (i.e., work) hours and recovery (i.e., non-work) hours. The following adjustments are not applicable to STEL, Ceiling or Excursion Limit OELs.
   (1) Recommended Adjustments Based on the Reference 3-6 Model of Brief and Scala.
      (a) Limitations of the Model. The adjustments in Equations 3-2 and 3-3 below are based on the Brief and Scala model for unusual work shifts which is discussed in Reference 3-7. This is a conservative model that accounts for both increased work shift exposures and decreased recovery time (i.e., non-occupational exposure periods). Following are some general application guidelines for the Brief and Scala model.
         1. The model does not account for biological half-lives of the stressor, as do the pharmacokinetic models. However, there is a general rule of thumb that PEL adjustments are not applied if the stressor half-life is less than 3 hours or greater than 400 hours. Toxicant studies show that only moderate half-life chemicals (i.e., 6-200 hours) are likely to have day-to-day accumulation during the week, even at exposures at or near the PEL.
         2. The model assumes average body burden for the stressor rather than peak burden.
         3. The model can be used if the PEL is based on systemic effects, regardless of whether the effects are acute or chronic.
         4. Adjustments can be applied only for extended work shifts/weeks, defined as >7 hours/day or >35 hours/week. Do not use these equations for shortened work schedule adjustments (i.e., the OEL shall NEVER be adjusted upward for

shortened work days or weeks). In addition, neither adjustment equation is appropriate for 24-hour (i.e., continuous) exposure.

5. Do not make PEL adjustments when the stressor is a primary irritant (i.e., PEL based on sensory irritation effects). In such cases, the stressor's action is based on "compartmental" vice whole body effects. Further, the irritation threshold is probably independent of the number of hours worked (i.e., exposed).

(b) Work Weeks of Less Than 7 days. Equation 3-2 is used to adjust the OEL, if the work week is less than seven days.

$$\text{Adjusted OEL} = \text{OEL} \times \left(\frac{8}{\text{h}} \times \frac{24 - \text{h}}{16}\right)$$

**Equation 3-2**

Where:
h = number of hours worked per day
8 = number of hours per traditional workday
24 = number of hours per day
16 = number of recovery hours per traditional workday

This adjusted OEL is then used for comparison with the employee's TWA exposure, and its upper or lower confidence limits as appropriate, calculated using the applicable form of Equation 3-1. Confidence limits are discussed in Chapter 4. Note that when the full shift is not sampled, you must make assumptions about the concentration during the unsampled portion of the work shift. The traditional assumptions are that the average exposure during the unsampled period is either equal to zero or equal to the average exposure during the sampled period. Any other assumptions are difficult to support and should be used rarely and with adequate documentation.

(c) 7-Day Work Weeks – If the non-traditional work schedule involves work on all 7 days of the week, adjust the OEL as shown in Equation 3-3:

$$\text{Adjusted } 7-\text{day work week OEL} = \text{OEL} \times \left(\frac{40}{\text{h}} \times \frac{168 - \text{h}}{128}\right)$$

**Equation 3-3**

Where:
h = number of work (exposure) hours per 7-day work week
40 = number of work hours per traditional work week
168 = number of hours per 7-day work week (7 days x 24 hours)
128 = number of recovery (exposure-free) hours per traditional work week

(2) Adjustments Mandated by OSHA in Some Standards (e.g., lead). Another model often used is the OSHA model which accounts for increased work shifts only (i.e., no adjustment for decreased recovery time). The adjustments, shown in Equations 3-4 and 3-5 are based on whether the stressor acts as an acute or cumulative (chronic) hazard (OSHA has a chemical categorization table where you can look up the hazard category). The OSHA model can be used to adjust for work shifts from 15 minutes to 24 hours per day. The acute hazard equation is intended to modify the PEL to a dose no greater than that of an 8-hour exposure at the PEL. The cumulative hazard adjustment is meant to prevent excessive accumulation following many days (years) of exposure such that workers exposed more than 40 hours per week will not develop body burdens greater than those of workers in a normal 8 hour/day, 40 hour/week schedule. If a chemical is considered both an acute and a chronic hazard, calculate both adjustments and apply the more conservative PEL.

$$\text{Adjusted PEL (Acute Hazard)} = \text{PEL} \times \frac{8 \text{ hours}}{\text{Hours of Exposure per Day}}$$

**Equation 3-4**

$$\text{Adjusted PEL (Cumulative Hazard)} = \text{PEL} \times \frac{40 \text{ hours}}{\text{Hours of Exposure per Day}}$$

**Equation 3-5**

(3) Adjustments based on other models. There are several other models, each with its own limitations and advantages. Consult Reference 3-7 for a complete discussion. Keep in mind that establishing limits for unusual work shifts is complicated by many factors, including individual susceptibilities, stressor biological half-lives, metabolic pathways and exposure schedules (e.g., recovery time allowances, means of elimination, consistency of exposure during extended work shift, etc.).

c. Mixtures.

(1) Additive Effects. Mixtures of stressors with ADDITIVE effects may be compared to a normalized OEL for the mixture of one (1) by calculating the concentration of each individual component of the mixture as a fraction of the OEL for that component (i.e., normalized to the OEL) and then summing these values as in Equation 3-6 below:

$$\text{Mixture summed, normalized OEL} = \frac{C_1}{OEL_1} + \frac{C_2}{OEL_2} + \cdots + \frac{C_n}{OEL_n}$$

**Equation 3-6**

Where:
$C_i$ = concentration of component of mixture

$OEL_i$ = exposure limit of the corresponding component

If the "mixture summed, normalized OEL" is greater than one (1) the measured mixture level is considered to exceed the OEL for the mixture.

(2) Independent Effects. If the chemical substances in the mixture have different biological actions (i.e., independent effects), the data must not be combined into a single exposure value. Instead the concentration of each chemical substance must be separately compared to its OEL.

(3) Synergistic effects. If the chemical substances in the mixture have synergistic effects, interpretation of the data should be done on a case by case basis and with great caution.

## 6. Sample Collection and Analytical Methods

All IH samples should be collected and analyzed using methods described in Reference 3-8, the Industrial Hygiene Sampling Guide for Comprehensive Industrial Hygiene Laboratories (CIHLs). Using the appropriate sampling and analytical methods promotes accuracy, sensitivity, and specificity in industrial hygiene analyses. After receiving the sampling result(s) from the lab, the sample concentration should be calculated using the formula provided in the analytical method described in Reference 3-8.

If the field blank results are equal to or exceeds the LOQ (i.e., not a less than value), a blank correction/subtraction can be performed to obtain the actual sample result(s). CIHLs do not suggest performing a blank correction unless it is specifically stated in the method. Blank correction is accomplished by subtracting the mass of the contaminant found on the field blank from the mass on the actual sample and dividing this result by the volume sampled to obtain the corrected sample concentration. The formulation may differ between methods; therefore, to properly blank correct a sample and determine its concentration, use the formula provided in the analytical method described in Reference 3-8. If upon subtracting the mass of the contaminant on the field blank from the sample mass your result is below the laboratory LOQ in micrograms, your results should be reported as a less than value. All sampling data to include blanks should be entered in DOEHRS-IH. For more information on DOEHRS-IH consult NMCPHC DOEHRS-IH webpage.

## 7. Minimum Sample Volume

The limit of quantitation of the analytical procedure establishes the minimum required volume of air for a sample. The minimum sample volume and the required sample time are computed using Equations 3-7 and 3-8:

$$\text{Minimum Sample Volume (liters)} = \frac{\text{Analytical Limit of Quantitation (µg)}}{\text{OEL } \left(\frac{\text{mg}}{m^3}\right) \times \text{Desired Fraction of OEL}}$$

**Equation 3-7**

$$\text{Required Sample Time (minutes)} = \frac{\text{Minimum Sample Volume (liters)}}{\text{Sample Flowrate } (\frac{\text{liters}}{\text{minute}})}$$

**Equation 3-8**

**NOTE:** Be careful when using laboratory results that are less than the LOQ. This is especially important when ordering an ICP (inductively coupled plasma) scan for metals, which gives results for a standard set of 14 metals. If "metal Z" was not present in the process being sampled, you should not use the “less than” result to make ANY evaluation of exposure to "metal Z."

## 8. Pre-Planning

When a positive determination is made that there is potential for an employee to be exposed to a chemical, physical or biological agent at or above the AL, sampling is usually conducted to determine the extent of the exposure. Since many decisions will be based on the sampling results, it is necessary to develop a standardized sampling protocol to ensure the highest level of confidence in reported exposure levels. Careful preparation is essential to facilitate and assure the collection of valid samples. The following checks are to be made prior to field sampling:

a. All sampling equipment is to be factory and/or field calibrated in accordance with manufacturer's instructions and/or in accordance with Chapter 8 of this manual.

b. Ensure that pumps are fully charged (voltage check) and are pre-calibrated to the proper flow rates.

c. Forms for documenting air samples, bulk samples, wipe samples and heat stress surveys, along with the associated form definitions and explanations, are discussed later in this chapter.

d. Use the correct collection media as specified in Reference 3-8. Check media expiration date to ensure that media does not expire until after laboratory analysis. You may need to consult with the laboratory before collecting samples, particularly for unusual analytes. The laboratory may require a bulk sample or extra tubes for desorption efficiency studies.

## 9. General Sample Collection Procedures Using Sampling Pumps

a. Select the employee to be sampled and discuss the purpose of the sampling strategy. Advise the employee not to remove or tamper with the sampling equipment. Inform the employee when and where the equipment will be removed.

b. Instruct the employee to notify the industrial hygienist or the supervisor should the sampling equipment require temporary removal.

c. Place the sampling equipment on the employee so that it does not interfere with work performance.

d. Attach the collection device (e.g., filter cassette, charcoal tube, etc.) to the shirt collar (i.e., within the employee's breathing zone). The inlet orifice should generally be in a downward vertical position to avoid contamination. Ensure the collection device inlet will not be covered by loose items of clothing. Position the excess tubing so as not to interfere with the work of the employee.

**NOTE:** For welding fume samples, place the cassette inside the welder's helmet.

e. Turn on the pump and record the time.

f. In order to determine if the desired flow rate is being maintained during sampling, the following methods should be used:

(1) A precision rotameter should be plugged into the cassette and the flow rate should be checked based on the center of the ball reading. Adjust the pump flow rate to the desired flow rate as indicated by the precision rotameter reading if the flow rate is greater than 5% difference from the original flow rate. Record the time and flow rate prior to adjustment on the sampling form. Also record the new adjusted flow rate and time. In this case two volumes for the sample will be calculated based on the lowest flow rate for each time period. See paragraph 10 for more details. The two volumes would then be added together for the total volume. Note that if the flow rate has changed greater than 5%, consideration should be given to change out the pump with a different calibrated pump. The pump that did not maintain the flow rate should be put out of service until repairs are made, such as changing out the battery. The pump should be retested prior to use following the procedures outlined in Chapter 8 of this manual.

**NOTE**: Per the OSHA Technical Manual, Section II: Chapter 1, Personal Sampling for Air Contaminants, Appendix F, Calibration, (updated 2/11/2014), [reference 3-4] OSHA no longer uses precision rotameters for calibration due to the potential measurement error that may occur due to pump pulsation. OSHA uses electronic flow calibrators instead. A precision rotameter can be used as a secondary standard as long as it is calibrated in accordance with Chapter 8 of this manual. Only use

calibration points where the rotameter ball is stable. For example, at lower flow rates the ball may not be stable and therefore should not be used.

(2) Built-in rotameters on pumps can be used for visual verification of flow rate stability during sampling. Do not use built-in rotameters for calibration purposes.

(3) As a minimum, the flow on all pumps should be checked after the first half-hour, hour and every 2 hours thereafter. During pump checks, check for filter loading. Particulate accumulation on the filter may affect the flow rate, especially on pumps that are not constant flow. If this occurs, replace the filter with a new one. Ensure that the collection device is still assembled properly and that the hose has not become pinched or detached from the cassette or the pump.

g. **Do not leave sampling equipment unattended.** Monitor the operation and employees throughout the work shift to ensure that sample integrity is maintained and cyclical activities and work practices are identified. Record the time course of events, taking detailed notes concerning airborne contaminants and other conditions to assist in determining appropriate engineering controls.

h. Prepare field blank(s) during the sample period. Field blanks are prepared in the same manner as the actual media used for sampling, except air is not drawn through them. Field blanks should also be from the same lot number as the media used for sampling. Remove both the inlet and outlet plugs from the cassette at the sampling site and immediately replace them. If using tubes, break off both ends of the blank tube at the sampling site and immediately cap. Field blanks are used to check for contamination due to sampling process and the background contamination due to the work site.

For each type of sample collected, generally submit at least one field blank per 20 samples for OSHA sampling methods. For NIOSH sampling methods, a minimum of 2 field blanks are required for each set of samples of a specific type. If a set contains more than 20 samples, the number of field blanks required by NIOSH is 10% of the total number of samples with all fractions rounded up. NIOSH states than in no case are more than 10 field blanks required regardless of the number of samples in the set. The CIHL requests at least one field blank with each batch (same sample type for same sampled location, process, and hazard) of samples. Field blanks should be labeled as field blanks along with the fields sample numbers for the associated samples. Consult with the CIHL for questions on blanks for samples being sent to the CIHL for analysis. All sampling data to include blanks should be entered in DOEHRS-IH. For more information on DOEHRS-IH consult NMCPHC DOEHRS-IH webpage.

i. Before removing the pump at the end of the sample period, check the flow rate to ensure that the rotameter ball is still at the calibrated mark. Record the pump or precision rotameter reading.

j. Turn off the pump and record the ending time.

k. Remove the collection device from the pump. Cap tubes. If using impingers (rarely, if ever used) the fluid is usually transferred to a glass bottle and the bottle is capped and tape is wrapped around the bottle and cap in a clockwise fashion. For cassettes, insert cassette plugs. For open face sampling, insert the inlet cap (top) into the retaining ring (spacer). A shrink band should be placed around the cassette covering the inlet cap, retaining ring and outlet cap (bottom) to ensure the integrity of the sample. Note shrink bands should already be used on the cassettes prior to sampling. For open face sampling, ensure the shrink band does not cover the inlet cap since this cap is removed during sampling.

l. Pumps should be post-calibrated after each day of sampling (before charging). Record the post-calibration results.

m. Prepare the samples for submission to the analytical laboratory.

n. Include the necessary media blanks along with the samples and field blanks.

   A media blank is an unopened sampling media from the same lot number as the media used for sampling. Media blanks are NEVER opened (i.e., plugs are never removed from cassettes and tubes are not broken open). Media blanks are used to check the media and analyte background levels, and also as a check for laboratory reagents and methodology.

   The CIHL requests at least one media blank with each batch (same sample type for same sampled location, process, and hazard). Media blanks should be labeled as media blanks along with the field sample numbers for the associated samples, and sent off to the laboratory with the field blanks and the samples. Consult with the CIHL for questions on blanks for samples being sent to the CIHL for analysis.

o. Activities are encouraged to develop provisions for sealing sampling media to prevent tampering and for using sample logs and chain of custody forms where such documentation is appropriate.

## 10. Sampling Pump Calibration and Sampling and Analytical Method Precision

a. If the initial (pre-) and final (post-) calibration flow rate differential is within 5%, a volume calculated using the lower flow rate should be reported to the laboratory. If the difference between the pre- and post-calibration flow rates greater than 5%, the pump may not be functioning properly. Check the battery first. If the problem is still not corrected, have the pump repaired.

   **NOTE**: If the pump flow rate differential is greater than 5%, the sample results may still be used for exposure evaluations. The total coefficient of variation ($CV_T$), or overall precision ($S_{rT}$), of a sampling and analytical method incorporates a ± 5% pump error. Depending on the $CV_T$ or $S_{rT}$ of the method, sampling conducted with a pump error greater than 5% may still be usable by factoring in an additional error in the $CV_T$ or $S_{rT}$

provided. However, the $CV_T$ or $S_{rT}$ should be within the required accuracy of ± 25% at the exposure limit criterion, with a confidence level of 95%.

Example: You are sampling for dichlorodifluoromethane by NIOSH method 1018. Your pump differential (i.e., pre and post calibration) is 7%. This is greater than the recommended 5%. You check the method and find the overall precision ($S_{rT}$) which in the past was referred to as the total coefficient of variation ($CV_T$), to be 0.063. Combined with an estimate of bias (B) for the method, the accuracy of the method is calculated to be approximately ± 12.3% (NIOSH lists the accuracy as 12.8% from the concentration range studied). Your increase of 2% pump error can be included in an adjusted $S_{rT}$ by calculating the cumulative error as shown below:

$$\text{Adjusted } S_{rT} = \sqrt{{E_1}^2 + {E_2}^2}$$

$$\text{Adjusted } S_{rT} = \sqrt{(0.063)^2 + ((7-5)|100)^2}$$

$$\text{Adjusted } S_{rT} = \sqrt{(0.063)^2 + (0.02)^2}$$

$$\text{Adjusted } S_{rT} = 0.066$$

Where: E1 = overall method precision ($S_{rT}$)

$$E_2 = \frac{(\text{Actual pump error in \%}) - (\text{Method's pump differential in \%})}{100}$$

The adjusted $S_{rT}$ of 0.066 equates to about ± 13% overall accuracy for the sampling and analytical method. An explanation of how $S_{rT}$ is used along with the method bias (B) to calculate the method accuracy is available on pages 39-43 of Reference 3-9. Since this is within the allowable ± 25%, the sample can be used to "screen" the sampled operation exposure to determine if further sampling is needed. Remember that overall precision is based on concentrations at 0.1 to 2 times the exposure limit (for NIOSH 1018, 495 to 9,900 mg/m3) and the $S_{rT}$ listed in the method may not be applicable at lower concentrations.

b. Estimating Overall Precision of a NIOSH Sampling and Analytical Method When $S_{rT}$ is Not Provided. If you want to determine the confidence interval limit on an exposure measurement (e.g., calculating the lower confidence limit [LCL] for determining non-compliance at 95% confidence or calculating the upper confidence limit [UCL] to determine with 95% confidence that the exposure was compliant) and only the method precision ($S_r$) is provided, you must also consider sampling (pump) error in the calculation of the UCL/LCL. The overall precision ($S_{rT}$) can be estimated as follows:

$$\text{Estimated } S_{rT} = \sqrt{S_r{}^2 + E^2}$$

Where: $S_r$ = Method precision for the analyte

$$E = \frac{(\text{Assumed or actual pump error in \%})}{100}$$

The following apply to NIOSH methods:
* Overall precision ($S_{rT}$) includes sampling errors (e.g., pump error).
* Method precision ($S_r$) relates to analysis only.
* For analytical methods used for multiple analytes (i.e., metal scans and many organics), the method precision ($S_r$) of the individual analytes is tabulated and included in the documentation.
* When providing an overall precision ($S_{rT}$) for a method NIOSH includes pump errors, other sampling errors and bias.

c. Calibration should be conducted at the same temperature and pressure as sampling.

**NOTE**: Per the OSHA Technical Manual, Section II: Chapter 1, Personal Sampling for Air Contaminants, Appendix F, Calibration, (updated 2/11/2014), [reference 3-4] OSHA recommends calibrating an open-face cassette by using the cover section (inlet cap) which comes with the cassette and attaching the tubing directly from the calibrator to the inlet port on the cassette cover. Be certain there are no leaks and do not use a Luer adapter. Calibrate as if it were a closed face cassette.

## 11. Sampling Methods for Respirable, Thoracic, and Inhalable or "Total" Particulates/Aerosols

Particulate/Aerosol samples may represent the respirable, thoracic or inhalable fractions of the particulate/aerosol or the nominal "total" particulate/aerosol. Each inspirable fraction requires a different sampling device. Care should be taken to determine which fraction an OEL refers to and to ensure that the correct sampling device is used. Care should be taken to enter the proper inspirability (i.e., respirable, thoracic, inhalable or total) into DOEHRS-IH for particulate/aerosol samples and to choose the appropriate OEL in DOEHRS for that particular inspirability of the hazard.

a. Respirable Sampling. Respirable fraction is collected using a clean cyclone at a flow rate recommended by the cyclone manufacturer to achieve the collection efficiencies cited below. The respirable fraction of a particulate/aerosol is defined as the fraction of particles collected according to a table of collection efficiencies agreed upon by the

International Organization for Standardization (ISO), the European Standardization Committee (CEN) and the ACGIH. The table of collection efficiencies is published in Reference 3-3. The most often cited characteristic is the median (i.e., 50%) collection efficiency which is for particles with an aerodynamic diameter of 4 micrometer (µm). Sampling is usually done with a cyclone upstream of the filter to preselect the fraction of particles of each size that pass through (i.e., penetrate) the cyclone and are collected on the filter. Several types of cyclones are available commercially the most common being the 10 mm nylon (i.e., Dorr-Oliver) cyclone and the Higgins and Dewell cyclone which evolved into the SIMPEDS cyclone. The flow rate through the cyclone is critical to obtaining the correct respirable size distribution. At present a flow rate of 1.7 L/min is used with the 10 mm nylon cyclone and a flow rate of 2.5 L/min is used with the SKC cyclone. As more cyclone performance test data becomes available flow rate recommendations change; therefore, the manufacturer should be consulted for the currently recommended flow rate to conform to the ISO/CEN/ACGIH respirable size distribution.

**NOTE**: When sampling for respirable dust for comparison to the ACGIH TLVs® per the International Standards Organization/ European Standardization Committee (ISO/CEN) protocol, no change is recommended for the measurement of respirable particulates/aerosols using a 10 mm nylon cyclone at a flow rate of 1.7 L/min (Reference 3-1).

b. Thoracic Sampling. Currently, the ACGIH TLV® for sulfuric acid is the only OEL generally used by Navy industrial hygienists that requires thoracic sampling. However, with international agreement on what this fraction is with respect to the size distribution (Reference 3-3), more such OELs may soon follow. NMCPHC is aware of only one personal sampler of this type which is the GK2.69, offered by BGI Incorporated. At present, the manufacturer's recommended flow rate for this cyclone is 1.6 L/min to collect a thoracic size distribution. When such devices are used, the manufacturer should be consulted to determine the correct flow rate to collect a thoracic size distribution.

c. Inhalable Sampling. There are some ACGIH TLVs® that are set for inhalable particulates/aerosols. Three inhalable samplers are widely available in the U.S. (i.e., the Institute of Occupational Medicine [IOM] sampler, the Button sampler (both distributed by SKC, Inc.) and the Conical Inhalable Sampler [CIS] distributed by BGI, Incorporated). The IOM sampler operates at 2 L/min, the button sampler at 4 L/min and the CIS sampler at 3.5 L/min. Other samplers are known to exist. As more OELs are set for inhalable particulates/aerosols, other samplers will probably be introduced. When such devices are used, the manufacturer should be consulted to determine the correct flow rate to collect the correct inhalable size distribution.

d. "Total" Sampling. All OSHA PELs for "total" particulates/aerosols are sampled with a closed face 37 mm filter cassette. Studies have shown that this sampling method collects less particulate/aerosol than an inhalable sampler.

e. Relationship of the Results Obtained with the 37 mm Filter cassette to the IOM Sampler. Studies indicate the 37 mm filter significantly under-samples for particulates/aerosols of larger particle sizes. One researcher (Reference 3-10) has proposed a range of conversion factors for estimating inhalable particulate/aerosol concentration based on measured "total" particulate/aerosol concentrations using a closed face 37 mm filter cassette. Table 3-1 presents suggested working conversion factors where the field evaluator deems it desirable to adjust exposure data for change in the assessment rationale between total and inhalable (IOM) particulate/aerosol results (Reference 3-10). Measured inhalable particulate/aerosol concentrations tend to exceed corresponding total particulate/aerosol concentrations except in welding environments due to the small particle sizes of fumes. For operations that may generate particle sizes other than smoke or fume, the field evaluator should sample using the IOM sampler or other inhalable sampler meeting the International Standards Organization (ISO) inhalation curve presented in Reference 3-3 when comparing exposures to an OEL based on the inhalable mass.

**NOTE**: With identical exposure limits, work environments with exposures only slightly below the total particulate/aerosol OEL could have inhalable particulate/aerosol concentrations above an inhalable ACGIH TLV®.

**Table 3-1**

| Particulate/Aerosol Classification/Process Category | Suggested Conversion Factor |
|---|---|
| Dust –<br>Mining<br>Ore and Rock Handling<br>Handling/transportation of bulk aggregate<br>Textiles<br>Flour and grain handling, etc. | 2.5 |
| Mist –<br>Oil mist and other machining fluids*<br>Paint sprays<br>Electroplating, etc. | 2.0 |
| Hot processes –<br>Metal smelting and refining<br>Foundries | 1.5 |

| Particulate/Aerosol Classification/Process Category | Suggested Conversion Factor |
|---|---|
| Welding – All types | 1.0 |
| Smoke and fumes – All types | 1.0 |

* NIOSH has a thoracic recommended exposure limit for metal working fluids assessed by using "total" particulate/aerosol sampling based on a specific applied conversion factor.

f. Use of Total Particulate/Aerosol Results to Which Inhalable Correction Factors Have Been Applied. When total particulate/aerosol sample results are corrected to estimate inhalable exposures that corrected result should only be used to determine if exposures would merit sampling with a true inhalable sampler. If an industrial hygienist wishes to compare exposures to an Inhalable OEL those exposures should be documented with true inhalable sampling not by correction of total particulate/aerosol sampling.

## 12. Sampling Method Using Filter Cassettes

a. Particulates/aerosols can be collected on polyvinyl chloride (PVC) filters, mixed cellulose ester filters (MCEF), glass fiber filters (GFF), etc., using a flow rate generally in the range between 1 to 4 liters per minute (L/min) – consult the Reference 3-8, the Industrial Hygiene Sampling Guide for Comprehensive Industrial Hygiene Laboratories (CIHLs) for specific requirements (e.g., media, sample flow rate, sample volume, open faces, special handling). Check media expiration date to ensure that media does not expire until after laboratory analysis.

b. For sampling where gravimetric analysis is needed to provide the quantity of total, respirable, inhalable, or thoracic particulates/aerosols (alone or in addition to analysis for any specific chemical hazard (e.g., lead, isocyanates)), tared or matched-weight filters need to be used. Tared and matched-weight filters are available from commercial sources.
   (1) Tared filters have been properly handled, desiccated, pre-weighed and loaded into a cassette in a strictly controlled lab environment to provide a pre-sampling tare weight. The difference between the pre-sampling tare weight and post-sampling analysis weight (after proper handling and desiccation) is the sample weight.
   (2) Matched weight filters are pairs of filters that are matched in weight, usually within 25 or 50 micrograms (µg), and loaded into a cassette in a strictly controlled lab environment. They are mounted one on top of the other in the same cassette. The top filter is used to collect the sample while the bottom filter acts as a reference filter which was exposed to the same environmental conditions (e.g., humidity) but has no weight gain due to capture of particulates/aerosols. The difference in their weights after sampling is the sample weight.

(3) Inhalable samplers have special considerations and the manufacturers' directions need to be consulted. The CIHLs can perform pre-weighing of inhalable samplers sent to the CIHLs. Contact the CIHLs directly for more information on this.

c. During sampling, ensure the cassette is positioned correctly (inlet on top and base towards the pump).

d. Plug the cassette with the supplied plastic plugs immediately after sampling.

## 13. Sampling Method Using Sorbent Tubes

a. Organic vapors and gases are collected on activated charcoal, silica gel or other adsorption tubes. Immediately before sampling, break off the ends of the adsorption tube to provide an opening approximately one-half the internal diameter of the tube. Do not use the charging inlet or the exhaust outlet of the pump to break the ends off the sorbent tubes. Check media expiration date to ensure that media does not expire until after laboratory analysis.

b. During sampling, position the adsorption tube with the arrow in the direction of air flow (i.e., toward the sampling pump). To prevent injury to the worker, tubes should be placed in tube holders.

**NOTE:** If there is no arrow on the adsorption tube, insert the tube so the backup (smaller of two segments in tube) portion is closest to the pump.

c. The air to be sampled should be drawn directly into the inlet of the adsorption tube and not be passed through any hose or tubing before entering the tube. When air sampling methods require tubes in a series, as in nitrogen dioxide/nitric oxide air sampling, they can be joined via the shortest practicable piece of tubing. Ensure the tubing will not absorb the analyte. Chemically inert tubing is available.

d. When sampling with tubes connected in a series, label each tube and any pre-filter(s) with a single sample number (i.e., your field sample number), followed by successive letters (A, B, C, etc.). For example, three tubes in series on field sample number 96-578 will be submitted to the laboratory as samples 96-578A, 96-578B and 96-578C. Since all of these tubes represent a SINGLE sample, they should be entered on a SINGLE column on the air sample form (NMCPHC 5100/13). Further, each tube's position in the sampling train should be noted on the sample sheet (i.e., primary (farthest from the pump) or secondary (closest to the pump).

e. Cap tubes with the supplied plastic caps immediately after sampling.

## 14. Sampling Method Using Midget Impingers/Bubblers

a. Add the specified amount of the appropriate reagent to the impinger flask either in the office or at the sampling location. If flasks containing the reagent are transported either to or from the sampling site, both the impinger stem and side arm should be sealed with caps or parafilm.

b. Collect impinger samples using a maximum flow rate of 1.0 L/min.

c. The impinger should be attached to the employee's clothing using an impinger holster. It is very important that the impinger does not tilt, causing the reagent to flow down the side arm to the hose and into the pump or to spill onto the worker's skin and clothing. Place a trap in line after the impinger to protect the pump from the absorbing solution.

d. In some instances, it will be necessary to add reagent during the sampling period to prevent the amount of reagent from dropping below one half of the original amount. Always remove the impinger from the employee before adding reagent.

e. After sampling, remove the glass stopper and stem from the impinger flask.

f. Rinse the absorbing solution adhering to the outside and inside of the stem directly into the impinger flask with a small amount (1 or 2 milliliters (ml)) of the sampling reagent. Stopper the flask tightly with the plastic cap provided or pour the contents of the flask into a 20 ml glass bottle. Rinse the flask with a small amount (1 or 2 ml) of the reagent and pour the rinse solution into the bottle. Use a Teflon® liner in the cap of the glass bottle. The cap should be taped securely in the same direction as the cap closes (clockwise).

**NOTE**: Sampling with impingers is rarely, if ever used, for new analytical procedures.

## 15. Sampling Methods Using Direct Reading Instruments

a. Detector Tube. Detector tubes should be used primarily as a screening tool. Samples are to be taken in the breathing zone of the employee.
   (1) Detector tubes may be used to determine what areas should receive full shift samples. They may also be used concurrently with full shift samples to trace sources of exposure and track variations in exposure levels throughout the work shift.
   (2) Detector tubes can be used only with the pump supplied by the manufacturer, as there may be differences in flow rate between different manufacturer's pumps. Flow rate determines the adsorption rate for the chemical reactions that produce the color change or length of stain. Calibrate pumps using the method described in Chapter 8.
   (3) Consult the manufacturer's instructions for information on interferences and relative standard deviations for the specific tube, as well as the number of strokes,

time between strokes, time for allowing color development, temperature, humidity and atmospheric pressure effects. Reliable readings may not be possible when interferences are present.

(a) Where there is a gradation of color change, the end point should be taken as that point where the color change can first be detected.

(b) If the indication occurs at an angle, take the reading of the longest and shortest discoloration and use the average as the end point.

(4) When interpreting the results of detector tube sampling, the largest relative standard deviation reported by the manufacturer (for the exposure range) should be applied. Where screening results may exceed the AL (after the standard deviation has been applied) then full shift sampling should be accomplished.

(5) Useful life can be adversely affected by improper care. Avoid exposing tubes to prolonged high temperatures (e.g., automobile trunks in the summertime). Refrigerated storage is recommended. Do not use detector tubes that have exceeded their expiration date.

(6) Consider the effects of temperature on chemical reaction speed. Tubes can be warmed in the winter by placing loose tubes in an inside pocket for approximately 15 minutes before use.

g. Direct Reading Gas Monitors. Direct reading gas monitors, including monitors for carbon monoxide, hydrogen sulfide, combustible gases, organic vapors and oxygen should be operated in accordance with the manufacturer's instructions. Readings should be taken as frequently as necessary to adequately characterize the exposure.

(1) Combustible Gas Meter.

(a) When measuring explosive levels in atmospheres where the identity of the explosive contaminant is known, calibrate the meter using the manufacturer's recommended calibration gas and use the manufacturer's response curves/conversion charts for that explosive contaminant.

(b) When measuring explosive levels in atmospheres where the identity of the explosive contaminant is not known and there is no manufacturer's response curve available for the explosive contaminant, many manufacturers consider it best to calibrate the meter with either propane or pentane, since they fall in the middle of the relative sensitivity/response chart, and most gases and vapors will respond within a reasonable safety margin. Consult the manufacture of the particular meter. This calibration, combined with an alarm set point of 10% of the lower explosive limit, minimizes the differences in meter readings that are due to the relative response of the combustible sensor. The subject of relative sensitivity/response is discussed in reference 3-11. When in an atmosphere where the identity of the explosive contaminant is not known, readings taken on a meter calibrated with methane usually underestimates the lower explosive limit. The actual relative sensitivity/response of a sensor would vary by manufacturer. Due to the effect of some substances (e.g., silicones, halogenated

hydrocarbons) to reduce the sensitivity or poison the combustible sensors or filaments of the meter, it is recommended that methane also be used to check the meter for loss of sensitivity to methane. This check is not a recalibration, but is to be done in addition to the propane or pentane calibration.

(c) This type of meter is not used to determine personal exposures to organic vapors.

(d) Each meter approved for potentially explosive atmospheres will be labeled with the approved classes, groups and approving organization. Only use the meter for the classes and groups for which it is approved. Do not use a meter without an approval label.

(e) Meters are not allowed in locations where fire or explosion hazards may exist unless the meter is certified intrinsically safe for the type (Group) of atmosphere present. When replacing batteries, use only those specified on the safety approval label.

(f) Consult and comply with manufacturer's instructions and directions regarding the operation, capabilities and limitations of the meter. Only use meters for their designed purpose and within the limitations specified by the manufacturer. (Reference 3-12).

1. Many meters will not give reliable results in oxygen-deficient atmospheres. For this reason and other obvious safety considerations, always measure the oxygen content of the location first.
2. Certain contaminants, including (but not necessarily limited to) silicones, silicates, lead containing compounds, halogenated hydrocarbons, acrylonitrile, carbon disulfide, formaldehyde, styrene, high concentrations of hydrogen sulfide or high concentrations of other combustible gases, may reduce the sensitivity or poison the sensors or filaments of the meter and produce false readings or failure. At times, sensitivity can tend to first be lost with respect to methane. Therefore, the meter may calibrate with and respond appropriately to other gases but have reduced sensitivity or not respond to methane. It is recommended that methane also be used to check the meter for this initial loss of sensitivity to methane. This check is not a recalibration, but is to be done in addition to the usual calibration. (Reference 3-12)
3. EMI resulting from the use of portable radios in close proximity to some meters can cause erratic or lower than normal readings of the meters.
4. Temperatures outside of the manufacturer's recommended range for the meter can cause erratic readings of the meter.

(2) Oxygen Meter.

(a) Following manufacturer's guidelines, calibrate the meter in air known to contain 20.9% oxygen and outside of the space to be tested.

(b) Consult and comply with manufacturer's instructions and directions regarding the operation, capabilities and limitations of the meter. Meters shall be used only for their designed purpose and within the limitations specified by the manufacturer. (Reference 3-12).

1. Changes of altitude or atmospheric pressure can affect the performance of some meters, requiring that the meters be calibrated for existing conditions.
2. EMI resulting from the use of portable radios in close proximity to some meters can cause erratic or lower than normal readings of the meters.
3. Temperatures outside of the manufacturer's recommended range for the meter can cause erratic readings of the meter.

h. Direct Reading Dust Monitor.

(1) Follow the manufacturer's instructions for the operation and calibration of the monitor.
(2) Use the monitor as a screening device to estimate total or respirable dust levels.
(3) The monitor is non-specific; it measures the airborne mass concentration of dust and not specific toxic substances. Some instruments are calibrated to a specific type of dust (e.g., Arizona road dust) and may not give accurate results for dusts with different size distributions.
(4) The monitor may give erroneous readings due to differences in collection efficiency for large particle sizes when measuring total dust.

i. Others. Other technical equipment may be used for field evaluation, such as toxic gas monitors, photoionization detectors, infrared analyzers, radiation monitors/meters, etc. All should be calibrated, maintained and operated according to the manufacturer's instructions and directions and within the limitations specified by the manufacturer.

## 16. Sampling Methods Using Passive Monitors

b. Instructions and limitations of the monitors are defined in the manufacturer's user's manual and should be carefully followed. Check media expiration date to ensure that media does not expire until after laboratory analysis.

c. As with any sampling method, an accuracy of ± 25% at the 95% confidence level within 0.5 to 2 times the PEL should be demonstrated. If this information is not available through the manufacturer, duplicate sampling can be useful in supporting the accuracy of the sampling method.

d. In high humidity environments some organic vapor monitors may experience problems due to competition of water vapor for adsorption sites on the charcoal leading to underestimation of actual concentrations.

e. Most monitors require a minimum air flow rate over the diffusion membrane to prevent creating an artificially low stressor concentration at the membrane. Therefore, many

monitors may not be suitable for area sampling. Consult the manufacturer for minimum required air flow rates and suitability for use as an area monitor.

f. Care should be taken to ensure that the diffusion membranes are not torn during sampling, which invalidates the sample. Since monitors are small and light-weight, they are easily turned over so that the sampling face is not exposed or may be covered by loose clothing. The industrial hygienist or technician should ensure that neither of these events occurs, otherwise the sample will be invalid.

**NOTE:** Passive monitors are usually designed for full-shift sampling of gases and vapors. Particulates, such as paint mist, may coat the monitor's diffusion membrane and invalidate the results.

g. Always record the manufacturer, model, series and serial number (if available) of the passive monitor on the sampling form. This information is needed to look up the appropriate sampling rates/uptake rates used during concentration calculations for the particular chemicals being analyzed. (e.g., for a SKC Formaldehyde dosimeter, the actual serial number of the passive monitor is needed in addition to the manufacturer, model and series to look up the sampling rate/uptake rates.) Sometimes the sampling rates/uptake rates are available on the passive monitor box or paperwork. If so, also recording the sampling rates/uptake rates for the particular chemicals being requested for analysis would be helpful. This passive monitor information can be recorded on the sampling form in the Media, Lot/Tube#, Time Course of Events/Comments or Calculations fields.

## 17. Sampling for Surface Contamination

a. General Information.
   (1) The terms "wipe sampling," "swipe sampling" and "smear sampling" are used synonymously to describe the techniques used for assessing surface contamination. The term "wipe sampling" will be used in this chapter.
   (2) There are a variety of reasons why surface contamination and especially removable surface contamination, may need to be assessed. Several reasons are listed below:
      (a) Many toxic materials may gain entry into the body via ingestion and, in some instances, via penetration (absorption) through intact skin.
      (b) Surfaces which may contact food or other materials which are ingested or placed in the mouth (e.g., chewing tobacco, gum, cigarettes) may be wipe sampled (including hands and fingers) to show contamination.
      (c) Skin irritants may be evaluated for potential contact by wiping surfaces, including exposed skin (e.g., fingers, hands).
      (d) Effectiveness of decontamination of surfaces and protective gear (e.g., respirators) may sometimes be evaluated by wipe sampling.

(3) There is a very strong possibility that wipe samples will give a false negative; that is, that some or all of the existing surface contamination will not be removed by a wipe sample.
(4) Available toxicological information concerning chronic skin absorption, dermatitis, etc. should be used to determine if the resulting exposure presents a potential employee hazard.

b. General Technique for Wipe Sampling.
(1) Generally, there are three types of media recommended for taking wipe samples:
(a) Glass fiber filters (37 mm) are usually used for materials that are analyzed by high pressure liquid chromatography (HPLC) and often for substances analyzed by gas chromatography.
(b) Paper filters are generally used for metals and may be used for anything not analyzed by HPLC.
(c) Pre-moistened wipes meeting ASTM E1792 requirements may be used for metals.
(d) Check media expiration date to ensure that media does not expire until after laboratory analysis.
(2) Pre-loading a group of vials with appropriate filters is a convenient method. The smear tabs should be inserted with the tab end out. Always wear clean disposable gloves when handling filters.
(3) The following procedures apply to the collection of wipe samples:
(a) At the worksite, prepare a rough sketch of the area(s) or room(s) and identify surfaces to be wipe sampled on the IH Bulk/Wipe Sample Survey Form under the Comments section.
(b) If sampling an employee's skin or personal protective equipment, prepare/position the employee or equipment so that further contact is not needed prior to wiping. Skin wipes should not be done for materials with high skin absorption. Under no conditions should any solvent other than distilled water be used on skin or personal protective gear that directly contacts the skin.
(c) Put on a pair of clean impervious disposable gloves. A clean set of gloves should be used with each individual sample. This avoids contamination of the filter and the hand and the subsequent possibility of false positives.
(d) If needed for sampling, moisten Smear Tabs or filters with deionized water prior to use.

**NOTE:** For some chemicals, wipe media may require specific solvents or derivation solutions for sampling and/or field treating. Consult laboratory for specific information.

(e) Withdraw the filter from the vial. If a damp wipe sample is desired, moisten the filter with the appropriate solution.

(f) Wipe approximately 100 square centimeters ($cm^2$) of the surface to be sampled.

**NOTE:** If a template is used to outline a 100 $cm^2$ (for example 10 cm X 10 cm) area, a new template should be used for each location where a sample is taken. This prevents contamination of other sample sites. Often a heavy piece of paper will suffice as a template.

(g) Start at the outside edge and progress toward the center of the surface area by wiping in concentric squares of decreasing size. Firm pressure should be applied when wiping.

(h) Without allowing the filter to contact any other surface, fold the filter with the exposed side in and then fold it over again. Place the filter in a sample vial, cap the vial, number it and place a corresponding number at the sample location on the sketch. Include notes with the sketch giving any further description of the sample. Also fill out the rest of the sample form.

(i) OSHA wipe method presented in ID-125G for metals: If using a pre-moistened wipe, remove it from its package and unfold it. Next fold the wipe in half. Wipe a 10-cm × 10-cm area by starting at the outside edge of the surface, applying firm pressure, wipe the surface and progress towards the center by making concentric squares of decreasing size. Fold wipe in half, with contaminant side in and wipe the surface again by making concentric squares of decreasing size. Fold the wipe in half, contaminant side in and wipe surface a third time. If using a Smear Tab or Whatman filter, wipe a 10-cm × 10-cm area by starting at the outside edge of the surface, applying firm pressure, wipe the surface and progress towards the center by making concentric squares of decreasing size. If possible wipe the area at least 3 times. Fold the wipe sample with exposed side in. Transfer the wipe sample into a 20 mL scintillation vial and seal with vinyl or electrical tape.

(j) At least one blank wipe or filter treated in the same fashion but without wiping, should be placed in a separate vial and submitted for each sampled area.

c. Special Techniques for Wipe Sampling.

(1) Acids and Bases. When examining surfaces for contamination with strong acids or bases, use pH (litmus) paper moistened with neutral distilled water (i.e., pH 7.0).

(2) Asbestos. When examining surfaces for asbestos contamination, a technique called micro-vacuuming may be used. Micro-vacuuming only identifies presence of fibers and quantifies levels of contamination in terms of number or mass concentration. The microvacuum method has been standardized in ASTM D5755-95 and ASTM D5756-95 (References 3-13 and 3-14), which should be followed when conducting such testing. There are no regulatory standards for interpretation of microvacuum results.

(3) Metals. Wipe sampling for metal-contaminated dusts should be conducted per paragraph 17b above.

(4) Polychlorinated Biphenyls (PCB). PCB wipe samples should be collected following the guidance in References 3-15 and 3-16. Special preparation is required for the collection media. Contact the laboratory where the sample will be analyzed for specific requirements.

## 18. Forms

a. NMCPHC 5100/13, Industrial Hygiene Air Sample Survey Form

b. NMCPHC 5100/14, Industrial Hygiene Single Stressor Air Sample Survey Form

c. NMCPHC 5100/15, Industrial Hygiene Direct Reading Single Stressor Survey Form

d. NMCPHC 5100/16, Industrial Hygiene Bulk/Wipe Sample Survey Form

e. NMCPHC 5100/19, Industrial Hygiene Heat Stress Ashore Survey Form

f. NMCPHC 5100/20, Industrial Hygiene Heat Stress Afloat Survey Form

g. NMCPHC 5100/23 (formerly NMCPHC 5100/15.2), Industrial Hygiene Direct Reading Multiple Stressors Sample Survey Form

## 19. References

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3-3. ACGIH. TLVs® and BEIs®, Threshold Limit Values for Chemical Substances and Physical Agents. Cincinnati, OH: American Industrial Hygiene Association. Latest edition.

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3-13. ASTM. Standard Test Method for Microvacuum Sampling and Indirect Analysis of Dust by Transmission Electron Microscopy for Asbestos Structure Number Concentrations. ASTM D5755-09(2014)e1. West Conshohocken, PA: American Society for Testing and Materials. 2014.

3-14. ASTM. Standard Test Method for Microvacuum Sampling and Indirect Analysis of Dust by Transmission Electron Microscopy for Asbestos Mass Concentration. ASTM D5756-08. West Conshohocken, PA: American Society for Testing and Materials. 2008. Note: Withdrawn 2017

3-15. Environmental Protection Agency (EPA). Sampling Requirements. Code of Federal Regulations, Title 40, Part 761, Section 130.

3-16. EPA.Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup. EPA-560/5-86. U.S. EPA. May 1986.