CDC 4B051

Bioenvironmental Engineering Journeyman

Volume 3. Occupational and Environmental Health (OEH) Risk Assessment: Sampling and Analysis

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THIS THIRD VOLUME of Career Development Course (CDC) 4B051, *Bioenvironmental Engineering Journeyman.* This work presents material pertaining to identifying potential hazards through the understanding of sampling methodologies, conducting sampling, and interpreting those results. Unit 1 introduces exposure assessment models, exposure limits, and sampling methodologies. Unit 2 addresses liquid sampling, liquid sampling equipment, collection procedures and result interpretation. Unit 3 continues by outlining these sampling concepts for air and gas, while Unit 4 presents this information about solid and soil sampling.

A glossary is included for your use.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Introduction to Sampling Strategies

RISK ASSESSMENT DECISIONS are based on informative data. Sampling is the act of making observations and collecting data upon which to base your decisions and recommendations. Accurate and reliable sample data are needed to support your risk-based recommendations. In order to collect accurate and reliable sample data, a detailed sampling strategy must be developed. This strategy provides a guideline for collecting samples and interpreting sampling results.

1–1. Introduction to Exposure Assessments

Exposure assessments determine the extent (i.e., level, duration, and pattern) of an exposure and the number of people exposed. [1] An exposure assessment evaluates how much of a substance an individual or population at risk ingests, inhales, or contacts over a period of time. Exposures may be long-term or short-term, and are identified as either occupational (exposures received in a work center during the performance of one's duties) or environmental (exposures received from materials, pollutants, or other sources outside the work center).

401. Exposure assessment models

The relationships between the Department of Defense (DOD) and Air Force (AF) exposure assessment models were introduced in volume two of this career development course (CDC). Restated, the difference between the two is that the AF model takes an iterative (continuous) approach, incorporating two courses of action, routine assessments and special assessments, as shown in figure 1–1.

During both routine and special assessments, bioenvironmental engineering (BE) personnel apply qualitative (subjective) and quantitative (objective) principles to determine whether a hazard presents a potential health risk. Qualitative principles are primarily applied during routine assessments but can include quantitative assessment data. At this point, BE identifies and scopes the *processes used and activities encountered* in a work center. To ensure that risks are accurately categorized, routine assessments are used to identify and prioritize the need for more exposure data. [2] When more detailed data is needed, BE conducts specials assessments, also known as *exposure assessments,* which involve taking measurements (e.g., air sampling, ventilation measurements, and noise measurements) to evaluate a worker's potential level of exposure to the identified hazard(s). The results of the exposure assessment are used to do the following:

- Determine the need for health hazard controls.
- Build or add to the longitudinal exposure record (LER).
- Demonstrate regulatory compliance [1].

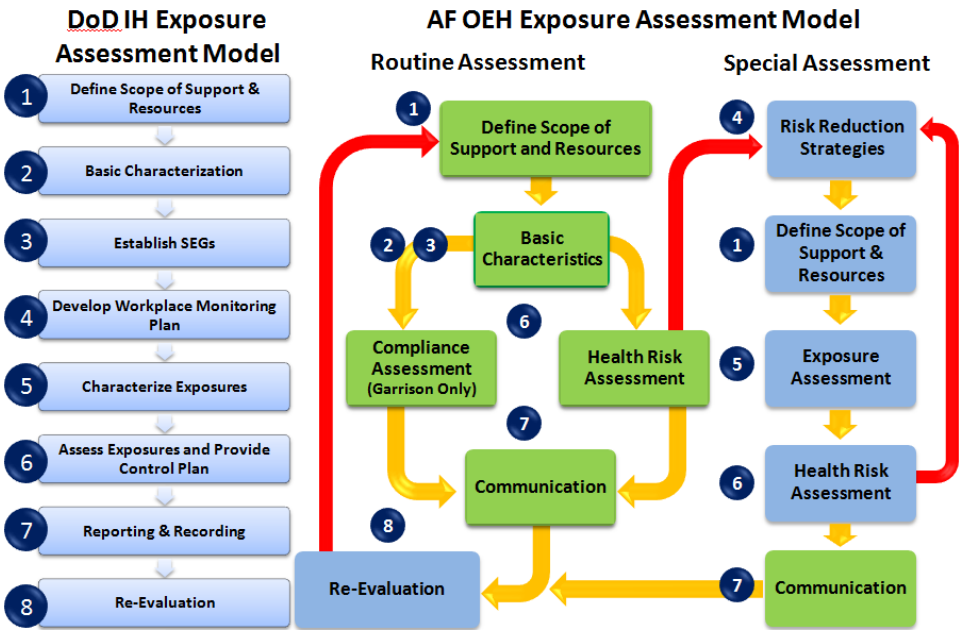


Figure 1–1. The DOD and Air Force Exposure Assessment Models [2].

The American Industrial Hygiene Association (AIHA) has developed an exposure assessment model, shown in figure 1–2. Both the DOD and AF exposure models (fig 1–1) are based on this model and parts of the AIHA model have been incorporated in Air Force Instruction (AFI) 48–145, *Occupational and Environmental Health Program*, and Air Force Manual (AFMAN) 48–146, *Occupational and Environmental Health Program Management*.

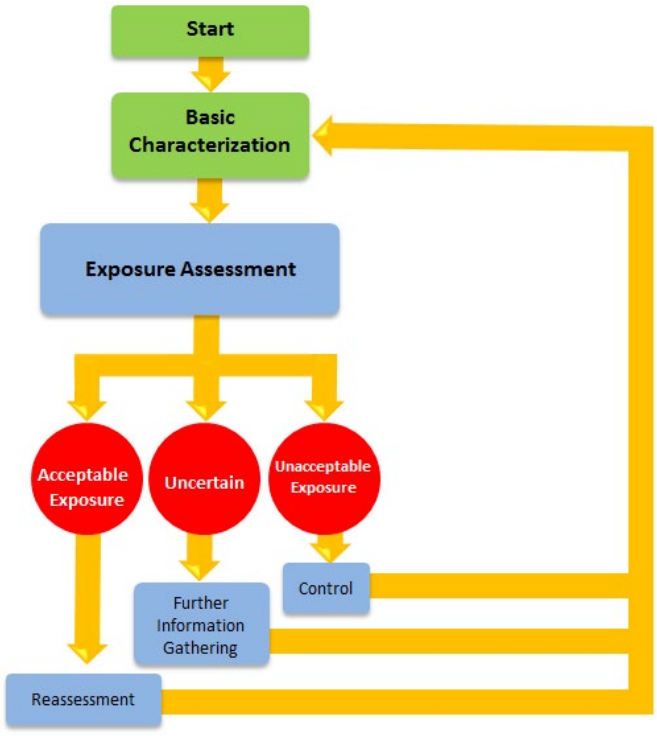


Figure 1–2. AIHA Exposure Assessment Model [3].

The AIHA model is cyclic in nature and is most effectively used in a recurring/repetitious manner that strives for continuous improvement. Early cycles begin by collecting available information and

prioritizing follow-up control and information-gathering efforts. As exposures are better understood and controlled, they drop in priority. A decision is ultimately made as to whether an exposure is acceptable. When an exposure is uncertain or not acceptable, further appropriate actions are taken to either control the exposure or gather more information. [1] Even though the AIHA assessment cycle looks very different from the AF model, the two processes are almost identical, as each identifies exposures through routine and special surveillance, determine the acceptability of the exposures, and establish controls when needed.

402. Conducting an exposure assessment

Once a decision has been made that additional exposure data is needed, BE assigns an exposure assessment priority (EAP) number (as outlined in volume 2 of this course). This number determines the priority of the exposure assessment. A special assessment is then conducted to gather the exposure data, following the steps listed below [2]:

- Step 1: Measure or estimate the exposure.
- Step 2: Compare results to the appropriate occupational exposure limit (OEL).
- Step 3: Determine the acceptability of the exposure.
- Step 4: Communicate and document assessment data.
- Step 5: Re-evaluate as needed.

Measure/estimate the exposure

Additional data is often needed to increase confidence in occupational and environmental health (OEH) hazard characterization and/or confidence in hazard control performance. This can be obtained by performing exposure monitoring, analyzing surrogate data from similar processes, or conducting exposure modeling.

Exposure monitoring

Exposure monitoring involves collecting data by taking measurements of a worker's or population at risk's (PAR) exposure. This is done by performing air sampling, noise surveys or thermal stress surveys, and other means. Data collected for a specific location/process under actual operating conditions provides an ideal estimate for a given exposure. [4] Exposure monitoring can be done by performing screening assessments or detailed assessments.

Screening assessments: Based on AFMAN 48–146, screening assessments may be used to provide an initial estimate of an OEH exposure. The results of the screening assessment determine what further action, if any, should be taken. For example, if the results of the measurements are far below an OEL and the amount of variance in the results is minimal, then three measurements may be all that is needed to characterize the exposure with high confidence. A summary of AFMAN 48–146 guidelines for performing screening assessments is shown below:

- A minimum of three samples is recommended to complete a screening assessment.
- Screening samples should be random, collected over time, and from different workers within the similar exposure groups (SEG).
- If possible, screening samples should be taken on three different days to account for inter-day process variability.
- The conditions during each sampling event must be fully documented using a sample narrative.
- If the 95th percentile of the exposure distribution estimated by the three screening sample results is less than the action level of the OEL, a fully qualified bioenvironmental engineer (BEE), civilian industrial hygienist, or BE Craftsman (4B071) determines whether further sampling is needed.

- A detailed assessment is necessary if the results from the screening assessment are inconclusive or indicate further assessment is required (i.e., over the OEL).

Detailed assessments: A detailed assessment is conducted to better characterize an exposure and is necessary if the results from the screening assessment are inconclusive or indicate further assessment is required. Detailed assessments include all available sample results including past sample results and corresponding narratives. The variance in operations, sampling methods, and limitations of analytical methods used must be taken into consideration when performing a detailed assessment. So, how many samples are needed to determine whether or not an exposure is acceptable or unacceptable?

OEH professionals have long struggled to come up with an acceptable answer to the question: "How many samples are necessary?" The number of measurements needed depends on a number of factors, the monitoring goal and the information already available for the exposure group; however, statistical sampling theory can help with making a decision. According to AIHA, statistical sampling theory reveals that, assuming a normal population distribution, a plateau is reached in estimating the mean and standard deviation after about 6 to 10 measurements. Fewer than six measurements leaves a great deal of uncertainty about the exposure profile which addresses the potential hazards that members of a SEG may be subject to. Although more than 10 measurements may provide additional refinements in the exposure profile estimates, the margin of improvement may be too small when compared to the cost per measurement. Based on the plateaus, at least 6 and generally up to 10 random measurements should be taken for each SEG monitored; however, 30 or more measurements may be needed, particularly when exposures are near the OEL. If the measured exposures are much less than the OEL (<10%) or greater than the OEL, it may be possible to reach a decision with fewer measurements. [3]

In addition to the AIHA guidance, AFMAN 48–146 Attachment 2 states that in order to characterize an exposure with a high degree of confidence, one should have a sufficient number of random measurements, ideally 6 samples.

Random sampling: According to AIHA, for a sample to be considered random, it must be collected so there is equal probability of selecting any exposure period for any worker in the SEG during the interval of the assessment. A source of random numbers would be used to select the dates, work shifts, and individuals in the SEG to monitor. However, real world constraints (i.e., schedules, logistical problems, available technicians, holidays, weather, etc.) affect schedules and priorities, and make true statistical random sampling difficult. AIHA offers the following step-by-step approach to random sampling as an option: [3]

- Identify the appropriate interval for the exposure assessment.
- Identify the OELs appropriate averaging time (8-hour permissible exposure limit (PEL) or threshold limit value (TLV), short-term exposure limits (STEL), etc.).
- Randomly choose dates from the exposure interval.
- Randomly choose work shifts from each date.
- Randomly choose workers from the SEG during the chosen shift.
- If appropriate to the OEL's averaging time (STEL, ceiling, etc.), randomly choose high exposure tasks during the shift.

Exposure modeling

It is possible to estimate exposures based on historic exposure data from other shops conducting similar processes or exposure data from another workplace performing the same process. This means that exposure data from a soldering operation in one workplace, for instance, may be used to document anticipated soldering exposures in another workplace if the processes, materials, and environments are similar. Only a fully qualified BEE, civilian industrial hygienist, or BE Craftsman (4B071) should, based on their professional judgment, consolidate data for similar operations/workplaces as an acceptable substitute. [4]

Exposure assessments do not always involve taking measurements. Modeling can be used to make a conservative estimate of exposure by demonstrating a worst-case scenario that will result in an exposure well below an established OEL; however, personnel must understand the limitations of any model before using it to estimate exposures [4]. Experienced assessors often conduct predictive modeling of some sort. This consists of available known or estimated parameters such as physical properties of the chemical of concern, room ventilation rates, and air volume of a workspace. Many different types of exposure models and tools exist for performing a predictive exposure assessment. For example, the industrial hygiene model (IHMOD), shown in figure 1–3 is an exposure modeling tool designed by AIHA. This tool makes performing a predictive exposure assessment relatively easy.

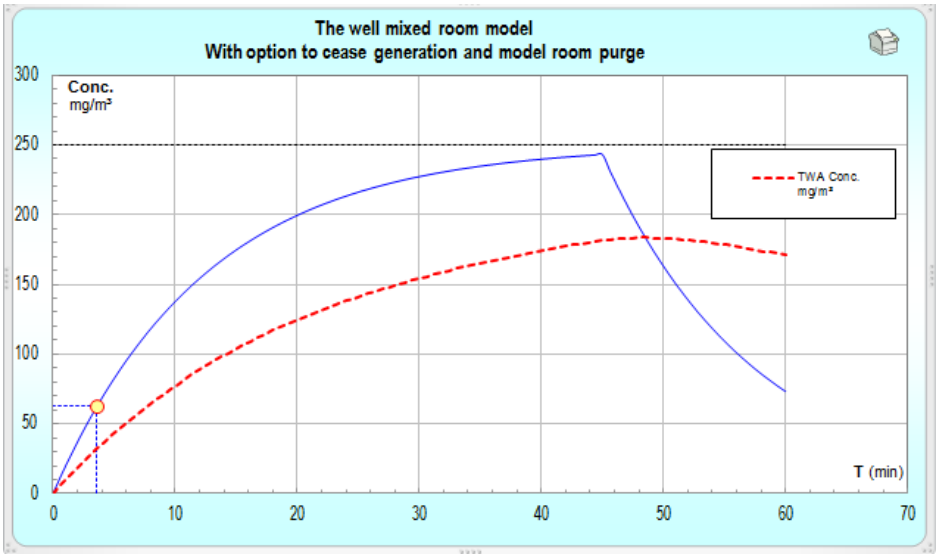


Figure 1–3. IHMOD Exposure Model Example.

Comparing the OEL with this predicted exposure should allow a qualified reviewer to determine if an exposure is acceptable or if more data is needed. Keep in mind that all scientific models, including occupational exposure models, are crude representations of actual conditions and should be interpreted with caution [1]. Contact the United States Air Force School of Aerospace Medicine (USAFSAM) for questions concerning exposure modeling.

Compare results to appropriate OEL

All exposure assessments are predicated on the availability of an OEL. [3] OELs, Occupational and Environmental Exposure Limits, are limits of exposure established to protect personnel from hazardous OEH threat exposures. Therefore, BE should determine which OEL to use when developing the sampling strategy. This should take place before collecting any samples. BE should use the most appropriate OEL adopted from established recognized standards including, but not limited to, those established by the Occupational Safety and Health Administration (OSHA), AF, American Conference of Government Industrial Hygienists (ACGIH), or other recognized organizations. [2] Selecting an appropriate OEL is discussed in detail later in this unit.

If there is not an established OEL for a collected sample, available chemical data can be used to establish an internal or working OEL. However, consult the local BEE or the USAFSAM Environment, Safety, and Occupational Health (ESOH) Service Center for assistance. Many OEH professionals will elect not to sample for a chemical if an OEL does not exist. It is very difficult to explain the significance of a result if there is no OEL to compare the results to.

Determine the acceptability of the exposure

In order to have an acceptable exposure, sufficient data should have been collected to draw a conclusion about the exposure level/profile with high confidence (i.e., 95% confident that the 95th

percentile result is less than the OEL). [4] Immediate action or further data collection other than documentation may not be needed for exposures judged acceptable until it is time for reassessment. Sampling is often performed to *verify exposure acceptability* and ensure that the *controls in place are working properly*.

When the exposure level/profile of a hazard is not well characterized and the acceptability or unacceptability of a SEG''s exposure assessment *cannot be rendered*, it is considered an uncertain exposure. The uncertainty may be due to the lack of accurate and/or reliable data as well as an uncontrolled environment. If an exposure is uncertain, an EAP must be assigned [4]. Refer to the EAP discussion in volume 2 of the CDCs for information on assigning EAPs. An uncertain exposure classification will typically result in a need to capture more data (collect more samples) to better understand an exposure and decide acceptability or unacceptability.

This is a condition for which the *probability of adverse health effects* is significant, or there is evidence of adverse health effects associated with a specific OEH hazard. If an exposure is unacceptable, an EAP must be assigned [4]. This classification can drive actions such as product substitution, implementation of new controls or the enhancement of existing controls to attain an acceptable exposure.

Communicate and document assessment data

The OEH assessment process is complete when the risks and results are communicated, and the report is sent to the workplace supervisor (or equivalent) by the workplace commander [4]. The findings and details of an assessment need to be reported in a clear and logical manner. Reports should contain, at a minimum, information about the process and hazard, the results of exposure assessment, and recommendations for controls, if needed. Specific formats and coordination requirements should be determined locally, but should include affected commanders, functional managers, and workplace supervisors (or equivalent). Do not delay reporting information when dealing with an immediately dangerous to life or health (IDLH) environment or when exposures are suspected or known to exceed the OEL.

Defense Occupational and Environmental Health Readiness System (DOEHRS) must be used to document all OEH exposure data for both garrison and deployed settings (classified areas exempt); the use of any other management information systems for OEH assessments in lieu of the AF-approved and mandated DOEHRS system is strictly prohibited [4]. Details of how to document data in DOEHRS is addressed in student manuals located on the DOEHRS Website. BE should contact the USAFSAM Customer Service Center if there any questions about the system.

Re-evaluate

As mentioned at the beginning, exposures assessment models strive for continuous improvement. Assessments are not only used to establish health hazard controls, but also to build exposure histories or demonstrate regulatory compliance. For these reasons, update the exposure assessments to ensure all new exposures are captured and products no longer present in the workplace are identified. The routine assessment is used to identify a majority of the changes in a workplace; however, changes can be identified whenever technicians are in the workplace performing special assessments.

It is also good practice to review the OEL selected for determining exposure acceptability. OELs published by regulatory and advisory agencies may change as new information on the toxicological effects from exposure is obtained.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Exposure assessment models

1. What are three potential uses of exposure assessment results?

2. According to the AIHA exposure assessment model, what actions are taken when an exposure's acceptability is *uncertain*?

3. What similarities do the AF model and AIHA model share?

402. Conducting an exposure assessment

1. What are the results from a screening assessment used for?

2. What type of sampling requires equal probability of selecting any exposure period for any worker in the SEG during the interval of the assessment?

3. Is it possible to assess worker exposure without collecting samples? If so, briefly describe how If not, briefly describe why collecting samples is always necessary.

1–2. Occupational Exposure Limits

OEH professionals have effectively used exposure limits as a means of protecting worker health and preventing occupationally related illnesses. The use of exposure limits as a means of protecting worker health has evolved from over 50 years of experience. The various exposure limits, although not always developed with the same goal in mind (e.g., to limit occupational cancer to 1 case in 1,000 exposed workers over a working lifetime, or to protect nearly all workers), were all designed to reduce the occurrence of worker illness or impairment resulting from exposure to chemical and physical agents. [4]

403. Selecting the appropriate occupational exposure limits

The term occupational exposure limits (OEL) is a DOD term that is broadly used to represent a level of concentration over a given period of time to which a person may be exposed. OELs aid health risk assessors with managing chemical exposure risks and are established to protect personnel from exposures to OEH threats. They apply to occupational and environmental exposures for individuals and/or SEG or a PAR in a particular area of concern (AOC) [5]. OELs can represent exposures that occur through inhalation, ingestion, skin contact (e.g., skin/eye irritation), or skin absorption. Many commonly used toxic industrial chemicals, where a large number of workers potentially may be exposed, have established OELs. As long as OELs are appropriately applied, they are widely believed to indicate whether an exposure is acceptable or not.

According to AFMAN 48–146, an OEL in the AF is the most conservative limit between the OSHA PEL or ACGIH TLV unless a specific OEL is designated bye the BE Associate Corps Chief on the BE Hive and Environmental and Occupational Safety and Health (EOSH) Service Center.

Numerous organizations have set OELs, as described later in this lesson. The values tend to be reported only for the most common industrial chemicals and are mainly based on inhalation hazards, but other routes of exposure also are addressed. When performing health risk assessments, keep in mind that no published OEL for a substance does not necessarily mean the substance is harmless. Furthermore, OELs are established to protect *most* workers; therefore, you must understand that exposures that are below an established OEL may still cause an adverse health effect in some people,

for example, people that are hypersensitive. BE determines the most appropriate OEL depending on the OEH threat. The table below lists common sources of OELs for chemical exposures. Keep in mind, however, that OELs also exist for physical hazards (i.e., radiation, noise) and biological hazards.

OEL	Published by
PEL	OSHA
TLV®	ACGIH
Recommended exposure limit (REL)	National Institute for Occupational Safety and Health (NIOSH)
Workplace environmental exposure level (WEEL)	AIHA
Military exposure guideline (MEG)	United States Army Public Health Command (USAPHC)
Maximum contaminant levels (MCL) and maximum contaminant level goal (MCLG)	Environmental Protection Agency (EPA)
New chemical exposure limits (NCEL)	EPA
Protective action criteria (PAC)	EPA, AIHA, and Subcommittee on Consequence Assessment and Protective Actions (SCAPA)

Types of occupational exposure limits

Because OEL is such a broad term, it's best to describe OELs based on how they are categorized. OELs can be categorized to be one or more of four classes [3].

Classification	Explanation
Regulatory	These are set and enforced by governmental agencies and have the support of the law behind them. Some of the primary organizations that set and enforce exposure level values are OSHA, the EPA, the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). Many of the standards from these organizations are derived from exposure limits developed by *authoritative* organizations.
Authoritative	There are a number of organizations that produce and publish standards for their respective organizations. Although they are not developed for use as legal standards, many organizations have their standards enacted into law. Organizations that are considered authoritative include the ACGIH, NIOSH, and AIHA.
Internal	Regulatory and authoritative OELs are only available for approximately 1 percent of the chemicals used in industry, and private industry groups may have unique chemicals that are used in their processes. The lack of OELs has prompted some private organizations or industries to develop their own internal OELs, based on toxicity testing or their handling experience. These standards do not have the effect of the law and may not be based on scientific consensus.
Working	In the absence of a formal OEL from a regulatory, authoritative or internal source, an industrial hygienist or other health risk assessors often can identify a working OEL to help differentiate an acceptable from an unacceptable exposure. Working OELS are informal limits, sometimes stated in ranges (i.e., 0.1–1.0 micrograms per cubic meter [mg/m^3]), and often incorporate large safety factors in order to account for the lack of data.

In addition to the four classes mentioned above, OELs can be further categorized based on the *type* of exposure (i.e., routine work, emergency response), the *toxicity* of the contaminant, and *length* of time of exposure.

The length of time of exposure is a critical part of establishing an OEL. Averaging time is the term used to address allowable lengths of exposure. The averaging time refers to the time span for which an average exposure is estimated. It set by the organization developing the OEL. In principle, *averaging time* can expend over any length of time; however, in typical occupational health assessments, the following three *averaging times* account for the majority of regulatory and authoritative OELs:

- 8 hours (for PEL, TLV-TWA (time-weighted averages), etc.).
- 15 minutes (STEL).
- Instantaneous (for ceiling/excursion limits).

The following are some of the more common OELs used by BE personnel.

Permissible exposure limit

OSHA sets exposure limits known as permissible exposure limits. PELs are regulatory limits meaning they are enforceable by law and *must* be complied with. These limits were established to protect workers against adverse health effects of airborne exposures to hazardous substances. PELs are 8-hour TWA unless otherwise noted. Since these are regulatory values, deviation is not allowed; however, more strict limits may be used. Some PELs contain a skin designation that serves as a warning of potential cutaneous absorption that should be prevented in order to avoid exceeding the absorbed dose received by inhalation at the PEL. There may also be other designations, for example, a "C" designation denoting a ceiling limit, which are discussed separately below.

PELs are addressed in specific standards for the general industry, shipyard employment, and the construction industry. OSHA standards are found in Title 29 CFR, Part 1910, *Occupational Safety and Health Standards*, Part 1915, *Occupational Safety and Health Standards for Shipyard Employment*, Part 1917, *Marine Terminals*, Part 1918, *Safety and Health Regulations for Longshoring*, Part 1926, *Safety and Health Regulations for Construction*, and Part 1960, *Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters*. PELs can be found at https://www.osha.gov/law-regs.html. BE personnel primarily refer to the general industry standards in Title 29 CFR Part 1910, which address approximately 500 PELs in Title 29 CFR 1910.1000, *Air Contaminants*.

As stated earlier, OSHA's PELs are enforceable by law, but OSHA's rulemaking and standards are also constrained by law. This means PELs are not always the most protective exposure limits. OSHA is not authorized to adopt or set PELs based solely on health or safety considerations alone. OSHA must demonstrate the need for a new standard based on risk factors. Furthermore, OSHA is limited by feasibility concerns, meaning they must demonstrate that the technology exists or may be developed to achieve compliance with the standard, and that the standard is economically feasible. [1]

Threshold limit value

ACGIH defines TLVs® as airborne concentrations of chemical substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects [6]. ACGIH TLVs® are *not* regulatory and are only enforceable through Air Force standards and Occupational Safety and Health Administration referenced standards; however, they serve as valuable recommended exposure limits and are often used by OEH professionals because, unlike PELs, TLVs® are developed using more current health/toxicological data.

ACGIH first started using the term *Threshold Limit Value* in 1948. The organization originally used the term maximum allowable concentration (MAC), which was the first list of concentrations to limit worker exposure to airborne contaminants. MACs were developed by ACGIH in 1939, in cooperation with the American Standards Association.

All measurements made for comparison to a TLV® must be made in the breathing zone of the worker being monitored and obtained in such a way that a TWA can be calculated. [7] There are three categories of TLVs® specified: 8-hour TWA, STEL, and a C. These three TLVs are discussed separately below in more detail.

Threshold limit value–time-weighted average

ACGIH identifies exposures with an 8-hour averaging time as TLV®–TWA. The ACGIH definition of TLV®–TWA, as defined in the TLVs® and Biological Exposure Indices (BEI®) book, is as follows:

> *"The TWA concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect."*

Short-term exposure limit

OSHA and ACGIH publish STELs for some substances in addition to the PEL or TLV®. The STEL, designated by OSHA as "PEL-STEL" and by ACGIH as "TLV®-STEL", is a 15-minute TWA exposure limit designed to limit exposures to substances that could be harmful due to the short exposure. If a worker is exposed to a material for which a STEL has been established, the worker's exposure must meet the following criteria in order for the exposure to be considered acceptable, or at a minimum, for the exposure to comply with the STEL:

- The STEL should not be exceeded *at any time* during a workday, even if the 8-hour TWA is within the 8-hour exposure limit.
- Individual exposures above the 8-hour OEL up to the STEL should be less than 15 minutes.
- Individual exposures should occur *no more than four times* per day.
- There should be *at least 60 minutes* between successive exposures in this range. [6]

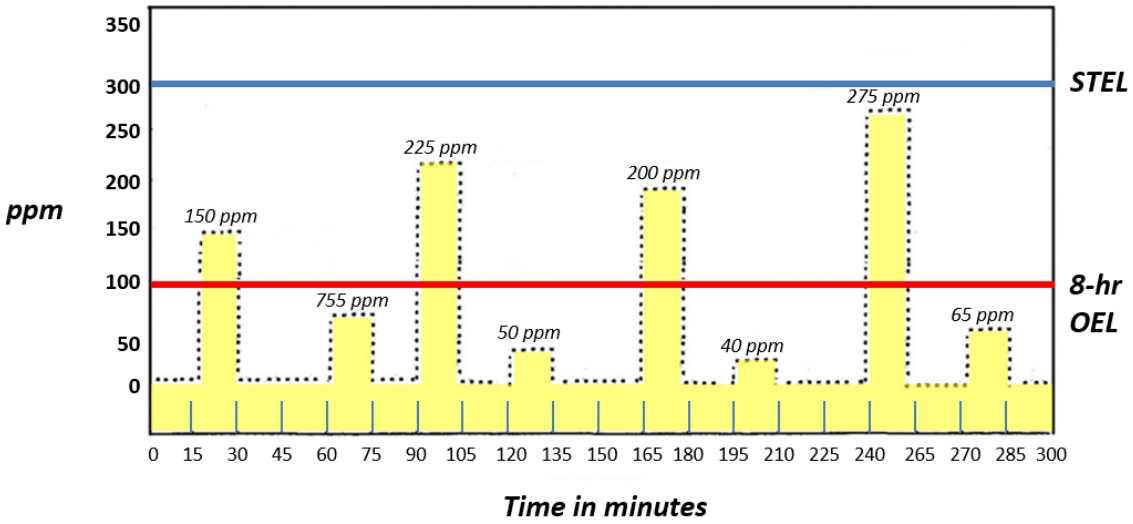


Figure 1–4. Acceptable STEL Exposure (Eight 15-Minute Samples).

Even when the acceptable STEL parameters are met, the 8-hour OEL cannot be exceeded. Notice that the STEL (fig. 1–4) is never exceeded. Individual exposures that fall in the range between the 8-hour (hr) OEL and the STEL are at least 60 minutes apart. If calculating the 8-hr TWA, the result would be 33.75 parts per million (ppm). This result is below the 8-hr OEL of 100 ppm (assuming there are no other exposures for the remainder of the day).

They must be enforced since PEL-STELs are regulatory OELs (published by OSHA). On the other hand, TWA-STELs are not regulatory and are therefore not enforceable by law. This is the case with

all exposure limits developed by ACGIH. ACGIH TWA-STELs serve as valuable recommended exposure limits for OEH professionals.

Ceiling limit

Ceiling limits are levels that should not be exceeded at any time during the workday. This is because the potential for adverse health effects, even if the exposure is very brief. Both OSHA and ACGIH have identified ceiling limits for materials. ACGIH identifies them as "C" or "TLV®-C;" OSHA identifies them as "(C)." Generally, ceiling limits should be assessed via instantaneous monitoring to verify that the levels are *never* exceeded. If instantaneous monitoring is not feasible, ceiling limits are typically assessed as 15-minute time weighted average exposures that shall not be exceeded at any time during the working day.

Excursion limit

For many substances with an 8-hour exposure limit, no STEL or ceiling limit is identified. As previously stated, worker exposures are averaged using a TWA calculation. The results are then compared to the applicable exposure limit. A worker's exposures are usually not fixed throughout the workday, but instead fluctuate. With this fluctuation, there is a chance that a worker may be exposed to a significantly higher level at some points throughout the workday, even though the TWA calculation indicates exposures are within established limits. These potential *excursions* (deviations or increases) should be controlled.

ACGIH states that excursion limits apply to TLV®-TWAs that do not have a STEL, and ACGIH outlines the following excursion limitations:

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

The following two examples demonstrate how an excursion limit can be exceeded for a substance that has a TLV®-TWA of 100 mg/m^3. Figure 1–5 demonstrates how the 30-minute total can be exceeded. Figure 1–6 demonstrates how the excursion is exceeded. The exposure exceeds 5 times the TLV®-TWA.

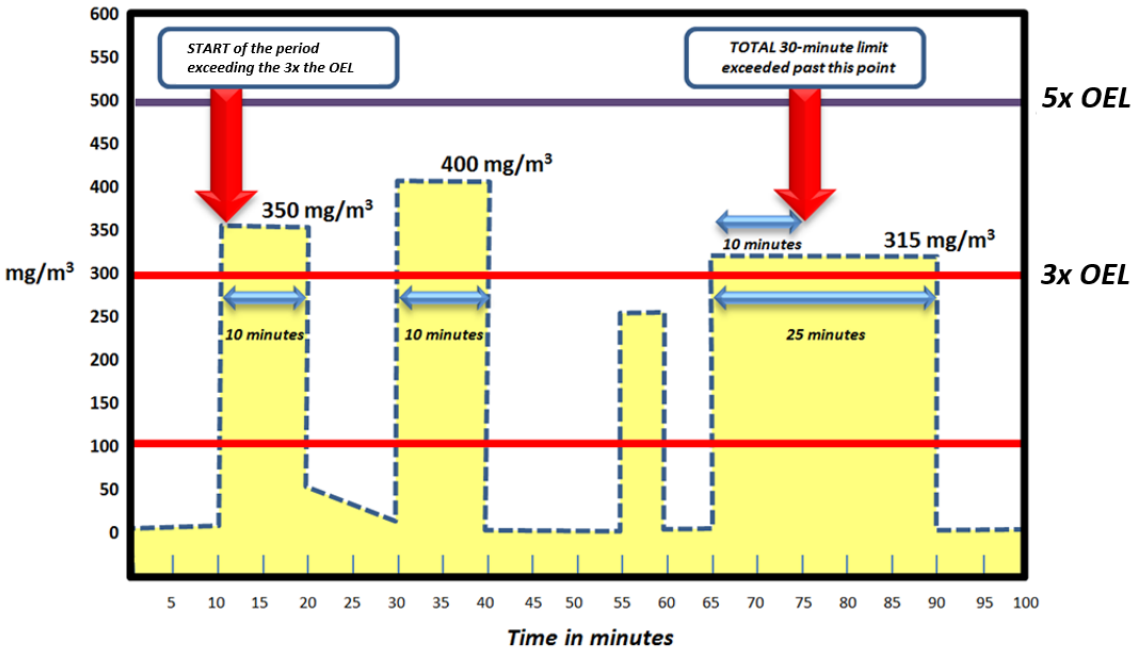


Figure 1–5. Excursion limit being exceeded with total time.

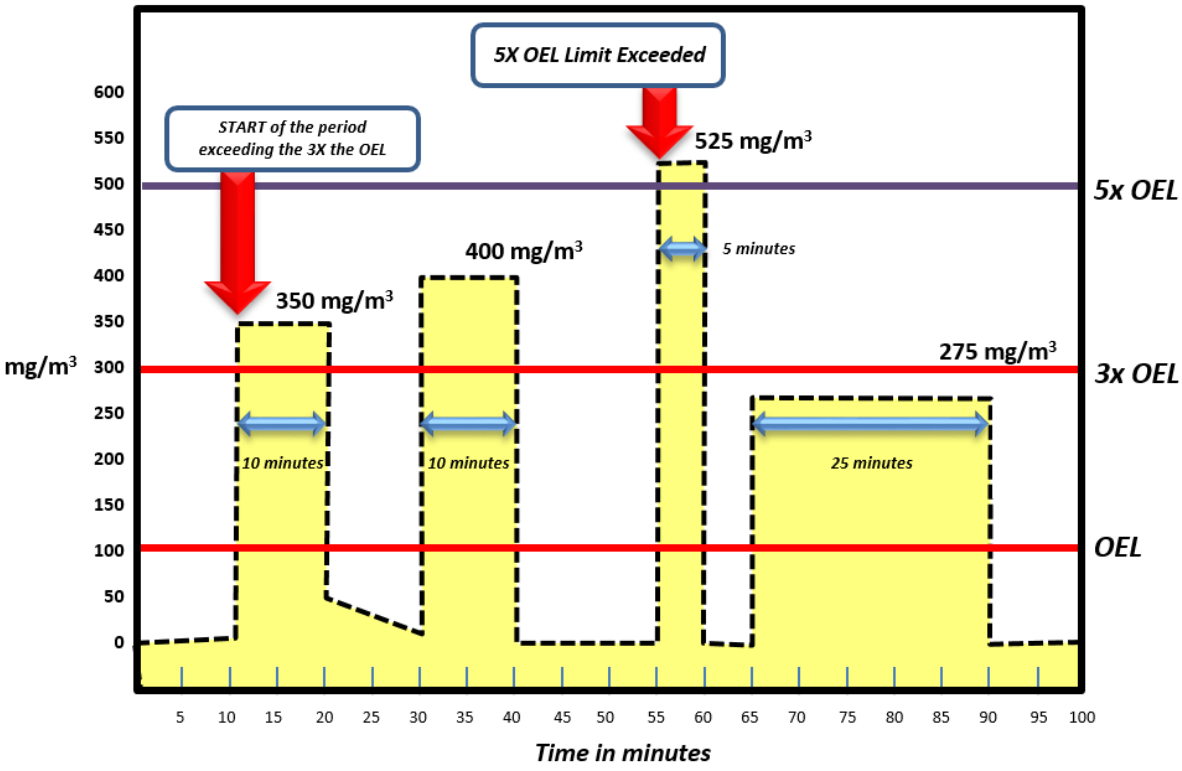


Figure 1–6. Excursion Limit Being Exceeded by Level of Concentration.

Note that in both examples, if you calculate the 8-hour TWA, you will find that the 8-hour TWA OEL is *not* exceeded, assuming there are no other exposures throughout the workday. Even though the 8-hr OEL is not exceeded, the excursions are, and therefore the exposure is unacceptable. It is important to consider that samples collected via an air-sampling pump at 15- or 30-minute intervals instead of using a continuous direct-reading instrument may *not* show whether the excursion limit is exceeded.

Action level

This is an exposure level that dictates some action must be taken (e.g., air monitoring, medical monitoring, and employee training) to monitor and evaluate exposures more frequently. The action level (AL) for airborne exposures is typically one-half the OEL for TWA exposures, except where Title 29 CFR 1910 Subpart Z, *Toxic and Hazardous Substances*, designates a different concentration or where the statistical variability of sample results indicates that a lower fraction of the OEL should be used as the AL. [4]

Recommended exposure limit

The recommended exposure limits from the NIOSH are published as criteria documents that were intended to serve as the scientific basis for compounds that could then be evaluated by OSHA for setting PELs. However, because of the breakdown in the PEL standard setting process, these documents remain as recommended limits without the force of law [1]. It should also be noted that NIOSH states that its RELs, given as TWAs, are appropriate for a 10-hour workday in the context of a 40-hour workweek [1]. The *NIOSH Pocket Guide to Chemical Hazards* includes the RELs and other key information and data, such as physicochemical properties, respirator selection, personal protective equipment (PPE), and health hazards in a concise manner for over 600 chemicals or substance groupings that are found in the work environment. [8]

Workplace Environmental Exposure Level

WEELs® are health-based chemical exposure limits. Over the years, many WEELs® were issued for low-volume chemicals or for chemicals for which there were no other limits, such as ACGIH TLVs® or OSHA PELs. WEELs® are developed in coordination with ACGIH and similar organizations to avoid duplication of effort in occupational exposure level development.

AIHA originally produced WEELs®; however, in 2013 the development of WEELs® was transferred from AIHA to the Occupational Alliance for Risk Science (OARS), which is managed by Toxicology for Risk Assessment (TERA). [9]

WEELs® are not intended for the general public, which includes sensitive populations such as infants, the elderly, or the infirm. WEELs® are based on repeated daily exposures over a working lifetime. They are normally averaged over an 8-hour workday and serve to protect against acute and chronic health effects. [9]

Military exposure guideline

The MEGs are health-based chemical concentrations for various deployed military exposure scenarios representing levels at which no, some, or significant health effects could occur within the exposed, deployed population. MEGs are derived in large part from existing Federal standards and guidelines; however, the MEGs themselves are not presented as standards or action levels. MEGs are published in the appendices of the United States Army Public Health Command (*USAPHC) Technical Guide 230*. The TG 230 provides two key types of information:

(1) Health-based MEGs for chemicals found in air, water, and soil.

(2) Risk assessment guidance on how to translate environmental data collected from deployment sites into the qualitative military risk management (RM) framework.

In addition, specific information is also provided regarding the type and severity of health effects resulting from exposures to varying chemical concentrations, the primary organs affected, odor/taste threshold information, and cancer classification when available. [10]

Maximum contaminant level

MCLs are legally enforceable primary drinking water standards set by the EPA. The EPA defines an MCL as “the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under user-controlled circumstances are excluded from this definition, except those contaminants resulting from pipe and plumbing corrosion caused by water quality.” [11]

Maximum contaminant level goal

The EPA defines an MCLG as “the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals.” [11]

New chemical exposure limit

NCELs are established by EPA to provide adequate protection to human health and include requirements addressing performance criteria for sampling and analytical methods, periodic monitoring, respiratory protection, and recordkeeping. Mandated by section 5 of the Toxic Substances Control Act (TSCA), EPA’s new chemicals program helps manage the potential risk to human health and the environment from chemicals new to the marketplace. If EPA determines that a new substance may present an unreasonable risk of injury to human health via inhalation exposure, EPA may require, among other things that potentially exposed employees wear specified respirators unless actual measurements of the workplace air show that air-borne concentrations of the new substance are below the NCEL.

Protective action criteria

PAC are OELs for planning and response to uncontrolled releases of hazardous chemicals. During an emergency response, these criteria may be used to evaluate the severity of the event, to identify potential outcomes, and to decide what protective actions should be taken. These criteria may also be used to estimate the severity of consequences of an uncontrolled release and to plan for an effective emergency response. There are three PAC levels:

- PAC–1: Mild, transient health effects.
- PAC–2: Irreversible or other serious health effects that could impair the ability to take protective action.
- PAC–3: Life-threatening health effects.

PAC are a collection of OELs developed by multiple agencies to provide exposure limit guidance for chemical releases and emergency response. According to the Emergency Management Issues Special Interest Group (EMI SIG) PACs are selected from available guidelines using the following BEE criteria:

- Use acute exposure guideline level (AEGL), if available.
- If AEGLs are not available for the chemical of concern, use Emergency Response Planning Guidelines™ (ERPG).
- If neither AEGLs nor ERPGs are available, use temporary emergency exposure limits (TEEL).

Acute exposure guideline levels

The EPA publishes AEGL values. AEGLs describe the risk to humans resulting from once-in-a-lifetime (or rare) *airborne chemical exposure*. They are intended to help both national and local authorities, as well as private companies, deal with emergencies involving spills, or other catastrophic exposures. There are three exposure levels for a chemical with an established AEGL:

- AEGL–1: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are also transient and reversible upon cessation of exposure.
- AEGL–2: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- AEGL–3: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Emergency Response Planning Guidelines™

ERPGs® are values developed by the AIHA Guideline Foundation's Emergency Response Planning committee. These instructions direct emergency response personnel in planning for accidental or intentional catastrophic chemical releases to the *community*. ERPGs® are developed to meet the need for community exposure planning guidelines, particularly for chemicals that have high potential for uncontrolled releases and those that might pose particular hazards because of their volatility and toxicity. The primary focus of the ERPGs® is to provide guideline levels for once-in-a-lifetime, short-term (typically 1-hour) exposures to protect the general public from rare, unanticipated chemical exposures. [12] The Emergency Response Planning Committee established a set of levels that could be used as boundaries between different degrees of emergencies [1]. The different boundaries (ERPG–1, ERPG–2, and ERPG–3) are described below.

- ERPG–1: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to an hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.
- ERPG–2: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to an hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.
- ERPG–3: The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to an hour without experiencing or developing life-threatening health effects.

Temporary emergency exposure limits

SCAPA develops TEELs. TEELs are developed and used only for chemicals without ERPGs. TEELs allow for the preliminary identification of hazardous situations for emergency planning when AEGLs and ERPGs are unavailable.

Emergency exposure guidance level

The military sponsored the NRC's EEGL effort [1]. EEGLs are designed to provide guidelines for military personnel operating under emergency conditions that are peculiar to military operations and for which regulatory agencies have not set standards. The National Academy of Sciences defines EEGLs as the ceiling concentration of a substance in air that may be judged by the DOD to be acceptable for the performance of specific tasks during rare emergency conditions lasting for periods of 1–24 hours. The word "emergency" connotes an unexpected situation with potential for loss of life. EEGLs are designed to pro"vide guidelines for military personnel operating under emergency conditions that are peculiar to military operations and for which regulatory agencies have not set standards. The methods used to derive the EEGLs are not always explicitly stated and EEGLs were *not* derived with the intent to protect the general public. [13]

Short-term public emergency guidance level

Recognizing that the EEGLs were not applicable to the general population, the National Research Council introduced the concept of short-term public emergency guidance levels (SPEGL). These guidelines are intended for public emergencies, but the NRC has recommended few of them [1].

Immediately dangerous to life or health

NIOSH developed IDLH values. The purpose of establishing an IDLH exposure concentration is to ensure that the worker can escape from a given contaminated environment in the event of failure of the respiratory protection equipment. The IDLH is considered a maximum concentration above which only a highly reliable breathing apparatus providing maximum worker protection should be permitted. In determining IDLH values, NIOSH considered the ability of a worker to escape without loss of life or irreversible health effects along with certain transient effects, such as severe eye or respiratory irritation, disorientation, and incoordination, which could prevent escape. As a safety margin, IDLH values are based on effects that might occur as a consequence of a 30-minute exposure. However, the 30-minute period was not meant to imply that workers should stay in the work environment any longer than necessary. IDLH values are listed in the *NIOSH Pocket Guide to Chemicals Hazards* for over 380 substances. [8]

Agency for Toxic Substance and Disease Registry minimal risk levels

These are probably the best guide for community exposure. The Agency for Toxic Substance and Disease Registry (ASTDR) derives minimal risk levels (MRL) for noncancerous toxic effects. MRLs are estimates of daily human exposures that are considered to be without an appreciable risk of adverse effects over a specified duration of exposure. MRLs are derived for acute (14 days or less), intermediate (15–364 days), and chronic (365 days or more) exposures for inhalation and oral routes.

MRLs are set below levels that, based on current information, might cause adverse health effects in the people most sensitive to such substance-induced effects. [14]

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

403. Selecting the appropriate occupational exposure limits

1. Match the type of OEL in column A with the appropriate definition in column B. Column B items can only be used once.

Column A	*Column B*
____ (1) Regulatory	a. In the absence of a formal OEL from a regulatory, authoritative or internal source, an industrial hygienist or other health risk assessors often can identify this OEL to help differentiate an acceptable from an unacceptable exposure.
____ (2) Authoritative	b. The lack of OELs has prompted some private organizations or industries to develop OELs based on toxicity testing or their handling experience. These standards do not have the effect of the law and may not be based on scientific consensus.
____ (3) Internal	c. These are set and enforced by governmental agencies and have the support of the law behind them.
____ (4) Working	d. Although they are not developed for use as legal standards, many organizations have their standards enacted into law.

2. What type of OEL should be selected to determine environmental exposure acceptability for deployed military personal?

3. Which of the following OELs is most appropriate for assessing exposure acceptability for emergency responders?

   a. PEL.
   b. PAC.
   c. IDLH.
   d. MCL.

1–3. Sampling Methodologies

Sampling is the collection of a representative portion of a larger group or medium (air, water, or soil). The characteristics of the sample, as determined through some form of analysis, can then be applied to the group or medium. In this way, sampling can be a valuable tool for determining the presence, type, and extent of OEH threats in areas of concern.

404. Sampling methodology

Sampling is not conducted simply because it is a required mandate. Sampling is performed in order to increase confidence in both characterizing potential threats and controlling them. When gaps in health risk assessment (HRA) data have been identified or when other special sampling needs arise, a special assessment will be needed to complete the HRA. This involves collecting samples through a routine workplace assessment, an occupational and environmental health site assessment (OEHSA), or by some other means. When strategically planned and executed, several samples can be infinitely more

valuable than hundreds of sporadic collections. This lesson presents the sampling methodologies (techniques, procedures, etc.) that can help increase confidence in characterizing health hazards.

Whether in support of an occupational exposure or a chemical, biological, radiological, and nuclear (CBRN) event, all sample collection should follow a *methodical approach*. This section discusses the events and actions performed when properly conducting sampling, including the preparation, collection, post-collection processing, and transporting of samples.

Types of sampling

Personnel may be exposed to OEH hazards including climate conditions (e.g., excessive heat or cold), infectious diseases, physical threats (e.g., radiation or noise), chemical and biological warfare agents (BWA), and a large number of chemicals in air, water, and soil. These hazards can come from industrial and community activities, military operations (e.g., aircraft maintenance), emergency response operations, and the natural environment. Sampling of air, water, or soil is done to help make decisions on whether to accept, minimize, or altogether prevent exposures to OEH hazards. In order to determine whether exposures to these hazards are acceptable or require control measures, BE may be required conduct various methods of sample collection. These methods are described in the text to follow.

Integrated sampling

Integrated sampling involves the collection of a sample from one location over a period of time and is most commonly performed when assessing air and water quality. [15]

For gases and vapors, integrated sampling involves the passage of a known volume of air through an absorbing or adsorbing medium to remove the desired contaminants from the air during a specified period of time. With this technique the contaminants of interest are collected and concentrated over a period of time to obtain the average exposure levels during the entire sampling period. [1]

For water, integrated sampling consists of a mixture of several individual grab samples collected at regular and specified time periods, each sample taken in proportion to the amount of flow at that time. It is different from composite sampling (discussed below) in that integrated samples are collected from the same location over the extended period of time. [15]

Composite sampling

In composite sampling, volumes of material from several of the selected sampling units are physically combined and mixed in an effort to form a single homogeneous sample, which is then analyzed. For BE personnel, this approach is primarily used when sampling soil. Compositing can be very cost effective because it reduces the number of chemical analyses needed. Compositing is often used in conjunction with other sampling designs when the goal is to estimate the population mean and when information on spatial variability (number of acres, miles of shore line, gallons of pond water, etc.) or temporal variability (seasonal variances, volatilization rate, etc.) is not needed. [14]

Direct-reading or instantaneous sampling

Direct-reading or instantaneous sampling involves using instruments to get *real-time or near real-time measurements* of a particular material. Proper operation of these sampling devices is essential to ensure that accurate information is obtained. [16] Some of the instruments used by BE personnel for this type of sampling include but are not limited to the Hazardous Air Pollutants on Site (HAPSITE®) the hazardous material (HAZMAT) identification (ID), the ADM–300 survey meter and Dräger detector tubes.

Personal (breathing zone) sampling

A breathing zone sample is a sample that is collected as close to the *worker's breathing zone* as possible (e.g., approximately nine inches from an individual's shoulder). [17] The purpose of a breathing zone air sample is to measure a worker's exposure to an airborne contaminant. In theory,

the sample reflects the worker's actual exposure. Breathing zone samples are usually collected over a specific period of time, often 8-hour shifts or a 15-minute period. After collection, the samples are compared to their respective OEL. To make sure the breathing zone is sampled, the measurement device (e.g., sample filter) is placed on the worker's lapel or as close as feasible to the nose and mouth region.

Area sampling

Area samples are collected to measure the ambient air concentration of a particular substance *in a given area* at a given period of time. OSHA states that area samples are samples that are obtained in an area representative of a process, a worst case exposure, or multiple workers' exposure. [18] When collected for this reason, the area samples are *not* used to establish an exposure for a particular worker. This is because area samples are often left unattended for hours or days at a time without the supervision of a trained technician, which results in unreliable data. Additionally, area sampling may underestimate exposure if the worker works close to a process but the measurement probe or collection device is at a farther distance from the exposure point. [7]

Area samples are also collected to measure the ambient air quality (e.g., particulate matter [PM]) in the local environment or to determine if hazardous materials are environmentally present that pose a health risk.

Grab/bulk/discrete sampling

A grab sample is an individual sample collected at a selected time and involves collecting a liquid or solid material or a volume of air into a sampling bag, canister, or other container to be analyzed using specialized equipment (e.g., HAPSITE, DREL, or HAZMAT ID) or by an accredited laboratory.

The term discrete sample is sometimes used to refer to an individual sample that is used to form a composite sample. All three terms—discrete, grab, and bulk—are used to refer to this type of sampling.

When conducting this type of collection, the technician must be aware of several things including:

- the sample holding times,
- the use of preservatives,
- collecting a specific amount of material, and
- ensuring the collection tools used are clean.

To help interpret the level of worker risk, samples can also be collected in conjunction with personal or area samples in occupational settings. [18]

Swipe sampling

Swipe samples are environmental samples collected to determine the amount of a contaminant (e.g., lead in the workplace/housing unit, areas potentially contaminated as the result of a radiological or nuclear event, etc.) *on the surface* of a particular area or item. They are different from grab, composite or integrated samples in that they are collected by using a pad or similar material to wipe the surface of the AOC (e.g., walls, floors, ceilings, containers, etc.).

Active sampling

Active sampling involves the use of an air-sampling pump to actively pull air through a collection device such as a sorbent tube, treated filter, or impinger containing a liquid media. Most integrated sampling methods published by OSHA or NIOSH use active sampling techniques [1], where the chemicals of interest accumulate on the sample device and the device is sent to an accredited laboratory for analysis.

Passive sampling

Unlike active sampling, passive sampling does *not* require active air movement from a pump. Instead, airborne gases and vapors are collected by a physical process such as diffusion through a static air layer or permeation through a membrane [1]. Passive samplers require no electricity, have no moving parts, and are simple to use; however, they do have a number of limitations. For example, passive samplers can be less effective in stagnant air as well as high air velocities. Some passive samplers have been validated for certain chemicals as a reliable, cost-effective and easy means of assessing workplace exposures as long as they are used within the operating guidelines established by the manufacturer and the respective analytical method.

405. Developing a sampling strategy for occupational exposures

One of the primary goals of sample collection is to acquire the maximum amount of information with the minimum number of samples. This is accomplished by defining and implementing a sampling blueprint prior to conducting any sampling survey. [19] This strategy becomes the overall plan or framework for the sampling. In order to create this framework, several pieces of information must be known, including the:

1. Size of the workforce in the sampling environment.
2. Accuracy of the sampling needed.
3. Measurement method to be used.

The sampling strategy should answer the *who, what, when, where, and how* of the sampling event. There are a number of sources that provide guidance for developing a sampling strategy, two of which are USAFSAM and AIHA. Although these sources vary slightly, their approaches are very similar. Both present useful information that is useful in assisting OEH professionals to collect the information needed for a thorough HRA. The sampling strategy should typically answer the following questions [1, 15]:

- What is the objective?
- What is being sampled?
- What type of sample will be collected?
- Where is the sampling taking place?
- Who is being sampled?
- When should sampling occur?
- How should sampling occur?
- How many samples should be collected?

What is the objective?

The purpose for sampling plays a vital role because it defines the type of sampling needed and leads to the selection of a sampling method. It's important to note that the evaluation may have a purpose other than controlling exposures in the workplace. For example, sampling is useful method to determine the degree of the hazard and whether controls need to be installed.

Degree of hazard

Most samples are collected to determine the degree of hazard associated with a particular exposure. This involves finding out the concentrations of the threat in the particular media of interest (air, soil, or water) that may cause acute or chronic damage to an individual's health. Collecting samples increases confidence in OEH threat exposure characterization so that sound, health risk-based conclusions regarding exposure can be made.

Evaluate controls

Samples are at times useful to determine the need to install controls and to ensure they are effective once in place. Samples also aid in determining if and when PPE is needed. The recommendation for the type of protection needed for a particular process will be based partly on the results of your sampling.

Compliance

At times, samples are required to meet the requirements of Federal and/or Air Force regulations. You should note that when you consider that the overarching tone of the BE Vision, Mission and Strategic Objective statements is health risk assessment and health risk management, compliance with health regulations is nevertheless an aspect of your duties that cannot be overlooked because the requirements were put in place to protect workers.

What is being sampled?

This is based on available information. What are the potential chemical hazards? The toxicity, exposure pathway, hazard quantity, task duration, and task frequency are factors to consider when selecting the chemical hazard to monitor. What is the physical state of the contaminant (i.e. gas, vapor, or aerosol)? Refer to the most current safety data sheets (SDS) of the materials being used to ensure decisions are being made with the most accurate information from the manufacturer [14].

What type of sample will be collected?

If collecting a sample to be analyzed in a laboratory, it is important to determine the type of sample to collect because it will determine where within the work center the sample will be collected. Sampling locations for air samples are divided into two types: general area samples and personal breathing zone samples. General area samples may be collected at a specific operation or just within the work space, while personal samples are collected in the worker's breathing zone. The type of information needed should determine the specific location (tied to the objective). The most frequent location is the personal breathing zone sample in order to determine worker exposure levels throughout a work shift. However, general area samples may be more appropriate when the purpose of the workplace monitoring is to determine the source of contamination. To evaluate engineering controls, general area samples may be more appropriate. There may be times when more than one specific type of sample may be necessary. [1]

The choice of instrumentation depends on the portability and ease of use of the instrument, the efficiency of the instrument and the testing and analytical method, the reliability of the instrument under various conditions of field use, and the type of analysis or information required, among others. The choice of instrumentation and testing and analytical procedures is ultimately dependent on the capabilities of the analytical laboratory.

Where is sampling taking place?

It's very important to find out where the expected exposure site is, to include the building, room, and work center where the potential hazard is generated. Make note of where chemicals are stored, transported, and used, and identify what ventilation and airflow patterns exist. [14].

Who is being sampled?

If you decide the type of sampling you need is a personal air sample, the next step is to determine who should be sampled. The answer of whom to sample depends on the purpose of the workplace monitoring. If compliance with the occupational exposure limits is the objective, then the maximum risk employees should be considered. However, if completing a *comprehensive* exposure assessment is the objective, then a random sample of employees in each exposure group should be considered [1].

- **Maximum risk employee**. As the title implies, this employee is the one with the greatest potential exposure. The best procedure for determining the maximum risk employee is to observe and select the employee closest to the source of the hazardous material being

generated. Sampling the employee presumed to have the highest exposure risk is often considered the most reasonable sampling strategy for the most efficient use of sampling resources; however, sampling data must be interpreted carefully because the data reflecting the worst-case exposure profile might not reflect the actual health risk for *all* workers in a given SEG [14].

- **Random sampling of employees**. The objective of random sampling is to select a subgroup of adequate size so that there is high probability that the random sample will contain at least one worker with high exposure. The table below, shown in the USAFSAM Laboratory Sampling Guide and obtained from NIOSH, provides the required sample size ***n*** drawn from a group of size ***N*** to ensure with 90 percent confidence that at least one individual from the highest 10 percent exposure group is contained in the sample. [14]

Size of Group (*N*)	Number of Required Samples (*n*)
8	7
9	8
10	9
11–12	10
13–14	11
15–17	12
18–20	13
21–24	14
25–29	15
30–37	16
38–49	17
50	18

When should sampling occur?

While it may seem obvious that you should sample during the task in which exposures will occur, there are other factors to consider as well. Multiple shift operations should be sampled at each shift, since workload may differ for each shift. Similarly, if temperature, workload, or other factors vary greatly from season to season, then sampling should be considered during all varying seasons [7]. The effects of seasonal variation in the use of general ventilation (i.e. air conditioning) and open windows, doors, etc. should be considered in the exposure assessment.

How long should sampling occur?

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 8 hours. Consider the factors below in determining the appropriate sample duration [14].

1. **Sampling method**. The sampling method depends on the requirements of the sampling strategy and on the purpose of the workplace monitoring. The following table lists typical sampling methods used by BE personnel.

Method	Purpose

Single grab sample	Collected over a short period of time (e.g., seconds to minutes), usually in bags/containers. Example situations include the following: • Field applications in which grab samples are analyzed on site using portable, direct-reading instruments • Leak, spill, or other emergency situations requiring quick sample collection and analysis so that appropriate control measures can be taken • Measurements of peak concentrations of contaminants from specific plant processes or worker tasks • Collection of gases or highly volatile compounds for which adsorption methods are not available or are not efficient
Integrated sampling	Used to collect longer duration samples, generally 15 minutes to 8 hours, for comparison to TWA or STEL OELs to determine exposure acceptability. Collected with sampling pumps, combined with filters, impingers, or solid sorbent media.
Direct-reading instruments	Used for instantaneous or real-time results. They provide data relative to exposure risks; however, may not provide the necessary specificity, detection limit, or precision for compliance monitoring or exposure assessment [16].

2. **Contaminant concentration and analytical method**. The concentration of a contaminant in the sampled air has a large effect on the sample duration. Generally, 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 laboratory's reporting limit; whereas maximum sampling times and volumes aim to avoid collecting too much mass of contaminant, which may result in sorbent breakthrough or filter overloading. For example, when dealing with air sampling where charcoal tubes are used, you may need to change the tubes more frequently to prevent breakthrough, a condition in which the mass of a collected gas or vapor in the backup section is greater than 10 percent of the mass in the front section. This means that a significant quantity of the contaminant may not have been collected, making the calculated concentration of questionable validity [7]. Since sampling methods specify sample volumes and recommended flow rates, 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.

   When developing a sampling strategy, you should review sampling and analytical methods available for the contaminants of interest for specific applications and carefully select the sampling and analytical methods most suitable for the specific application [1]. Several governmental and consensus organizations have compiled and published manuals of sampling and analytical methods. The OSHA, NIOSH, and the EPA methods are the primary methods encountered and used by BE personnel. If air sampling is done to comply for the purposes of OSHA, the choice of a NIOSH or OSHA method may be most appropriate; however, OSHA does not mandate the sampling method [1]. The following table summarizes the purpose of the OSHA, NIOSH, and EPA methods.

Method	Purpose
OSHA	These procedures were designed and tested for internal use by OSHA personnel to determine compliance with OSHA standards [16].

Method	Purpose
NIOSH	Used for sampling and analysis of contaminants in the workplace air and in the blood and urine of workers who are occupationally exposed [19].
EPA	Used to analyze physical and chemical pollutants; evaluating properties, such as toxic properties, of chemical substances; or measuring the effects of substances under various conditions. The EPA does not have a test method for all chemicals, only those which it in some way regulates [20]. These methods are designed to measure the lower levels typically found in these environments. [1]

The United States Air Force School of Aerospace Medicine Analytical Services Division (USAFSAM/OEA) provides an online application known as the Automated Sampling Guide (ASAGE) to aid in industrial hygiene and environmental health sample plan development. The ASAGE, available on the lab's Website, is an online application that provides method-specific details including handling, stability, media, and reporting limits based on the analyte of concern. The ASAGE lists available methods, including OSHA, NIOSH, and the EPA, for a given analyte and indicates the preferred method for in-house analysis. The ASAGE is only associated with industrial hygiene and environmental chemistry at the Wright-Patterson Air Force Base (WPAFB) lab [14] and does not include methods for the USAFSAM Radioanalytical Laboratory or for overseas locations.

BE personnel should consult the following analytical laboratories before collecting samples:

- BE personnel at continental United States (CONUS) locations primarily use USAFSAM/OEA at WPAFB.
- BE personnel at Pacific Air Forces (PACAF) locations primarily use USAFSAM Detachment 3 laboratory at Kadena Air Base, Japan.
- BE personnel at United States Air Forces in Europe (USAFE) or United States Air Forces Central Command (USAFCENT) or locations typically use the United States Army Public Health Command-Europe (USAPHC-Europe) laboratories.

It is essential to contact the appropriate lab for your location in order to ensure their measurement methods are compatible with your sampling needs. It is also essential to contact the respective lab if an analysis other than their preferred in-house method is required. Additional information about the analytical laboratories is discussed in more detail in the next lesson.

3. **Type of OEL to Which the Sampling Results Will Be Compared**. Samples collected for 100 percent 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, often described as the averaging time. For example, samples for chemicals with standards reported as eight-hour time-weighted averages (TWA) should generally consist of a single eight-hour sample or several consecutive samples totaling the eight-hour period. Samples for chemicals with STELs or ceiling standards, on the other hand, should consist of 15-minute periods.

How many samples should collect be collected?

The number of samples to collect is dependent on the purpose of the workplace monitoring. There is no set rule regarding the number of samples to collect. Historically, personal experience was used to

plan a sampling strategy for collecting the optimal number of appropriate samples within budgetary constraints [1].

According to AFMAN 48–146, a minimum of three random screening samples should be collected, and depending on the results, additional random samples may be required to have an adequate number of samples to determine whether an exposure is acceptable [4]. As stated at the beginning of this unit, for a *detailed* exposure assessment strategy, the recommended minimum number of samples per exposure group is *six* to characterize an exposure with a high degree of confidence [4], and AIHA recommends that exposure monitoring should consist of at least *six to ten* measurements taken from workers and time periods that are selected as randomly as possible [3].

406. Developing a sampling strategy for exposures to environmental hazards

As mentioned earlier, developing a sampling strategy is essential before conducting any assessment for determining the health risk in an occupational environment, since the sampling strategy is the overall plan or framework for sampling. Developing a sampling strategy for exposures to environmental hazards is no different. Similar pieces of information must be known in advance to plan the strategy in order to answer the *who, what, when, where, and how* of the sampling event. The primary sources for developing a sampling strategy for environmental health hazards are the USAFSAM Laboratory Sampling Guide as well as guidance from the EPA.

The EPA has developed the data quality objectives (DQO) process, which achieves two major objectives:

1. It ensures that the type, quantity, and quality of data collected are appropriate for the decision at hand.
2. It eliminates the collection of unnecessary, redundant, and overly precise data.

In the case of BE, the data helps determine whether there is a health risk associated with an exposure to hazards found in the environment. The DQO process is defined in the EPA report titled, *Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G–4*, and is addressed in the *USAFSAM Laboratory Sampling Guide*. The steps of the DQO process are:

Steps	DQO Processes
Step 1	•**State the Problem.** Define the problem that necessitates the study; identify the planning team, examine the budget, schedule.
Step 2	•**Identify the Decision.** State how environmental data will be used in meeting objectives and solving the problem, identify study questions, define alternative outcomes.
Step 3	•**Identify Information Inputs.** Identify data and information needed to answer study questions.
Step 4	•**Define the Study Boundaries**. Specify the target population and characteristics of interest, define spatial and temporal limits, scale of inference.
Step 5	•**Develop the Analytical Approach.** Define the parameter of interest, specify the type of inference, and develop the logic for drawing conclusions from findings.
Step 6	•**Specify Performance and Acceptance Criteria.** Develop performance criteria for new data being collected or acceptable criteria for existing data being considered for use.
Step 7	•**Develop the Plan for Obtaining Data.** Select the resource-effective sampling and analysis plan that meets the performance criteria.

If there are potential health hazard concerns from exposures to materials in the environment, BE should only be dealing with environmental sampling. The seven steps of the DQO process are briefly discussed in the paragraphs below. Information that is more detailed will be addressed in the liquid and solid sampling sections of this career development course. Additional information can be

obtained by referencing the EPA report (mentioned above). Keep in mind: environmental samples collected strictly due to environmental policies and regulations (e.g., hazardous waste characterization and wastewater sampling) are typically managed and/or performed by the CE community. Generally, these are *not* performed by BE. The focus of these samples are in compliance with EPA standards—not health risk assessments.

Step 1—State the problem

Before developing a detailed sampling plan, the first step is to state the problem or determine what question or questions are to be answered by the ERA. What initiated the need to do an assessment? During this step, also identify available BE resources for sampling and the primary decision makers (e.g., commanders, public health (PH) and flight medicine). Give a concise description of the environmental health threat and exposure pathway (see the conceptual site model in unit 2 of volume 2 of this CDC).

The most important activities in this step are to:

- Describe the problem, develop a conceptual site model (CSM) of the environmental hazard to be investigated, and identify the general type of data needed.
- Establish the planning team and identify the team's decision makers.
- Discuss alternative approaches to investigation and solving the problem.
- Identify available resources, constraints, and deadlines associated with planning, data collection, and data assessment [21].

Step 2—Identify the decision

This step of the DQO Process involves identifying the key questions that the assessment attempts to address, along with alternative actions or outcomes that may result based on the answers to these key questions.

- State the questions needing to be answered with qualitative and/or quantitative sample results. For example: "Do contaminants in the drinking water source exceed acceptable levels?"
- What will be done the analytical results? What will the potential course(s) of action be if results are high or low? For example: "If the contaminants exceed acceptable levels, then distribute bottled water."

For decision-making problems, develop a decision statement by combining the information from these two items (questions plus potential courses of action). This is critical for defining decision performance criteria in Step 6.

A decision statement may look something like this: "Determine whether or not the concentration of contaminants in the drinking water source exceeds acceptable levels. If they do, implement the bottled water distribution plan until a secondary drinking water source is secured."

Step 3—Identify information inputs

This step determines the types and sources of information needed to resolve the decision statement or produce the desired estimates. It also determines whether new data collection is necessary and the information basis the planning team will need to establish appropriate analysis approaches and performances, or acceptance criteria. Additionally, it determines whether appropriate sampling and analysis methodology exists to properly measure environmental characteristics for addressing the problem [21]. In most cases, it will be necessary to collect data or new information to achieve the risk assessment goal. Examples of information gathering include available sampling/analysis methods, candidate sampling devices, risk assessment standards/OELs, and required detection limits. Researching applicable OELs is typically a critical part of DQO step 3. Several environmental risk assessment standards and toxicological information sources are listed below, which may aid selecting an appropriate OEL for environmental hazards. Refer to the OEL selection discussion earlier in this

unit of the CDCs, as well as the USAFSAM Laboratory Sampling Guide, for additional information on available standards.

- ASTDR minimal risk levels.
- MEG.
- United States EPA National Ambient Air Quality Standards (NAAQS).
- EPA MCLs.
- EPA NCELs.
- EPA Integrated Risk Information System (IRIS).
- ACGIH TLVs®, NIOSH RELs, and OSHA PELs.

Step 4—Define the study boundaries

This step identifies the target population of interest. Clearly define the area to be sampled, including spatial boundaries (number of acres, miles of shoreline, gallons of pond water, etc.) and temporal boundaries (i.e., seasonal variances, volatilization rate). Define the media to be sampled, such as air, water, or soil, and the sampling unit as some area, volume, or mass that must be collected. Define the physical area to be studied, distinguish where samples will be collected and determine the time frame when the samples should be taken. A sampling device should then be selected based on its ability to:

1. Obtain the correct size, shape, and orientation of the sample.
2. Meet other performance goals specified by the planning team.

Step 5—Develop the analytical approach

The main objective of this step is to select a result parameter and AL. These two should then be combined to develop the decision rule (see fig. 1–7).

Result parameter

The sample results parameter is the statistical parameter (e.g., mean, median, or upper confidence limit) that will be used with the HRA to make a decision. Will a recommendation be based on average conditions or extreme, worst-case conditions? The statistical parameter chosen can be based on what the AL is intended to represent. In general, if an AL is based on long-term average health effects, the parameter of interest could be the mean sample value. If the AL represents a value that should never (or rarely) be exceeded, then the parameter of interest could be an upper percentile, which can serve as a reasonable approximation of the maximum value.

Action level

Define the AL, either using a predetermined AL from fixed standards such as a published drinking water MCL or using a more conservative investigation-based AL (e.g., 1/10 or 1/2 of the OEL). Document the detection limits for the analytical methods identified in step 3. If the detection limit for the method exceeds or is very close to the AL, then a more sensitive method should be used.

Decision rule

The AL and the result parameter should be combined to construct the "If…then…else…" decision rule (fig. 1–7).

Figure 1–7. Decision Rule.

An example of a decision rule is as follows:

If the mean concentration in the surface 2 inches of soil area defined as 20 feet by 100 feet exceeds 1 parts per billion (ppb), *then* remove a 6-inch layer of soil, *else* leave the soil intact.

Parameter	Definition	Appropriate Conditions of Use
Mean	Average	Estimate central tendency, compare middle part of population to an AL. Appropriate for a chemical that could cause cancer after a long-term chronic exposure. Use of the mean and the total amount of media (i.e., mass of soil or water) allows you to estimate the total amount of contaminant contained in the soil or water body. The mean is greatly influenced by extremes in the contaminant distribution and not very useful if a large portion of values are below the detection limit.
Median	Middle observation of the distribution; 50th percentile; half of sample results are above and below	Better estimate of central tendency for a population that is highly skewed (nonsymmetrical). Also may be preferred if the population contains many values that are less than the measurement detection limit. However, the median is not a good choice if more than 50 percent of the population is less than the limit of quantitation because a true median does not exist in this case. The median is not influenced by the extremes of the contaminant distribution.
Percentile	Specific percent of sample that is equal to or below the given value	For cases where it is necessary to demonstrate that, at most, only a small portion of a population could exceed the AL. Sometimes selected if the decision rule is being developed for a chemical that can cause acute health effects. Also useful when a large part of the population contains values less than the detection limit. Often requires larger sample sizes than mean or median.

Step 6—Specify performance and acceptance criteria

In this step, realize that there is no access to perfect information on unlimited data as assumed in Step 5. There is no perfect information from which to formulate conclusions. Furthermore, these data are subject to various types of errors due to such factors as how samples were collected and how measurements were made. [21]. Identify sources of error (e.g., sampling error, analytical error, etc.). Determine the desired confidence level in your results before collecting samples (e.g., 99, 95, 90, 80, or 70 percent confident that a correct decision is being made). Identify the gray area (typically in AF operations this is the range between the AL and the OEL) [14].

Step 7—Develop the plan for obtaining data

Step 7 incorporates the outputs from steps 1–6 into a resource-effective sampling plan that will meet or exceed the objectives. This step summarizes previous steps and outlines the field-sampling plan including the following:

- Number of samples.
- Sample design.
- General collection techniques.
- Sample matrix and quantity.
- Sample locations.
- Timing issues for sample collection, handling, and analysis.
- Analytical methods.
- Statistical sampling scheme.

Common pitfalls to avoid during sample plan development include:

- Nonrepresentative sampling.
- Instability or contamination of samples between sampling and analysis.
- Interferences and matrix effects in analysis.
- Inability to determine the relevant forms of the parameter being measured.
- Improper calibration.
- Failure to blank-correct.

407. Sample collection quality assurance and quality control

Quality assurance and quality control measures are those activities undertaken to demonstrate the accuracy (how close the results are to the true conditions) and precision (how reproducible the results are) of the monitoring.

Term	Definition
Quality Assurance (QA)	Generally, refers to a broad plan for maintaining quality in all aspects of a program. This plan should describe how to undertake the monitoring effort: proper documentation of all procedures, training of volunteers, study design, data management and analysis, and specific quality control measures.
Quality Control (QC)	This consists of the steps to be taken to determine the validity of specific sampling and analytical procedures.

The quality of data collected depends primarily on the quality of the sample, that is, how well it represents the area from which it was collected. Even the most accurate and precise analytical technique is useless without quality samples. Samples must be taken in an appropriate manner with thought given prior to actually taking the sample to requirements such as the analytical procedures, proper handling, sample preservation, and documentation. Several other factors should be controlled, or at least accounted for, to reduce sample variability and accuracy, to include an individual's training level and attitude, their attention to detail, how representative the samples are, environmental factors (i.e., temperature, humidity, barometric pressure, etc.), and handling and transportation of the samples, just to name a few.

To maximize the validity of the samples and increase the timeliness of receiving results, USAFSAM recommends samples undergo a base level QA/QC process prior to shipping the samples to the lab. The QC process should include, as a minimum, a review of sample collection dates, volumes, IDs, media, requested analyte/analytical method, preservation methods, and base contact information as applicable. It is best practice to have detailed QA/QC procedures as a part of base-level standard operating procedures for sampling; therefore, USAFSAM has provided a template QC checklist in Appendix J of the *USAFSAM Laboratory Sampling Guide* for reference (fig. 1–10). The template is designed as an example industrial hygiene QC protocol. Additional radiation and environmental sample QC protocols may be developed and included in base level standard operating procedures. [14]

Analytical services customer support

The USAFSAM analytical services provides several means of support to address sampling questions. ASAGE, the online application is designed to be the first stop, self-service site to address basic industrial hygiene and environmental sampling/analysis questions. Beyond ASAGE, laboratory customer service personnel and the ESOH service center are available for telephone consultation, as shown below in figure 1–8.

CUSTOMER NEED	CUSTOMER SERVICE *WPAFB DSN 798–2523* *DET 3 DSN 315–632–8275*	ESOH SERVICE CENTER *DSN 798–3764*	ASAGE WEBSITE
Selecting appropriate analytical method	X	X	X

Requesting rush analyses	X		
Technical information on analyses	X		
Reprint of historical results	X		
Sample collection procedures	X	X	X
Shipping guidance	X		X
Sample processing/final report status	X		
Sample plan development		X	
Appropriate occupational and environmental exposure limit recommendations		X	
Sample collection volumes/flow rates			X
Reporting limits	X		X
Analytical Error	X		

Figure 1–8. USAFSAM Customer Support Services.

USAFSAM Laboratory Sampling Guide

Samples sent to a laboratory for analysis should be collected using equipment and procedures appropriate to the matrix, parameters and sampling objectives. The samples must also be collected and handled in a manner that ensures the quality of the results and supports the overall QA/QC program. The USAFSAM laboratory has a sampling guide, *USAFSAM Laboratory Sampling Guide*, that *must* be used when preparing to collect a sample, regardless of the type of sample. USAFSAM has provided a quality control checklist (fig. 1–9) in the guide to assist BE personnel with the sampling process. The following guidance is provided for samples being submitted to the USAFSAM laboratory for analysis. Refer to the guide for additional information.

Hazardous materials

When sending hazardous materials, compliance with laws governing the transportation of hazardous materials is mandatory. A list of hazardous materials can be accessed from the International Air Transport Association (IATA) *Dangerous Goods Regulations Manual,* or Title 49 CFR 172.101, *Hazardous Materials Table*. The shipper must comply with any regulatory requirements such as proper labeling and packing. All labels and forms must be complete, legible, and accurate. Personnel must be trained and certified to ship hazardous materials. The US DOT provides regulations governing the transport of hazardous materials under the Hazardous Materials Transportation Act of 1974.

Liquid shipments

Place an adsorbent in the shipping container when shipping liquids. This is absolutely necessary if any samples contain, or are suspected of containing, hazardous material. Be sure to include enough material to absorb *all* the liquid in the shipment if sample leakage occurs. Any leakage from the container will halt the transportation by the carrier.

Temperature-sensitive shipments

To prevent sample degradation, some methods require samples be shipped cold (i.e., ice packs) or frozen (i.e., dry ice). Use refrigerants and a cooler, when necessary, to maintain the samples at the temperature required for special handling and shipping. Store the samples in the refrigerator or freezer until just prior to packing. Use pre-frozen gel blocks whenever possible. Do not allow blocks to come in direct contact with the samples. Keep samples and gel blocks sealed in one or more plastic bags. Always send for next-day delivery when shipping temperature-sensitive samples and do not ship on Fridays; OEA is unable to accept Saturday deliveries for routine shipments.

Dry ice

The most routinely encountered hazardous material used during USAFSAM sample shipments is dry ice (carbon dioxide solid, United Nations (UN) 1845). Dry ice is classified as a Class 9 miscellaneous dangerous goods, and must be in packaging designed and constructed to permit the release of carbon dioxide gas to prevent the buildup of pressure that could rupture the packaging. When shipping with dry ice, you must provide the correct identification, classification, markings, and labeling on your outer carton to comply with current IATA regulations.

Sample labeling

All samples submitted to USAFSAM for analysis must be properly labeled with a unique identifier (i.e., DOEHRS sample identification). Sample IDs cannot contain more than 13 characters, and each physical sample ID has to correspond to an ID on the sample paperwork. Incorrectly labeled samples will delay analysis. If a discrepancy in sample IDs is found, it must be resolved before the lab can proceed with the analysis. The lab follows strict QC protocols that require them to receive customer approval before modifying any IDs on submission paperwork/physical samples even if it is obvious a transcription error occurred.

DOEHRS Sample Submission Forms

The standard industrial hygiene sample submission paperwork should be the DOEHRS Discoverer Viewer – "USAFSAM Sample Submission" workbook. The workbook presents instructions for entering data directly into DOEHRS along with necessary data needed by the lab in order to process the sample(s). Appendix E of the *USAFSAM Laboratory Sampling Guide* has detailed instructions for accessing and printing the sample submission workbook. Refer also to the DOEHRS Technical Guide for general assistance in entering samples into DOEHRS. Personnel at PACAF locations without access to DOEHRS should refer to Appendix A of the sampling guide for the alternative sample submission form.

Chain of custody

Sometimes samples are collected as evidence in the event a crime was committed. In such cases, the samples must be handled in a careful manner to avoid later allegations of tampering or misconduct. Possession of the samples must be traceable from the time the samples are collected until the analysis is completed.

Samples that do not require refrigeration and are not time sensitive should be sent via the US Postal Service using Registered Mail with a Return Receipt Request to ensure a proper chain of custody; however, whenever a legally defensible chain of custody is required, it's best to contact the USAFSAM Customer Service department to address the labeling, packing, and shipping procedures.

APPENDIX J: QUALITY CONTROL CHECKLIST

PLANNING	☐	Was the sampling objective clearly defined prior to sample collection (e.g., ensure compliance, select proper personal protective equipment (PPE), evaluate engineering controls, etc.)?
	☐	If the sampling was non-routine, was a laboratory Customer Service representative contacted to confirm analytical method, media, and specific shipping and handling requirements?
	☐	Were all physical states of the contaminant considered (gases, vapors, aerosols: dusts, fumes, mists, fibers, smoke, fogs, etc.)?
	☐	Was the contaminant of concern verified (verify via a MSDS, ESOH-MIS, etc.)?
	☐	Was the correct analytical method selected (verify via ASAGE and/or Customer Service)?
	☐	Does the type of media used match the media specified in the analytical method?
	☐	Did the sampling plan account for the presence of potentially interfering compounds?
SAMPLE COLLECTION, HANDLING, AND SHIPPING	☐	Will the lab receive the samples prior to the sample stability duration expiring?
	☐	Are the correct sample handling and shipping procedures being followed?
	☐	Was the employee's entire exposure captured?
	☐	Was the sampling narrative accurately documented with enough detail that the operation could be recreated if necessary including: hazardous chemicals, equipment, PPE, engineering controls, environmental conditions, etc.?
	☐	Was the DOEHRS Discoverer Viewer Sample Submission workbook completed properly including: ✓ Requestor name, signature, phone numbers, and email address? ✓ Do the physical sample IDs match the paperwork? ✓ Is the sample type correct (media blank, field blank, sample, etc.)? ✓ Is the collection date correct? ✓ Is the sample volume and collection time correct? Are all blank volumes reported as "0"? ✓ Is the correct analytical method shown on the discover report? ✓ Are the correct analyte(s) listed? ✓ Is the type of sample media listed in the comments? ✓ If the final report should be sent to multiple recipients, are their names listed in the comments?
	☐	Was the pump pre- and post-calibration information properly documented for each sampling pump including serial numbers, date, and flow measurements?
	☐	Were the pre- and post-calibration flow rates within 5%?
	☐	Were the sample volume and flow rate within the recommended range identified in the analytical method? If not, were deviations well documented and justified?
	☐	If particle size selective samplers were used (cyclone, IOM, button sampler, etc.), was the manufacturer's recommended flow rate used?
	☐	For low level detection, was the laboratory reporting limit used to determine the minimum required air volume?
	☐	Was the sampling conducted under the close guidance of a properly trained and certified individual IAW the 4B0X CFETP?
	☐	Were a sufficient number and type of blanks submitted to the lab?
	☐	If gravimetric sampling is being conducted (i.e., NIOSH 0500/0600), was preweighed/matched-weight media used?
	☐	If samples are being sent to a USAFSAM contract lab, was approval received prior to shipping?
RESULTS	☐	Was a letter written to the shop NLT 15 days after receipt of sample results or sooner IAW with specific expanded standards? Was a copy provided to the individuals sampled, wing safety, unit safety rep, union, and public health as necessary?
	☐	Were individual results loaded in DOEHRS, TWA calculated, and the IH SEG assessment updated?
	☐	Was the OEHED updated and briefed at the OEHWG and ESOHC as necessary?

Figure 1–9. Quality Control Checklist from the Laboratory Sampling Guide

Blanks/control samples

There are two types of blanks BEs will deal with when collecting air samples for exposure assessments as part of an occupational health risk assessment: *media* and *field*. The number of air sampling blanks required to be submitted with your samples depends on the sampling method and should be annotated on the method documentation. If media blanks are not specified in the method, they may still be submitted to the lab. This is important when a certain media has a history of background contamination. For example, background hexavalent chromium (Cr[VI]) can be found on all commercially available polyvinyl chloride (PVC) filters as a result of the manufacturing process. Most media blanks analyzed by NIOSH Method 7605, *Chromium, Hexavalent,* will have measurable amounts of Cr(VI). A general rule when information is not annotated in the sample method documentation is to submit two field blanks with your samples (up to 10 samples), with a maximum of 10 field blanks for each sample set. Following this rule, if there are 15 samples, submit four blanks: two to go along with the first ten samples and two more to cover the remaining five samples. Air sample blanks should be tracked and logged into DOEHRS just as a field sample is.

Media blanks

The purpose of media blanks is to check for pre-existing presence of the contaminant (media background), generally in air sampling. These blanks should not be brought into the work environment, and they should never be opened. It is important that these blanks come from the same lot as the field samples. Media blank results with detectable amounts of contaminants may be used to blank correct the field sample results.

Field blanks

Also for air sampling, field blanks should be handled in the same manner as the actual field samples, except no air is drawn through the field blank media. Field blanks must be brought out to the same work environment where the field samples are collected and should be opened and immediately capped. It is important that these blanks come from the same lot as the field samples. Field blanks can help establish if contamination was introduced during sample handling and shipping. Field blank results should ***not*** be used for blank correction. **NOTE:** When sending solid sorbent tube field blanks, remember to break the ends of the glass sampling tube and reseal with the plastic caps.

In addition to the two type of blanks mentioned for occupational exposures assessments, there are at least seven types of blanks that may need to be submitted when submitting environmental samples. Again, the number of blanks required varies and depends on the media type, method, and so forth. The following summarizes some of the types of environmental sample blanks you may encounter, as described in the *USAFSAM Laboratory Sampling Guide*.

Background samples

Background samples demonstrate the ambient concentrations of a substance from both naturally occurring and anthropogenic non-site sources. They are collected in areas assumed to be free from site-specific contamination. Background samples are collected from each media of concern: soil, sediment, surface water, ground water, and air. The sample locations should have the same basic characteristics as the medium at the site. The number of background samples is site specific and dependent on the media samples, the type of contaminant, and the availability of background sample locations.

Field QC samples

A number of field quality control samples should be taken during environmental health sampling. The specific quantity of QC samples should be determined as part of the sample plan prior to the start of field activities. For additional details on when to send blank samples, contact Customer Service.

Trip blanks

Trip blanks (also known as field reagent blanks [FRB]) are required to identify possible interferences associated with the shipping, collection, and storage of samples. Trip blank sample bottles are provided by the lab and must be included when the samples are returned. Trip blanks must be handled along with each sample set, which is composed of the samples collected from the same general sample site at approximately the same time; however, they must never be opened and must always be kept with the samples. Trip blanks must remain sealed until analysis and must be shipped back to the laboratory with the samples that were collected.

Equipment blanks

Equipment blanks (also known as rinsate blanks) serves as a check on sampling device cleanliness and will be affected by the site and sample handling conditions. The equipment blank is a reagent grade aqueous or organic solution that is as free of analytes as possible and is transported to the site, opened in the field, poured over or through the sample collection device, collected in a sample container, and shipped to the laboratory, but without adding any preservatives. This type of blank will be analyzed in the laboratory just like any other sample.

Temperature blanks

Temperature blanks are used to verify that samples are maintained at less than 4 °C, which is necessary with for many analytical methods. These are containers of water that are shipped to the laboratory along with the samples. The laboratory will measure the temperature of the blank upon receipt.

Duplicate samples

Duplicate samples are intended to identify variability in the analytical results associated with field and laboratory methods and the inherent heterogeneity of the media. Samples are taken at the same location employing the same collection methods.

Split samples

Split samples are often used to identify variability between sample handling methods or between laboratories. The sample material is homogenized in the field and placed into two separate sample containers for submittal to two separate labs.

Field documentation

Each sampling event should be accompanied by detailed documentation, to include a sampling narrative. Sampling narratives should be chronological and provide a written record of industrial activities performed by the employee being sampled. In general, capture a word-picture of the setting, actions and conversations as well as any important thoughts, ideas, questions and concerns based on the process being sampled. It is important to be accurate and detailed enough to recreate the sampling event and to ensure information can be validated during subsequent data reviews. In addition to narrative comments, actual photos are a great complement to written observations. Sampling narratives are important, since sample results will reflect worker habits, movements, and behavior in relation to the source(s) of contamination. Table 1–9 obtained from Appendix K of the *USAFSAM Laboratory Sampling Guide* provides information on what should be included in the sampling narrative (fig.1–10).

Also, when air sampling it's important to capture information such as hazardous material, national stock number (NSN), weapon system, pump start and stop times, pump and calibration equipment model and serial numbers, air temperature, relative humidity, and atmospheric pressure to name a few. Clicking and printing the "Generate Blank Sample Report Form" in DOEHRS allows you to document this information easily. Refer to the USAFSAM Laboratory Sampling Guide for additional details on how to print the Blank Sample Report Form.

GENERAL OBSERVATIONS
Date
Shop and organization
Building/room number
Operation being conducted
Hazardous materials used and % of contaminant of concern
Location of task (e.g., inside fuel cell #2)
Regulated area (Y/N)
Environmental conditions: temperature, pressure, relative humidity, wind
Analysis method (e.g., NIOSH 7300)
Sampling media, expiration date, and lot number
Type of sample collected (full period consecutive samples, partial period consecutive, etc.)
Name of personnel sampled
Name of sample collection personnel
PPE utilized (respirators, welding helmets, gloves, hearing protection, etc.)
Engineering controls (ventilation systems, vacuum sanders, welding curtains, etc.)
Air sampling pump and calibrator manufacturer, model, and serial number
Pre- and post-calibration measurements
Sample collection start and stop times
Total sample collection time (minutes)
Total sample collection volume
Sample numbers
Pictures of industrial operations (if possible)
Shipment and preservation information
Sample stability
Shipping information (carrier, tracking number)
Associated samples (bulk/wipe samples)
Potential interferences

Figure 1–10 Basic Air Sampling Narrative Observations

United States Army Sampling Guide

You may be required to use the sampling guide developed by the US Army—the USAPHC Department of Laboratory Sciences (DLS) *Customer Guide*—particularly when assigned to an overseas base (except PACAF) or when in a deployed environment. It's important to note that Air Force personnel assigned to PACAF should initially work with the USAFSAM Det 3 laboratory located at Kadena Air Base, Japan.

The Army guide assists with the following four steps of submitting samples to their lab:

1. Submitting a request for services.
2. Collecting and handling samples correctly.
3. Completing the required paperwork.
4. Shipping samples to DLS.

The USAPHC DLS *Customer Guide* must be used when preparing to collect a sample to be submitted to the *USAPHC DLS*. The Army guide for personnel in the European region can be obtained online at http://phc.amedd.army.mil/topics/phcrspecific/europe/ls/Pages/Publications.aspx.

References

[1] AIHA, "The Occupational Environment: Its Evaluation, Control and Management, 2nd Edition",Fairfax, AIHA Press, 2003.

[2] AFI 48–145, Occupational and Environmental Health Program, 10 July 2018.

[3] AIHA, "A Strategy for Assessing and Managing Occupational Exposures, 3rd Edition", 2006.

[4] AFMAN 48–146, "Occupational and Environmental Health Program Management", 14 October 2018.

[5] AIHA, "AIHA's White Paper on Permissible Exposure Limits", September 29, 2002.

[6] ACGIH, TLVs® and BEIs® book, 2013.

[7] B. A. Plog and P. Quinlan, Fundamentals of Industrial Hygiene, 5th Edition, National Safety Council, 2002.

[8] NIOSH, ""NIOSH Pocket Guide to Chemical Hazards"," [Online]. Available: http://www.cdc.gov/niosh/npg/pgintrod.html#idlh.

[9] AIHA, "WEELs", [Online]. Available: http://www.aiha.org/get-involved/AIHAGuidelineFoundation/WEELs/Pages/default.aspx.

[10] USAPHC, Technical Guide 230. Environmental Health Risk Assessment and Chemical Exposure Guidelines for Deployed Military Personnel, 2010.

[11] EPA, "Vocabulary Catalog List Detail - Drinking Water Technical & Legal Terms", [Online]. Available: http://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=Drink%20Water%20Tech/Legal%202009#formTop.

[12] AIHA, "Emergency Response Planning Guidelines™," [Online]. Available: http://www.aiha.org/get-involved/AIHAGuidelineFoundation/EmergencyResponsePlanningGuidelines/Pages/default.aspx.

[13] Board on Toxicology and Environmental Health Hazards, National Research Council, "Criteria and Methods for Preparing Emergency Exposure Guidance Level (EEGL), SPEGL, and Continuous Exposure Guidance Level (CEGL) Documents", Washington, National Academy Press, 1986.

[14] AFRL, "USAFSAM Laboratory Sampling Guide", 11 May 2012.

[15] M. E. Byrnes, *Field Sampling Methods for Remedial Investigations, Second Edition*, Boca Raton, CRC Press, 2009.

[16] OSHA, "Safety and Health Topics", US Department of Labor, [Online]. Available: https://www.osha.gov/SLTC/.

[17] OSHA, "OSHA Technical Manual", 24 June 2008. [Online]. Available:

https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html.

[18] OSHA, "Chemical Exposure Health Data," n.d.. [Online]. Available: https://www.osha.gov/opengov/healthsamples.html.

[19] NIOSH, "NIOSH Manual for Analytical Methods, 4th Edition", Centers for Disease Control and Prevention (CDC), [Online]. Available: http://www.cdc.gov/niosh/docs/2003–154/.

[20] EPA, "Forum on Environmental Measures: Test Collection Methods", [Online]. Available: http://www.epa.gov/osa/fem/methcollectns.htm.

[21] EPA, "Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G–4", February 2006.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

404. Sampling methodology

1. What type of sampling method is used to measure exposure over a period of time?

2. What is to establish an exposure for a particular worker?

3. What sampling method would be effective for assessing cadmium contamination on shop table surfaces?

405. Developing a sampling strategy for occupational exposures

1. Under what circumstance is it appropriate to sample selectively the worker with maximum exposure risk?

406. Developing a sampling strategy for exposures to environmental hazards

1. What are two main purposes for using the DQO process for environmental sampling?

2. How does an OEHSA conceptual site model (CSM) assist with sampling strategy development?

407. Sample collection quality assurance and quality control

1. What is the difference between QA and QC?

2. When is *Chain of Custody* documentation required?

Answers to Self-Test Questions

401

1. (1) Determine the need for health hazard controls.
   (2) Build or add to the longitudinal exposure record (LER).
   (3) Demonstrate regulatory compliance.
2. Gather further information.
3. Identify exposures through routine and special surveillance, determine the acceptability of the exposures, and establish controls when needed.

402

1. The results of the screening assessment determine what further action, if any, should be taken.
2. Random sampling.
3. Yes. Exposure may be estimated using surrogate data and models to make a predictive assessment.

403

1. (1) d.
   (2) c.
   (3) a.
   (4) b.
2. Military exposure guidelines (MEG).
3. PAC.

404

1. Integrated.
2. Area samples.
3. Swipe sampling.

405

1. Compliance sampling.

406

1. It ensures that the type, quantity, and quality of data collected are appropriate for the decision at hand. It eliminates the collection of unnecessary, redundant, and overly precise data.
2. The CSM provides data inputs for the DQO process, including the *who, what, where, etc.* for the sampling strategy.

407

1. Quality Assurance (QA) - generally refers to a broad plan for maintaining quality in all aspects of a program. Quality Control (QC) - consists of the steps you will take to determine the validity of specific sampling and analytical procedures.
2. A chain of custody is required when samples are collected as evidence in the event a crime was committed.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) What is the difference between the Department of Defense (DOD) and Air Force (AF) assessment models?
   a. There is no difference.
   b. The AF model is an "iterative" approach.
   c. The DOD model does not include a control plan.
   d. Each process is designed to yield different results.

2. (401) Which phrase *most* accurately describes the American Industrial Hygiene Association (AIHA) exposure model?
   a. The AIHA model does not establish controls for exposures.
   b. The AIHA model strives for continuous improvement.
   c. The AIHA model is *best* used as an initial assessment.
   d. The AIHA model is very different from the Air Force (AF) model.

3. (402) According to the American Industrial Hygiene Association (AIHA), to be considered *random* a sampling must
   a. obtain data for documentation.
   b. produce results via a "shoot from the hip" method.
   c. produce a cyclical process for prioritizing controls needed.
   d. achieve equal probability of selecting an exposure period for any worker in the similar exposure group (SEG) during the assessment.

4. (402) What do you do if there is *not* an established occupational exposure limit (OEL) for a collected sample?
   a. Use available data to establish a working OEL.
   b. Conduct interviews to produce a basis for estimating needed limits.
   c. Select a safety data sheet (SDS) of a product with similar media properties.
   d. Notify the commander and recommend he or she contact the Environmental Safety and Occupational Health (ESOH) Service Center.

5. (403) What type of occupational exposure limit (OEL) is set and enforced by governmental agencies?
   a. Working.
   b. Internal.
   c. Regulatory.
   d. Authoritative.

6. (403) A 15-minute time weighted average (TWA) exposure limit designed to limit exposures to substances that could be harmful due to short exposures is known as a
   a. permissible Exposure Limit (PEL).
   b. short-term Exposure Limit (STEL).
   c. excursion Limit.
   d. ceiling Limit.

7. (404) What type of sampling involves collecting a sample from one location over a period of time?
   a. Direct reading.
   b. Composite.
   c. Integrated.
   d. Area.

8. (404) Composite sampling is *primarily* used when sampling
   a. air.
   b. soil.
   c. water.
   d. chemicals.

9. (404) What type of sampling is being conducted if a technician is using a Hazardous Air Pollutants on Site (HAPSITE) to sample at a selected time?
   a. Area.
   b. Grab.
   c. Swipe.
   d. Active.

10. (404) Sample holding times, preservatives, and collection tool hygiene are things that a technician should be aware of when conducting which type of sampling?
    a. Integrated.
    b. Passive.
    c. Area.
    d. Grab.

11. (405) Three pieces of information used to create a sampling strategy framework are
    a. sample size, holding time(s), and objective.
    b. process used, type of samples, and equipment used.
    c. workforce size, sampling accuracy, and measurement method.
    d. workforce breathing zone, type of composite sample, and sampling approach technique.

12. (405) When developing an occupational exposure strategy, the purpose of evaluating existing controls is to
    a. determine workforce size.
    b. determine if they are effective.
    c. determine the maximum risk employee(s).
    d. acquire funding for additional personal protective equipment (PPE).

13. (405) When determining the analytical method for sampling, it important to contact the appropriate lab you will be using to
    a. establish a point of contact (POC).
    b. request supplies needed for sampling.
    c. acquire sample submission requirements.
    d. ensure compatibility of measurement methods.

14. (406) You are developing a conceptual site model (CSM) to identify type(s) of data needed. Which step of the data quality objectives (DQO) process is being conducted?
    a. Step 1-State the problem.
    b. Step 2-Identify the decision.
    c. Step 3-Identify information inputs.
    d. Step 5-Develop the analytical approach.

15. (406) What is the decision rule?
    a. Describe, establish, discuss.
    b. Identify, define, develop.
    c. Mean, median, percentile.
    d. If, then, else.

16. (407) What is the definition of quality control?
    a. The broad plan for maintaining quality in all aspects of sample collection.
    b. The steps to be taken to determine the validity of specific sampling and analytical procedures.
    c. A checklist of pitfalls to avoid when developing, implementing, and completing a sampling strategy.
    d. The specific procedures recommended by the *United States Air Force School of Aerospace Medicine (USAFSAM) Laboratory Sampling Guide*.

17. (407) The quality of sample data collected depends primarily on the
    a. inclusion of field samples.
    b. sample matrix/quantity.
    c. location of the sample.
    d. quality of the sample.

18. (407) Chain of custody means that the possession of samples
    a. must be verified prior to analysis.
    b. must be traceable from collection through analysis.
    c. should be sent by standard United States Postal Service (USPS) mailing procedures.
    d. should be redundantly labeled according to Title 49 Code of Federal Regulations (CFR) Part 172.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Liquid Sampling

AS A PART OF health risk assessment duties, BE is required to perform liquid sampling in order to determine health risks to base populace or a specific PAR. According to AFI 48–144, *Drinking Water Surveillance Program*, BE is responsible for performing drinking water surveillance associated with the protection of PH. As per this mandate, BE manages and executes a drinking water surveillance program throughout its constituents. This directive is carried out by performing liquid sampling, thereby, maintaining compliance with the Safe Drinking Water Act (SDWA) requirements and, thereby, ensuring safe drinking water is available for all base personnel.

2–1. Liquid Sampling Strategies

There are other liquids (besides drinking water) that may need to be sampled for health risks. The intent of OEHSA is to identify exposure pathways associated with OEH hazards that require additional data collection (i.e., sampling). If the exposure pathway environmental medium of concern is water (surface or ground water), liquid sampling may need to be performed to determine exposure pathway completion or PAR exposure. Furthermore, potential OEH hazards associated with unknown liquids may need to be identified during an emergency response. You will be required to perform some form of sampling to identify or characterize the hazard associated with the liquid as a part of the overall HRA.

Specific elements and management requirements associated with the drinking water surveillance program will be discussed in volume 5 of this publication. This unit focuses on sampling strategies associated with drinking water surveillance and other liquid sampling events. The ultimate purpose of liquid sampling is to obtain credible and applicable data about the health risks associated with drinking water or other liquids.

The following table lists potential HRA objectives that would require a liquid sampling strategy and sample analysis plan.

Drinking Water (Potable)	Other Liquids (Non-Potable)
• Ensure compliance with SDWA and AF drinking water (DW) requirements	• Identify OEH hazards
• Determine treatment requirements	• Determine exposure pathway completion
• Recommend DW source(s) to commanders	• Determine health risks associated with recreational waters
	• Perform comprehensive exposure assessment
	• Recommend controls options to commanders/incident commanders

Accurate data is critical. This information is used to advise the commander of health risks. Furthermore, the data disseminated assists them in making appropriate operational risk management decisions about potential OEH threats associated with drinking water and other liquids. Before beginning any sampling event, develop a sampling strategy to ensure that reliable and accurate data is collected.

408. Liquid sampling strategies and sampling, analysis, and monitoring plans

Drinking water (potable)

The water used for consumption (i.e., drinking, cooking, and showering) is normally monitored under an active and ongoing drinking water surveillance program. Sampling and analysis of the quality of source water and treated water at the production point and at representative points of use in the distribution system are captured in an installation's sampling and analysis monitoring (SAM) plan. Sample results can indicate potential health risks associated with the potable water delivery system in use at your base/deployment site. The results are also used to ensure compliance with applicable SDWA and field water requirements.

Sampling, analysis, and monitoring plan

Your BE flight, in coordination with civil engineering (CE), develops and updates annually the installation-specific SAM plan. The SAM plan contains detailed information that explains type, range, and scope of the drinking water sampling, analysis, and monitoring that is conducted on a routine basis at your base. The plan should be prepared based on the regulatory requirements for your drinking water system. The following information provides general guidance on what to include in the SAM plan. The SAM plan can be quite comprehensive.

- A listing of all regulatory guidance that governs your drinking water sampling, analysis, and monitoring.
- Identification of all drinking water sampling sites used to determine compliance with the SDWA. BE will maintain certification documents from the primacy (state or federal agency that has primary enforcement responsibility) on these sampling sites where appropriate (e.g., lead and copper sampling sites and bacteriological sites).
- Annual and long-range drinking water sampling schedule.
- Description and classification (e.g., community/noncommunity or transient/nontransient) of each public water system and approval of the description by the primacy. Typically, your responsibilities concerning these types of systems include recreational areas and geographically separated units supported by the parent wing or medical group.
- Locally developed procedures for conducting the drinking water surveillance program. These procedures should include a schedule for routine monitoring, monitoring of aircraft watering

points, increased monitoring for CBRN agents during contingencies or heightened force protection condition, and monitoring performed before placing new connections and repaired water mains or storage tanks into use.

- QA and QC plan for bacteriological, chemical, and radiological drinking water monitoring.
- Identification of the support laboratory for each contaminant and a confirmation annually that the laboratory holds the appropriate certification for the analyte(s) in question. Obtain, from the laboratory, documentation as part of the geographical information system and track locations of water system maintenance locations and complaints.
- Procedures (which should be approved by the base environmental, safety and occupational health council) to take when violations of OELs occur.

At a minimum, the SAM plan should also include the sections shown in the following table.

Section	Explanation
Sample types	• List sample matrix (ground water, surface water, etc.). • Sampling method (grab). • Any field tests and measurements required.
Chemical contaminants	• List the names of all chemical contaminants that will be sampled/analyzed.
Sampling procedures	• Describe why the samples are being collected (e.g., identify or characterize a potential hazard, determine drinking water quality, etc.). • Specify step-by-step procedures how the samples are to be collected and any field descriptions or analyses that are required (e.g., potential of hydrogen [pH], temp, and flow rate). • Include instructions on filling out appropriate forms such as sampling and chain of custody forms. • Describe if any preservatives need to be added to sample and if chilling is required. • Describe shipping requirements and documentation.
Sampling locations and frequency	• List the frequency of sampling if periodic samples are required (e.g., monthly, quarterly, and annually) as specified by permit or regulatory requirements. • List the required location and frequency of each type of sample. • List the required time when samples need to be collected (if relevant).
General sampling information	For each type of sample, describe: • Sample containers needed (number, size, type, material, and cleanliness requirements). • Sample volumes to collect (minimum quantity required per container). • Preservation techniques if required by the method. • Holding times (time from sample collection to sample analyses). • Packaging and shipment requirements. • Number and type of QC samples. 1. Field duplicates—a second sample identical to one of the original samples; verifies proper sampling methods. 2. Matrix spike/matrix spike duplicates—samples that contain known amount of contaminant; confirms accuracy of laboratory analysis. 3. Field blanks samples known to contain no contaminant that are opened and reclosed at the sample site; checks for cross-contamination while handling samples. 4. Trip blanks—samples known to contain no contaminant that are carried to sample site, but are not opened; used to look for cross-contamination in storage/shipping.

Section	Explanation
	5. Equipment decontamination blanks—samples of deionized water collected with sampling equipment after decontamination; verifies proper decontamination procedures.
Documentation	• Specify how/where each type of sample will be documented (i.e., field logbook) and what type of information will be documented. • Specify the sample results' reporting requirements/procedures for each type of sample.
Sampling equipment and supplies	• List the different types of sampling equipment and describe what each piece of equipment will be used to sample for. • List calibration information (procedures and frequency). • List the materials and supplies used during sampling.

The SAM plan is normally already established at your base. However, there will be times when you may be required to revamp the current plan (i.e., changes within the drinking water system or a new installation). Therefore, it is important to have an understanding of how the plan is developed. A SAM plan for drinking water sampling is developed using the DQO process. This is the same process used to develop a sampling strategy for other liquids related to exposure pathway assessment or emergency response.

Other liquids (non-potable)

As previously stated, you may evaluate OEH threats associated with other liquids besides potable water. An assessment may be conducted to determine health risks associated with recreational waters, to identify potential OEH hazards as part of an overall health risk assessment or to identify hazards associated with an unknown liquid during an emergency response to determine controls options. In each of these situations sampling may be necessary to assess exposure or determine if a health risk is present. Here are a few examples.

- When evaluating recreational waters, conduct sampling to determine if contaminants or microorganisms harmful to human health are present. The primary exposure routes associated with recreational waters are dermal contact and incidental ingestion. The focus of sampling should generally be geared toward detecting indicators of harmful bacteria, which includes fecal contamination, specifically Escherichia coli (E. coli). E. coli and enterococci are present in the gastrointestinal tract of humans and other warm-blooded animals. Their detection in recreational waters presents potential health risks and indicates the possible presence of other intestinal-based organisms that may pose a risk to human health.
- Additionally, evaluation of other non-potable liquids to characterize a potential OEH hazards as part of an overall health risk assessment. Some examples of liquids you may encounter are oils, gasoline, chlorinated solvents, such as trichloroethylene. Consider a scenario where various acids and alkalines produced from metal plating operations were improperly disposed near a PAR. In this situation, a complete exposure pathway will be identified before determining the need to conduct sampling. Once the exposure pathway is identified, a sampling plan will be devised in order to conduct sampling. This sampling will determine if any unacceptable exposures exist.
- Finally, evaluations to identify hazards associated with an unknown liquid during an emergency response. However, in an emergency response situation, sampling may be conducted to simply identify the unknown liquid (even if an exposure pathway has not been determined). Whether dealing with non-portable water or other liquids, once a partial or complete exposure pathway has been identified and additional data is needed, a sampling strategy must be developed before conducting the sampling.

409. Developing liquid sampling strategy

The sampling strategy is the overall road map that details the entire sampling process from beginning to end. The EPA DQO process establishes specific objectives for sampling and focuses data collection to meet those objectives. The DQO process is the best way to develop a sampling strategy and works with drinking water as well as other liquids. However, as stated earlier, since most bases have an established SAM plan, the DQO process is used less frequently for drinking water monitoring.

Developing the sampling strategy

A sampling strategy is developed when a potentially complete or complete pathway has been identified and additional data is needed to fully assess the health hazard. The DQO process consists of seven steps:

- Step 1: State the problem.
- Step 2: Identify the decision or goal.
- Step 3: Identify information inputs to the decision.
- Step 4: Define the boundaries.
- Step 5: Develop the decision rules and analytical approach.
- Step 6: Determine performance or acceptance criteria.
- Step 7: Develop the detailed sampling plan.

Step 1: State the problem

Before any other aspect of a sampling strategy can be determined, the sampling objective must be clearly identified. What is the reason for exposure assessment sampling? A concise description of the exposure pathway (whether complete or incomplete) must be given from an OEH threat to the PAR. Use a conceptual site model to provide this description; it provides pertinent information about the site, potential contaminant(s) of concern (COC), exposure route(s), environmental media, and potential receptors (i.e., PAR). Existing reports, intelligence sources, experience, and professional judgment can also be used to describe justification for the assessment.

Step 2: Identify the decision or goal

In order to determine why further data analysis and/or collection are needed, a clear decision must be concluded. This is established by conducting selective inquiries, including questions you should ask yourself:

- Does the OEH threat pose an acute or latent health risk to the PAR?
- Does an exposure pose an acceptable or unacceptable risk?
- Is the work center out of compliance?
- What impact do the OEH threats have on the mission?

You also need to identify what you intend to do with the results and what potential actions will be taken. For example, if your study question was “Does lead from birdshot, which collects at the bottom of the fish pond, contribute to a decrease in fish population on base?”, the possible outcome of the sampling is 1) the lead pellets are a factor in the decrease of fish population or 2) the lead pellets are not a factor in the fish population. If the lead is a contributing factor, the action may be to remove the lead from the bottom of the pond and regulate the type of pellets used by the hunters. If the lead pellets are not contributing to the decrease in the fish population, then no action will be taken.

Step 3: Identify information inputs to the decision

This step is very comprehensive and in depth. The CSM will identify the OEH threat, environmental media (surface or ground water), routes of exposure (ingestion or contact), and population affected. Use interviews, site reconnaissance, and observations to determine the appropriate sampling types,

methods, locations, and equipment to be used. This information will also be used to determine where and how samples will be taken for assessing exposure point concentrations.

Type of sample

The most frequently used sampling type for liquid sampling is a grab sample. The grab sample is an individual sample that characterizes the water quality at a particular location and time. Multiple grab samples can be taken at different times or locations. This technique provides information on minimum and maximum concentrations of constituents over a longer period of time.

Sampling collection method

Grab samplings are obtained by the manual sampling method. The human element is the key to the success or failure of manual sampling programs. Remember, the success of the sampling strategy is directly related to the care exercised in the sample collection. Optimum performance will be obtained using trained personnel.

Sampling point locations

Generally, the reasons for sampling, historical data, and intelligence will help to determine the approximate locations for sampling. When you are using an established sampling plan for a potable water system, the locations for routine surveillance will typically be specified and should include loops, dead-ends, low pressure areas, and points that serve mass populations.

No specific guidelines can be given on the exact sampling locations to develop a new sampling strategy; however, you must make sure that the locations allow for representativeness and homogeneity. Other considerations are pronounced degradation of water quality in specific areas, convenience, and accessibility.

Representativeness

It is important for the sample to accurately characterize the condition of the water or liquid being sampled. Surface water and groundwater contamination levels are important and necessary components of the evaluation of water contamination. An equally important component is the evaluation of water that is used by humans for drinking and non-drinking purposes. A sufficient number of samples should be collected from both upstream and downstream so that statistically valid contamination concentrations can be determined.

There are some guidelines that you can follow which will help you to obtain representative water samples:

- Collect the sample where the water or liquid is well mixed.
- Collect samples in the center at a depth that avoids bottom bed loads and top floating materials—unless you are sampling for those particular analysis.
- When sampling a deep stream or lake, collect the samples at different depths. Place the mouth of the collecting container below the liquid surface and facing the flow—this avoids collection of excess of floating material(s).
- When collecting samples from a closed conduit via a valve or faucet, allow sufficient flushing time—this ensures the sample is representative of the supply.

In a deployed setting where non-potable water sampling is required, choose the most appropriate sampling locations, such as:

- Representative sites in the main stream of rivers, estuaries, coastal areas, lakes, or impoundments.
- Major water use areas, such as public water supply intakes, commercial fishing areas, and recreational areas.
- Representative sites in the individual waste streams.
- Mouths of major or significant tributaries to mainstreams, estuaries, or coastal areas.

Sampling rationale may affect the choice of sampling locations. For example, if the interest is in an oil and grease sample, the sample would be collected at the top of the water. In contrast, if the interest is determining the concentration of heavy metals in an area, the sample would be taken from the bottom of a surface water source.

Another way to think of obtaining representative samples is to eliminate sampling bias meaning it's conducted in a standard, consistent, non-objective manner.

Homogeneity

Uniform distribution of constituents, or homogeneity, is a desired effect of turbulence and good mixing. Poor mixing results in different densities of the constituents, such as floating oils and settling suspended solids. In order to ensure homogeneity, you should sample from several locations to obtain the required information. Suggested areas to collect samples include:

- Significant outlets and inputs of lakes, impoundments, estuaries, or coastal areas that exhibit eutrophic characteristics—nutrient-rich water with an abundance of plant life and reduced oxygen content.
- Upstream and downstream of major population and/or industrial centers which have significant discharges into a flowing stream.
- Upstream and downstream of representative land use areas.

Sampling devices

The selection of sampling devices is dependent on where the sampling site is located. Whatever equipment is selected, always read the manufacturer's specifications to ensure that that the device is being used properly. Sampling equipment will be discussed in depth later in this volume.

Selecting occupational exposure limit for liquids

In order to determine exposure acceptability and to assist with decision making, an exposure standard must be determined and selected. A network of government agencies exist to enforce drinking water standards, such as EPA, state departments of health and environment, and local PH departments. These agencies make sure public water supplies are safe. The Air Force Surgeon General is the Air Force's office of primary responsibility for potable water quality and compliance with the Safe Drinking Water Act. The Air Force Medical Support Agency develops Air Force policy for water surveillance and establishes Air Force unique drinking water standards to protect the health of Air Force personnel. This agency approves and publishes implementing guidance. The United States Air Force School of Aerospace Medicine publishes and updates the *Drinking Water Surveillance Technical Guide*. The purpose of this guide is to provide specific technical information to assist BE personnel in ensuring all personnel have safe drinking water.

The selection of OELs for OEH threats in liquids other than drinking water (such as raw water and liquid emergency responses) is more difficult. Many references exist that contain information concerning analytical standards. Therefore, selection of the correct standard is not necessarily a straight-forward process. The generally accepted practice is to select the most appropriate and current occupational and OEL adopted from established, recognized standards include (but are not limited to):

- AFIs and AFOSH Standards.
- Title 40 CFR Parts 141 and 142, *National Primary Drinking Water Regulations*, and Part 143, *National Secondary Drinking Water Regulations*, or local standards promulgated by the states granted primary enforcement responsibility for public water systems (i.e., primacy agency).
- Air Force medical services agency policy letters.
- Technical reports or guidance documents provided by USAFSAM.
- In deployment locations, see also:

- Technical Guide (TG)-230, *Chemical Exposure Guidelines for Deployed Military Personnel*, published by the United States Army Center for Health Promotion and Preventive Medicine (USACHPPM).
- AFMAN 48138_IP, *Sanitary Control and Surveillance of Field Water Supplies*. Departments of the Army, Navy, and Air Force, Washington, DC, 1 May 2010.

Below is a list of possible environmental risk assessment standards and toxicological information to aid in selecting an appropriate OEL for environmental hazards.

The following table identifies possible sources to identify OELs:

Guideline	Target	Author	Summary	Duration
MEG	Military	USAPHC	Deployed exposure guidelines, TG–230	From 10 minutes (min) to 1 year (yr)
AFMAN 48–138_IP, *Sanitary Control and Surveillance of Field Water Supplies*	Military	Tri-Service	Field water guidelines	7 and 14 days
IRIS	Public	EPA	References does for noncarcinogenic toxicity and carcinogenic potency factors	Lifetime
MCL	Public	EPA	US primary safe drinking water standards	Lifetime

MEG - Military Exposure Guideline, Technical Guide 230, U.S. Army Public Health Command
AFI - Air Force Instruction
IRIS - Integrated Risk Information System, Environmental Protection Agency
MCL - Maximum Contaminant Level, Environmental Protection Agency

In the absence of recognized standards, use your chain of command. This, most likely, may lead to you contacting USAFSAM/OE for guidance on exposure limits for potential OEH threats. However, the determination of an unacceptable level of exposure to a potential OEH threat and, subsequently, the need for controls will require your local BE office to work with the affected unit commander to effectively apply operational risk management principles outlined in AFI 90–802, *Risk Management,* as well as professional judgment.

Step 4: Define the boundaries

In this step, definition is made of the exposed population, the number of samples, the physical boundaries from which representative exposure can be determined, and the smallest sampling unit on which a decision will be made. Some factors to consider when completing this step include:

- Time and resources constraints on the data.
- Military operational factors (sorties and convoys).
- Military objectives may impose restrictions (force protection).
- Industrial operations (shift work, 24-hour operations).
- Meteorological conditions (temperatures).
- Spatial boundaries (geographic limitations).

Step 5: Develop the decision rules and analytical approach

We have learned earlier that this step is to select a result parameter and AL to be combined to develop the decision rule for the sampling. In other words, you will select an AL level based on HRA objectives and identify the action(s) that will be taken if the AL level is exceeded (*If…then…else…* decision rule). A very simple example of this is: *If* the chlorine measurement in the pool is less than 1 ppm, *then* remove swimmers from the pool and notify facility manager to correct chloride levels, *else* retest on routine schedule.

Step 6: Determine performance or acceptance criteria

In this step, define how good that data needs to be for a decision to be made on the situation and results. Determine the desired confidence level in your results before collecting samples (e.g., 99, 95, or 90 percent confident that a correct decision is being made). Sampling activities may often involve rapid assessment of potential health threats to meet the time constraints faced by operational commanders for risk management decision making. On-site analyses for health threats allow on-scene personnel to determine the location of or need for additional sampling. Field analytical screening methods that are direct reading/real-time produce immediate data, which can be advantageous when an immediate answer is necessary or time is a constraint. [1]

When onsite analyses are not achievable, collection of samples for shipment to laboratories may be necessary. Some of the questions to be considered when evaluating whether to use field analytical methods or off-site laboratories may include:

- How quickly must the decision be made?
- Can the specific chemicals or classes of potential contaminants of concern be quantified with the available instrumentation?
- Does the onsite analytical instrument possess the required sensitivity to yield a result usable for assessing potential impacts to health?
- Is it necessary to ship samples to the laboratory for additional analysis to support quality assurance?
- Do any of the samples require special handling or preservation?
- Will shipping samples result in possible loss of sample integrity?

Step 7: Develop the detailed sampling plan

The finalized number of samples and sample location must achieve the desired confidence level needed for step 6. This final step incorporates the outputs from steps 1-6 into a resources-effective sampling strategy. (**NOTE:** There is no official form or document for citation of this information.)

This lesson has discussed the SAM plan, considerations, and steps for developing a sampling strategy. In conducting liquid sampling, potable drinking water as well as other liquids (non-potable) is assessed. It is critical to determine the existence of a complete exposure pathway before conducting sampling for HRA. Sampling events must be planned out and conducted using an EPA DQO process sampling strategy.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Liquid sampling strategies and sampling, analysis, and monitoring plans

1. Where are sampling and analysis of source and treated water captured?

2. Who is responsible for developing and updating the installation specific SAM plan?

3. What are some of the items listed in the sampling procedure section of the SAM plan?

4. Once a pathway is determined, why would sampling be conducted?

5. Why is sampling conducted in recreational waters?

6. What is the primary concern associated with exposure to non-potable liquids?

409. Developing liquid sampling strategy

1. What is a sampling strategy?

2. What process is used in developing a sampling strategy?

3. What are the steps in developing a sampling strategy?

4. What information is needed in step 3 of the DQO process?

5. Where can you find information on the selections of OELs?

2–2. Liquid Sampling Equipment

Identifying the correct analyte to sample and selecting the correct sampling equipment are vital aspects of a liquid sampling plan. Understanding and knowing how to properly use and maintain the sampling equipment are equally important.

410. Water sampling and analysis equipment

There are various pieces of water sampling equipment available through a variety of vendors. The HAPSITE, DREL 2800, and HAZMAT ID are three pieces of equipment found on the BE equipment standard that are available for liquid sampling and field analysis.

Portable gas chromatograph/mass spectrometer

Gas chromatographs (GC) combined with a mass spectrometer (MS), are powerful laboratory tools used to identification and quantification of volatile and semi-volatile contaminants. The HAPSITE is an example of a field portable GC/MS. The system is designed for harsh environments and rough handling and is intended for fieldwork. It provides on-scene detection, identification, and quantification of toxic industrial chemicals and chemical warfare agents. The HAPSITE has less

potential for false positives and a greater sensitivity to nerve and blister agents. It identifies and measures numerous volatile organic compounds (VOC) as well as identifies compounds in unknown mixtures. An advantage of the HAPSITE is its capability for detecting COCs at levels below other detectors' threshold levels.

The HAPSITE, used in combination with the headspace sampling system (HSS), provides the capability to perform water analysis for quantitative results in the field (fig. 2–1). Because the HAPSITE is designed to analyze for VOCs in air, water samples must be introduced in a gas phase. The water samples are heated in a closed sample container to a known temperature. The heat forces the volatile components to a partition between the sample and the headspace above the sample. After a sufficient amount of time has passed, a portion of the headspace is introduced to the HAPSITE and a result is provided. [2]

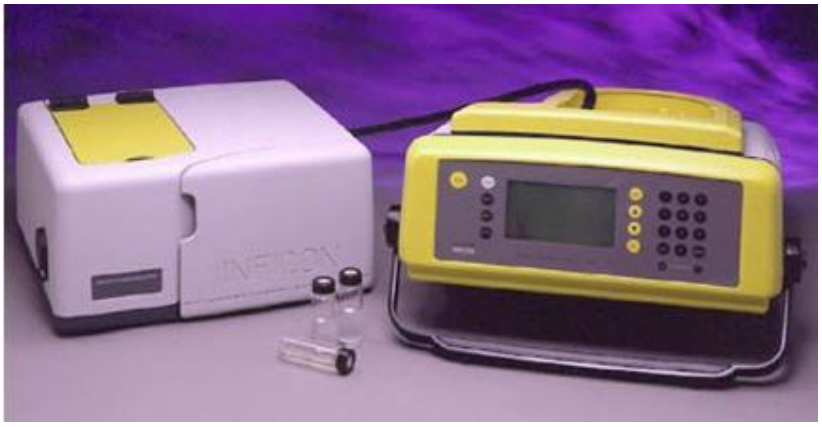


Figure 2–1. HAPSITE with headspace module for liquid sample analysis.

Portable laboratory analysis kit

The DREL 2800 is designed to function as a fully equipped portable water sample analysis laboratory (fig. 2–2). The kit includes a portable spectrophotometer and reagents needed to run approximately 100 tests on 20 different parameters. Turbidity and pH meters can also be added to this kit. The 2800 is often used for determining fluoride levels.

Figure 2–2. DREL water analysis kit.

Fourier-transform infrared spectroscopy

Fourier-transform infrared (FT-IR) spectrophotometers can identify substances by matching the substance's unique spectral absorption to a chemical library database using infrared spectroscopy (fig. 2–3). The BE equipment package includes the portable FT-IR HAZMAT ID. The HAZMAT ID can analyze solids, liquids, and pastes (compounds with covalent bonds only) and identify any substance loaded in the instruments spectral library database. It will not identify:

- Substances with ionic bonds.
- Elemental substances such as metals.
- Individual components of a mixture that are <10% of the mixture.
- Substances in diluted water solutions.
- Cannot definitively identify biological agents (IDs as a protein).

A significant limitation of the HAZMAT ID is that it cannot quantify concentration; it only determines presence/absence. It verifies the presence or absence of chemical compounds in solids or liquids as long as the chemicals are included in the database. Another limitation is that the HAZMAT ID will only identify the substance when it constitutes 10 percent or more of the sample media being analyzed. [3]

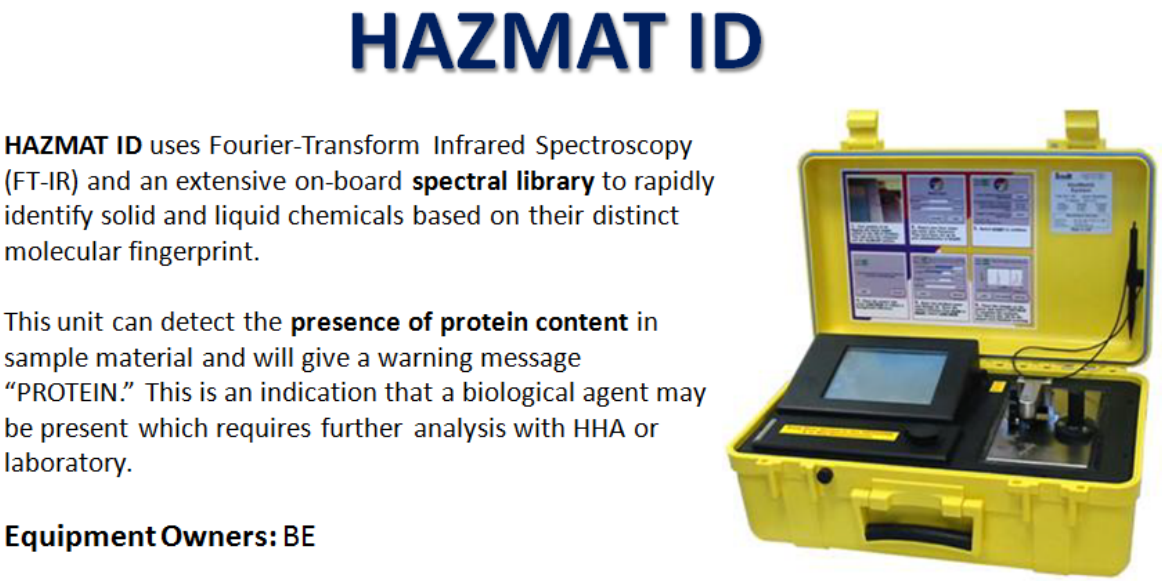
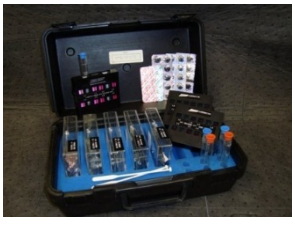
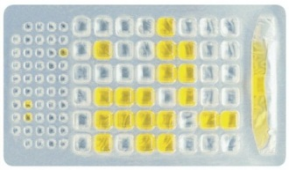
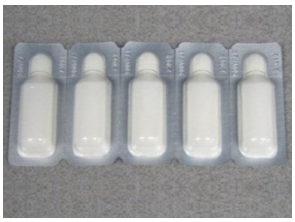


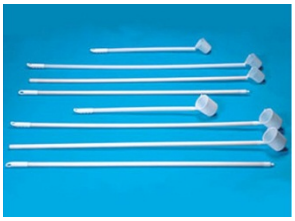
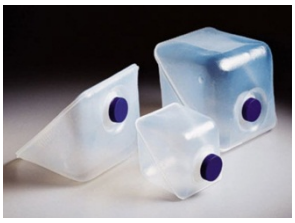
Figure 2–3. Portable FT-IR HAZMAT ID.

The table below provides an overview of other common water sampling equipment also found on the BE allowance standards/equipment listings. The table provides a list of equipment items, including a brief description, NSN (if applicable) and photograph to help you become more familiar.

Name	Description	National Stock Number (NSN)
Color Comparator	Used to determine hydrogen ion concentration, residual chlorine content, phosphate content, and/or other characteristics of water by visually comparing a sample to which a specified quantity of an appropriate indicator solution has been added with a color standard. The color standards used for these tests are mounted in a suitable holder and graded to represent the indicator colors for various pH values, concentration of chlorine, phosphate, or other substance.	6630-01-027-3914 

Name	Description	National Stock Number (NSN)
Colilert® Color Comparator	The Colilert® comparator is a liquid color reference test for coliforms and E. coli. Its purpose is to assist in distinguishing a minimal positive from a negative test result. At 24-48 hours, each reaction vessel is compared against the color comparator. Any yellow color or fluorescence equal to or greater than the comparator is considered positive.	6630-01-388-4098 
SimPlate®, Heterotrophic Plate Count	Used to detect heterotrophic plate count bacteria in water. The reagent contains multiple unique enzyme-substrates, each targeting a different bacterial enzyme. The most common enzymes of waterborne bacteria are all targeted.	6665-01-530-8830 
Water Sampling Test Reagent, Coliform	Colilert® reagent is used around the world for the detection of coliforms and *E.coli* in water. Colilert® is EPA approved and is included in *Standard Methods for Examination of Water and Wastewater*. Reagent is packaged in plastic snap-packs with perforations for tearing to remove powdered reagent. Each packet is added to a 100 milliliter (ml) water sample and incubated for 24 hours to determine the presence or absence of coliform in drinking water.	6630-01-362-8299 
Water Test Kit, Bacteriological	A self-contained water test kit designed for field testing total coliforms in water. The kit has basic field test apparatus for sterile 0.45 µm Millipore 47 millimeter (mm) disc filter use and can accommodate 24 analyses under field conditions.	6665-00-682-4765 
pH Tester	Pocket-sized instrument that reads both pH and temperature (degrees [°] Celsuis [C]).	6640-01-511-8271 
Hach pH Meter	Used to determine the acidity or alkalinity of a solution in the measuring of hydrogen ions concentration – pH.	6630-01-509-8565 

Name	Description	National Stock Number (NSN)
Chlorine Test Paper	Used for monitoring strength of chlorine sanitizer in wash and rinse solutions.	6630-01-012-4093 
pH Litmus Papers	Color bonded pH strips. Blue litmus paper turns red in an acidic solution below pH 4.5 and will stay blue in a base. Red litmus paper turns blue in an alkaline (base) solution above pH 8.3 and stays red in an acid.	6640-01-521-0449 
Hydrion pH Paper	Hydrion pH papers come with a color chart and a 15-foot roll of pH short range testing paper which shows a distinct color change for each half pH unit.	6640-01-264-1387 
Glass vials–40 ml (29 mm x 81 mm)	Multipurpose screw top glass vials that hold a total sample volume of 40 ml.	6640-01-509-4802 
Plastic polypropylene lined glass sampling jars	Glass sampling jars that come with a polypropylene lined lid.	6640-01-509-4471 
Teflon® PTFE lined glass sampling jars	Glass sampling jars that come with chemical-resistant Teflon® PTFE liner inserted and a screw cap attached.	6640-01-509-3620 

Name	Description	National Stock Number (NSN)
Bacon Bomb sampler	Used for obtaining samples at various levels from tanks, tank cars, and drums.	
Dippers	Long handle polyethylene dipper for collecting samples from streams, basins, and large tanks.	
Cubitainer® sampler	Flexible sampler used in numerous field applications for quick, easy, convenient, and cost-effective collection of samples.	
Whirl-Pak® sample bags	All Whirl-Pak® bags feature puncture proof tabs and are guaranteed sterile. They are constructed of durable polyethylene and provide safe, spill-free use for liquid samples. By whirling or tightly folding the tab over three times, the Whirl-Pak® bag becomes a leak proof container.	
Plastic, polyethylene pasteur pipet–6.102 inches nominal/5.000 milliliters nominal	Tubular in shape and made of glass or plastic. With or without a flexible bulb. Used in fluid transferring.	6640-01-495-7529 
Sealing tape	Flexible thermoplastic sealing tape used for sealing laboratory glassware.	6640-01-185-3289 

Name	Description	National Stock Number (NSN)
Water Testing Kit, Chemical Agents (M272)	Designed and fielded to answer the need for a test to detect water contamination by nerve agent, blister agent, cyanide (blood) agent, or lewisite. An enclosed instruction card enables individuals to conduct all the tests required to identify the threat agents. Each kit contains enough reagents for tests on 25 separate water samples.	6665-01-134-0885 

411. Calibrating/operating water-sampling and analysis equipment

Many decisions are based on the results of drinking water evaluations. That's why it is necessary to make sure drinking water samples are properly collected using the correct sampling equipment. To minimize errors and most accurately approximate drinking water sampling analysis results, it is necessary to ensure the proper calibration and operation of your water sampling equipment.

Users should first calibrate and operate water-sampling equipment according to the manufacturer's operating instructions. There are many makes and models of equipment available for water sampling. Operation and calibration vary on each piece of equipment. This section briefly discusses the importance of operation and calibration principles.

Principles of calibration

For sampling equipment to be considered accurate it must first be calibrated. Calibration is defined by the American National Standards Institute (ANSI) as the set of operations which establishes, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, and the corresponding standard or known values derived from the standard. Basically, the calibration process is a comparison of one instrument's response with that of a reference instrument of known response and known accuracy. [4]

Principles of operation

After receiving a new piece of water sampling equipment, the first thing you should do is read the instruction manual. In order to avoid serious injury to yourself or damage equipment, you should pay attention to all danger and caution statements. Operate equipment according to manufacturer's operating instructions. Keep equipment and accessories clean and properly stored when not in use.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

410. Water sampling and analysis equipment

1. What water sampling equipment provides on-scene detection, identification and quantification of toxic industrial chemicals and chemical warfare agents?

2. What can the HAPSITE be use to analyze?

3. What is a major weakness of the HAZMAT ID?

4. What equipment is used to determine the acidity or alkalinity of a solution?

411. Calibrating/operating water-sampling and analysis equipment

1. What is the benefit of ensuring the proper calibration and operation of water sampling equipment?

2. Cite the frequencies when water sampling equipment should be calibrated.

3. When receiving a new piece of water sampling equipment or you've never operated a particular piece of equipment, what is the first step you should take?

2–3. Collecting and Analyzing Liquid Samples

The process of going out to a site and collecting a liquid sample might sound simple. Regardless, of whether you are sampling drinking water (potable) or other liquids (non-potable) it is critical throughout the entire sampling effort to use standardized procedures and methods for analyzing, and documenting procedures to maintain sample identification, integrity, and representativeness at all times. This section will cover water sampling and analysis procedures.

412. Collecting potable water samples

Involvement in the safe drinking water surveillance program includes performing potable water surveillance in garrison and in deployed operations for the protection of PH and regulatory compliance. The most reliable way to monitor contaminants in drinking water is through sampling.

Sampling and analysis of potable water

The object is to obtain a representative sample of drinking water for analysis, without affecting the sample. Any unusual environmental conditions should be noted before sampling. The following are examples of unusual conditions:

- Leaking tap gland.
- An attachment to the tap to be sampled is present and cannot be removed.
- Tap selected for sampling is difficult to sterilize.
- Evidence of a dirty tap.
- Sudden changes in water flow or pressure.
- Presence of discolored water.

Again, each sample should be representative of the water being received by the consumer and not contaminated by any material that could affect any future chemical or bacteriological testing.

Collection from tap

Samples requiring multiple analyses from a single sample point must be taken in a specific order:

1. Metals.
2. Chemicals.
3. Microbiological samples.

Any metals sample must be taken from the first draw of the tap without rinsing the bottle. For chemical samples, the tap must be flushed for at least two minutes before the sample is collected.

To ensure samples are properly collected, the following general procedures should be used (note that some contaminants may require method specific or primacy agency mandated procedures; additional, procedures for sterilizing the tap and collecting bacteriological sampling are described separately below). The analytical method the laboratory will use should always be checked for specific sample collection requirements.

- While not mandatory, the use of gloves while sampling is a best management practice. At a minimum, properly washing your hands is recommended before collecting samples.
- Use approved sample containers. Note that the container may be provided by the laboratory.
- Sample containers are to remain closed until the samples are ready to be collected. Do not rinse the sample container. Rinsing or overflowing the container removes any preservatives.
- Before collecting the sample, all attachments (aerator, screen, etc.) should be removed from the tap. Note that the aerator should not be removed when taking lead and/or copper samples.
- The tap should be fully opened in order to obtain a representative sample, flush the tap for at least 3-5 minutes or until the water temperature stabilizes at approximately ground temperature. If the sampling point is a tap indoors and connected to the building plumbing system and a sample truly representative of the distribution system is needed, it is necessary to know the volume of the line (calculated from line inside diameter and line length) and to measure water flow. Additional time required to clear the service line is calculated as volume divided by flow rate. Note that first draw samples will not follow these flushing procedures.
- Reduce the flow so that the stream is approximately ¼ inch in diameter (of the width of a pencil). Do not change the flow rate until sampling is completed.
- Remove the cap to the container; do not place the cap down on a dirty surface.
- Fill the sample container. Avoid contact between the tap and the mouth of the container. Do not overflow the container because this can wash out preservatives (if already added by the lab).
- Once the sample has been collected, replace the cap to the container. The sampling location ID number, time, date, and the person's name that collected the sample should be written on the container and in a sample collection log. In addition, all laboratory forms should be completed.

The following list gives additional sample collection procedures for volatile organic chemicals:

- Remove the aerator, screen, and any other attachments to prevent loss of the target contaminant to volatilization.
- The vial or bottle must be filled in a manner that does not pass any air bubbles through the water and that does not leave any headspace.
- Fill the vial or bottle to form a meniscus at the top of the container.
- Replace the cap on the vial or bottle and check for absence of headspace.
- Invert two or three times and check for bubbles.

Sterilizing the tap using chlorine solution

Always wear gloves (disposable or non-disposable) and safety glasses when handling chlorine solutions. Start by removing any attachments, filter and/or devices from the tap, clean the inner and outer surfaces of the tap spout with a clean tissue moistened with chlorine solution or alternatively, a disinfectant wipe. This procedure should be repeated until the surfaces of the taps are clean. However, if a tap cannot be satisfactorily disinfected with the attachment, filter and/or devices removed, another

tap must be sampled where possible. Taps should be in good repair, if they leak between the spindle and the gland when the tap is turned on, ideally, they should not be used.

Sterilizing taps with chlorine solution can be done either by:

- Immersing the spout of the tap.
- Wiping with a chlorine-soaked tissue.
- Spraying the tap with the chlorine solution.

Fill a bottle-cap full of 1 percent chlorine solution for sterilizing the tap—enough to immerse the bottom half of the tap. Hold the bottle-cap so that the spout of the tap is immersed in the chlorine solution for approximately 30 seconds. Remove the bottle-cap from the tap and allow the chlorine solution to remain in contact with the tap for a further two minutes before flushing.

If the tap cannot be immersed in the solution, soak a piece of tissue in the chlorine solution and hold around the end of the tap for approximately 30 seconds. Remove the tissue from the tap and allow the chlorine solution to remain in contact with the tap for a further two minutes before flushing. At the end of the two minutes, wipe off any excess chlorine solution from the outside of the tap with a clean tissue dampened with the chlorine solution—avoiding contaminating the tap. Now, you are ready to flush the tap for about 2-3 minutes to make sure the chlorine solution is rinsed away.

You can also sterilize a tap by using a wash/spray bottle filled with 1 percent chlorine solution to spray inside the tap as far up the spout as possible. Again, wait for two minutes to allow the chlorine solution to disinfect the tap. After two minutes, wipe away the excess chlorine solution with a clean tissue dampened with the chlorine solution and allow the tap to flush for 2-3 minutes before collecting the sample.

Bacteriological sampling and analysis

The main purpose of bacteriological analysis of water is to determine its potability. The EPA requires testing of all public drinking water systems for two types of bacteria, total coliform organisms and E. coli in drinking water, on an ongoing basis.

Bacteriological sampling is taken following chemical sampling and tap sterilization. Bacteriological sampling is extremely sensitive to contamination; therefore, procedures must be rigorously followed regarding to handling, flushing, labeling and storing bottles, as well as to tap flow and personal hygiene. When collecting potable water samples for bacteriological analysis:

- Never hold the bottle by the neck.
- Never flush out the bacteriological bottle before taking the sample.
- Never lay the bottle down on the ground, or any other area that may cause cross contamination of bacteriological samples.
- Always use good personal hygiene practices.

Using the current edition of the EPA's *Microbiological Methods for Monitoring the Environment* increases the likelihood of an accurate analysis. It is crucial to eliminate practices that might contaminate your sample (like those mentioned above) or otherwise you could produce erroneous results. Glass or plastic containers can be used for sample collection as long as they are sterilized. Wide-mouthed glass bottles with plastic screw caps or wide-mouthed, heat-resistant plastic bottles with screw caps are acceptable if the closures are nontoxic and give a tight seal. A minimum capacity of at least 120 ml (4 ounces) is needed to provide enough air space for the standard 100 ml sample. This air space lets the sample mix thoroughly with the chlorine-neutralizing agent in the bottle. Pre-sterilized plastic bags, with dechlorinating agent, such as Whirl-Pak® bags, are commercially available and may be used.

Containers and closures should be perfectly clean without any chips, cracks, or extensive etching; any residue left behind could kill the bacteria or provide a nutrient medium for their growth. Either

reaction prevents an accurate determination of the overall water quality. Most containers are received pre-cleaned, pre-sterilized and with a dechlorinating agent already in them. In this case, just check that the expiration date is not exceeded. If this is not the case, at your base or deployed location, then, before sampling, containers should be cleaned with warm water and a suitable detergent recommended for laboratory glassware. Don't use any type of solvent such as acetone or harsh detergents like those used in dishwashers. After washing, rinse several times with hot tap water, ensuring all detergent is removed. The final step in cleaning (before sterilization) is to rinse the containers with sterile distilled or deionizer water at least three times—this is to remove all minerals and other foreign matter and to provide a good neutral environment for the bacteria that may be in the sample water.

Preparing bottles for biological samples

The coliform bacteria used to check the biological quality of the water are easily destroyed by chlorine. They may be present in your sample when you collect it, but after a time they are killed if there is chlorine residual. This results in a false negative in your analysis that can lead to a false sense of security. A dechlorinating agent, sodium thiosulfate, is added to eliminate such a possibility. A standard 10-percent sodium thiosulfate solution should be kept on hand to use in the sample containers each time they are prepared. The solution is easily made by dissolving 5 grams of powered sodium thiosulfate in distilled water (about 25 ml at first) and bringing the final volume to 50 ml. A 50- or 100-ml graduated cylinder makes the task quite simple. After mixing, transfer the solution to a bottle and store it in a refrigerator. Be sure to mark the bottle with the type of solution, percentage, who prepared it, and the date.

If the sodium thiosulfate solution has been stored for some time, it should be checked before use. Although there is no definite time for which you can establish an expiration date, discard it when it becomes turbid or has sediment. This won't usually be a problem, since it's recommended you mix up only 50 ml at a time. Use 1-ml pipets to add the solution to the sample containers. Be careful—their small size means they fill up very quickly. The amount of solution you need for 120-ml bottles is 0.1 ml; for 250-ml bottles, use 0.2 ml of solution. This is enough to dechlorinate up to 15 milligrams per liter (mg/L) of residual chlorine2. After adding the dechlorinating agent, place the caps loosely on the containers so pressure can escape during sterilization. Place sterilization indicator tape on the containers and then sterilize the bottles in an autoclave for 15 minutes at 121°C. The tape on the container will indicate (through black slashes) that the sterilization process was effective.

A preferred method of preparing bottles is to order disposable bacteriological sample vessels. They are 120-ml, sterile until opened, and already contain powdered sodium thiosulfate. No other preparation is needed for these containers.

Taking a tap sample

When you arrive at the sampling location, follow these steps:

- Prepare the cold-water faucet by removing any aerator, strainer, hose, and so forth. These often have grit and organic matter that may harbor bacteria. Remember, you're sampling the quality of the distribution system water, not the faucet, the pipes in the building, or feeder lines that come off the main water line.

- Flush the faucet at high flow for at least two to three minutes to clear the line of standing water; make sure your sample is coming from the main. For a mixing faucet, first flush the hot water for 2-3 minutes, then the cold water for 2-3 minutes.
- Adjust the faucet to a steady, even flow and take the sample.
- Select a sampling bottle. Make sure the sterile tape indicator on the collection bottle is unbroken and that the expiration date is not past. If the sterile tape indicator or the expiration date is not satisfactory, the bottle should not be used.
- Slow water flow; remove the top from the pre-sterilized bottle. Do not lay the lid down (this prevents cross-contamination).
- Hold the top firmly between the fingers of one hand with the open end down. Be sure you don't contaminate the container or closure with your fingers, or lay the closure down somewhere. Do not turn the cap over. Don't rinse the bottle, or you will lose the dechlorinating agent.
- Place the bottle in the stream of water from the tap and fill to the base or shoulder of the neck of the container leaving a small gap at the top to allow mixing in the laboratory. Do not allow the bottle to overflow. (If the bottle does overflow or the top or lip of the bottle touches either your hand or the tap, you will need to discard this bottle and take another sample using a new pre-sterilized bottle.)
- Carefully replace the top and then turn off the tap and replace the strainer/aerator.
- It is best to label the bottle(s) at the time of sampling with the appropriate pre-printed or hand written label. Bacteriological sample bottles should be stored upright in a cool, insulated container and delivered to the laboratory as soon as possible.
- Use a DD Form 686, Fluoride/Bacteriological Examination of Water, or a local form to record the specific collection point, date and time, free and combined available chloride, pH, and any comments that might be helpful.

If using a Whirl-Pak® bag, tear off the top serrated seal and carefully open the bag using the two side tabs; place the bag under the faucet to collect your sample. Be careful not to overfill the bag as it will be difficult to close the bag. Once you have your sample in the bag, twirl the bag around a few times, and then use the wire end tabs to secure the bag. You should store the bags in an upright position to reduce the possibility of leakage and contamination.

Preparing biological sample(s) for transport and analysis

Samples should be placed in a clean/sanitary thermally insulated pack or container with ice packs for transport to follow-on sites and ultimately to the lab. For the best results, you should have your samples to the laboratory and analyzed in about one hour. For samples that must be shipped to an approved laboratory, the absolute maximum time between collection and examination can be no more than 24 hours. If you can't meet this limit, state that fact on the DD Form 686 (or equivalent) and resample the site. The sample must be refrigerated or iced to slow bacterial action if the time lapse is to be over one hour.

It's possible you will collect samples of ice for bacteriological analysis, but it is not a routine procedure. PH is responsible for monitoring the quality of ice used for consumption, but they may request your assistance to analyze ice samples. In this case, collect the ice using a sterile scoop into the same type of container used for drinking water samples. Allow the ice to thaw in the container, and then analyze as drinking water.

Collection from surface waters

The aim in collecting samples directly from a river, reservoir, or spring is to obtain samples that are representative of the water as a whole. For this reason, samples should be taken at mid-depth, midway across small stream and for larger water sources, at least 8 feet out from the bank and approximately

one-fifth depth. Samples should not be taken too near the bank or from too deep. In addition, avoid retrieving samples from stagnant areas and take care not to damage the bank area as this can contribute to contamination of the sampling area. The sample should be collected as follows:

- Remove the cover and stopper from the bottle and retain them in one hand.
- Hold the bottle by the base with the other hand and plunge it neck downwards below the surface to a depth of about 1 foot.
- Tilt the bottle so that the neck points lightly upwards and point the mouth towards the current. Where no current exists, as in a reservoir, push the bottle forwards horizontally until full.
- Remove the bottle and replace the stopper (or screw on the top) immediately.
- Take care throughout that no water entering the bottle is likely to have come into previous contact with your hand.

If it is impossible to fill the bottle directly, as for example, where there is a high bank, the sample may often be obtained from a bridge by lowering a suitable container into the water to collect the sample. Alternatively, a long pole fitted with a clamp to hold the sterile sampling bottle can be used.

Collection from wells

Where pumping is mechanical, the sample should be collected from a sterilized tap before any tanks or reservoirs, or from the sterilized mouth of a hand pump (if used). Sampling equipment will include protective gloves (for sterilizing), safety glasses, chlorine wash/spray bottle, beaker, stopwatch, paper tissue, lighter, and disinfectant wipes.

Refer to the USAFSAM *Drinking Water Surveillance Technical Guide* for specific sampling procedures.

Contaminants that may be present in source water include:

- Microbiological contaminants such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural operations and wildlife. Cryptosporidium is an example of a microbiological contaminant affecting surface water sources.
- Inorganic contaminants such as salts and metals, which can be naturally occurring or result from urban storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming.
- Pesticides and herbicides that may have a variety of sources such as agriculture, urban storm water runoff and residential uses.
- Organic chemical contaminants that are by-products of industrial processes and petroleum production and also can come from gas stations, urban storm water runoff and septic systems.
- Radioactive contaminants that can be naturally occurring or the result of oil and gas production and mining activities.

The amount of a specific contaminant in your water sample will be expressed as a concentration—a specific weight of a substance in a specific volume of water. Commonly used concentration units for drinking water are:

Milligrams per liter (mg/L)	Equivalent to or ppm, which means one part of the concentration for every million parts of water, both by weight.
Micrograms per liter (µg/L)	Equivalent to ppb, which means one part of chemical per billion parts of water, both by weight.

Summary of sample collection and preparation

For the purpose of this discussion, the assumption has been made that an installation SAM plan exists at your installation per AFI 48–144. This information plays a supporting role in accomplishing the task of collecting a potable water sample for analysis.

Always be sure to reference your installation's SAM plan before any sampling effort. If an SAM plan is not available at your installation, consult your supervisor for proper guidance. The task of collecting potable water sample for chemical analysis can typically be simplified into the following basic steps:

- Review your installation-specific SAM plan, *Standard Methods for Examination of Water and Wastewater* (current edition), servicing laboratory guidance and/or state requirements to identify sampling requirements (i.e., site location, pollutant parameters, sample method, equipment).
- Gather sampling supplies.
- Select proper container(s).
- Prepare sample container(s) per appropriate guidance document, if needed.
- Remove attachments from the tap, if needed.
- Flush water line long enough to get a representative sample.
- Use aseptic technique to avoid contaminating the sample.
- Collect required volume and recap the container(s).
- Determine physical properties (i.e., pH, temp, etc.) of water samples.
- Properly label the container(s).
- Initiate preservation methods, if needed.
- Document field information (i.e., name, date, time, location, sample number, etc.) on appropriate form/log.
- Clean/rinse equipment between samples where necessary to prevent cross-contamination.

413. Performing chlorine and potential of hydrogen analyses

The chlorination of water supplies serves to destroy or inactivate disease-causing microorganisms; it is essential that proper chlorine testing procedures be used. Testing for chlorine residuals is performed in conjunction with collecting bacteriological samples. Chlorine residual analysis is an important field test that is critical when evaluating field water supply safety.

The most common method used for measuring chlorine residuals and pH is the color comparator method. Figure 2–4 shows an example color comparator test kit. The standard comparator kit consists of:

- Test tubes with caps.
- Five different reagent tablets.
    1. Free available chlorine.
    2. Monochloramine.
    3. Dichloramine.
    4. Total residual chlorine.
    5. Phenol red for pH.
- Three color comparators kit.
    1. One pH comparator.
    2. Two diethyl-p-phenylenediamine (DPD) chlorine comparators.

Figure 2–4. Color comparator test kit.

Perform water sampling for chlorine analysis

The chlorine tests you will most likely perform are:

- Free available chlorine (FAC).
- Total residual chlorine (TRC).
- Total combined chlorine (TCC).

If your base drinking water must have FAC residuals, you'll be testing for FAC and TRC. The TRC concentration is needed to determine the amount of chlorine that is combining with impurities to form chloramines. If marginal chlorination or chlorine-ammonia treatment is used, you only need to test for TCC.

To begin chlorine analysis**, you** perform the following 8 steps:

1. Remove the faucet's aerator or strainer.
2. Run the cold water for about 2 to 3 minutes to flush the service connections and to ensure your water sample comes from the main water distribution line.
3. Get testing equipment (color comparator, reagent tablets, and test tubes) ready while the faucet is running.
4. Fill vial to line indicated (10 ml).
5. Add reagent table you are testing for to tube filled with water. (**NOTE:** Do not use any tablets that are discolored or broken or have been exposed to air and moisture for more than a few minutes).
6. Place cap on tube.
7. Compare color with color comparator.
8. Document results.

Free available chlorine

The first chlorine test we will discuss according to the steps you must perform is the FAC:

- Slow the water down to a trickle and rinse the test tube with sample water; this removes any residue from a previous test.
- Fill the vial to the 10 ml mark with test water and add one Chlorine DPD #1R Tablet to the tube without touching the tablet.
- Cap and mix the water until the tablet dissolves.

- Immediately insert test tube into the DPD chlorine comparator and match the sample color to a color standard.
- Record your results as ppm FAC. If there's no color in the water after the tablet dissolves, repeat the test with a new tablet.

If the test tube color doesn't exactly match any of the standards, record the residual as the reading between two standards. If the color is stronger than the standard for 0.3 ppm, but weaker than that for 0.4 ppm, simply record 0.35 ppm as the residual. If the test color is less than 0.1 ppm, remove the tube and compare it to a blank sheet of white paper. A tinge of color means there's a measurable residual, but less than 0.1 ppm. You cannot take too long to make the comparison or the precipitate will settle out. If this occurs, shake the vial so the precipitate will resuspend then retake your measurement.

Total residual chlorine

TRC is the next chlorine test we will discuss.

- Using the same water from the FAC sample.
- Add one Chlorine DPD #3R tablet to the tube without touching the tablet.
- Record results in units of ppm TRC. Ideally, the TRC should be equal to the FAC reading.

If there is not FAC sample water, a single DPD #4R tablet can be used to obtain the TRC in a previously unanalyzed sample.

Total combined chlorine

To determine the TCC, simply subtract the FAC results from the TRC results. Ideally, the combined chlorine should not exceed 0.2 ppm.

Perform water sampling for pH analysis

The pH level of our drinking water reflects how acidic it is and refers to the amount of hydrogen mixed with the water. The pH is measured on a scale that runs from 0-14 (fig. 2–5). A pH of 7 is neutral, indicating the sample is neither acidic nor basic. A measurement below 7 indicates the sample is acidic and a measurement above 7 indicates it is basic, also called alkaline.

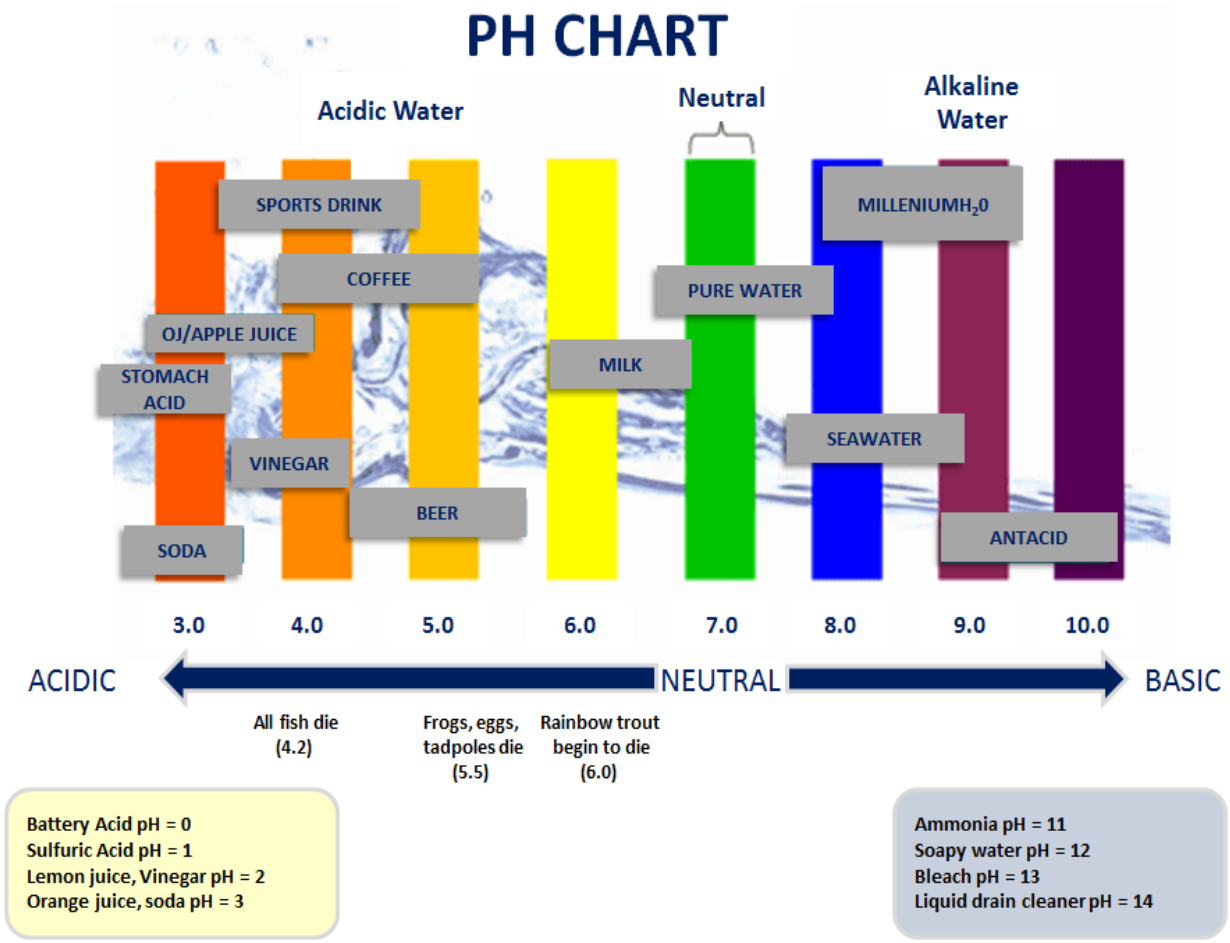


Figure 2–5. pH scale.

Water with a low pH can be acidic, soft and corrosive. This water can leach metals from pipes and fixtures, such as copper, iron, lead, manganese, and zinc. It can also cause damage to metal pipes and cause aesthetic problems, such as a metallic or sour taste. Drinking water with a pH level above 8.5 could indicate that the water is hard. Hardness can cause aesthetic problems and a build-up of mineral scale on pipes and fixtures than can lead to lower water pressure. A neutral pH level in drinking water is optimal for allowing a long interaction time between chlorine and the microorganisms which results in an effective disinfection process. It's for these reasons we test pH when we check chlorine residuals. You can test pH by colorimetric means (e.g., DPD test kit) or electrometrically with a pH meter.

pH analysis using DPD test kit

As stated previously, the most common device used for measuring chlorine and pH in the Air Force is the color comparator method—DPD kit. To measure pH levels perform the following steps:

- Remove the faucet's aerator or strainer.
- Run the cold water for about 2-3 minutes to flush the service connections just like you did during your chlorine sample analysis.
- Rinse the test tube with sample water.
- Fill the tube to the 10 ml line with sample water.
- Add one phenol red tablet; cap and gently mix sample until tablet dissolves.
- Immediately insert the test tube into the phenol red comparator and match the sample color to a color standard.

- Record your sample results as pH units. Once the sample results have been recorded, empty and rinse the test tube.

Potential of hydrogen analysis using potential of hydrogen pen

The electrometric method involves placing an electrode sensor in the sample water and reading the pH value from a digital meter—generally referred to as a pH pen (fig. 2–6) Calibrate the pH pen with a buffer solution before each series of tests. Handle the electrode with care since touching it with your fingers or failing to rinse it with deionized water after each use can interfere with accurate pH measurements. Calibrating a pH meter can be somewhat time consuming; however, this method gives the most accurate and precise results. Extreme differences in temperature can affect pH readings, so most electrometric pH meters come equipped with a temperature sensor.

Before you take any measurements, check the battery level indicator to ensure the batteries will not need to be replaced mid-analysis.

Figure 2–6. pH pen.

For consistent accuracy, frequent calibration of the instrument is recommended. In addition, the instrument must be calibrated whenever:

- The pH electrode is replaced.
- After testing aggressive chemicals.
- Where high accuracy is required.
- At least once a month.

After properly calibrating the meter, submerge the pH electrode in the sample and stir gently. Allow the reading to stop fluctuating; the measurement should be recorded when the stability symbol on the top left of the liquid crystal display (LCD) disappears.

If taking measurements in different samples successively, rinse the probe thoroughly with deionized water between samples to eliminate cross-contamination, and after each cleaning, rinse the probe with the sample to be measured. Once analyses are complete, rinse the electrode with deionized water and store it with a few drops of storage buffer solution in the protective cap to prevent it from drying out.

414. Performing presence-absence coliform tests for monitoring drinking water quality

A presence/absence (P/A) test is used to obtain qualitative information on the presence or absence of coliforms. It is based on the theory that no coliforms should present in 100 ml of a drinking water sample. The type of P/A test we are going to discuss and use is the self-contained Colilert® test developed by IDEXX Laboratories.

For this method, simply snap the top of the package and add the powdered Colilert® media directly to 100 ml of sample. This can be done in the original purchased Colilert® sample container or a sterile glass or plastic bottle prepared as described above. The sample is then placed in a dry air incubator at 35ºC ± 0.5ºC for 24 hours. The interpretation of whether a sample is positive or negative is simply to check if there is a color change in the sample. The procedures for reading the results are:

- At 24 hours, remove the sample from the incubator.
- If the color is not evenly distributed throughout the sample, shake to mix the sample.
- If no yellow is observed (clear), the test is negative for total coliforms and E. coli organisms.
- When yellow is observed, the sample contains total coliform organisms.

If there are questions as to whether the water sample is yellow enough, compare it to the color comparator you can order with the media. If the sample is lighter than the comparator, incubate for another four hours, but do not exceed 28 hours.

If you have determined the sample contains total coliform organisms, you can confirm if the sample contains E. coli by placing a 6-watt (W) 365-millimeters (mm) ultraviolet (UV) lamp within 5 inches of the sample container. If the sample fluoresces (glows), the presence of E. coli is confirmed. If the sample is yellow but does not fluoresce, the sample is positive for total coliform but negative for E. coli.

415. Collecting water samples from recreational waters

Routine monitoring of swimming pools, spas and hot tubs, and other natural bathing areas provides patrons with sanitary and safe conditions and a safe and healthful workplace for employees. As a BE team member, you may be called upon to provide water quality supervision of swimming pools, spas and hot tubs, and natural bathing areas under Air Force jurisdiction. You will participate in pre-season, post-season, and other inspections, as necessary, and submit recommendations to the installation commander and other responsible persons for the safe and sanitary operation and maintenance of the facilities.

Swimming pools

According to AFMAN 48-114, *Recreational Waters and Mission Training Pools*, the bathing facility manager or lifeguard is required to measure the pH and disinfectant residual (chlorine) at all four corners of a pool at least once every two hours during operational hours. The average of the values is entered on AF Form 708, Swimming Pool Operational Log. On a monthly basis, you are required to measure the pH and chlorine residual levels of the swimming pool using sampling procedures previously discussed. Enter the results on AF Form 708 and compare the results to the facility manager and/or lifeguard's. The goal is to take measurements of pH and chlorine levels during maximum loading conditions—preferably the busiest time of the day. If your readings differ significantly from those taken by the facility manager or lifeguard, make every attempt to determine the cause of the discrepancy and make sure the lifeguards are following the correct measurement procedures.

In addition to pH and chlorine measurements, you might perform bacteriological sampling for heterotrophic plate count (HPC) and fecal coliform (FC) in support of specific requests attributed to disease outbreaks. In this event, consult with USAFSAM, your service laboratory or follow guidance in *Standard Methods for the Examination of Water and Wastewater*, current edition.

Bacteriological sampling is not required in routine surveillance of swimming pools but can be performed through a special request. [5]

Hot tubs and spas

Bathing facility managers are required to take temperature, pH, and chlorine readings, at a minimum, daily at opening and hourly thereafter. How often you take readings is based on past performance history. Because conditions in a hot tub or spa change so rapidly, research indicates there is no need to collect bacteriological samples unless an illness occurs. If an illness occurs, follow the same sampling procedures as you followed for swimming pools. The table below lists some water quality requirements from AFMAN 48-114 that you will need to know:

Parameter	Acceptable Range	Applicability
Free Available Chloride FAC	1.0-4.0 ppm	Pools
	3.0-5.0 ppm	Spas & Hot tubs
pH	7.2-7.8	Pools, Spas & Hot tubs

Natural bathing areas

According to AFMAN 48-114, water quality sampling at natural bathing areas is based on risk. Some risk factors include but are not limited to proximity to suspected pollution source, level of bathing area use, historical water quality data and occurrence of sewage spills. If you decide not to sample at the natural bathing area, the rational must be documented. If bacteriological sampling is conducted with the primary concern being *E.coli* and *Enterococci*, refer to Title 40 CFR 131.41, *Bacteriological Criteria for Those States not Complying with Clean Water Section 303(i)(1)(A)*, for guidance. The use of certified laboratories for bacteriological analyses is not required if you adhere to *Standard Methods for Examination of Water and Wastewater.* [5] If the local health department or other health/environmental agency routinely collect water quality samples, you should work with these agencies to share data to avoid duplication of sampling.

Periodically, throughout the swimming season, sampling for contaminant(s) with the potential to exceed acceptable limits based upon environmental conditions should be considered. If local or state agencies have current data, the data may be used and you can determine what, if any, additional parameters need to be evaluated.

Remedial actions

When the bacteriological water quality of the swimming pool or hot tub/spa does not meet standards, you will need to:

1. Collect repeat samples from the points of the original collection.
2. Conduct an immediate investigation to determine if any unusual conditions (e.g., repairs to facilities, storms, etc.) might be the cause. CE can provide the repair history and determine if the filtration and disinfection systems have been operating properly.
3. Ensure the pH and chlorine is within acceptable ranges.
4. Notify PH whenever conditions are encountered that may pose a health hazard to patrons.

If the results of the resample again exceed standards, the medical group commander will recommend closing the facility until the cause of the problem is determined. Shock treatment (super chlorination) may be required for pools and spas/hot tubs. Measurements necessary to initiate surveillance or investigate the occurrence of illnesses associated with unhealthy water quality are conducted by PH.

416. Sample collection quality assurance/quality control

AFI 48–144 requires that a QA/QC program is implemented and conducted. This program is mandated to ensure the integrity of sampling data. An effective drinking water surveillance program includes establishing QA/QC protocols; these measures ensure that the laboratory receives accurate sample representations of the conditions existing at the sample site and the results of the analyses are

traceable to the specific sample location or event. Proper collection protocol and preservation/transport guidelines ensure that water quality data is accurate and useful. Approved drinking water analytical methods can only produce reliable, high quality data when personnel use best practices at every point of the sample collection process.
At a minimum, QA/QC must include:

- Recording periodic equipment calibration data.
- Ensuring personnel training is relevant and current.
- Incorporating proper sample collection techniques.
- Implementing chain-of-custody tracking of samples. [6]

A QA/QC plan may also include quality control checks and samples, ensuring personnel are qualified for the tasks performed (including primacy certification of personnel collecting samples, if applicable), periodic audits, requesting and reviewing primacy agency audit reports for contract laboratories, side-by-side field analyses, ensuring field equipment calibration, and verifying accuracy of DOEHRS entries. Positive and negative bacteriological controls should be analyzed as part of in-house procedures.

Field quality control samples.

A number of field quality control samples should be taken during environmental health sampling of surface waters and groundwater monitoring wells. The specific quantity of quality control samples should be determined as part of the sample plan before the start of field activities. These quality control samples usually entail the use of blanks and replicate samples.

Blanks

Trip blanks (also known as field reagent blanks [FRB]) are provided by the lab as required and must be included when the samples are returned. **NOTE:** Trip blanks must never be opened and must always be kept with the samples. Trip blanks are required to identify possible interferences associated with the shipping, collection, and storage of samples. Trip blanks must be handled along with each sample set, which is composed of the samples collected from the same general sample site at approximately the same time. Trip blank sample bottles are filled with reagent water, sealed, and shipped to the sampling site with the empty sample bottles. Trip blanks must remain sealed until analysis and must be shipped back to the laboratory with the filled sample bottles. Preservatives must not be added to the trip blanks because of the potential for preservative decomposition when sampling kits are stored under deployment conditions.

Equipment blanks (also known as rinsate blanks) must be collected like a regular sample but without adding the preservatives. The equipment blank is a reagent grade aqueous or organic solution that is as free of analytes as possible and is transported to the site, opened in the field, poured over or through the sample collection device, collected in a sample container, and shipped to the laboratory. This serves as a check on sampling device cleanliness and will be affected by the site and sample handling conditions. This type of blank will be analyzed in the laboratory just like any other sample.

Temperature blanks are containers of water that are shipped along with the samples en route to the laboratory. The laboratory will measure the temperature of the blank upon receipt. This is used to verify that samples are maintained at less than 4°C, which is necessary with for many analytical methods.

Replicates

Duplicate samples are intended to identify variability in the analytical results associated with field and laboratory methods and the inherent heterogeneity of the media. Samples are taken at the same location employing the same collection methods.

Split samples are often used to identify variability between sample handling methods or between laboratories. The sample material is homogenized in the field and placed into two separate sample containers for submittal to two separate labs.

417. Preparing and/or preserving liquid samples for shipment

You might be wondering why you should be concerned about taking the time to meticulously prepare and preserve the liquid samples you collected prior to shipping them to an off base laboratory. The answer is quite simple – proper sample preparation and preservation will ensure your samples are maintained in the condition necessary for proper analysis between the time you collect the samples and the time the samples are analyzed. You can reference the *USAFSAM Laboratory Sampling Guide* or *Standard Methods for Examination of Water and Wastewater*, Section 9060 B, *Preservation and Storage.* These guides provide the detailed information you will need to follow when your sample collection is complete. Time doesn't permit us to talk about each and every sample preparation and preservation technique available. Therefore, the information that follows is intended to present *general* considerations for sample preservation prior to shipping.

Sample preparation

It has always been, and will continue to be, a very important responsibility for you to verify the correctness and representativeness of data and to ensure you use proper sample collection, tracking, and preservation techniques. The chain of custody form is a legal document you will use to track your samples. Properly designed and executed chain of custody forms help to ensure sample integrity from collection to data reporting. This includes the ability to trace possession and handling of the sample from the time of collection through analysis and final disposition.

Labels

Labels should be used to prevent sample misidentification. Gummed paper labels or tags generally are adequate. Your label should include a unique sample number, sample type, your name, date, and the time you collected the sample, the sample location (where the sample was taken from), and sample preservation. Also include date and time of preservation so that you can compare it with the date and time of collection. Labels should be affixed to the sample containers before, or at the time of your sample collection.

Sample seals

Seals should be used to help detect unauthorized tampering with samples up to the time of analysis. Self-adhesive paper seals or plastic shrink seals can be used and should include your sample number (identical to the number on your sample label), your name, and the date and time of sampling. Be sure to attach the seal in such a manner that it would break if the sample container was opened.

Documentation and management

As part of your sampling, it is important that you fill out the applicable sampling, shipping, and chain of custody forms appropriately. Be sure to reference USAFSAM, your servicing laboratory and shipping carrier's guidance. Other ways that have proven beneficial to maintaining effective sampling operations include:

- Having written instructions on sampling procedures.
- Maintaining sampling equipment in proper condition. In order to ensure equipment is 'ready for use' in response operations, clean equipment after each sampling event and properly follow the manufacturer's maintenance specifications.
- Holding training sessions for sampling teams to make sure individuals know how to operate equipment properly.
- Checking sampling equipment, before each use, to ensure proper operating conditions and cleanliness.

In addition to properly documenting all sampling forms, AFMAN 48–146 and AFI 48–145 state that you are required to document all OEH exposure and incident data for both garrison and deployed setting. This means, you need to input all liquid sampling information and results into the environmental health section of DOEHRS (fig. 2–7). Consult USAFSAM and/or DOEHRS Guidance Document on the specific requirements on how to enter data.

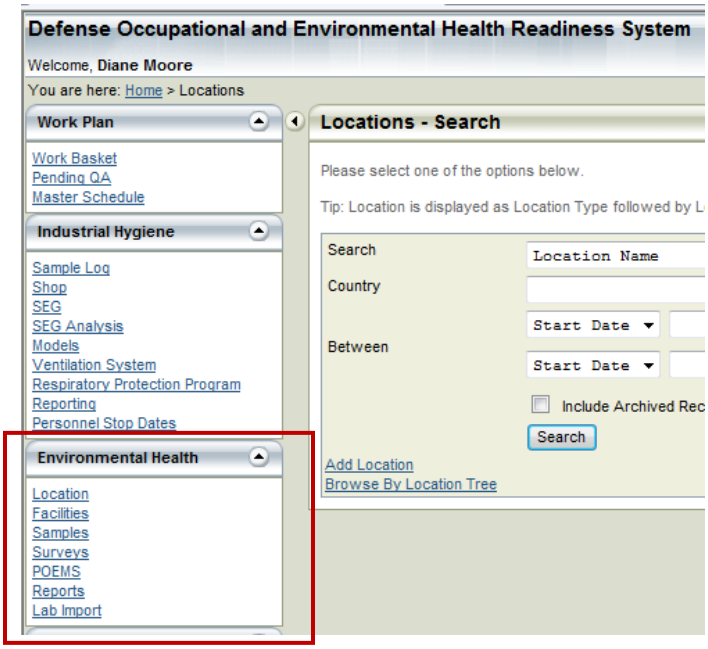


Figure 2–7. DOEHRS Environmental Health Module.

Log books

Log books are used to record all information pertinent to a field survey or sampling. If used include the following information in the log book:

- Purpose of sampling.
- Location of sampling
- Name and address of field contact.
- Procedure of material being sampled and address – if different from location.
- Type of sample.
- Method, date, and time of preservation.

A log book should provide enough detailed information so that one could reconstruct the sampling event without reliance on the sampler's memory.

Chain of custody record

Chain of custody procedures provides accountability for and documentation of sample integrity during each stage of a sample's life cycle, that is, during collection, shipment, storage, and the process of analysis. These procedures are necessary to guarantee our ability to support data and conclusions adequately in a legal or regulatory situation. The chain-of-custody form should contain the following information at a minimum:

- The name and signature of the individual and organization transferring the samples to the laboratory.
- The name of the laboratory being used.
- The name of the laboratory employee who is receiving the samples and the date and time samples were received.

- The number of samples being transferred to the laboratory.
- The sample ID number.
- The date, time, and sampling location of where each sample was collected.
- The date and time that the samples were received by the laboratory.

Sample analysis request

According to USAFSAM Laboratory Sampling Guide sample submissions must be done by a complete sample submission form. The standard industrial hygiene sample submission form is the DOEHRS Discoverer Viewer Sample Submission workbook. Environmental health samples not analyzed in-house may require the use of sample submission forms generated by the commercial lab; contact Customer Service for additional details. Clearly label all sample submission paperwork with the base code of the sender. If samples are collected incorrectly and/or incompletely documented, every effort will be made to obtain the necessary information to convert the invalid sample into a valid sample. Make sure all samples are collected according to this guide and shipped appropriately and the submission forms are correct and complete**.**

Delivery to laboratory

Sample delivery should take place as soon as practicable after the sample collection is complete—typically within two days. Where shorter sample holding times are required, you will need to make special arrangements, in advance, to insure timely delivery of your samples to the laboratory. Where samples are shipped by a commercial carrier, be sure to include the waybill/tracking number in the sample custody documentation. Include a completed chain of custody record and your sample analysis request sheet. Once the sample is in the laboratory, the supervisor or analyst becomes responsible for its care and custody.

Sample preservation

Before heading out to the sampling site, you will need to determine if any of the samples you will be collecting require special handling and/or preservation. In general, the shorter the time that elapses between collection of a sample and its analysis, the more reliable will be the analytical results. When immediate analysis of the collected sample is not possible, be sure to take the necessary precautions to ensure that sample characteristics are not altered. Proper handling of the samples includes following the storage requirements listed in the analytical method description and the appropriate chain of custody procedures.

Most water samples are preserved by pH and temperature adjustments; however, you should consult the specific storage and preservation directions (listed in the analytical method description) for each analyte. Before you begin sampling, plan how and when you will transport the samples back to the laboratory so that all samples are preserved and delivered to the laboratory as quickly as possible and within recommended holding times. This is especially important for samples like Nitrate/Nitrite that have holding times of 24 hours or less. Maintaining compliance and avoiding notices of violations and fines are dependent on accurate results; not exceeding sampling hold times.

Many regulatory methods place a limit on the amount of time that can occur between collection and analysis.

Steps for preservation and transportation may include:

1. Once the sample has been collected, the sample should be stored in a cooler and kept at a temperature of 4°C or < 10°C depending on the analyte. If ice is used in shipping, it is recommended that it be bagged separately to eliminate any contamination of the sample.
2. Add preservatives or adjust pH, if required and containers with preservatives were not provided by the lab. Use appropriate personal protective equipment.
3. All samples should be transported to the laboratory and analyzed within the applicable holding time.

The table below provides examples of some special sampling and handling requirements you might encounter.

Determination	Container	Minimum sample size (ml)	Sample type	Preservation	Maximum Storage: Recommended	Maximum Storage: Regulatory
Chlorine, total, residual	Plastic (polyethylene or equivalent) Glass	500 ml	Grab	Analyze immediately	0.25 hours	0.25 hours
Fluoride	Plastic (polyethylene or equivalent)	100 ml	Grab, Composite	None required	28 days	28 days
Nitrate + Nitrite	Plastic (polyethylene or equivalent) Glass	200 ml	Grab, Composite	Add H_2SO_4 to pH <2, refrigerate	1-2 days	28 days
Solids (per Title 40 CFR Part 136, Table II, *Required Containers Preservation Techniques, and Holding Times*)	Plastic (polyethylene or equivalent) Glass	200 ml	Grab, Composite	Refrigerate	7 days	2-7 days

General sample preservation and holding times for most analytes can be found in Table 1060: I, 21st Edition of *Standard Methods for Examination of Water and Wastewater* (or Table 7010: I for radionuclides) or *USAFSAM Laboratory Sampling Guide*.

Even if you collect and preserve your samples in the most meticulous way possible, there's nothing worse than getting a call from your servicing laboratory informing you that some of your sample containers arrived broken. To ensure your samples arrive unbroken, make sure you use the proper type and amount of packing material and a sturdy/durable container for shipping.

Packaging samples

When packaging water samples for shipment, remember all bottles need to be protected from breaking and/or leaking. You will need to ensure that the bottle labels are waterproof and that the information is legible. Be sure to tighten each cap to prevent leakage. Even if it doesn't contain ice, your shipping container should be lined with doubled heavy-duty plastic bags. Use adequate packaging material to prevent bottle breakage, such as foam sleeves for glass bottles or bubble wrap for poly-coated glass bottles, and pack bottles so that they do not touch each other. The remaining open spaces can be filled with vermiculite or some other absorbent material so in the event of seepage or broken container, all of the samples will not be contaminated.

Samples designated for chilling should be packed in coolers (insulated) and chilled with ice. The volume of ice should be equal to or greater than the volume occupied by the samples. During warmer weather, twice the volume of ice to samples is recommended. Do not use blue ice or other types of commercial refreezing containers that have freezing points below 0°C. This can cause the bottles to freeze and ruin samples or break bottles. Samples that do not require chilling can be shipped in heavy-duty cardboard boxes or coolers.

418. Decontaminating sampling equipment

As part of your BE team member duties, you will spend valuable time performing sampling. The validity of your results will depend, to a large degree, on how well you followed the procedures for the specific type of sampling you performed as well as the cleanliness of the sampling equipment you

used. If any of the sampling equipment was contaminated, it could cause erroneous and invalid sampling results—something you definitely want to avoid. It's for this reason you will need to properly decontaminate your sampling equipment each time you finish any type of liquid sampling. You might also need to decontaminate the equipment before sampling if you are unsure of its cleanliness.

Sources of contamination

You might not think of yourself as a source of contamination, but if you are not careful when sampling, you can easily contaminate the sampling equipment and even the material you are sampling. For example, if you get some of the material you are sampling for or other material on your hands and then handle the sampler and/or touch the inside of the sampler or sampling container, you have just caused cross-contamination.

What about the sampling containers and sampling equipment you are using? Are you sure they are free of contamination? If not, you will need to decontaminate the container and/or equipment. If you are using containers such as plastic bottles, it might be best to get new bottles. Use caution when using reagents such as solvents, detergents/soaps, acids, and other chemicals used to decontaminate sampling equipment. These substances can leave residue that must be removed before you use the equipment again.

Decontamination equipment and procedures

Depending on what you are decontaminating, and the availability of supplies and equipment, you will normally use the following to decontaminate equipment: stiff bristle brushes, pressurized spray with rinse water, sprayers for solvents, waste containers, plastic wash tubs and buckets, plastic tarps, trash bags, paper towels, and metal and plastic containers for wash solution disposal. Soap and water are effective for most situations, but there are times when a solvent, such as hexane, will be required to decontaminate samplers and equipment.

In this lesson, we touched on some of the more general steps for preserving your water samples and getting them ready for shipment. In order to ensure your samples are properly prepared and preserved, follow your local SAM plan, USAFSAM Automated Sampling Guide, State, or servicing laboratory guidance for each type of sample collected. The most current version of *Standard Methods for Examination of Water and Wastewater* also provides a tremendous amount of detailed information on specific sample collection and preservation techniques. Simply put, use the resources available to you.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

412. Collecting potable water samples

1. What is the specific order that water samples (required from a specific sampling point) taken?

2. If water sampling containers are not perfectly clean, what effect can this have on sampling?

3. The final step in cleaning sample bottles is: rinse the containers with sterile or deionized water at least three times. Why?

4. Why is a dechlorinating agent added to a water sample checked for biological quality?

5. Before conducting any sampling, what installation-specific document should be referenced?

6. Under what condition can you use either glass or plastic containers for water sample collection?

7. What indicators should be looked for to indicate that sodium thiosulfate should not be used?

8. Why is it important ***not*** to rinse the bottle prior to collecting a sample to check for biological quality?

413. Performing chlorine and potential of hydrogen analyses

1. Why is it even more critical to test for chlorine residuals when evaluating field water supplies?

2. What is the most common Air Force sampling device used for measuring chlorine and pH?

3. Explain the benefits of running the faucet water for about 2-3 minutes prior to testing for chlorine.

4. What are the effects of low pH on water?

5. Why is it necessary to have the correct pH level in drinking water?

414. Performing presence-absence coliform tests for monitoring drinking water quality

1. What theory is the presence/absence test based on?

2. Once it has been determined that a sample contains total coliforms, how can you confirm the presence of E. coli?

415. Collecting water samples from recreational waters

1. Why is routine monitoring performed for swimming pools, spas and hot tubs, and other natural bathing areas?

2. When is the use of a certified laboratory for bacteriological analysis of a natural bathing area ***not*** required?

3. When is bacteriological water sampling of a swimming pool performed?

416. Sample collection quality assurance/quality control

1. What is the purpose of a QA/QC program?

2. What are the minimum requirements of a QA/QC program?

417. Preparing and/or preserving liquid samples for shipment

1. What does the proper preparation and preservation of samples do?

2. What form is used to track samples?

418. Decontaminating sampling equipment

1. Explain two factors that can influence the validity of sample results.

2. What is the importance of decontaminating sampling equipment?

3. Why must caution be used when using reagents and other chemicals to decontaminate sampling equipment?

2–4. Interpreting Analytical Results

All of the time and effort put into preparing a liquid sampling plan and going out and collecting samples culminates when you sit down with a relevant standard and interpret the results of your sampling. The importance of this step cannot be underestimated. Sampling results could potentially be used to design and implement a long-term course of action.

419. Water sample result interpretation

So now that sampling has been conducted, results have been quantified, and the appropriate standard has been selected, what is the next step? The sampling results need to be carefully interpreted. This is done by comparing them to the selected standard and determining whether the results exceed the applicable standard. Since the results will be the basis for OEH making decisions that will affect personnel and the environment, there are a few things that need to be taken into consideration.

When comparing results to a standard be sure that:

- The sample and standard have the same exact spelling (many chemicals and constituents have similar spelling).
- The correct units of measurement are being for both sample and standard (convert units of sample to match sample, if needed).
- The results are compared to the correct type of standard.
- The correct laboratory analysis method was conducted (they may be different for the same analyte depending on whether the sample was for Safe Drinking Water Act or Clean Water Act).
- The *c*orrect calculations are used (if sample calculations are needed).
- Notations or footnotes that might be included in the reference are read and understood.
- Sample results are properly documented according to the latest standard operating procedures/data management system.

References

[1] United States Air Force (USAF), Occupational and Environmental Health Site Assessment, April 2012.

[2] USAFSAM, "Guidance Document for the Use of the HAPSITE Portable GCMS," USAFSAM, San Antonio, 2008.

[3] S. Detection, "Training Course Infrared Spectroscopy for Hazardous Materials Identification," Smiths Detection, Danbury, 2006.

[4] B. A. Plog, Fundamentals of Industrial Hygiene, National Safety Council, 2012.

[5] AFMAN 48-114, *Recreational Waters and Mission Training Pools*, 2012.

[6] Equipment Manuals.

[7] S. R. DiNardi, The Occupational Environment: Its Evaluation, Control, and Management, Fairfax: American Industrial Hygiene Association, 2003.

[8] USAF, USAFSAM Drinking Water Surveillance Technical Guide, Apr 2011.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

419. Water sample result interpretation

1. Why is it important to properly interpret sampling results?

2. Why must you ensure the sample analyzed and standard used both have the same name/spelling?

Answers to Self-Test Questions

408

1. SAM plan.
2. BE flight and CE.
3. (1) Describe why the samples are being collected.
   (2) Specify step-by-step procedures how the samples are to be collected and any field descriptions or analyses that are required (i.e., pH, temp, flow rate).
   (3) Include instructions on filling out appropriate forms such as sampling and chain of custody forms.
   (4) Describe if any preservatives need to be added to sample and if chilling is required.
   (5) Describe shipping requirements and documentation.
4. Sampling will be conducted to determine health risks associated with recreational waters, identify potential OEH hazards as part of an overall health risk assessment or to identify hazards associated with an unknown liquid during an emergency response to determine controls options.
5. Sample to determine whether contaminants or microorganisms could affect human health is present.
6. The primary concerns associated with exposure to non-potable liquids are dermal contact and incidental ingestion.

409

1. It is the road map which details of the entire sampling process from beginning to end.
2. EPA DQO process:

   Step 1: State the problem.

   Step 2: Identify the decision or goal.

   Step 3: Identify information inputs to the decision.

   Step 4: Define the Boundaries.

   Step 5: Develop the decision rules and analytical approach. You will identify OEELs to characterize OEH threat levels and what actions will be taken if the OEELs are exceeded.

   Step 6: Determine performance or acceptance criteria. In this step, you will define how good that data needs to be for a decision to be made on the situation and results.

   Step 7: Develop the detailed sampling plan.

3. Identify information inputs to the decision.
4. Those in AFIs and AFOSH Standards.
   - Title 40 CFR Parts 141 and, 142, *National Primary Drinking Water Regulations*, and Part 143, *National Secondary Drinking Water Regulations*, or local standards promulgated by the states granted primary enforcement responsibility for public water systems (i.e., primacy agency).
   - Air Force Medical Services Agency policy letters.
   - Technical reports or guidance documents provided by USAFSAM.
   - In deployment locations, see also:
     - TG–230, *Chemical Exposure Guidelines for Deployed Military Personnel*, published by the USACHPPM.
     - AFMAN 48–138_IP, *Sanitary Control and Surveillance of Field Water Supplies*. Departments of the Army, Navy, and Air Force, Washington, DC, 1 May 2010.
5. Use your chain of command. Also contact USAFSAM/OE for guidance on exposure limits.

410

1. HAPSITE.

2. VOCs in air, water samples in a gas phase.
3. It can only identify unknown substances, it cannot quantity chemicals.
4. pH meter.

411

1. To minimize errors and most accurate drinking water sampling results.
2. According to manufacturer's operating instructions.
3. Read the instruction manual.

412

1. Metals first, then chemicals, and then microbiological samples.
2. Any residue could kill the bacteria or provide a nutrient medium for their growth.
3. It removes all minerals and other foreign matter and provides a good neutral environment for the bacteria in the water sample.
4. It removes the chlorine, which if left in the water, could kill the bacteria resulting in a false negative sample.
5. Your installation's SAM plan.
6. They must be capable of being sterilized.
7. If it has become turbid or has sediment.
8. You will lose the dechlorinating agent.

413

1. Because in the field you can't always analyze for bacteria.
2. The color comparator test kit/method.
3. It flushes the service connections and ensures your water sample comes from the main water distribution line.
4. Water can be acidic, soft, and corrosive; the water can leach metals from pipes and fixtures, such as copper, iron, lead, manganese and zinc; low pH can also cause damage to metal pipes and aesthetic problems, such as metallic or sour taste.
5. It allows for a long interaction time between chlorine and the microorganisms to take place, which results in an effective disinfection process.

414

1. The theory that no coliforms should be present in 100 ml of a drinking water sample.
2. If the sample fluoresces when placed within 5 inches of a 6-watt (W) 365 mm UV lamp.

415

1. It provides patrons with sanitary and safe conditions and a safe and healthful workplace for employees.
2. If you adhere to *Standard Methods for Examination of Water and Wastewater*.
3. In support of a special request.

416

1. The purpose of a QA/QC program is to ensure the integrity of sampling data.
2. At a minimum, QA/QC must include recording periodic equipment calibration data, ensuring personnel training is relevant and current, incorporating proper sample collection techniques, and implementing chain-of-custody tracking of samples.

417

1. Will ensure samples are maintained in the condition necessary for proper analysis between the collection and analysis time.
2. Chain of custody.

418

1. How well the procedures for the specific type of sampling performed and the cleanliness of the sampling equipment used were followed.

2. Contaminated sampling equipment can cause erroneous and invalid sampling results.
3. These agents can leave residue that must be removed before using the equipment in the future.

419

1. The results are used as the basis to make OEH decisions and recommendations effecting personnel and the environment.
2. Many chemicals and constituents to have similar names.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

19. (408) Developing your flight's environmental sampling, analysis, and monitoring plan is based on the
    a. requirements provided by your major command (MAJCOM) bioenvironmental engineering (BE).
    b. criteria provided to you by civil engineering.
    c. historical performance of your drinking water system.
    d. regulatory requirements for your drinking water system.

20. (408) Include field blanks along with the liquid samples you send to the laboratory because they
    a. check for cross-contamination while handling samples.
    b. check for cross-contamination in storage and shipping.
    c. confirm the accuracy of laboratory analysis.
    d. verify proper sampling methods.

21. (409) Your bioenvironmental engineering (BE) has informed you that you need to collect a water sample that characterizes the water quality at the dining hall at 0900. Which type of sample do you need to collect?
    a. Bulk.
    b. Grab.
    c. Integrated.
    d. Composite.

22. (410) If you need to determine the residual chlorine content in a drinking water sampling, which piece of equipment would you use?
    a. Color comparator.
    b. Litmus test paper.
    c. Colilert color comparator.
    d. Heterotrophic plate count.

23. (410) What type of sampler is *best* suited to collecting a water sample at various levels from tanks, tank cars and drums?
    a. Bacon bomb.
    b. Long pipette.
    c. Handheld dipper.
    d. Plastic polypropylene line glass jar attached to a rope.

24. (410) Fluid transfer is *best* accomplished using a
    a. plastic, polyethylene pasteur pipet.
    b. *Whirl-Pak*® sample bag.
    c. Cubitainer® sampler.
    d. 40-milliliter (ml) glass vial.

25. (411) You have just received a new water test kit that you have never used before. What should you do before using the kit the first time?
    a. Find out if anyone in your flight is familiar with the equipment.
    b. Run an operations check on the equipment.
    c. Charge the battery for at least 6–8 hours.
    d. Read manufacturer's operating instructions.

26. (411) Which statement *best* describes how the calibration process works?
    a. Compares equipment response against instruction manual guidelines.
    b. Compares equipment response against an accurate reference source.
    c. Compares readings against accurate reference readings.
    d. Compares unknown values against know values.

27. (412) When collecting drinking water samples, in what order should you collect them?
    a. Chemicals, microbiological, metals.
    b. Microbiological, metals, chemicals.
    c. Metals, chemicals, microbiological.
    d. Chemicals, metals, microbiological.

28. (412) When sterilizing a water tap, what is the percentage of chlorine solution you should use and how long should the tap be immersed in the solution?
    a. 1 percent chlorine solution; 0.5 minutes.
    b. 1 percent chlorine solution; 2 minutes.
    c. 1 percent chlorine solution; 1 minute.
    d. 1 percent chlorine solution; 3 minutes.

29. (412) When collecting potable water samples for bacteriological analysis, you should adhere to all of the following guidelines *except* which one?
    a. Never hold the bottle by the neck.
    b. Always use good personal hygiene.
    c. Never lay the bottle down on the ground.
    d. Always flush out the bottle before taking the sample.

30. (412) If you ship your bacteriological water samples to an approved laboratory, what is the *maximum* time between collection and examination?
    a. 12 hours.
    b. 24 hours.
    c. 36 hours.
    d. 48 hours.

31. (413) What is the *first* step you perform when taking a water sample for chlorine analysis?
    a. Fill the sampling vial to the 5 mL mark.
    b. Rinse the test tube with sample water.
    c. Run the water for about 2 to 3 minutes.
    d. Remove the faucet aerator.

32. (413) How is total combined chlorine (TCC) determined?
    a. Subtracting the total residual chlorine (TRC) results from the free available chlorine (FAC) results.
    b. Subtracting the FAC results from the TRC results.
    c. Multiply the FAC results by the TRC results.
    d. Adding the TRC results to the FAC results.

33. (413) Drinking water with a high pH level (above 8.5) indicates to you the water
    a. is soft.
    b. is corrosive.
    c. is a health risk.
    d. can cause aesthetic problems.

34. (413) What type of water/liquid do you use to calibrate the pH pen?
    a. Distilled.
    b. Deionized.
    c. Buffer solution.
    d. Calibration fluid that comes with the pH pen.

35. (414) What test do you use to obtain qualitative information on whether or *not* your water sample contains coliforms?
    a. Absence/confirmation method.
    b. Presence/deficiency method.
    c. Absence/validation method.
    d. Presence/absence method.

36. (415) When should you take pH and chlorine measurements of the base swimming pool?
    a. Before anyone enters the pool.
    b. During minimum load conditions.
    c. During the busiest time of the day.
    d. When requested by the swimming pool facility manager.

37. (415) When is the only time you collect bacteriological samples of a hot tub and spa?
    a. Weekly during times of high usage.
    b. When readings indicate there is no chlorine in the water.
    c. If an illness occurs as a result of someone using the hot tub or spa.
    d. Immediately after the hot tub/spa has been drained and cleaned.

38. (415) What action should you take first if the bacteriological quality of the swimming pool water does *not* meet standards?
    a. Immediately recommend the pool be superchlorinated.
    b. Collect repeat samples from different sections of the pool.
    c. Recommend to the medical group commander the pool be closed.
    d. Collect repeat samples from the sections where you originally took samples.

39. (416) Why are proper collection protocol and preservation guidelines important elements of a quality assurance/quality control (QA/QC) program?
    a. These ensure water quality data is accurate and useful.
    b. These affect the reporting procedures required.
    c. These eliminate the need for equipment calibration.
    d. These eliminate the need for field quality control samples.

40. (416) In the liquid sampling quality assurance/quality control (QA/QC) process, what is the difference between trip blanks and equipment blanks?
    a. Equipment blanks contain preservatives.
    b. Trip blanks are provided by the laboratory.
    c. Trip blanks only measure the temperature of the blank.
    d. Equipment blanks are analyzed differently than other samples.

41. (417) It is important to use a chain of custody form because it helps ensure sample integrity from
    a. collection to analysis.
    b. analysis to data reporting.
    c. collection to data reporting.
    d. sampling shipment to analysis.

42. (417) You should seal your liquid sample containers because it
    a. ensures your samples will not leak during transport.
    b. helps detect unauthorized tampering of your samples.
    c. prevents unwanted contaminates from getting into the container.
    d. prevents your sample containers from being damaged during shipment.

43. (418) If any of your sampling equipment was contaminated it could cause
    a. invalid sampling results.
    b. skin contact hazard to the user.
    c. damage to the sampling equipment.
    d. no problem as long as the contamination was minimal.

44. (418) Why do you need to use caution when using reagents to decontaminate sample equipment?
    a. Reagents can damage the soil if not collected after use.
    b. Reagents can leave residue on the sampling equipment.
    c. Reagents must be stored separate from any non-compatible materials.
    d. Reagents can cause inhalation hazards if not used in a well-ventilated area.

45. (419) Water sample result interpretation is conducted by
    a. conducting a thorough quality assurance/quality control (QA/QC) process.
    b. comparing results to a selected standard.
    c. comparing current results to previous survey(s).
    d. using your chain of command for their decision.

46. (419) Which is *not* a consideration when conducting water sample result interpretation?
    a. Correct type of standard.
    b. Correct units of measurement.
    c. Correct personnel assigned to task.
    d. Correct laboratory analysis method.

47. (419) Sampling results must be properly documented according to
    a. the applicable Air Force Office of Safety and Health (AFOSH) Standard.
    b. the Occupational Safety and Health Act (OSHA) criteria.
    c. the latest data management system.
    d. flight's locally developed criteria.

Please read the unit menu for unit 3 and continue ➔

Student Notes

Unit 3. Air/Gas Sampling

AIRBORNE CONTAMINANTS IN THE WORKPLACE and ambient environment can pose a threat to the health and safety of Air Force personnel. Contaminant identification and exposure assessment through air monitoring is an important part of a health and safety program. Reliable air sampling data are useful for the following:

- Confirming the presence of a suspected air contaminant.
- Assessing health risk from exposure.
- Recommending appropriate controls.
- Determining need for medical surveillance.
- Demonstrating compliance with federal and state regulations.

3–1. Air Sampling Strategies

Air sampling provides key data used for assessing health risk from exposure to airborne contaminants in both occupational and environmental settings. Before beginning to sample, a strategy must be formulated so that the data collected is accurate and informative. This begins with answering the following six questions:

1. What is the purpose for sampling?
2. Will a personal or area sample be collected?
3. Should a high or low volume sampler be used?
4. What media should be used?
5. How many samples are needed?
6. How long should sampling be done?

These decisions will form the basis of the air sampling strategy. In order to answer these questions, it is essential to thoroughly understand the principles of air sampling. The purpose for conducting air

sampling and the specific COC will determine the type of sampling conducted and the analytical method applied.

420. Types of air samples

Two basic types of air sampling are performed to assess exposure: instantaneous sampling and integrated sampling.

Grab sampling

Instantaneous sampling is also known as grab sampling. A grab sample represents the air quality at the time of sampling at the location sampled. This instantaneous sample is taken over a short period of time (usually less than 5 minutes). [1] Grab sampling is used to verify the presence of a contaminant and to determine if additional sampling is needed to better quantify airborne concentrations. Grab sampling is frequently used in the following situations:

- To provide quick estimates of air quality.
- Screening for presence of OEH threats during initial assessments, site selection, and reconnaissance during bed-down of expeditionary forces.
- Emergency response situations.
- Special OEH assessments in occupational settings.

DRIs are often used for grab sampling to provide a qualitative or quantitative analysis at the sampling location. Other grab sampling methods include using air sample collection devices such as Summa Canisters or Mylar bags. This method involves collecting a grab sample of a known volume of air for laboratory analysis.

Grab samples are inexpensive, simple to use and are ideal for sampling short and intermittent processes. A disadvantage is that grab sample results are not representative of average exposures and can only be compared to instantaneous OELs like ceiling limits (C) or excursion limits. Multiple grab samples may be collected over time, however attempting to use multiple grab samples to estimate full shift exposure is not recommended. [2] Grab samples cannot be collected for reactive gases such as hydrogen sulfide, nitrogen dioxide and sulfur dioxide unless the samples are analyzed immediately since the reactive gases can react with atmospheric dust particles, other gases, moisture, container sealant compounds, or the container itself, producing erroneous results. [1]

Integrated sampling

Integrated sampling may also be referred to as indirect reading or continuous monitoring. This involves collecting one or more air samples over a specific period of time for laboratory analysis and integrating all of the concentrations to which the worker has been exposed during the sampling period to determine the *average* exposure or *average* air concentration of the contaminant. Integrated sampling methods can be used when performing personal or area sampling. Results are typically compared to an 8-hour TWA like the OSHA PEL or ACGIH TLV®. Integrated sampling is performed using active sampling equipment such as portable sampling pumps with sampling media (charcoal tubes, cassette filters, and cyclones) or passive diffusion monitors.

Integrated sampling methods are often required when demonstrating compliance with AF and OSHA health standards. They are a more accurate evaluation of workers' average exposures while being consistent with OSHA requirements. Samples must be analyzed by an accredited laboratory. [3]

Laboratory analytical methods will specify a minimum air sample collection volume required to detect the contaminant. If the minimum air volume is not collected during the sampling event, laboratory results may be inaccurate or invalidated.

421. Air sampling devices

There are two general categories of air-sampling equipment: direct reading instruments and air sample collection devices. [1]

1. Direct reading instruments provide an immediate measurement or response in the field.
2. Air sample collection devices are used to collect a sample of air that is analyzed at a laboratory.

Direct reading instruments

Direct reading instruments (DRI) are important instruments for gases, vapors, and aerosols. They perform both sampling and measurements to provide highly reliable screening results for basic characterization of exposure. DRIs can provide on-the-spot information and are ideal when immediate data is needed. Air contaminants are drawn into the instrument, analyzed, and the concentration displayed in a digital readout or color change. Depending on the type of DRI used, the results can provide instantaneous and short-term exposure estimates.

There are a wide range of DRIs manufactured by different companies, each designed for a specific purpose. The selection of the appropriate DRI will depend on the application for which it will be used. No single instrument can be used to measure all contaminants in the air. Most DRIs are designed to be used within a designated detection range. If the instrument can be calibrated, you will need to calibrate it before field use (according to manufacturer's instructions). DRIs are often separated into two groups:

- Instruments designed to measure **one or a group** of compounds.
- Instruments designed to measure a **broad range** of compounds.

The following are some common DRIs used to detect or identify hazardous materials and perform exposure assessments.

Combustible or multi-gas monitors

As indicated by the group name, these DRIs are used to measure combustible gases and vapors and the results are usually expressed as a percent lower explosive limit (LEL), which is the lower limit of flammability of a gas or vapor in a particular volume of air. Combustible gas monitors require calibration using a reference gas and the results must be interpreted using a correction graph/chart if measuring a gas different then the reference gas. These DRIs are based on one of two principles:

- The change in resistance of a conductor subjected to heat released by gas combustion.
- The change in electrical conductivity of a metallic oxide semiconductor with a combustible gas.

Some multi-gas monitors contain additional sensors that allow for the measurement of percent oxygen and ppm levels of toxic gases such as carbon monoxide and hydrogen sulfide simultaneously. An example of a common multiple gas monitor can be seen in figure 3–1.

Figure 3–1. Multiple Gas Monitor (courtesy raesystems.com).

Oxygen monitors

Oxygen monitors are used to determine the oxygen content of the air. Oxygen content becomes important when processes require individuals to enter enclosed spaces, such as in underground storage tanks or manholes, or where combustion or other processes may use up the available oxygen because an oxygen deficient or oxygen enriched atmosphere can be life-threatening. Monitoring oxygen content in these situations is important because an oxygen deficient or oxygen enriched atmosphere can be life-threatening. Air normally contains about 21 percent oxygen by volume; 16.9 percent oxygen is considered the minimum to support life, while an oxygen content >23 percent is considered excess oxygen and should be considered an extreme fire and explosion hazard. Certain processes can create excess oxygen such as oxyacetylene welding. Aside from the fact that an oxygen deficient or oxygen-enriched atmosphere can be life-threatening, another reason to measure oxygen content in the air is that some combustible gas meters require an adequate supply of oxygen. Having a combustible gas meter operate improperly is just as life threatening as having oxygen deficient or oxygen enriched atmospheres. Therefore, *always* monitor for oxygen content *first*.

Carbon monoxide monitors

Carbon monoxide (CO) monitors are battery-powered instruments which can measure carbon monoxide in the atmosphere. Because CO is odorless, tasteless, and colorless and can be deadly even in small concentrations, it is considered as one of the most dangerous toxic gases. Carbon monoxide is a contaminant of concern for areas such as vehicle maintenance shops and aerospace ground equipment maintenance shops. Most CO monitors measure carbon monoxide in the atmosphere in the range of 1–2,000 ppm by volume and feature both visible and audible alarms that alert the user if pre-set dangerous levels are reached.

Indoor air quality monitors

Indoor air quality (IAQ) monitors are used to assess the air quality in buildings. These monitors are designed and used to assess the quality of indoor air by measuring key indicators/parameters of indoor air quality such as temperature, relative humidity, and carbon dioxide (fig. 3–2).

Figure 3–2. IAQ monitors (courtesy tsa.com and quest.com).

Mercury vapor monitors

Mercury vapor monitors are for monitoring mercury vapors. A common monitor, the Jerome Mercury Vapor Analyzer, relies on the change in electrical conductivity of a gold foil when it comes into contact with mercury vapor. Occasionally, you may receive requests to survey dental suites. The mercury vapor monitor is also helpful in evaluating cleanup efforts of spilled mercury or reports of a broken mercury-containing thermometer.

Colorimetric tubes and badges

Direct reading colorimetric tubes and badges are designed to detect a specific chemical or several different chemicals (depending on the device). They use the reaction of an airborne contaminant with a color-producing agent to show a stain length or color change/intensity, which can then be read

directly to provide an instantaneous or estimated time-weighted average. Because they are relatively inexpensive, easy to use, and widely available for the detection of numerous chemicals, these are popular DRI devices, especially as a screening method. One disadvantage associated with these DRIs is the low level of accuracy, which can be as low as 25 percent.

Colorimetric tubes, also called detector tubes, (fig. 3–3) are designed for use with a specialized hand-held pump. Long-duration color detector tubes can be used with a personal air-sampling pump for on-the-spot TWA measurements.

Colorimetric badges detect airborne contaminants without drawing air into the device. When placed in a contaminated environment, air moves across the badge and the badge will change color depending on the contaminant concentration. The color change is compared against a color comparator to interpret results. For some passive badges, you can determine an estimated TWA if the workers' exposure time to the specific contaminant is known.

Figure 3–3. Colorimetric tubes and hand pump (courtesy draeger.com).

Particulate monitors

Direct reading particulate monitors (also known as particle counters) measure the concentration of particles in the air. Airborne particles (i.e., aerosols) may include solid (dust), liquid (mist), or condensed vapor from a high-temperature process such as combustion or welding (fume). A majority of particulate monitors are based on the light-scattering properties of the particulate matter and are sensitive to the size, shape, and refractive capability of the particles (fig. 3–4).

Figure 3–4. Particle counter.

Gas chromatographs/mass spectrometers

GC can separate mixtures of chemicals in an air stream into individual components. The basic function uses each component's chemical and physical properties to influence the ease or difficulty it has moving through a long narrow tube called a column. Coating the column with a material that

attracts or repels each chemical and heating the column influence the rate at which each chemical flows through the column. A MS identifies chemicals as they emerge from the column. It breaks each chemical into predictable ion fragment patterns, and much like fingerprints, can be compared to a library of known chemical ion fragmentation patterns to identify the chemical. A GC/MS is powerful because a trained technician can use it to separate components in a very low concentration of a chemical mixture and specifically identify each component. Certified laboratories generally use this method to analyze samples.

The INFICON HAPSITE®, shown in figure 3–5, is an example of this technology in a portable format. The instrument was designed for response situations where on-scene detection, identification, and quantification of chemical warfare agents and toxic industrial chemicals are required. The HAPSITE can detect the presence and identify numerous compounds by name, and provide concentration levels, giving you on-scene results within minutes that are often necessary when having to make critical risk management decisions.

Figure 3–5. HAPSITE® GC/MS.

DRIs are only available for specific substances and are rarely sensitive enough to measure the lower concentrations of a contaminant which may be considered health hazards (e.g., parts of contaminant per billion parts of air). In order to detect the lower concentrations, air samples must be collected to be analyzed in a laboratory.

Air sample collection devices for later laboratory analysis

The most common devices used for air sample collection include active sampling pumps and passive sampling devices. Both are discussed in more detail below.

Active sampling pumps

Active air sampling pumps (fig. 3–6) draw air through a sampling train (collection device/media, tubing, air flow meter, and suction pump) to collect the contaminant on a filter or sorbent material. Most of the pumps you will use are light-weight and relatively quiet, operate using rechargeable batteries and can be easily attached to a worker. Some high flow pumps that are designed for area sampling are much larger and heavier.

Figure 3–6. Active sampling pumps

To select the correct type of pump you must consider the required flow rate and the pump's suitability for use in a potentially hazardous or flammable environment. Air sampling devices that are to be used in potentially explosive environments must be identified as *intrinsically safe*. [4] Air sampling pumps are generally available in the following airflow ranges:

- Low-flow pumps (0.05 – 0.5 liters per minute)—used for solid sorbent tube sampling.
- High-flow pumps (0.5 – 5.0 liters per minute)—used for filter, cyclone, and impinge sampling.
- Heavy-duty high-flow pumps (2.0 – 30 liters per minute)—used for area sampling.

Passive sampling devices

Passive sampling devices are also referred to as passive monitors or diffusive samplers. Passive samplers collect contaminants through the process of diffusion, which allow you to conduct personal or area sampling without having to use a sampling pump. Diffusion is the movement of air contaminant molecules from an area of high concentration to an area of low concentration. If the airborne concentration of a gas or vapor is greater than the concentration inside the passive monitor, the gas or vapor molecules will diffuse into the monitor and be collected by a sorbent material. As the sorbent adsorbs the gas or vapor, the concentration gradient is maintained so that contaminants will continue to be collected. [2]

Figure 3–7. Passive air monitor. [3]

Some passive monitors are designed to collect a broad range of compounds, while others collect a single chemical or family of chemicals. Figure 3–7 is an example of a passive air monitor. Passive monitors are inexpensive, small, lightweight, and easy to use. Monitoring starts when you clip the device on the worker or in the area and remove the device's cover. Some passive monitors are direct

reading based on colorimetric techniques while others require laboratory analysis. Each gas or vapor being sampled has a specific diffusion coefficient that determines the effective air sampling rate. Even though most commercially available passive monitors meet or exceed NIOSH accuracy requirements, you need to ensure the monitors you select/use meet these requirements.

Evacuated canisters

An evacuated stainless steel canister that has had the internal surfaces specially treated using a Summa process is called a Summa canister (fig. 3–8). This process (known as passivation) combines an electro polishing step with chemical deactivation to produce a surface that is chemically inert. Summa canisters are often used to sample for VOC's in the environment. This technique has also been applied to other situations, such as indoor air quality problems and other situations involving low levels of volatile contaminants. The evacuated canisters offer a number of advantages for environmental sampling, including elimination of the need for a sampling pump and avoidance of potential laboratory analytical collection and recovery issues that sorbent media are susceptible to.

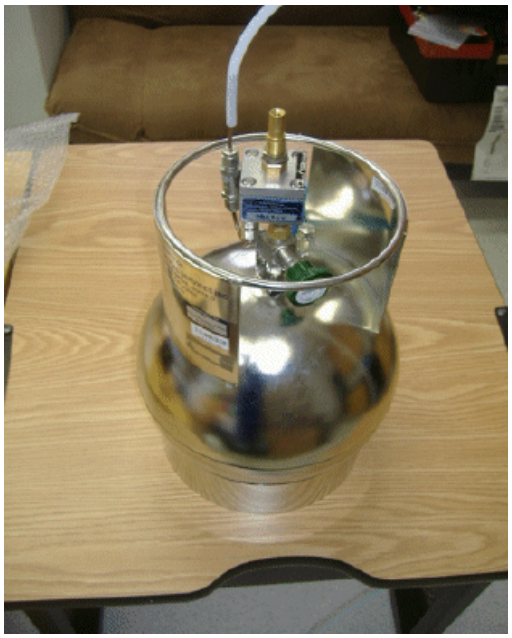


Figure 3–8. Summa canister (epa.gov).

422. Air sample collection devices and media

As mentioned earlier, when using air sampling devices to collect contaminants for analysis in a laboratory, the contaminant is collected on sampling media. Air sampling media refers to devices or material (i.e., filter or sorbent material) that retains the airborne contaminants for later analysis. Selecting the correct sampling media is critical to the air sampling process. The type of media is determined by the chemical constituent(s) being sampled and the physical state of the chemical.

Gases and vapors

The absorption technique pulls air through an absorption liquid where gases or vapors are removed and contained in the liquid for later analysis. The absorption liquid can be highly soluble and nonreactive with the gas or vapor or it can contain a reactive reagent. Absorption devices include gas wash bottles, spiral absorbers and fritted bubblers. [1]

The most simple absorption device is the gas wash bottle, which forces air through a nozzle into the absorbing solution. The most commonly used gas wash bottle is the midget impinger (fig. 3–9). Impingers are glass tubes designed to collect airborne contaminants by forcing the sampled air through an absorbing liquid. Spiral absorbers force air to follow a spiral path through the absorption

liquid, increasing the contact time, which increases the amount of chemical being absorbed. Bubblers are similar to impingers except that they break incoming air into smaller bubbles to improve the collection efficiency of the vapors. [4]

You must take care when handling these devices. Because they use liquids and they are normally placed inside a holster that is attached to the person's shirt collar, spilling or suction through the pump tubing can result in loss of the sample. The use of an empty impinger (connected to the sampling train) or a spill proof impinger can minimize this problem. Once you complete your sampling, you must be careful when transferring the liquid to a suitable container for shipping.

Figure 3–9. Absorption sampling device (standard midget impinger).

Adsorption is used for air sampling insoluble or nonreactive substances using tubes filled with granular sorbent such as charcoal or silica gel. [1] Figures 3–9 and 3–10 are examples of this type of sample media. The gas or vapor is adsorbed (collected or retained) on the surface of the sorbent material. The sample media is then sent to a laboratory for analysis.

Activated charcoal is the most widely used solid sorbent for organic vapor sampling and the sample media is typically referred to as a charcoal tube. The charcoal provides a large adsorptive surface area and has the ability to adsorb a large range of organic vapors. A standard charcoal tube is divided into two sections. The tube contains 100 milligrams (mg) of charcoal in the front and 50 mg in a backup section. The backup section is provided in case contaminant breaks through the front section. If the backup section contains a mass greater than 10 percent of the mass of the front section, then breakthrough has occurred.

> ***Breakthrough*** *describes a condition in which the mass of a collected gas or vapor in the backup section is greater than 10 percent of the mass in the front section. This means a significant portion of the contaminant sampled may not have been collected and/or the tube was overloaded.* [1]

When breakthrough occurs, the sample results are considered invalid and you will need to repeat the sampling. To minimize breakthrough, ensure you do not exceed the maximum sampling volume or recommended flow rates since these parameters are designed to prevent breakthrough. [1]

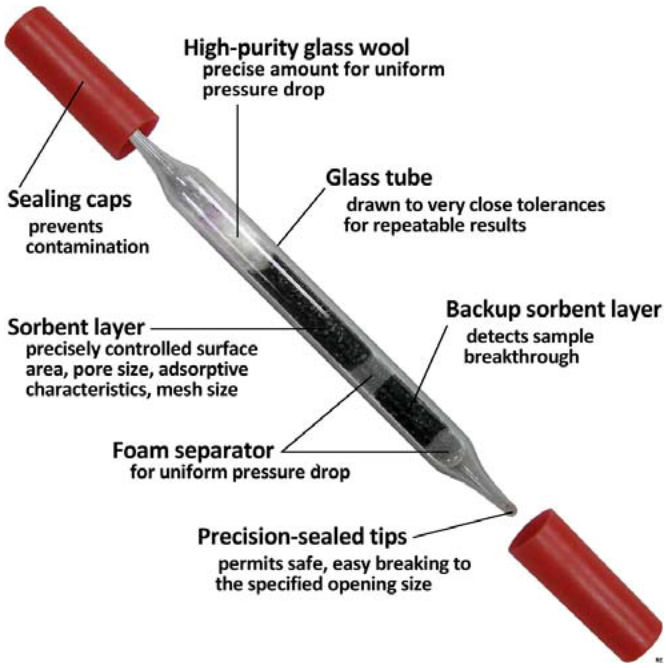


Figure 3–10. Solid sorbent tube.

Another common air sample adsorption media used is silica gel. Silica gel tubes look very similar to charcoal tubes. Silica gel tubes are used to sample for gases and vapors that cannot be efficiently collected or extracted from activated charcoal. They are constructed in the same manner as charcoal tubes except that an amorphous form of silica is used as the adsorbent material. Other solid sorbent materials with chemical coatings have also been developed to sample for reactive gases and vapors, to include XAD–2, Tenax-GC, Ambersorb, and Chromosorb tubes. [1]

Aerosols

The term *aerosol* is often referred to as the droplet spray produced from an aerosol can containing a liquid and compressed gas propellant, but in the scientific world an aerosol is an assemblage of solid or liquid particles dispersed in a gaseous medium. In the context of OEH assessments the gaseous medium is almost always air. [2] Because of that, particulate matter suspended in air is known as an aerosol. [5] Solid particulates include dusts, fumes, smoke and fibers; liquid particulates include mists and fogs.

Aerosol particles can enter the body through the skin, eyes, and gastrointestinal system, but generally the most sensitive route of entry into the body is through the respiratory system. [6] There are a variety of sampling media available based on contaminant and particulate size. Most aerosols are sampled using filters, electrostatic precipitators, cyclones, impactors, or impingers, each of which is discussed in more detail below.

Filters

Filters are the most common media for sampling particulates. The filter is normally contained in a collection device, typically a cassette, and attached to a sampling pump. As air is drawn through the filter by the pump, the filter collects or traps the airborne particulates on or in the filter.

Filter media

The type of filter media used for sampling is determined by the sampling and analytical method for the contaminant of concern. There are several types of filter media including:

- Glass fiber (GF).
- Mixed cellulose ester (MCE) fiber.
- PVC filters.

MCE filters, for example, are most commonly used when sampling metal dusts and fumes, and for situations where the total weight of a particulate is of concern, PVC filters are used because they can be weighed easily by a laboratory to determine the airborne concentration.

Cassettes

As mentioned above, cassettes are often used to hold particulate filters in place. A common particulate filter cassette is the 37-mm diameter cassette, supported with a cellulose backup pad. Another common cassette is the one used for asbestos sampling. Asbestos sample cassettes contain a 25-mm filter and the cassette has a 50-mm conductive extension cowl. Cassettes may be used open-faced or close-faced.

- *Open-faced*–a three-piece cassette (top, middle spacer and bottom) is needed because the top (cassette inlet) section of the cassette is removed during the sampling and the middle spacer of the cassette is used to hold the filter in place.
- *Close-faced*–only the small cassette end plugs are removed to allow airflow through the cassette during sampling. A two- or three-piece cassette may be used since the top section of the cassette is *not* removed (fig. 3–11).

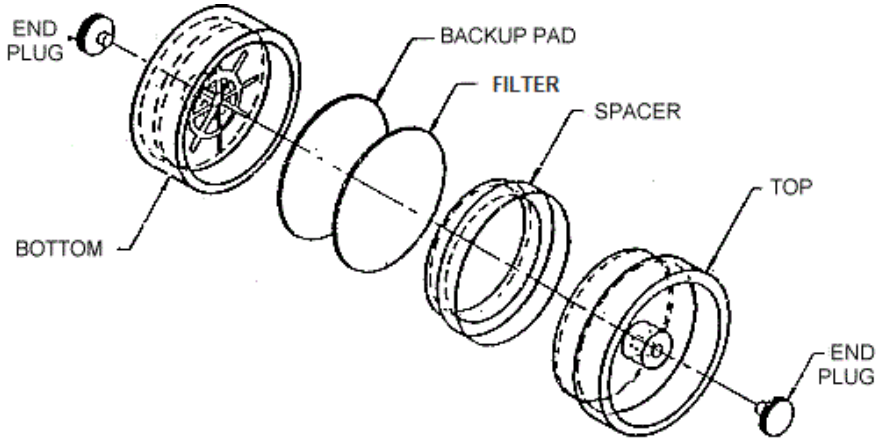


Figure 3–11. Membrane filter and cassette (osha.gov).

It is very important to pay attention to the recommended sampling method to determine the type of cassette needed and whether to sample using an open-faced or closed-face configuration. For example, asbestos samples are collected using an open-face approach because an even distribution of airborne fibers on the filter is required for microscopic analysis, and the 25 mm filter reduces the number of asbestos fibers attracted to the sides of the cassette by static electricity.

Size-selective aerosol sampling

People are not typically exposed to single particles, but rather to large masses of particles suspended in air, commonly called particle clouds. These particle clouds may be monodisperse (fall within a very narrow size range) or polydisperse (can contain a wide range of particle sizes). The majority of occupational aerosol-generating activities make polydisperse particle clouds. [1]

Particle size determines the deposition site within the human body and the resulting health effect. The smaller the particle, the deeper it will penetrate within the respiratory system ultimately reaching the gas-exchange region of the lung. Therefore, exposure limits and sampling methods have historically been issued for different particle sizes. It is important that health and safety professionals choose a sampling method that is appropriate for (a) the particulate size fraction and (b) the regulatory standard or guideline being addressed. [7]

Occupational health and safety professionals have traditionally sampled for two particulate size fractions: *total* or *respirable* because OSHA uses these size fractions for regulatory standards and compliance monitoring.

1. Total—this includes both respirable and non-respirable particles that are collected onto a closed-face 37-mm filter cassette loaded with the appropriate filter. Studies have shown that this sampling method collects fewer particulates than *inhalable* samplers that are described below. [3]
2. Respirable—this includes only the smaller particles than can penetrate to the alveolar or gas-exchange region of the lung.

Several agencies including ACGIH® have adopted the following new size-selective criteria for particulates (see fig. 3–12) to better assess exposures and to provide consistency in exposure measurements [7]:

- *Inhalable*—these include particles that are hazardous when deposited anywhere in the respiratory system, including the nose and mouth.
- *Thoracic*—these include particles that are hazardous when deposited within the lung airways and the gas-exchange region
- *Respirable*—these include particles that are hazardous when deposited within the gas-exchange (alveolar) region of the lung.

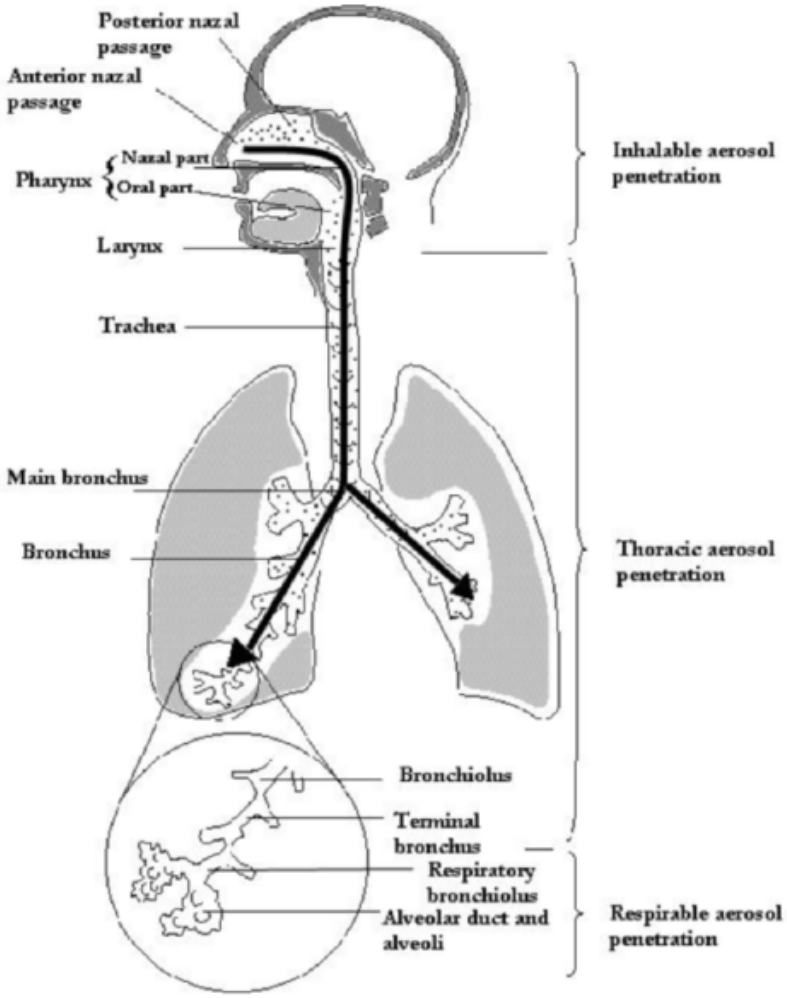


Figure 3–12. Respirable, Thoracic, and Inhalable Particulates. [3]

Sampling protocols that meet precise sizing requirements are available to collect the particles in all of these size fractions and are discussed in the paragraphs that follow.

Institute of Occupational Medicine inhalable dust sampler

The Institute of Occupational Medicine (IOM) sampler was the first inhalable sampler and is the most commonly used at this time. [7] It more closely simulates the particle collection behavior of the nose and mouth than the traditional closed-face 37-mm cassette sample method. [6] The IOM sampler allows the collection of many different dust fractions, either individually, or at the same time. The IOM Sampler consists of a sampling head, reusable cassette, and 25-mm filter appropriate for the contaminant of interest. It is connected to a pump calibrated to a flow rate of 2 liters (L)/min. [3] Follow the manufacturer's recommendations for specific sampler assembly, use, shipping and handling. A typical IOM assembly is shown in figure 3–13 below.

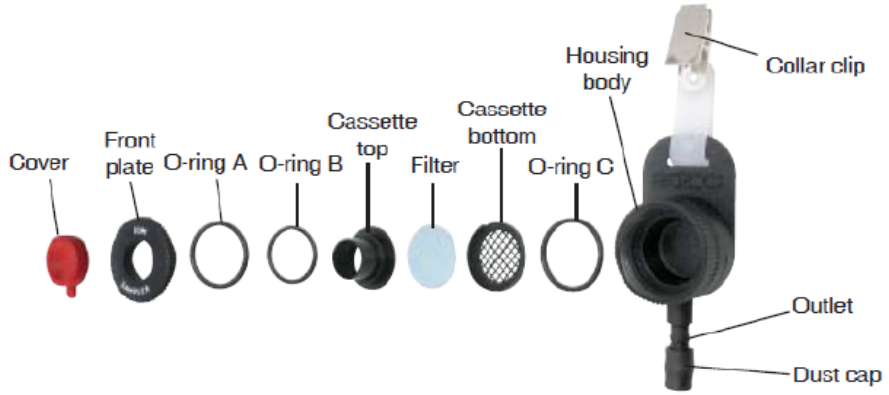


Figure 3–13. IOM Sampler Assembly. [3]

Button inhalable dust sampler

The Button Sampler (fig. 3–14) is also for inhalable particulates, and is similar in design to the IOM. The Button Sampler, however, features a screen over the inlet to keep large, non-inhalable particles from being projected onto the filter by blasting operations or other workplace activities. A 25-mm filter is placed onto a stainless steel support screen for sample collection at 4 L/min. [7]

Figure 3–14. Button Sampler. [7]

Cyclones

Cyclones are used to collect respirable sized particles. Cyclones allow for separation of particles by size. Respirable particles are retained in the lung. Looking at Figure 3–15, the cyclone works by taking in air and separating the larger particles from the smaller ones by using a centrifugal motion of air inside the device. Before you use a cyclone, you must install a filter cassette and connect the cyclone to an air sampling pump.

Use of a 10 cm nylon or aluminum cyclone is currently the most common method of collecting respirable dust samples. [1] Once the pump is turned on, the cyclone draws air through a small orifice. As the air is drawn inside, the cyclone separates the larger particulates that then fall out of the bottom of the cyclone while the lighter ones are drawn upward onto the filter. After sampling is

completed, the filter is usually sent to a laboratory where it is analyzed or weighed to determine how much airborne material has been collected.

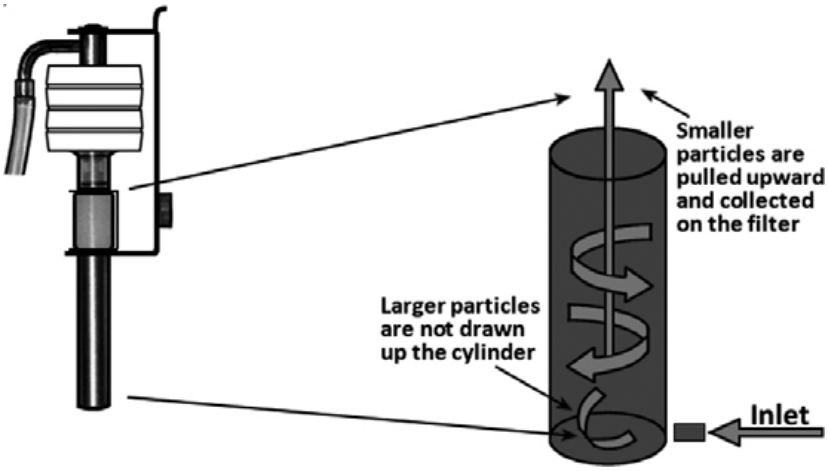


Figure 3–15. Cyclone theory of operation.

Inertial impactors

Inertial impactors collect particles by impacting them onto a collection media (fig. 3–16). They are used to sample particles of a specific aerodynamic diameter (e.g., $PM_{2.5}$) or determine particle size distribution. For example, the mini-cascade impactor is constructed with a series of stages, each of which is calibrated to collect particles of a certain aerodynamic size range. [1] The deployable particulate sampler (DPS) is another example of an inertial impactor.

Inertial impactors are devices used to sample specific sized particles. The impactor is attached to an air pump that pulls a stream of air through a nozzle and impacts upon a collection plate. Particulates in the aerosol stream having large enough inertia will impact the collection plate while the other particles will follow the airflow out of the impaction region.

Figure 3–16. Inertial impactor collection device used with the DPS.

Other aerosol sample media

There are two other aerosol sample media we will discuss: electrostatic precipitators and impingers.

Electrostatic precipitators

Electrostatic precipitators use an electric charge to remove particulates from the air being sampled. As particulates pass through a high-voltage electric field, they acquire a charge and are attracted to an oppositely charged electrode. Electrostatic precipitators are used when the required sample volume is large, high collection efficiency is required for very small particles (such as fumes), there is a potential of filter clogging, or high temperature airstreams must be sampled.

Impingers

Earlier we discussed how impingers are used to samples gases and vapors, but impingers can also be used for collecting particulates such as bioaerosols. Impingers use the same particle collection method

as the inertial impactor, except the contaminants, if you recall, are collected in liquid (usually water). Air is drawn at high velocity into the liquid-filled flask through a glass nozzle or jet. The airborne particulates strike the bottom of the impinger, lose their velocity, and are collected in the liquid, which is sent off to a laboratory for analysis.

423. Establishing air sampling strategies

An air sampling strategy is an overall plan for the sampling effort. This plan considers the sampling principles previously discussed in this volume. A sampling strategy answers the *who, what, when, where, and how* of the sampling event. A definitive strategy will maximize the likelihood of the sampling efforts generating accurate, meaningful data.

It creates a sampling framework by answering relevant questions regarding the situation, goals and challenges of the task. At a minimum, the following questions should be applied to an air-sampling situation. These considerations will provide valuable components from which a strong sampling strategy structure can be built.

Air sampling strategies for occupational exposures

A comprehensive sampling strategy should answer the following questions:

- What is the objective?
- What are you sampling?
- What type of sample will you collect?
- Where are you sampling?
- Who are you sampling?
- When should you sample?
- How long should you sample?
- How many samples should you collect?

What is the objective?

What is the purpose of the sampling event? Clearly define the objective for sample collection.

- Health risk assessment—samples are collected to determine whether the exposure is acceptable or unacceptable.
- Evaluation of controls—samples are collected to confirm that a control (e.g., ventilation) is adequate and operating correctly.
- Compliance—AF and Federal regulations may mandate sampling for certain chemicals.

What are you sampling?

In most cases, routine shop assessments will drive health risk assessment for specific chemicals of concern. [8] When selecting the chemicals to sample consider toxicity, task duration and frequency, exposure routes, and applicable OELs. There are Federal regulations that require periodic monitoring for certain hazardous chemicals (i.e., OSHA expanded standards).

What type of sample will you collect?

- Grab sample or integrated sample?
- Area sample or personal breathing zone sample?

The choice of collection methods usually depends on the goal for sampling, type of contaminant, availability of equipment, and recommended sampling and analytical method.

One of the best resources for you to use to determine the correct sampling and analytical method for airborne contaminants is the National Institute of Occupational Safety and Health Manual of

Analytical Methods (NMAM). This reference guide is available on the CDC Website. The NMAM is organized in alphabetical order; therefore, it is relatively easy to use. First, you will locate the chemical of concern. Once you have located the chemical and method number you will be provided with all of the information you will need to set up your air sampling equipment properly: sample media type, minimum and maximum sample volume, and minimum and maximum sample flow rate.

Sampling locations for air sampling are divided into two kinds: area and personal. Area air samples measure airborne exposures not of a particular worker, but rather the air concentration of a particular substance(s) in a given area at a given point of time. Area sampling is not used for compliance sampling in occupational settings for several reasons.

1. The conditions at a fixed or general location may not be the same as those experienced by the worker.
2. They do not take into account the wide variations that normally result from a worker's movement and the effect of air currents.
3. In addition, there are no specific occupational exposure standards for area sampling; standards are based on worker exposures.

Although area sampling is not the preferred method in some applications, area air samples can be extremely useful for performing hazard identification and health hazard control evaluation. For example, during emergency management (EM) settings you will use area air sampling to identify and quantify airborne CBRN threats, and then use that information along with other tools at your disposal to predict health impact and recommend controls. Area sampling is also useful to determine the source of a contaminant of concern or to evaluate effectiveness of existing controls.

Personal air samples, which are collected in a person's breathing zone, are much more accurate at quantifying someone's exposure. In theory, this type of sampling reflects a person's actual exposure. This is because these samples measure the air as close as possible in an individual's breathing zone, which is the area within a 6–9 inch radius in front of the mouth and nose (fig. 3–17). Breathing zone sampling is performed over a specific time, often an 8-hour work shift or 15-minute period to ensure compliance with OSHA permissible exposure levels or other approved OEL.

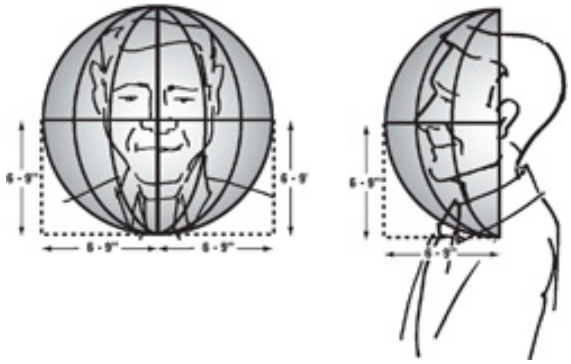


Figure 3–17. Breathing zone (osha.gov.)

Where are you sampling?

The location of sampling is dictated by the circumstances of the process or event, the information needed, and more than one sample location may be needed. For example, during a radiological incident response air sampling will be needed upwind from the incident site, at the incident site, downwind from the incident site, at the decontamination area, and possibly other areas. Among other things, wind direction and speed will influence sample location. In contrast, in an industrial setting you may only be interested in sampling a painting process performed in the same location every time.

Who are you sampling?

Generally, the person at risk of receiving the maximum exposure is sampled when performing initial assessments or assessing compliance with a health standard. Results over the action level indicate more extensive sampling is needed. Action level is a value typically one-half any OEL-TWA. It may be necessary to select several people who are similarly exposed to represent the worst-case exposures. This can improve your chances for accurate data when the similar exposure group is large.

In your first search for the maximum risk worker, you may not have enough information and your choice may be a rough one. Without prior air sampling, you must rely on a comparison of estimated exposure levels for each operation. In general, it is best to choose the worker who is closest to the point of contaminant generation—the person working with the material. People further away are likely to have less exposure since the chemical is diluted and dispersed further away. However, be sure to observe the operation carefully since the maximum risk worker is not always the one closest to the point of contaminant release. A worker in another part of the room who has nothing to do with this aspect of the operation may receive the highest exposure. Air movements within a room can carry contaminants to others in the room especially in operations involving heated materials.

You can observe disturbances that air movement causes with contaminants such as smoke or welding fumes. For others, smoke tubes or similar methods can show the air patterns. Always check the following major factors affecting airflow patterns:

- Ventilation inlets and outlets.
- Location and size of windows and doors.
- Size and shape of work area.
- Barriers near the operation such as partitions or lockers.

Some workers constantly move from one part of a process to another. A mobile worker may be absent when the highest concentrations are being released. For instance with some automatic machines, the worker spends a few minutes preparing, setting, or turning on the machine and then leaves. Once again, careful observation is needed.

It is possible for two workers doing an identical task using the same materials to have very different exposures. Individual methods of doing a particular job usually vary. Some people are naturally neat and careful in what they do. Others do things more sloppily, do not follow operating instructions, and may be in a hurry or simply use a different technique. You may find that a person using a heated solvent vat follows the recommended procedure and uses the minimum heat required. Another person may find that a higher temperature setting gives faster results but it also results in higher contaminant concentrations in the air. One worker may apply more pressure when using a pneumatic sander. Another may spray paint by holding the nozzle farther from the surface. That technique could increase the overspray. All of these factors must be considered when selecting the maximum risk worker.

You may find instances in which you cannot accurately determine a maximum risk worker. A shop may have almost all workers doing very similar jobs with exposures that are estimated to be the same. These situations call for employing a random sampling technique.

When should you sample?

When developing a strategy, do you think you should consider the *season*? We all know temperatures vary with the seasons. In occupational settings, workers are more likely to open doors and windows in warmer months to ventilate workplaces diluting contaminants. Samples collected in the summer may not be representative of exposures in the winter when windows and doors are kept closed. If an assessment of a worst-case exposure is your goal, sampling should be done when the doors are closed.

Time of day can also be a factor. Consider a chemical warfare agent delivered to your base that is located in a region that has cold mornings and hot afternoons. Volatile chemicals vaporize more rapidly in warmer temperatures. The concentration of vapors will increase with temperature. There

could be a significant difference in airborne concentrations in the morning as opposed to the afternoon. Is this important when considering health impact and individual protective equipment (IPE) recommendations?

Finally, many industrial shops work several shifts per day. The industrial processes conducted by each shift can also vary, and therefore, airborne concentrations of contaminants as well. For example, aircraft fuel cell replacement generally requires purging, depuddling of excess fuel, fuel cell foam removal, fuel bladder removal, maybe some repairs, and then replacing everything. It can take several days to complete the process, each work shift performing their part of the process and airborne concentrations of fuel vapors will vary with each part of the process.

How long should you sample?

Minimum sampling time is often determined by the length of time needed to collect a sufficient volume of air to assure analytical accuracy. If you do not collect at least this amount the sample will not be valid. The minimum volume also allows the laboratory to analyze the sample to concentrations below the OEL. This is called the limit of detection (LOD) and is the smallest amount of chemical the laboratory can detect. The NMAM provides minimum and maximum sample volume to guide you. The LOD is built into the NMAM recommendations, so you should meet the LOD when sampling according to their guidelines. If you collect less than the minimum air volume, you cannot be certain an overexposure has not occurred just because no contaminant was detected.

The maximum sample volume is necessary to prevent breakthrough when sampling for gases and vapors or overloading the filter when sampling for particulates. Overloading invalidates sample results. Typically the maximum sample volume is set to handle up to two times the OEL of a single contaminant.

The OELs for the contaminant of concern can also determine the length of your sampling event. For example, when your interest is assessing a person's short term exposure to a contaminant of concern that has a STEL, the length of sampling would be 15 minutes. In contrast, if your interest is assessing a person's 8-hour exposure, the length of sampling would be 8 hours. That is not to say you would collect one sample during the entire 8-hour period. You may collect all 8 hours on one or several samples.

In some instances, sample duration will be influenced by the situation, for example, grab samples taken with a DRI. For most instruments, sample length is a matter of how long it takes the meter to analyze the contaminant and respond with a measurement. The information below discusses principles of sample length and combinations of samples in more detail. You should refer to Figure 3–18 as we go through the discussion.

Full-period single sample

The strict NIOSH definition of this strategy is a sample taken over the full period of the chemical standard. For 8-hour OELs, the period is 8 hours while for ceiling and STEL sampling, 15 minutes is usually used. For our purposes, we must modify the definition to coincide with the OSHA term, full-shift sampling. Our full period sample now becomes one that is taken over the entire work shift with an allowable 1 hour that can be subtracted for transportation, equipment set up, and similar tasks (examples of various full period single sampling are shown in fig. 3–18). This would be 7 hours sampling of an 8-hour shift or 11 hours out of a 12-hour shift.

When using a single sample for a full 8-hour period, you have the benefits of an automatic time weighted average and less depletion of your sampling supplies. However, there are problems with this method. A single sample does not provide the best statistical data and periods of fluctuating concentrations cannot be determined. Also, you may not have a sampling device for some chemicals that will allow you to sample the entire shift. The problem can be as simple as getting too much of the contaminant in the sampling device until some begins to pass through and is lost.

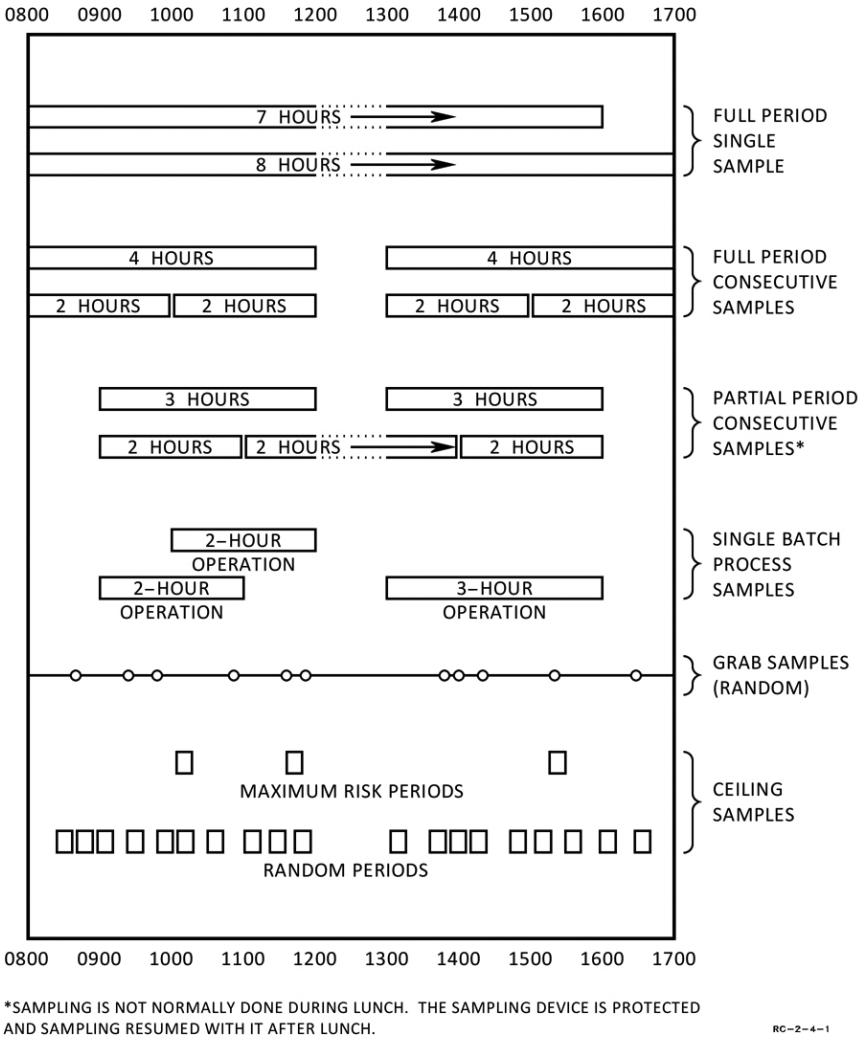


Figure 3–18. Principles of sample length and combinations of samples.

Full-period consecutive samples

Most of the problems previously discussed can be eliminate by taking two or more samples over the work shift. Under this concept, very reliable data can be obtained by using eight 1-hour samples for each worker. This is more expensive in terms of greater numbers of sampling devices and analyses, so a compromise is usually made. From a standpoint of a balance between cost and accuracy, the best strategy is generally considered to be the use of two consecutive samples covering the full shift (about 4 hours each for an 8-hour shift). Although taking more than two samples during the shift yields better confidence limits, this increased benefit may not be significant compared to the costs involved. Full-period consecutive samples are appropriate for compliance sampling.

Partial-period consecutive samples

As the name implies, this type of sampling does not cover the full shift as defined earlier. Partial period consecutive sampling consists of one or more individual samples that cover at least 70 to 80 percent of the shift. For best results you should always try for a minimum of 6 hours out of the period. Avoid this type of sampling whenever possible and rely on full-period samples. It may seem foolish to sample clean air during the periods before and after a task that causes an exposure. This method, however, is the most reliable way to show that exposures from other sources did not occur. Indeed the air may not be clean during the other periods because of residual contamination. Partial period sampling is not a valid for demonstrating compliance.

Single-batch process samples

This involves taking one or more samples that cover only the period of a specific operation. Many Air Force operations are sampled in this way because they do not last very long. There are even more problems with single-batch process samples than with the method just discussed. Single-batch process samples are useful tools for screening sampling. Again, unless the worker leaves the area, BE cannot assume zero exposure during the periods when task is not being accomplished. These samples are not useful for demonstrating compliance.

Grab samples

Recall that a grab sample is an instantaneous sample taken over a short time that represents air quality only at the time of sampling. Normally no TWA can be calculated unless many samples are collected over the span of a work shift. A high number of samples can more readily characterize the exposures, but this is not a good method for compliance sampling.

Ceiling samples

The procedures used in sampling for compliance with ceiling values also apply to STELs and the ceiling values described in federal regulations. Although true ceiling limits are not exceeded instantaneously, a 15-minute period is generally sampled to test compliance due to analytical limitations. This can be a single sample or a series of consecutive samples totaling 15 minutes. For beryllium, formaldehyde, and carbon disulfide, use a period in excess of 30 minutes since this is the period specified for their excursions.

You should sample a minimum of three 15-minute periods at times of maximum expected concentration during the shift. This will probably require a lot of observation. The period of highest concentration is taken as the best estimate of the worker's upper exposure for that shift. You can better determine whether your choice of a maximum concentration period is correct by taking separate 30-minute samples before and after. If you have observed accurately and your actual ceiling sample shows higher concentrations than both the before and after sample, you have probably chosen correctly. You can use the subgroup size table to find out the required number of sampling intervals. For example, in an 8-hour shift, there is a total of 16 intervals of 30 minutes each, 32 intervals of 15 minutes each, 48 intervals of 10 minutes each, and 96 intervals of 5 minutes each. The number of intervals you would be required to sample from an 8-hour shift is:

- 13 of the 30-minute intervals.
- 19 of the 15-minute intervals.
- 21 of the 10-minute intervals.
- 28 of the 5-minute (or less) intervals.

After finding the number of intervals to sample, select them at random using the same technique for random grab sampling. You can see from the number of random samples needed that every effort should be made to find the periods of maximum exposure so that you can avoid random sampling.

How many samples to collect

The number of samples to be taken depends on the purpose for sampling and the tasks being performed. Time and budget constraints and the availability of supplies can also affect how many samples you can collect. Experience and statistical analysis of results can help you make this decision.

Recall that AFMAN 48–146 dictates that a minimum of three random screening samples should be collected and, depending on the results, additional random samples may be required to have an adequate number of samples to determine whether an exposure is acceptable. [9] At least 6 samples are required for statistical analysis of air sample results in DOEHRS.

Air sampling strategy for exposures to environmental hazards

Environmental health air samples are collected to assess health risk from exposure to ambient air quality (e.g., particulate matter from sand storms, radon gas intrusion into buildings, etc.), off-site and on-site industrial air emissions affecting personnel on base, or other airborne OEH threat impacting non-occupationally exposed personnel. [3, 10] It is recommended that sampling strategies for environmental health exposures follow the EPA DQO process. [3]

Step 1—State the problem

Use the conceptual site model you have created during the OEHSA process to state the problem and define a clear objective.

- What is the reason the exposure assessment sampling?
- What health risks are associated with the exposure pathway?

For the purpose of this example, assume that a complete exposure pathway has been identified. An oil well drilling site located 1 km away, and upwind, regularly operates a gas flare. Wind carries the black smoky emissions directly into base camp several times per day. The oil drill gas flare emissions may pose an acute or chronic health risk to site personnel. Consider the following CSM:

Source	Environ-mental Media	Health Threat	Route of Exposure	Population At Risk	Existing Controls	Freq-uency/ Duration	Severity	Prob-ability	Risk
Oil drill gas flare (off-site industrial operation)	Air	Particulate matter, Benzene	Inhalation	All site personnel working outdoors	None	7 days/week (wk) 24 hrs/day	Marginal	Occasional	Moderate

- The objective is to determine whether drilling emissions present a health risk to military personnel on site.

Step 2—Identify the decision

- State the question you intend to answer.

For example, your question may be: “Does the OEH threat pose an acute or latent health risk to the PAR?”

- What do you intend to do with the analytical sampling results?

Consider potential actions that may be taken. For example, if the exposure exceeds MEGs, brief the commander and arrange a meeting with the oil well site manager.

Step 3—Identify information inputs

- Where and how do you take the samples to assess exposure point concentrations?
- What type of samples (e.g., integrated or grab; active sampling or summa canister)

These are largely defined by the exposure pathway. Consider the environmental media, route of exposure (i.e., inhalation), and the PAR. Choose representative exposure points, for example, the locations of personnel who work outdoors.

- What OELs will you use?

For deployed environmental exposures you might consider using MEGs as your OEL.

	Short-term MEG	Long-term MEG
Benzene	8-hr negligible (29 mg/m^3)	1-year negligible (0.055 mg/m^3)
$PM_{2.5}$	24-hr marginal (250 micrograms per cubic meter (µg/m^3)	1-year marginal (65 µg/m^3)

Step 4—Define the study boundaries

- How many samples are needed?
- When will samples be collected?
- What are the spatial boundaries for sampling?

Step 5—Develop the analytical approach

- Develop the decision rule. Consider what options are available if an OEL is exceeded.

If the average exposure to benzene exceeds ½ the OEL, ***then*** brief commander and recommend medical surveillance, ***else*** continue periodic air monitoring.

If the acute exposure to $PM_{2.5}$ exceeds the OEL, ***then*** move operations indoors, ***else*** continue periodic monitoring.

Step 6—Determine performance criteria

Determine the desired confidence level in your results before collecting samples (e.g., 99, 95, or 90 percent) confident that a correct decision is being made). Identify the sampling and analytical error of the sampling method and laboratory analysis.

Step 7—Develop the detailed sampling plan

Gather all the information from your strategy into a sampling plan. The following table is an example of a potential air-sampling plan based on example scenario.

Air Sampling Plan					
OEH Threat	**Sampling Device / Media**	**Analysis Method**	**Sampling Rate**	**Sampling Duration**	**Sampling Frequency**
$PM_{2.5}$	*DPS with 47 mm quartz filter*	*Gravimetric*	*10 liters per min*	*24 hours*	*Daily*
Rationale: Monitor for 14 consecutive days to determine typical ambient air exposure concentrations associated with the normal ambient conditions and emissions from the oil well site.					
Procedures: Place one DPS at the central location identified by the geospatial coordinates identified below and one DPS at the boundary location identified by the geospatial coordinates identified below. Sampling at each location will be accomplished at approximately 4 to 6 feet above ground level to account for the breathing zone. Samplers will be placed at a distance of at least twice the height from any on-site/off-site obstruction (buildings, trees, etc.), to mitigate boundary layer effects. Filters will be changed-out every 24 hours.					

OEH Threat	Sampling Device / Media	Analysis Method	Sampling Rate	Sampling Duration	Sampling Frequency
Benzene	*Deployable cartridge sampler (DCS) with XAD cartridge*	*EPA TO–17*	*10 liters per min*	*24 hours*	*Daily*
Rationale: Monitor for 14 consecutive days to determine typical ambient air exposure concentrations associated with the normal ambient conditions and emissions from the oil well site. Procedures: Place one DCS at the central location identified by the geospatial coordinates identified below and one DCS at the boundary location identified by the geospatial coordinates identified below. Sampling at each location will be accomplished at approximately 4 to 6 feet above the ground level to account for the breathing zone. Samplers will be placed at a distance of at least twice the height from any on-site/off-site obstruction (buildings, trees, etc.), to mitigate boundary layer effects. Samples will be collected via preconditioned XAD cartridges obtained from the USAPHC laboratory. Cartridges will be changed-out every 8 hours.					
Sampling Locations Coordinates					
1. Center of site	32° 4’ 8.84” N	20° 15’ 44.56” E			
2. Boundary location nearest oil well	32° 4’ 42.65” N	20° 15’ 18.66” E			
Rationale: Sampling from the center of the site will be representative of typical ambient conditions. The sampling point nearest the oil well will take into account worst case conditions when wind direction causes the site to be downwind from the plant.					
QA/QC Requirements					
The DPS and DCS must be calibrated pre- and post-sampling in accordance with manufacturer’s specifications and sampling and analytical methods. Trip blanks and collocated samples: PM2.5 samples: Submit one trip blank for each 10 field samples taken, or fraction thereof. Benzene samples: Submit trip blank and duplicate sample for each 10 field samples taken.					
Occupational and Environmental Exposure Limits (OEL)					
OEH Threat	**MEGs**				
$PM_{2.5}$	24-hr marginal: 250 µg/m^3	1-year marginal: 65 µg/m^3			
Benzene	8-hr negligible: 29 mg/m^3	1-year negligible: 0.055 mg/m^3			

After developing the sampling strategy but *before* sampling, prepare the equipment. Preparation includes such things as an operational check and calibrating. Methods of calibration will vary with the type of sampling equipment. We’ll begin our discussion of air sample collection with DRIs.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

420. Types of air samples

1. List the types of air samples.

2. Which air sample is taken over a short time?

3. Describe how integrated samples are collected.

421. Air sampling devices

1. List the sampling instruments that are designed to measure one or a group of compounds.

2. What kind of sampling device detects airborne contaminants *without* drawing air into the device?

3. What instrument is designed for on scene detection of chemical warfare agents and toxic industrial chemicals?

422. Air sample collection devices and media

1. Describe breakthrough.

2. What is an electrostatic precipitator used for?

423. Establishing air sampling strategies

1. When considering where to sample, how are sampling locations divided?

2. Briefly explain full-period consecutive samples.

3–2. Air Sample Collection

In air sample collection, analytical methods typically stipulate minimum and maximum recommended sample collection flow rates and volumes. While there are technical reasons for these recommendations such as collection efficiency to support the analytical method, they also allow for some flexibility in your sampling strategy.

424. Calculating sampling rates and volumes

It is up to you to decide rates and volumes that are within the recommended ranges based on such things as the *goal* for sampling, *how much time* you have to sample, and the *concentration of contaminant* you expect to encounter in the area of concern.

The minimum and maximum flow rates referenced in the NMAM are set to provide the greatest collection efficiency for the chemical being sampled. This means that for gases and vapors being sampled with tubes, the contaminant will be in contact with the collection media long enough to be captured. When collecting a particulate sample with a filter the minimum and maximum flow rates are also set to ensure that the sample is collected without damaging the media.

You can calculate how much time you must sample in order to achieve a specific sample volume using the following formula:

$$Volume_{liters} = flow\ rate_{lpm} \times time_{min}$$

For example:

If you have a recommended flow rate of 0.1 to 0.2 liters per minute (lpm) and the minimum sample volume is 5 liters, what is the minimum amount of time you can sample and still meet the LOD?

Step 1: Choose the flow rate. Since for this example you want to find the minimum amount of time you can sample, you choose the maximum recommended flow rate (0.2 lpm).

Step 2: Manipulate the formula for $Time_{min}$

$$Time_{min} = \frac{Volume_{liters}}{Flowrate_{lpm}}$$

Step 3: Solve for time

$Time_{min} = 25$ min

You can see you have to let the sample pump run for 25 minutes before you collect enough sample volume to meet the LOD.

What would happen if you already knew you wanted to collect 8 consecutive samples for 60 minutes each? Well, you could calculate the required flow rate that would give you the recommended sample volume during the amount of time you want to sample. Here is an example:

You want to sample for toluene for the entire work shift (8 hours). You want to take the samples as 8 consecutive samples for 60 minutes each. The NMAM recommendations for toluene are:

Flow rate: ≤ 0.20 lpm

$Volume_{min} = 1$ liter

$Volume_{max} = 8$ liters

What flow-rate will you use to collect between 1 and 8 liters of sample volume in the 60 minutes you want to sample?

Step 1: Choose the sample volume you want to collect. Since there is such a wide range between the minimum and maximum volumes, we need to make a judgment call on the exact volume we will collect. In general, you should collect less volume if concentrations are expected to be high and more volume if concentrations are expected to be low. For this example, let's collect 75 percent of the maximum volume. 75 percent of 8 liters is 6 liters, so we will collect 6 liters of sample.

Step 2**:** Manipulate the equation for Flow $rate_{lpm}$.

$$Flowrate_{lpm} = \frac{Volume_{liters}}{Time_{min}}$$

Step 3: Solve for our flow rate

Flow $rate_{lpm} = 0.1$ lpm

Step 4: Compare our calculated flow rate to the NMAM recommendations. In this case our flow rate is 0.1 lpm, which is less than 0.2 lpm. If this flow rate had ended up higher than the maximum flow rate listed in NMAM, we would need to readjust our sample volume.

Unfortunately, you may run into the following situation: there is no minimum listed sample volume or the NMAM minimum sample volume is too high to meet in the amount of time you'll be sampling. The values in the NMAM consider worst-case concentrations and are adjusted with buffers to ensure enough sample volume is collected. In this situation, you can calculate the absolute minimum you need to collect to get the LOD low enough to meet your sampling needs.

Here is an example:

You are sampling an activity that only lasts 20 minutes; the NMAM says you need a minimum sample volume of 10 liters, and the flow rate range is 0.1–0.4 lpm. The OEL for the chemical is 13.0 mg/m^3 and the LOD is 100 micrograms (µg). Using the NMAM recommendations, if you sample at the maximum flow rate (0.4 lpm) for 20 minutes you will only collect 8 liters of sample. There are a couple of things to consider in this situation. We want to collect enough sample volume to consider the action level as well as the OEL when evaluating our air sample results. Let's calculate the minimum sample volume required to compare our results to both the AL and OEL. We will use the following formula:

$$\text{Volume}_{\text{min}} = \frac{\text{LOD}}{\text{EL} \times \text{F}}$$

Where:

LOD = the limit of detection in µg.
EL = the exposure limit in mg/m^3.
F = the fraction of the exposure limit you expect in the atmosphere.

Let's consider the sample volume to compare our results to the OEL first. In this calculation we will use the OEL value as EL and since we are considering 100 percent of the OEL; F will be 1.0.

$$\text{Volume}_{\text{min}} = \frac{100\ \mu\text{g}}{13\text{mg/m}^3 \times 1.0}$$

$$\text{Volume}_{\text{min}} = 7.7 \quad \textit{liters}$$

As you can see, the minimum sample volume to meet the LOD with no safety buffers involved, you will need at least 7.7 liters of sample. Looking back at our example, you are collecting 8 liters of sample. You just made it; the sample will be valid when comparing results to the OEL.

Now let's see if our sample will be valid if we compare it to the action level. We will use 50 percent for the fraction of the OEL we want to see.

$$\text{Volume}_{\text{min}} = \frac{100\ \mu\text{g}}{13\text{mg/m}^3 \times .50}$$

$$\text{Volume}_{\text{min}} = \frac{100\ \mu\text{g}}{6.5\text{mg/m}^3}$$

From this calculation, you can see that we need at least 15.4 liters to compare our sample results to the action level and we will only collect 8 liters. You will not be able to sample for 20 minutes at 0.4 lpm and compare our results to the action level. Your efforts are not wasted, however, and you can still sample. An easy way to sample and still meet the LOD is to increase the sample time. In this case you would need to sample at least 40 minutes to reach the LOD for the action level. **NOTE:** Put the pump on 10 minutes before they start and let it run 10 minutes after they finish. If you calculate the sample volume for 40 minutes you will get a total of 16 liters. This is enough sample volume to compare sample results to the action level and the OEL.

425. Calibrating/operating direct reading air sampling instruments

Before data produced by any sampling device can be relied upon to be accurate, the limitations and possible sources of error associated with the device must be understood. Additionally, most types of sampling equipment require periodic calibration. Calibration, in the simplest terms, is a comparison of a device's response to a calibration source with a known value and making adjustments if necessary. Many instruments must be laboratory calibrated and also field calibrated or field checked by the user. Examples of field calibrated items are personal sampling pumps, toxic gas monitors, combustible gas monitors, and oxygen meters. An example of an item that must be field checked but cannot be calibrated is a hand-held sampling pump for detector tubes.

Laboratory/manufacturer calibration

Certain equipment must be calibrated periodically by a calibration laboratory. Recommended calibration laboratories include your installation Precision Measurement and Equipment Laboratory, those operated by the equipment manufacturer, or other accepted calibration laboratory. To determine calibration requirements new equipment items should be processed through Medical Logistics and the installation Precision Measurement and Equipment Laboratory. Those items requiring laboratory calibration will be entered into a calibration program for periodic recall. A permanent record of calibration procedures, data and results should be kept.

Field calibrating gas and vapor meters

Field calibration should always be done according to the manufacturer's recommended procedures. Gas and vapor meters should be field calibrated before and after use. Most gas and vapor meters require a standard gas for field calibrating. A standard gas is a gas that contains a known concentration of a specified gas-air mixture. The air-gas mixture is passed through the meter after which the reading is compared to the known concentration of the standard gas to verify the proper response.

Detector tubes or chips

Detector tube systems (e.g., Dräger Civil Defense Simultest [CDS] kit) should be field checked before use. A leakage test on the pump should be performed according to the manufacturer's instructions to minimize erroneous readings due to air leaks around the seals, or pinholes in bellows type pumps.

This is usually done by inserting an unopened detector tube into the pump tube holder and withdrawing and locking the piston in the outer position, or fully squeezing the bellows. The vacuum generated by charging the pump in this manner should hold for the minimum time specified by the manufacturer.

First, let's look at the detector tube system functional check procedure:

1) Insert an unopened detector tube into the pump socket.
2) Squeeze the pump completely and release.
3) After 15 minutes, look for the end-of-stroke indicator.
4) If the pump is deemed leak-proof, remove the tube and reset the counter on the pump to zero.

Lastly, we will look at the operate detector tube system:

1) Select the detector tube(s) for chemical(s) of concern.
2) Score and break off detector tube tip(s) on pump side only (direction of arrow).
3) Insert the open end(s) of the tube(s) into the tube adapter (flow arrows pointing in).
4) Score and break off tip(s) on other side.
5) Expose the detector tube to the environment and squeeze the pump to collect the sample.
6) Remove the used tubes from the adapter and cap both ends.
7) Purge pump.

Portable GC/MS (HAPSITE®)

Because the HAPSITE® is typically stored in a ready-to-use state, it must be calibrated on a regular schedule (e.g., weekly or monthly checks) and before use. In many cases a single blank (i.e., clean air) run is a sufficient operational check because the HAPSITE® contains internal gas standards.

HAPSITE® calibration and functional check procedure:

1. Insert the internal standard and nitrogen canisters (if not installed) and take the HAPSITE® out of extended standby mode and/or wait to power up.
2. Run the 15 minute air (loop or concentrator) method (not the survey method) in a clean air environment.
3. When complete, review the blank run chromatogram. It should show the following:
    a. Air Peak (CO_2) at 1:20 minutes +/- 10 seconds.
    b. Internal Standard #1 (TRIS) at 2:30 minutes +/- 10 seconds.
    c. Internal Standard #2 (BPFB) at: 8:00 minutes +/- 10 seconds.
    d. No additional peaks and low background.
4. All four criteria constitute a satisfactory blank run. See the figure below for an example of a good blank chromatogram with all three peaks identified and no additional peaks. If your sample blank run does not appear similar to figure 3–19 below, consult the USAFSAM ESOH Service Center for assistance.

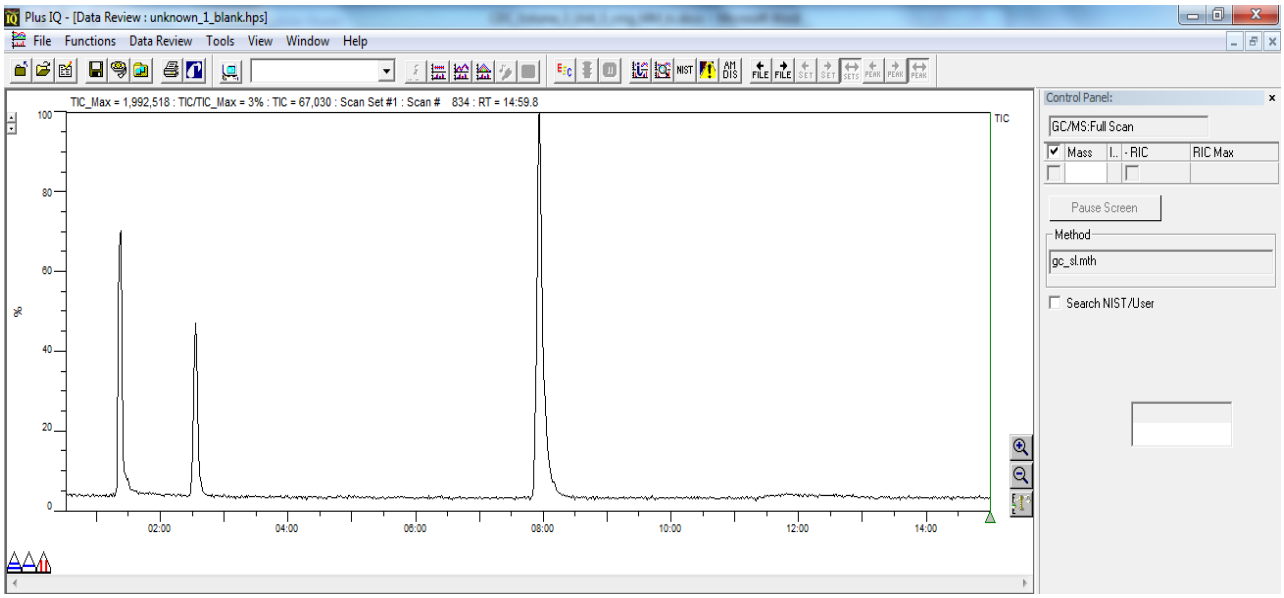


Figure 3–19. Sample blank run.

5. Return HAPSITE® to extended standby mode and remove the internal standard and nitrogen canisters.

Combustible gas meters

Like the PID/FID, combustible gas meters must be calibrated against a standard gas before each use. A calibration and functional check ensures the device will respond as expected should the operator encounter a combustible gas hazard.

Combustible gas meter calibration and functional check procedure:

1. Apply zero gas (or clean air) and verify combustible gas meter reads zero.
2. Apply standard span gas mixture (typically 50 percent LEL and 20.9 percent oxygen) and verify the combustible gas meter reads the same concentration reported on the span gas canister label.

3. After calibration, the instrument is ready to use.

Combustible gas meter operation:

1. Expose the instrument to the environment.
2. The display updates continuously with any detection results and the instrument will alarm if combustible gases are detected at a pre-set level.

Equipment that fails to field check or calibrate within the manufacturer's specifications, fails to hold calibration, or is damaged in such a way as to render the results unreliable should not be used.

Calibrating air sampling pumps for integrated sampling is unlike calibrating DRIs and requires calculating sampling rates and volumes.

426. Calibrating air sampling pumps

Air sampling pumps must be calibrated to the recommended airflow described in the sampling method. Proper calibration is important to determine air sample volume. Volume is a function of sample time and flow rate. There are two categories of calibration devices: primary and secondary.

Primary standard

A primary standard calibration device provides a direct measurement of airflow based on direct and measurable linear dimensions. For example, a bubble burette is a primary device because it directly measures the airflow by tracking the time it takes to pull a soap bubble though a fixed volume of air. [2]

Soap-bubble buret

A soap-bubble buret is the most commonly used primary calibration instrument (fig. 3–20). It consists of an inverted volumetric glass burette that is connected to the sampling train (pump, tubing, and sampling media). It is important that the sampling train contain the same type of media that will be used to conduct air sampling because each media causes a different/unique pressure drop; the pressure drop can affect the sampling pump's flow rate. For high volume pumps, a 1,000-milliliter (ml) burette is used and the soap bubble is timed as it travels up from 0 to the 1,000 ml mark. For low flow pumps, a 100-ml burette is used.

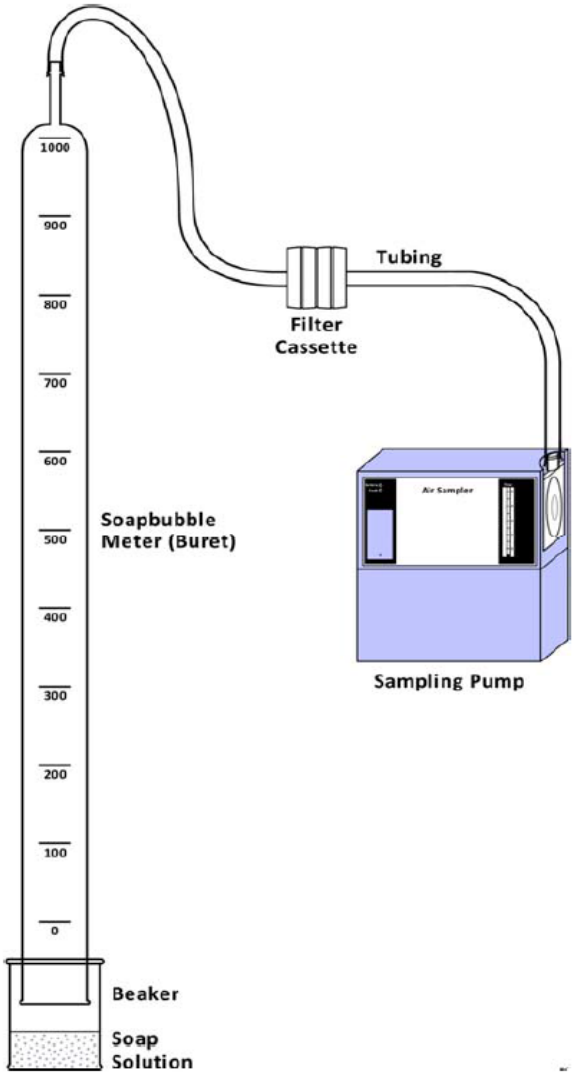


Figure 3–20. Calibration with soap-bubble buret.

Electronic soap-bubble meters and near-frictionless piston meters

An electronic soap-bubble meter calibrates a sampling pump in *less time* and with *greater accuracy* than the traditional soap-bubble method. This type of meter employs light beams at each end of the graduated cylinder, which, when intercepted by the soap bubble, sends a signal to a microprocessor, which, in turn calculates the travel time for the bubble and air volume per unit time. Near-frictionless piston meters operate similarly (fig. 3–21), except that a piston is pulled through the flow cell rather than a soap bubble. [2]

Figure 3–21. Calibration with near-frictionless piston meter.

Secondary standard

Secondary standard calibration devices must be frequently calibrated against a primary standard. Records of calibrating the secondary calibrator must be maintained. Secondary standards are typically used to calibrate sampling pumps in the field when it is inconvenient or impractical to use a primary standard. The most common secondary standard device is the precision rotameter, which consists of a float, or a ball that is free to move in a vertically tapered tube. As air is pulled through a tube, by the sampling pump, the ball rises until there is equilibrium between the force of gravity and the air traveling upward. The airflow rate is determined by simply reading the height of the ball, typically at its widest point, on the attached numerical scale. Although OSHA allows the use of precision rotameters, the devices are no longer recommended and should only be used if absolutely necessary. [4] Secondary standards must be periodically calibrated using a primary standard calibration device. Before we discuss the calibration steps, we must talk about an important part of the setup—the calibration train.

Set up the calibration train

This term refers to the sequence of items that are connected to one another by tubing. The calibration train should be set up with the same pump and type of collection device (e.g., cassette) and filter that will be used for sampling. Do not use the actual filter you intend to collect the sample with. This allows for calibration to be performed in the same mode as for sampling—the pressure drop and subsequent reduced flow will be the same. [4]

The calibration train (see fig. 3–20 and fig. 3–21) should consist of the following:

- Sampling pump.
- Tubing.
- Collection device (e.g., cassette, cyclone, etc.) with sample media.
- Primary or secondary standard calibrator.

This lesson will focus on using the bubble burette calibration device; there are nine functional steps for calibrating and using the device:

1. Set up the calibration equipment as shown in figure 3–20. Wet the inside of the burette with the soap solution before setup.
2. Allow the sampling pump to run for five minutes to stabilize.
3. Check the battery on the pump. If the battery is low, recharge the pump.
4. To create a bubble, raise the beaker of soap solution to the bottom opening of the buret. The airflow from the pump will draw a bubble from the beaker. Draw two to three bubbles up to the top of the burette and make sure they rise smoothly; if not, rewet the inside of the buret.
5. Adjust the pump to the desired flow rate.
6. Create a soap bubble and, using a stopwatch, measure the time it takes the bubble to travel through a predetermined volume (usually from the 0 to the 1-liter gradations).
7. Calculate the flow rate using the following formula. The flow rate is determined by measuring the time required for the bubble to pass between two scale markings indicating a specific air volume.

$$\text{Flowrate}_{\text{lpm}} = \frac{\text{volume}_{\text{liters}}}{\text{time}_{\text{minutes}}}$$

Where: $\text{volume}_{\text{liters}}$ is the air volume of the buret in units of liters

$\text{time}_{\text{minutes}}$ is the time (in minutes) it takes for the bubble to travel through the buret.

For example, let's say it took 30 seconds for the air bubble to travel from 0 to 1 liter.

$$\text{Flowrate}_{\text{lpm}} = \frac{1\,\text{liter}}{30\,\text{seconds}} \times \frac{60\,\text{seconds}}{1\,\text{minute}}$$

$$\text{Flowrate}_{\text{lpm}} = \frac{60}{30}$$

$$\text{Flow rate}_{\text{lpm}} = 2\ \text{lpm}$$

8. Note the pump flow rate and adjust to the desired flow rate, if necessary. Repeat steps 5 and 6 until the desired flow rate is achieved. Once the desired flow rate is achieved, repeat steps 5–7 three times, then average the flow rate.
9. Record the following calibration information:
    - Volume measured.
    - Elapsed time.
    - Air temperature.
    - Atmospheric pressure.
    - Relative humidity.
    - Make, model and serial number of the sampling pump.
    - Name and date of person performing calibration.

Always calibrate the air sampling equipment before starting any sample collection. Most air sampling pumps have built-in rotameters. These are not calibration devices, but they can be used to estimate whether a pump is still pulling the same airflow it was when it was calibrated. After calibration, mark the position of the rotameter so you can check it periodically while sampling. If collecting consecutive samples, a good time to do this is when switching media.

A post calibration is performed after sampling is complete. This should be performed before recharging the pump. Perform the same calibration steps to ensure the flow did not fluctuate. If there is a change in the flow rate, use the lowest flow rate to calculate the volume collected because that is the most conservative.

427. Collecting area air samples

Area sampling can be performed using an integrated method or DRIs. The choice of sampling instrument will depend on several factors, such as the following:

- reason for sampling
- capabilities of sampling instrument
- chemical/hazard
- projected length of sample time
- facility/work area layout
- location and movement of workers
- location of any control measures
- environmental conditions

Many of these same factors are used to determine where the sampling instruments will be positioned or located.

Your first decision is to determine whether to conduct screening sampling with direct reading instruments or collected integrated samples for laboratory analysis.

Integrated method

Collecting integrated samples for laboratory analysis can be used to provide a good indication of the airborne concentration of a chemical contaminant in a room/area over a relatively long time (e.g., 8 hours).

- To begin, pre-calibrate your pump(s) and set up your sampling train.
- Strategically place your pump(s) in a fixed location that will obtain the most representative air sample possible.

This is important because critical, and in some cases costly, decisions will be based on the sampling results. You must make sure the location(s) where you place the instrument(s) will be in areas where the pump(s) will not be tampered with or damaged.

Normally if the importance of air sampling is discussed with the workplace supervisor before placing your pumps in a fixed location, you should not experience any problems.

- After sampling, conduct a post-calibration of all sampling pump(s).
- Finally, package and ship the sample media to an analytical laboratory.

Direct reading instruments

Depending on the instrument and the nature of the hazard, some instruments are portable enough to allow you to walk around and take measurements; in some cases, the instrument will be placed in a fixed location for a set time. Some DRIs are designed for fixed monitoring (e.g., IAQ monitors or particle counters).

- Before using any DRIs, make sure the battery has been charged and an operational check and calibration (if required) has been performed.
- If using DRI for fixed location monitoring, choose sample locations that offer the most representative air sample possible.
- Post-calibrate (if required) and gather data logged to the instrument for analysis.

428. Collecting breathing zone air samples

Most breathing zone air samples are collected using an active sampling instrument such as a portable air-sampling pump. The breathing zone is defined as the hemisphere forward of the shoulders within a 9-inch radius centered at the nose. Breathing zone samplers must pull air from this zone in order to represent true breathing zone air contaminant concentrations.

Remember that your sampling strategy outlines the objective, analytical methods, time and location for sampling, and personnel to be sampled among other important details. When you are ready to actually begin the sampling event, gather all equipment and media and be sure all sampling pumps are fully charged.

- Pre-calibrate sampling pump(s).
- Do not open sample media (i.e., filter cassette, sorbent tubes) to the environment until ready to turn on the pump (opening it sooner may cause cross-contamination).
- Set up the sampling train and document which sample media is attached to which pump.
- When ready to attach to the worker, document the worker ID and sample number, as well as the start time.

To discourage the people from tampering with the sampling device and possibly affecting results, explain the purpose and importance of sampling, and expectations of everyone involved in the sampling. Additionally, explain that only you or another BE technician should remove the equipment.

- Work with the employee to attach and adjust the pump to a location that will be least intrusive to the work.

Concerning the best place to attach the pump, since most pumps come with an attachment clip, the easiest place is on the individual's belt. For unique situations, such as wearing coveralls or lying in a position where the pump would be a hindrance, it is best to collaborate with the person on the best location for the pump.

- Attach the sample media to the person's shirt collar or lapel approximately 6 to 9 inches from the worker's nose. The sample media must be free of any obstruction(s) that would prevent air from being pulled through the media.
- Make sure the tubing does not restrict the individual in any way and that the tubing does not become kinked or detached from the pump.

The best location is to run the tubing from the pump up the back so the media protrudes from the top of their shirt/coveralls (see fig. 3–22). If this is not possible, ask the person if you can tape the tubing to his or her back.

- Open and position the sample media.

The media should be positioned facing downward so dust, particles, and so forth cannot contaminate the media.

Figure 3–22. Personal sampling.

- Turn the pump on, take note of the time and flow rate, and watch the pump for a few minutes to ensure there is a steady flow rate.

Ideally, you should remain at the workplace during the entire air sampling process so you can monitor the pump's flow rate, sampling train and make noteworthy observations concerning the process.

- Make periodic observations for the sample narrative.

Observations and a documented narrative are important since the sample results will reflect worker habits, movements, and behavior in relation to the source(s) of contamination. If you cannot remain to observe, be sure to coordinate with the individual when you return; you want to be there when the process ends so you can record the stop time, turn off the pump, and close/secure the media. You do not normally sample during lunch unless the person stays in the area of concern. If they do not stay in the area, turn the pump off at the start of the lunch period and seal or remove the sample media to prevent cross-contamination. It is not always necessary to remove the rest of the sampling train unless the individual prefers to remove the pump and tube during lunch. After lunch, resume sampling with the same media or use new media (if you have reached or are close to reaching the maximum air volume). If you do not sample during lunch, the time is not used in your TWA calculations.

One important and sometimes overlooked aspect of collecting breathing zone samples is the preparation of field blank samples. Blanks are sent to the laboratory along with the rest of the sample media to determine if any contamination occurred from the time the media was opened until the time it reached the laboratory. To prepare a blank, open and immediately seal the media in the area being sampled. Include a minimum of one lot blank tube (per manufacturer's lot of tubes) per sampling event. For example, if you sampled using charcoal tubes from two lots and silica gel tubes from two lots, you would need to submit four blanks.

After the time for the sampling period has elapsed, record the flow rate of the pump and the time it was turned off. If the flow rate has changed since sampling began, do not average the flow rates; it is very unlikely that you would know when the change occurred. As a worst-case measure, use the lowest flow rate observed to determine the volume collected. Remove the sampling device and the sampling train. Be sure you have positively identified each sampling device if you used more than one during the course of sampling. A stick-on label noting the start-time and the stop-time works well for this; include the names of the workers sampled on the label.

When you get back to your office and before you re-charge the pump, perform a post-calibration on the pump/sampling train to verify the pump maintained the appropriate flow rate. Properly package and send the sample media to a laboratory for analysis.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

424. Calculating sampling rates and volumes

1. If you have a recommended flow rate of 0.1 to 0.2 and the minimum volume is 3 liters, how long will you have to let the sample pump run before collecting enough sample to meet the LOD?

2. Why are minimum and maximum flow rates set?

425. Calibrating/operating direct reading air sampling instruments

1. List the items which require field calibration.

2. What happens to items requiring laboratory calibration?

426. Calibrating air sampling pumps

1. List the primary standard devices used for calibrating air-sampling pumps.

2. What is the piece of equipment most commonly used to calibrate sampling pumps?

427. Collecting area air samples

1. Why is integrated sampling useful for area sampling?

2. Where should you place a sampling pump for area sampling?

3. What is the goal for area air sampling?

428. Collecting breathing zone air samples

1. Why are blanks sent to the laboratory?

2. Briefly describe how to connect the sampling train to a worker.

3. How should the sampling media be placed?

4. Why should you be present when the process ends?

3–3. Interpreting and Evaluating Results

Your sampling is complete and now it's time to assess the results. This is where the math you learned in high school comes into play! There are several calculations that you will use when it comes to interpreting your air sampling results. Most of this section is dedicated to illustrating how and when you will use these various calculations. However, before we talk about calculations we will begin our discussion with a general discussion of OELs as they relate to interpreting air samples. Let's get started!

429. Calculating equivalent occupational exposure limits for non-standard work hours

Exposure limits are generally based on a conventional 8-hour day/40-hour week. Standards based on 8-hour exposures may not provide appropriate protection when nontraditional work schedules are used (e.g., four 10-hour days per week). Comparison of the full-shift exposure measured during a nontraditional work schedule requires adjustment of the 8-hour OEL to account for differences in the number of exposure hours and recovery hours.

The two well-known methods for exposure limit adjustment are the OSHA model and the Brief and Scala model. Choosing to adjust an exposure limit and selecting a method should be based on the chemical's biological half-life and the severity of health effects. Short-term exposure limits; ceiling standards; and the exposure limits for irritants, simple asphyxiants, and chemicals with a biological half-life of less than 3 hours are not typically adjusted. In general, substances with acute effects should be adjusted if the shift exceeds 8 hours; substances with chronic effects should be adjusted if the week exceeds 40 hours. [3]

The lead standards for construction and general industry require PEL adjustments with respect to extended work shifts when determining compliance. To reduce employee level of exposure, the occupational exposure to the cotton dust standard also has a requirement to adjust extended work shifts when employees are required to wear respirators for a portion of the work shift. With these two exceptions, there is no additional regulatory requirement to adjust PELs for extended work shifts. The OSHA model categorized air contaminants into one of six categories based on their toxic effects. Depending on the type of toxic effect, an appropriate adjustment procedure was selected and applied to the exposure limit. This model has been removed from the current OSHA Field Operations Manual, and while still an available option in DOEHRS, this method is not recommended. [3]

The Brief and Scala model is the preferred method for adjusting the 8-hour OEL. The Brief and Scala model is a conservative approach to adjusting OELs for unusual work shifts, incorporating increased work shift exposures and decreased recovery time. The model is based on the number of hours worked per 24-hour day and the period of time between exposures. The following assumptions apply when using the Brief and Scala method:

- The model does not account for biological half-lives of the stressor, as do pharmacokinetic models. Generally, OEL adjustments using this model should not be applied if the chemical half-life is less than 3 hours or greater than 400 hours. Studies show that only moderate half-life chemicals are likely to have day-to-day accumulation during the week, even for exposures at or near the OEL.
- The model assumes average body burden for the chemical rather than peak burden.

- The model can be used if the OEL is based on systematic effects, regardless of whether the effects are acute or chronic.
- 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. Additionally, neither adjustment equation is appropriate for a 24-hour exposure.

The adjusted OEL is then used for comparison with the employees' TWA exposure and its upper or lower confidence limits as appropriate.

Calculation

There are two variations to this mathematical model. First, there is the formula you will use when the work shift exceeds the standard 8-hour day but does not exceed the traditional 40-hour week (no more than 5 days per week). You will use a different formula in situations where work shifts do not exceed an 8-hour workday but the 40-hour work week has been exceeded.

In both instances, you must begin with determining the daily and weekly radio frequency (RF). The formula to calculate the daily RF is (*h* is representative of the hours worked per day):

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

Let's look at an example:

You are evaluating a process where a shop works 10 hours per day / 5 days per week. The chemical you are evaluating is ethyl alcohol (OEL-TWA $_{8\text{-hr}}$ = 1000 ppm). What is the OEL-TWA$_{10\text{-hr}}$?

$$OEL_{Adjusted} = 1000ppm \times \frac{8}{10} \times \frac{(24-10)}{16}$$

OEL $_{\text{Adjusted}}$ = 1000 ppm x 0.8 x 0.875

OEL $_{\text{Adjusted}}$ = 700 ppm

Recall that at the beginning of our example, we established the OEL-TWA $_{8\text{-hr}}$ to be 1000 ppm. The calculated OEL-TWA$_{10\text{-hr}}$ enables us to establish a new exposure limit of 700 ppm for a 10-hour work shift.

Now, what if the shop changed their schedule to 8 hours per day/6 days per week? In situations where the workweek has increased from the traditional 5-day work week, you will need to use the 7-day work week formula to determine the equivalent OEL-TWA. In this example, we will be determining the adjusted OEL for a 6-day workweek.

$$OEL_{Adjusted} = 1000ppm \times \frac{40}{48} \times \frac{(168-58)}{128}$$

OEL$_{\text{Adjusted(weekly)}}$ = 750 ppm

There could be a variety of work shift combinations where you will need to adjust the established exposure limit. It is imperative to remember you *cannot* compare an OEL-TWA $_{8\text{-hr}}$ to an exposure that occurred during a work schedule in excess of 8 hours per day and/or 5 days per week. That is why the Brief and Scala model is so helpful; it allows for the modification of the exposure limit for both situations.

After you have determined the equivalent OEL, compare it to the sampling results that you have based on the full exposure period. That is, if the work shift was 10 hours a day, calculate a 10-hour TWA. Using the TWA formula, you divide the actual time you sampled by 10 hours instead of 8 hours.

It is important to note that not all substances/situations warrant using an equivalent OEL. The following is summary of situations for which you should not calculate equivalent OELs:

- To justify very high exposures as allowable where the exposure periods are short.
- When exposures to hazardous chemicals/materials are 8 hours or less even though the shift is over 8 hours.
- For chemicals whose only or primary effect is irritation.

It is not every day that you will encounter situations where workers are exposed to potentially hazardous substances during a continuous process in excess of 8 hours a day or 40 hours a week. When you do, use the Brief and Scala model to ensure you have the correct (adjusted) exposure limit to which you can compare your air sampling results.

430. Converting raw air sampling results

When you receive your air sampling results back from the analytical laboratory, in most cases you will need to calculate the TWA and compare the results to the applicable OEL. For those cases where the laboratory uses the air volume you provided and calculates the concentration in milligrams per cubic meter (mg/m^3) or ppm, at normal temperature and pressure (NTP), no corrections are required; you can simply compare your results directly to the applicable OEL as long as the OEL is in the same units. If the units are not the same, you will need to use one of the following formulas to convert to the same units—either *mg/m³* or *ppm*:

$$mg/m^3 = \frac{MW \times ppm}{24.45} \qquad \text{OR} \qquad \text{ppm} = \frac{\text{mg/m}^3 \times 24.45}{\text{MW}}$$

In situations where the laboratory reported your results as a *weight of contaminant* collected on the sample media, such as milligrams (mg) or micrograms (µg), these results cannot be compared to the OEL. When this happens, you must first determine the volume of air drawn through the sample then calculate the mass/volume in mg/m^3. If necessary, you may be required to convert the results to ppm (using the above formula) if the OEL is in ppm units. Remember, the units must be the same in order to make a comparison; otherwise, it is like comparing apples and oranges.

Volume

When using air-sampling pumps, the pumps collect air volumes in lpm. Knowing this, the total volume of sample collected can be determined by simply multiplying the pump's flow rate by the sample time (in minutes). This is illustrated in the following examples:

Volume (liters) = flow rate (lpm) x time

Example One: In this example, the sample flow rate was 0.5 lpm and total sampling time was 120 minutes. Use the formula above to calculate to determine the sample volume:

Volume (liters) = 0.5 lpm x 120 minutes

Volume (liters) = 60 liters

Because OELs and TWA calculations rely on volume in units of cubic meters (m^3), liters must be converted to m^3 by dividing liters by 1000 (since there are 1000 liters per cubic meter):

$$Volume\left(m^3\right) = \frac{\text{liters}}{1} \times \frac{1\text{m}^3}{1000\text{ liters}}$$

Using the information from example one, the volume of air tis determined to be 60 liters. This result is plugged into the formula above to determine how much 60 liters would be in m^3:

$$Volume\left(m^3\right) = \frac{\text{liters}}{1} \times \frac{1\text{m}^3}{1000\,\text{liters}}$$

$$Volume\left(m^3\right) = \frac{60\,\text{liters}}{1} \times \frac{1\text{m}^3}{1000\,\text{liters}}$$

$$Volume\left(m^3\right) = 0.06\,m^3$$

An air sample volume of 60 liters is equivalent to a sample volume of 0.06 m^3.

Mass/volume concentration

The air sampling results received back from the analytical laboratory will typically be reported as mass only (grams or milligrams of the contaminant found in/on the sampling media). When this happens, simply apply the corrected air volume (that you calculated) to the sample mass to calculate the mass/volume concentration in mg/m^3 (use the formula below). If the results are reported in grams, before using the calculation, first convert the results to milligrams by multiplying the results (in grams) by 1000 (since there are 1000 milligrams per gram). Once the results are in milligrams, enter the numbers into the equation to determine the mass/volume concentration.

$$\text{Concentration}\,(\text{mg/m}^3) = \frac{\text{mass reported (mg)}}{\text{volume}\,(\text{m}^3)}$$

In this formula, the mass reported (mg) is the sample results from the laboratory, and the volume (m^3) is the total volume of air sampled.

Example Two: The sample results are returned from the laboratory; report the results as a mass of 42 mg. What are the results in mg/m^3? For this example, it is not necessary to convert the results (since they are already in milligrams). Since it is already known that the corrected sample volume in m^3 = 0.06, simply enter the numbers into the equation and solve.

$$\text{Concentration}\,(\text{mg/m}^3) = \frac{\text{mass reported (mg)}}{\text{volume}\,(\text{m}^3)}$$

$$\text{Concentration}\,(\text{mg/m}^3) = \frac{42\,\text{mg}}{0.06\,\text{m}^3}$$

$$\text{Concentration}\,(\text{mg/m}^3) = 700\ \text{mg/m}^3$$

Repeat the above procedures for each sample.

After determining volume and mass/volume concentration, the next step is calculating the TWA for the samples.

431. Correcting sample results for atmospheric conditions

In most cases, the volume as calculated above can be used without further correction, but for extreme changes of temperature and elevation, barometric pressure can sometimes present problems in air sampling calculations. Calibration at different conditions is one of the most significant sources of error. 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 laboratory is the volume actually measured. Where sampling is conducted at a substantially different temperature or pressure than calibration, an adjustment to the measured air volume may be required depending on sampling pump used in order to obtain the actual air volume

sampled. This actual volume of air delivered through the sampling media at the sampling site is reported and used in all calculations.

All OELs and environmental exposure standards and limits are expressed at 25°C (77°F) and 1 atmosphere (760 mm mercury (Hg), the NTP. If the field conditions vary substantially from NTP, the volume of air sampled in the field must be corrected by either the laboratory or the sampling technician. This is the primary reason that temperatures and pressures must be documented on your calibration and sampling forms. It's especially important to understand this issue if the uncorrected results are close to an action level or OEL; however, in practice the rule of thumb is to correct for atmospheric conditions if there is a difference from NTP greater than 30°F or 1000 feet change in elevation. Since atmospheric conditions are documented on your sample forms, the laboratory may already correct the results.

In cases when we need to correct for our atmospheric conditions, we will distinguish between the terms *field volume*, which is the volume under field conditions, and the *volume delivered*, which refers to the volume that would have been drawn through the sampling media by the pump under standard conditions. We start by calculating the volume in cubic meters as shown above to get the field volume. Next, using the ideal gas laws we can calculate the volume delivered with reference to NTP conditions.

$$\frac{P_S \times V_S}{T_S} = \frac{P_F \times V_F}{T_F} \qquad \text{This formula can be rearranged to give} \quad V_S = V_F \left(\frac{P_F \times T_S}{P_S \times T_F} \right)$$

Where:

V_S = volume delivered at standard conditions

T_S = temperature in Kelvin (K) at standard conditions (298°K).

P_S = barometric pressure at standard conditions (760 mm Hg, 760 torr, or 29.92 inches (in) Hg). Remember to keep the units the same.

V_F = volume collected under field conditions.

T_F = temperature in Kelvin (°C + 273) at the field conditions.

P_F = barometric pressure (station pressure*) at the field sampling site.

*The US Weather Bureau references station pressure to indicate measured atmospheric pressure not corrected to sea level.

Using the result for volume we calculated in the example above (0.006 m^3); let's consider an extreme case where both temperature and pressure have an effect on air density. What would be the delivered volume if we sampled at a small site on a mountain where the temperature was 32°C and barometric pressure was 722 mm Hg?

Using field volume and the field atmospheric conditions, we can determine the volume delivered by the pump as though it was collected at NTP.

$$V_S = 0.006 m^3 \left(\frac{722 mmHg \times 722 K}{760 mmHg \times 305 K} \right)$$

$V_S = 0.006(0.93)$

$V_S = 0.0056 m^3$

This is an example of a condition where there is a lower air density because of both reduced pressure at elevation and increased temperature. The volume of air delivered by the sampling pump is significantly reduced by extreme conditions. This is important to remember because the concentration

from our sample directly depends on the volume. One final point—if you're sampling at a location that is geographically separated from your base, such as a remote radar site, it's more likely that you will encounter extreme changes in temperature or elevation. In such cases, it is prudent to calibrate the air-sampling pump at the site rather than your home base to avoid having to do volume corrections.

432. Calculating a time weighted average

Once you have determined the airborne concentration of the material sampled, you are now ready to compare that concentration level with the applicable exposure standards. After all, that is why you conducted air sampling—to determine if airborne concentrations are above or below the exposure standard.

The airborne concentration of a single sample taken over an 8-hour shift can be directly compared to the 8-hour exposure limit. When you collect more than one sample during an 8-hour period or do not sample the entire period, TWA calculations are required.

The TWA is the average of all samples in the same sample set that were collected over a period of time, usually 8 hours, and is the number you will compare to the 8-hour exposure limit. Below is the formula we use to calculate a TWA:

$$TWA_{8\text{-hour}} = \frac{C_1T_1 + C_2T_2 + ...C_nT_n}{T_1 + T_2 + ...T_n}$$

Where: C = the concentration of each sample period
T = the specific time of each sample period

Here is an example using the formula above to calculate the TWA for the following air sampling results. In this example, let's say you were sampling for toluene which has an OSHA-established 8-hour permissible exposure limit of 200 ppm.

	Sample time	Concentration
Sample 1	0700 – 0900 hrs	30 ppm
Sample 2	0900 – 1100 hrs	50 ppm
Sample 3	1200 – 1330 hrs	62 ppm
Sample 4	1330 – 1600 hrs	42 ppm

Using the sampling results from the table, solve for the TWA as follows:

$$TWA_{8\text{-hour}} = \frac{30\text{ ppm}(120\text{ min}) + 50\text{ ppm}(120\text{ min}) + 62\text{ ppm}(90\text{ min}) + 42\text{ppm}(150\text{ min})}{120\text{ min} + 120\text{ min} + 90\text{ min} + 150\text{ min}}$$

$$TWA_{8\text{-hour}} = \frac{3600 + 6000 + 5580 + 6300}{480\text{ min}}$$

$$TWA_{8\text{-hour}} = \frac{21480}{480\text{ min}}$$

$$TWA_{8\text{-hour}} = 44.75\text{ ppm}$$

Compare the results of 44.75 ppm to the permissible exposure limit of 200 ppm and determine that the person's exposure to toluene did not exceed the regulatory exposure standard.

For contaminants that have an OEL-STEL, you must calculate a time-weighted average short-term exposure limit (TWA_{STEL}) in addition to calculating 8-hour TWAs. TWA_{STELs} are used in conjunction with an 8-hour TWA, not in place of them. Since OEL-STELs are for 15-minute exposures, if you

take one sample for 15 minutes you can compare the raw results directly to the OEL-STEL; you do not have to calculate the TWA_{STEL}. If calculations are necessary, the TWA_{STEL} formula is similar to the $TWA_{8\text{-hour}}$ formula, only the total sample period value will differ. The total sampling time should be 15 minutes rather than the 480 minutes (8 hours) used in the $TWA_{8\text{-hour}}$ formula.

Here's an example for TWA_{STEL} using the same formula used for determining the $TWA_{8\text{-hour}}$. In this example, sampling was performed for benzene, a chemical found in jet fuel.

	Sample time	Concentration
Sample 1	1400 - 1405 hrs	2.5 ppm
Sample 2	1405 - 1410 hrs	3.1 ppm
Sample 3	1410 – 1415 hrs	2.2 ppm

Using the sampling results from the table, plug the numbers into the TWA_{STEL} equation and solve.

$$TWA_{STEL} = \frac{C_1T_1 + C_2T_2 + ...C_nT_n}{15\ \text{min}}$$

$$TWA_{STEL} = \frac{2.5\ \text{ppm}\ (5\ \text{min}) + 3.1\ \text{ppm}\ (5\ \text{min}) + 2.2\ \text{ppm}\ (5\ \text{min})}{15\ \text{min}}$$

$$TWA_{STEL} = \frac{12.5 + 15.5 + 11}{15\ \text{min}}$$

$$TWA_{STEL} = \frac{39}{15\ \text{min}} = 2.6\ \text{ppm}$$

$$TWA_{STEL} = 2.6\ \text{ppm}$$

During the 15-minute sampling period, the total exposure to benzene was 2.6 ppm. Compare those results to the OEL-STEL for benzene, which is 2.5 ppm. The TWA_{STEL} exceeds the health standard.

Unsampled periods

Another consideration when conducting air sampling are those situations where a worker uses a potentially hazardous substance for a period less than 8 hours. In these situations, if you are able to determine and document that no other exposures to the same chemical occurred at any other time throughout the day, then you can assume zero exposure and still use 480 minutes (8 hours) in your calculation.

In this example, the worker is exposed to a chemical for 4 hours of an 8–hour work shift, and then has no other exposures to the same chemical the rest of the day.

	Sample time:	Concentration:
Sample 1	0830 - 1030 hrs	50 ppm
Sample 2	1330 - 1530 hrs	120 ppm

The table tells you sample concentrations of 50 ppm for 2 hours and 120 ppm for the other 2 hours. Since the worker was exposed to the chemical for only 4 hours of the 8-hour shift, the remaining 4 hours would have zero concentration.

$$TWA_{8\text{-hour}} = \frac{50\ \text{ppm}\ (120\ \text{min}) + \ 120\ \text{ppm}\ (120\ \text{min}) + 0\ \text{ppm}\ (240\ \text{min})}{480\ \text{min}}$$

$$TWA_{8\text{-hour}} = \frac{6000 + 14400}{480\ \text{min}}$$

$$TWA_{8\text{-hour}} = 42.5\ \text{ppm}$$

Even though the actual sampling event only lasted for 4 hours (240 minutes), the 8-hour exposure as is 42.5 ppm since there were no other exposures throughout the day.

433. Calculating upper and lower confidence limits

From calibration to analysis, all sampling measurements have errors associated with every step of the process. When we calculate a final air concentration the result is an estimate whose accuracy depends on how the different errors of each step fell into place during that particular sampling and analysis event. The measured average is very rarely ever the same as the true average concentration and if it were, you would not know it. The point is: how *confident* are you that your sample results are near the true average?

Sources of error

Here we will discuss two sources of errors.

Systematic errors

Errors of this type are primarily due to human factors in taking and analyzing the sample. Examples are improper calibration, inadequate equipment maintenance, incorrect equipment operation, and erroneous recording of data. These systematic errors can be prevented by proper training, experience, and attention to detail.

There are difficult errors you can prevent caused by the systematic changes in the contaminant's concentration. This does not refer to normal fluctuations but those caused by the worker. A worker causes systematic changes by turning off a ventilation system designed to remove the contaminant, opening windows, inconsistent work practices, or simply moving to an area with a different concentration.

Random errors

Random fluctuations in equipment response and reading accuracy cannot be prevented. In addition, random fluctuations in concentrations over time and over a sample area are normal and expected to occur. The sampling system and method used to analyze the samples also have associated random errors. Normal fluctuation in the pump flow rate is an example of a random error. Uncertainties in the percentage of contaminant desorbed from a charcoal tube and fluctuations in analysis procedures are random analytical errors. Sampling and analytical errors are normally small but they should be considered in the evaluation of sampling data. The magnitude of these errors is known for most methods used in sampling and analysis. When great care is taken to minimize all other errors, we can use the known error of the sampling and analytical method to estimate how close the measured concentration was to the actual concentration.

Sampling and analytical error

The sampling and analytical error (SAE) of a method actually refers to the precision and accuracy of the method.

Precision is a measure of how consistent a method is when repeated multiple times. For example, if 100 measurements were taken and 99 of them had the same value, the method would be said to be precise.

Accuracy is the degree of agreement between a measured value and the true value. If the measurements were done on a known concentration of 50 ppm and 99 of them showed 49 ppm, the

method could be said to be both precise *and* accurate. It is precise because most measurements gave the same value, and accurate because that value was so close to the true value.

You can have precision without accuracy (or the opposite) but both are needed to produce reliable exposure estimates. Figure 3–23 below illustrate the relationship between precision and accuracy.

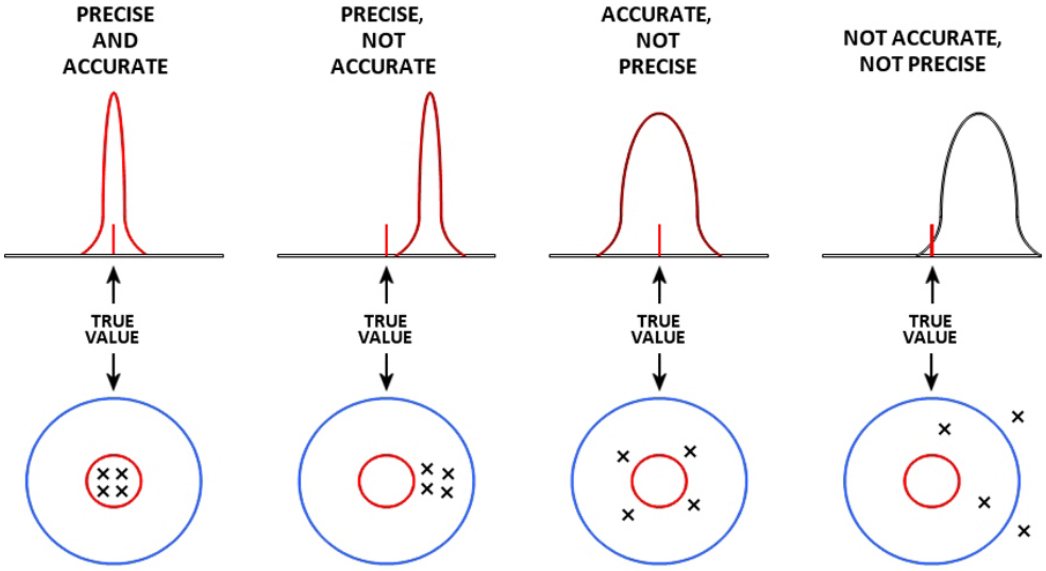


Figure 3–23. Accuracy versus precision.

Primacy regulatory agencies stipulate specific requirements for the accuracy of sampling and analytical methods. Accuracy is required to have a 95 percent confidence limit. This means that 95 percent of the sample results should be within a certain percentage (such as 25, 35, or 50 percent) of the true concentration.

Adherence to a NIOSH sampling method not only assures that accuracy requirements will be met, but also provides a means of finding the total error of the method. This is known as the coefficient of variation (CV). In NIOSH methods, you'll see it referenced as "S_r", which is an equivalent term indicating the measure of precision. The CV takes into account all of the small individual errors of sampling and analysis to provide one cumulative estimate of the total error.

The CV is directly related to the total range of random error for a specific sampling and analytical method. A large S_r means a less accurate method. The S_r just calculated corresponds to a method that will give us results within plus or minus 5.9 percent (0.059) for 95 out of every 100 samples.

OSHA uses the term sampling and analytical error to account for the total error of a method. In this specific context, a SAE is nothing more than the S_r multiplied by 1.645 (a statistical constant).

$$SAE = S_r(1.645)$$

You can look up the S_r in the NMAM. Be careful and make sure that the method you are using matches the method for which the SAE or S_r is listed. The NIOSH methods are used for most OSHA compliance sampling but there are certain OSHA methods that are different.

Upper and lower confidence limits

Calculating the upper confidence limit (UCL) and lower confidence limit (LCL) enables your account for SAE. The UCL is computed to determine whether the TWA *could* be above the OEL. The LCL is computed to determine if the TWA *could* be below the OEL. Why are these concepts important?

Looking at Figure 3–24, consider an example of a TWA of 95 ppm calculated from air sampling results for a chemical with an OEL of 100 ppm. If the SAE was such that a UCL of 105 ppm was calculated, you could not be sure that the exposure was in compliance. This means that, due to the

error of the method, the exposure could actually have been as high as 105 ppm. On the other hand, if the UCL was only 99 ppm, you could be 95 percent confident that the exposure was in compliance.

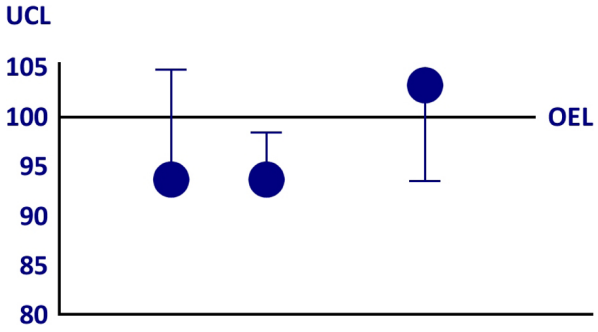


Figure 3–24. Analysis results exceeding OEL when UCL is applied.

If the TWA is already above the OEL there is no need to calculate the UCL for the exposure; however, it would be prudent to calculate an LCL. OSHA compliance officers can issue citations for exposures that do not comply with standards. However, no citation would be issued if an LCL was below the OEL because the compliance officer could not be 95 percent confident that the exposure exceeded the OEL.

Now, I bet you are asking yourself what all this means. OSHA classifies the exposure according to the following classification system below. Although compliance with health standards is important and should be a concern, the point is the confidence you have in the data characterizing the threat. If you are not confident, consider additional sampling.

- If the UCL < 1, you are 95 percent confident a violation/overexposure does not exist.
- If the LCL < 1 and the UCL > 1, you are not certain, classify as a possible overexposure.
- If the LCL > 1, you are 95 percent confident that a violation/overexposure exists.

Calculating confidence limits

Confidence limits are calculated one of three ways depending on how the sample was collected. You can calculate UCLs and LCLs with formulas that consider the following sample methods:

- Full-period continuous single sample.
- Full-period consecutive samples—different sample times.
- Full-period consecutive samples—same sample times.

The examples below will help provide further clarification. Let's start with an example using a full-period continuous single sample. This process can be summarized in three steps:

1. Calculate for Y.
2. Determine the SAE.
3. Solve for the LCL or UCL.

Here are the formulas you will need for calculating the UCL and LCL.

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

$$SAE = S_r(1.645)$$

$$UCL\,(95\%) = Y + SAE$$

$$LCL\,(95\%) = Y - SAE$$

Where: Y = standardized concentration
X = the full period sampling result.

Example: You have just calculated your TWA from a single sample from n-heptane. The laboratory reported the results of 350 ppm. The OEL for n-heptane is 400 ppm. How confident are you that the actual exposure is below the OEL? Let's calculate the UCL first. The first step is to determine your standardized concentration, Y:

$$Y = \frac{350\text{ppm}}{400\text{ppm}} = 0.875$$

Next, find the SAE (or the S_r and covert to SAE) from the NIOSH method. We find that n-heptane has a Sr of 0.014. Converting this to SAE, we have 0.023.

$$SAE = 0.014 \times 1.645 = 0.023$$

To determine the UCL, add the SAE to Y. Let's continue with our example of n-heptane and assume the SAE is 0.023. The UCL would be calculated as follows:

$$UCL = 0.875 + 0.023 = 0.898$$

Based on the result, you can be 95% confident that levels are below the OEL. This method is also used for ceiling samples.

For the LCL, you would (in essence) subtract the SAE from Y but the LCL would not be needed in this case since the TWA is below the OEL. Thus the LCL would appear as:

$$LCL = 0.875 - 0.023 = 0.852$$

The use of multiple consecutive samples will result in slightly lower sampling and analytical errors than the use of one continuous sample since the inherent errors tend to partially cancel each other. The mathematical calculations, however, are somewhat more complicated. Normally, you can first determine if compliance or noncompliance can be established using the easier calculation method listed above for a full period, continuous, single-sample measurement. If results fall into the possible overexposure region using this method, a more exact calculation should be performed using the equation below.

To do this, you must first (after finding Y) square each sample concentration, multiply by its time squared, sum the multiplied values, divide by the total sampling time, and find the square root. Then proceed with the calculations as before. Here are the formulas:

$$UCL = Y + \frac{SAE\sqrt{\left(T_1\ X_1\right)^2 + \left(T_2\ X_2\right)^2 + ...\left(T_n\ X_n\right)^2}}{OEL(T_1 + T_2 + ...T_n)}$$

$$LCL = Y - \frac{SAE\sqrt{\left(T_1\ X_1\right)^2 + \left(T_2\ X_2\right)^2 + ...\left(T_n\ X_n\right)^2}}{OEL(T_1 + T_2 + ...T_n)}$$

Where:

T_n = Time of each sample

X_n = Concentration of each sample squared

An illustration will show that this is not as formidable as it appears. For example: Let's say that our sample results revealed the following concentrations (**NOTE:** For this example we will assume that zero exposure occurred during the last hour):

42 ppm over 3 hours of sampling

56 ppm over 2 hours of sampling

48 ppm over 2 hours of sampling

The chemical we sampled for has an OEL of 50 ppm and the analytical method has a S_r of 0.023 corresponding to an SAE of 0.038. (**NOTE:** 0.023 x 1.645 = 0.0378, rounded to 0.038). We must first determine a TWA from the sample concentrations above.

$$\text{TWA}_{\text{8-hour}} = \frac{42\text{ppm} \times 3\text{hr} + 56\text{ppm} \times 2\text{hr} + 48\text{ppm} \times 2\text{hr} + 0\text{ppm} \times 1\text{hr}}{3\text{hr} + 2\text{hr} + 2\text{hr} + 1\text{hr}}$$

$$\text{TWA}_{\text{8-hour}} = \frac{(334\text{ppm/hr})}{8\text{hr}} = 41.75\text{ppm}$$

After calculating the TWA we can solve for Y using the TWA of 41.75 ppm and the OEL of 50 ppm:

$$\text{Y} = \frac{41.75\text{ppm}}{50\text{ppm}} = .835$$

Finally, we can determine the UCL by entering the information into the formula below:

$$UCL = .835 + \frac{0.38\sqrt{(3\text{hr} \times 42\text{ppm})^2 + (2\text{hr} \times 56\text{ppm})^2 + (2\text{hr} \times 48\text{ppm})^2}}{50(3\text{hr} + 2\text{hr} + 2\text{hr})}$$

$$UCL = .835 + \frac{0.38\sqrt{(126)^2 + (112)^2 + (96)^2}}{50(7)}$$

$$UCL = .835 + \frac{0.38\sqrt{15876 + 12544 + 9216}}{350}$$

$$UCL = .835 + \frac{0.38\sqrt{37636}}{350}$$

$$UCL = .835 + \frac{0.38 \times 194}{350}$$

$$UCL = .835 + \frac{73.72}{350}$$

$$UCL = .835 + 0.21$$

$$UCL = .856$$

This UCL indicates that the exposure is < 1; therefore, there is no exposure in excess of the OEL. It is important to use the exact sampling time in this UCL formula regardless of how you figured the TWA. For example, you may have sampled over a partial period of 6 hours but determined the TWA by dividing by 8 (indicating that the worker left the area after the 6 hours). You must use only the 6 hours in the UCL formula. Note also that minutes can be used; just be sure to stick with the same units throughout the UCL calculation.

434. Total exposure health risk

Now that we are able to get our sampling results into a usable form, we can compare them to the standards. When one contaminant is involved the process is straightforward. However, what do we do when multiple contaminants are involved? And what if multiple contaminants affect the same target organ? When these situations arise, the compliance factor is what we use to determine if worker

exposures are above or below OELs. The method of figuring a compliance factor depends on the toxicological effects produced by exposures to different chemicals.

When a worker is exposed to two or more chemicals on the same shift that have similar toxicological effects, you must consider their combined effect. For instance, xylene, methyl chloride, and perchloroethylene all affect the liver and central nervous system. They are said to have additive effects because they act on the same organ system or systems. If air sampling showed that a worker is exposed to concentrations of 30 ppm xylene (OEL, 100 ppm), 25 ppm methyl chloride (OEL, 50 ppm), and 20 ppm perchloroethylene (OEL, 50 ppm), the tendency is to consider the exposure to be safe. This is certainly what it looks like at first when the exposures are considered individually. However, when you consider the additive effects, the exposure is much more serious than it appears because the three chemicals act together as one chemical in their attack on an organ system (or systems). In the example mentioned, it is like being attacked by a chemical with a concentration of 75 ppm, the total atmospheric concentration of the mixture (30 ppm + 25 ppm + 20 ppm).

Although we know that air sampling is an inexact science, we too often fail to consider how different a true exposure may be from the picture presented by our air sampling results. Many factors have an impact on the reliability of sample results. You need to understand them before making statements using absolutes.

Now that we've covered the concept of total health risk exposure, let's see how we account for total exposure.

435. Calculating compliance factors

As stated above, when a worker is exposed to two or more chemicals on the same shift that have similar toxicological effects, you must consider their combined effect by calculating a compliance factor. The following formula is used for comparing sampling results when chemicals in a mixture have additive effects:

$$\text{Compliance factor} = \frac{C_1}{OEEL_1} + \frac{C_2}{OEEL_2} + \ldots \frac{C_n}{OEEL_n}$$

This process can be summarized in three steps:

1. Determine concentrations for contaminants of concern.
2. Determine the OEL for each contaminant.
3. Solve for the compliance factor.

The standard for this formula is always unity, or one. A compliance factor of more than one means that the OEL of the mixture has been exceeded. Exposures resulting in a compliance factor of one or less are in compliance. The compliance factor for the mixture described above (air sampling showed that a worker is exposed to concentrations of 30 ppm xylene (OEL, 100 ppm), 25 ppm methyl chloride (OEL, 50 ppm), and 20 ppm perchloroethylene (OEL, 50 ppm)) would be:

$$\text{Compliance factor} = \frac{30}{100} + \frac{25}{50} + \frac{20}{50}$$

$= 0.3 + 0.5 + 0.4$

$= 1.2$

Since unity has been exceeded, the OEL for the mixture has been exceeded.

Sometimes you may find mixtures of chemicals in the air in which some are additive in one way and other chemicals are additive in another way. Take the example below of a mixture showing the OEL, hypothetical sample results TWA, and principle effects:

1-nitropropane: OEL: 25 ppm, sample: 5 ppm, liver effects.

Mesityl oxide: OEL 15 ppm, sample: 5 ppm, narcosis and liver effects (among others).

Ethyl formate: OEL: 100 ppm, sample: 70 ppm, narcosis.

In this mixture, 1-nitropropane is additive to mesityl oxide (because of liver effects) but not to ethyl formate. However, mesityl oxide is additive to ethyl formate because of the potential for narcosis. You would need two compliance factors:

1-nitropropane and mesityl oxide:

$$\text{Compliance factor} = \frac{5}{25} + \frac{5}{15} = 0.53$$

Mesityl oxide and ethyl formate:

$$\text{Compliance factor} = \frac{5}{15} + \frac{70}{100} = 1.03$$

The requirement for a compliance factor for additive chemicals points out the need for careful study and understanding of the substances used in workplaces. Many chemicals are irritating or produce somewhat similar effects (some minor compared to their major effects) at high concentrations. This does not make them additive, especially when the OELs were based on very different actions on the body. Do not apply the additive compliance factor indiscriminately. Make sure the chemicals impact the organ in the same way to produce the same injury.

Normally the organization that established the OEL will document thoroughly its basis for establishing exposure limits. The NIOSH Pocket Guide lists target organs in the far right hand column. When you cannot determine whether the substances are additive after this thorough research, you must assume them to be additive and use the compliance factor with care.

References

[1] B. A. Plog, “Fundamentals of Industrial Hygiene,” National Safety Council, 2012.

[2] AIHA, The Occupational Environment: Its Evaluation, Control, and Management, 3rd Ed, 2011.

[3] USAFSAM, *Laboratory Sampling Guide,* 11 May 2012.

[4] OSHA, “OSHA Technical Manual (OTM),” 2008. [Online]. Available: https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html#organic_vapors_gases. [Accessed December 2013].

[5] OSHA, “Glossary of Terms,” May 2006. [Online]. Available: https://www.osha.gov/doc/outreachtraining/htmlfiles/hazglos.html. [Accessed December 2013].

[6] P. Kulkarni, P. A. Baron and K. Willeke, Aerosol Measurement: Principles, Techniques, and Applications, Third Edition, John Wiley & Sons, Inc., 2011.

[7] NIOSH, “Size-selective Sampling for Particulates (White Paper).”

[8] AFI 48–145, *Occupational and Environmental Health Program,* 10 July 2018.

[9] AFMAN 48–146,*Occupational and Environmental Health Program Management,* 14 October 2018.

[10] Air Force Tactics, Techniques, and Procedures (AFTTP) 3–2.82, *Occupational and Environmental Health Site Assessment,* 31 March 2012.

[11] USAF, *Occupational and Environmental Health Site Assessment,* April 2012.

[12] EPA, “Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA

QA/G–4," February 2006.

[13] Air Force Research Laboratory (AFRL), *"USAFSAM Laboratory Sampling Guide,"* 11 May 2012.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

429. Calculating equivalent occupational exposure limits for non-standard work hours

1. Which mathematical model is used for unusual work schedules by proportionally reducing the exposure limit for both the increase in exposure time and the reduction in recovery time?

2. What formula is used to calculate and equivalent OEL while taking into account the decreased recovery time between exposures?

430. Converting raw air sampling results

1. What are the formulas to convert to the same units?

2. Your sample flow rate was .6 lpm and your total sampling time was 120 minutes, what is your sample volume?

3. Using the information from the previous answer, what is the equivalent sample volume in m^3?

431. Correcting sample results for atmospheric conditions

1. If you calibrated your air sampling pump to 0.6 lpm and sampled for 2 hours at NTP, what is your adjusted air volume (V_s) if the sample site temperature was 32° C and the barometric pressure was 722 mm Hg?

2. Your air sample volume is 0.136 m^3 and the laboratory results indicate 0.97 mg of methyl bromide. The molecular weight of methyl bromide is 95. Calculate the results in ppm.

432. Calculating a time weighted average

1. Use the following sample data to calculate a TWA. The worker left the area immediately after sampling and is not exposed during the remainder of the 8-hour shift.

   30 minutes 80 ppm.
   2 hours 60 ppm.
   3 hours 50 ppm.

30 minutes 120 ppm.

2. Use the following sample data to calculate a TWA. The worker stayed in the area after sampling for the remainder of his shift.

   45 minutes 75 ppm.
   1 hour 105 ppm.
   4 hours 60 ppm.
   15 minutes 165 ppm.

433. Calculating upper and lower confidence limits

1. S_r for NIOSH method 1614 is 0.062. The OEL is 1 ppm. What is the UCL if the TWA is 0.8 ppm?

2. Using the same NIOSH method and S_r as question #1, calculate the UCL for the following sampling results:

   1 hour 0.5 ppm.
   2 hours 1.1 ppm.
   3 hours 0.7 ppm.
   2 hours 0.8 ppm.

434. Total exposure health risk

1. What must you consider if a worker is exposed to two or more chemicals on the same shift?

435. Calculating compliance factors

1. Calculate the compliance factor using the following sampling data and determine whether the exposure is acceptable. All 4 chemicals cause damage to the lungs.

Chemical	TWA	OEL
#1	20 ppm	80 ppm
#2	70 ppm	300 ppm
#3	0.5 ppm	1 ppm
#4	12 ppm	25 ppm

2. Calculate the compliance factor using the following sampling data and determine if the exposure is acceptable.

Chemical	Target Organs	TWA	OEL
#1	Eyes, lungs	22 ppm	90 ppm
#2	Lungs, liver	15 ppm	140 ppm
#3	Skin, kidneys	0.9 ppm	1 ppm
#4	Blood, lungs	10 ppm	35 ppm

Answers to Self-Test Questions

420

1. Grab and Integrated.
2. Grab.
3. Integrated samples are collected over a period of time, usually hours, to integrate the high and low concentrations for an average. One or more samples can be collected for the duration of a particular period of time.

421

1. Combustible gas monitors, oxygen monitors, carbon monoxide monitors, indoor air quality monitors, mercury vapor monitors, colorimetric tubes and badges.
2. Colorimetric tubes.
3. HAPSITE

422

1. If the backup section contains a mass greater than 10 percent of the mass of the front section, then breakthrough has occurred.
2. Electrostatic precipitators are used when the required sample volume is large, high collection efficiency is required for very small particles (such as fumes).

423

1. Sampling locations for air sampling are divided into two kinds: area and personal.
2. Taking two or more samples over the work shift.

424

1. 15 minutes.
2. The minimum and maximum flow rates referenced in the NMAM are set to provide the greatest collection efficiency for the chemical being sampled.

425

1. Personal sampling pumps, toxic gas monitors, combustible gas monitors, and oxygen meters.
2. Those items requiring laboratory calibration will be entered into a calibration program for periodic recall. A permanent record of calibration procedures, data and results should be kept.

426

1. Soap-bubble buret and electronic soap-bubble meter.
2. Soap-bubble buret.

427

1. Integrated sampling can be used to provide a good indication of the airborne concentration of a chemical contaminant in a room/area over a relatively long time (up to 8 hrs).
2. Strategically place your pump(s) in a fixed location that will obtain the most representative air sample possible.
3. You want to obtain the most representative air sample possible.

428

1. Blanks are sent to the laboratory along with the rest of your sample media to determine if any contamination occurred from the time the media was opened until the time it reached the laboratory.
2. First, attach the sampling pump using the clip to attach it to the worker’s belt. Then attach the tubing, prepare and attach the sampling media just before attaching it to the sampling train.
3. The media should be positioned so it faces downward so dust, particles, etc., cannot contaminate the media.
4. You want to be there when the process ends so you can record the stop time, turn off the pump and close/secure the media.

429

1. The Brief and Scala mathematical model is used.
2. OEL-TWA $_{10\text{-hr}} = RF_{daily} \times OEL - TWA$.

430

1. Mg/m^3 = MW x ppm ÷24.45 and ppm = mg/m^3 x 24.45 ÷ MW.
2. 72 liters.
3. .072 $m^{3.}$

431

1. 0.067 m^3.
2. 1.84 ppm.

432

1. 46.25 ppm.
2. 73.75 ppm.

433

1. 0.9.
2. 0.93.

434

1. Chemicals with similar toxicological effects, you must consider their combined effect. The exposure is much more serious than it appears because the chemicals act together as one chemical in their attack on an organ system.

435

1. Compliance factor is 1.46. The exposure is not acceptable.
2. Compliance factor is 0.64. The exposure is acceptable.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

48. (420) Which statement describes grab sampling?
    a. Sample collected over a period of time.
    b. Samples taken must be analyzed by a certified laboratory.
    c. Instantaneous sample to provide a quick estimate of air quality.
    d. Samples taken to demonstrate compliance with health standards.

49. (420) Integrated sampling is also referred to as
    a. compliance screening.
    b. instantaneous sample.
    c. direct reading or screening compliance.
    d. indirect reading or continuous monitoring.

50. (421) Which type of instrument is *best* suited for determining a life threatening oxygen deficient environment?
    a. Indoor air quality monitors.
    b. Carbon monoxide monitors.
    c. Oxygen monitors.
    d. Multi gas meters.

51. (421) What type of device is capable of separating mixtures of chemicals into individual components?
    a. Multi-gas monitors.
    b. Colorimetric tubes.
    c. Gas Chromatographs.
    d. Indoor air quality monitors.

52. (421) What is a common device used for collecting air samples for laboratory analysis?
    a. Hazardous Air Pollutants on Site (HAPSITE).
    b. Active sampling pumps.
    c. Mercury vapor monitor.
    d. Carbon monoxide monitor.

53. (422) Which is an example of an adsorption device?
    a. Filters.
    b. Cyclone.
    c. Sorbent tube.
    d. Fritted bubbler.

54. (422) What are the *most* commonly used devices for particulate sampling?
    a. Filters.
    b. Sorbent tubes.
    c. Fritted bubblers.
    d. Passive dosimeters.

55. (422) Which device allows separation of particles by size?
    a. Fritted bubbler.
    b. Sorbent tube.
    c. Cyclone.
    d. Filters.

56. (423) What is an air sample that is collected for 11 hours of a 12-hour shift?
    a. Full-period single.
    b. Single-batch process.
    c. Full-period consecutive.
    d. Partial-period consecutive.

57. (423) Although the true limits are not to be exceeded, which can be a single sample or a series of consecutive samples totaling 15 minutes?
    a. Grab.
    b. Area.
    c. Random.
    d. Ceiling.

58. (424) When sampling for vapors, minimum and maximum flow rates are used with a solid sorbent tube to ensure
    a. the tube is correctly placed.
    b. flexibility in your sampling strategy.
    c. the sample is collected without damaging the media.
    d. the contaminant will be in contact with collection media long enough to be captured.

59. (424) The recommended flow rate of an example chemical is 0.5 to 1.0 liters per minute (lpm). If you wanted to calculate the *minimum* amount of time you can sample and still meet the limit of detection, what flow rate would you use?
    a. 0.25 lpm.
    b. 0.5 lpm.
    c. 1.0 lpm.
    d. 1.5 lpm.

60. (424) When determining the collection volume for an air sample, you would opt to collect less volume of air when
    a. media collection efficiency is low.
    b. media collection efficiency is high.
    c. concentrations are expected to be low.
    d. concentrations are expected to be high.

61. (425) What item *must* be field checked but *cannot* be calibrated?
    a. Toxic gas monitors.
    b. Personal sampling pumps.
    c. Hand-held sampling pump.
    d. Combustible gas monitors.

62. (425) When should gas and vapor meters be field calibrated?
    a. Monthly.
    b. After use.
    c. Before use.
    d. Before and after use.

63. (425) When performing a detector tube system check, how many minutes should you wait after squeezing the pump to look for the end of stroke indicator?
    a. 5.
    b. 10.
    c. 15.
    d. 40.

64. (425) Why is a single "blank" run sufficient as an operational check for the HAPSITE®?
    a. The HAPSITE® contains internal gas standards.
    b. The survey method completes calibration.
    c. Additional peaks and a high background is indicated.
    d. Standby mode sufficiently calibrates the instrument.

65. (426) When setting up the calibration train, you *must* assemble the sample pump, tubing, primary or secondary standard calibrator and
    a. rotometer.
    b. pump holder.
    c. sample media.
    d. buret holder.

66. (426) When performing post sampling calibration, if there is a change in the flow rate use the *lowest* flow rate for calculating the volume collected because
    a. it is the most conservative.
    b. it exploits the device's capabilities.
    c. this accounts for atmospheric changes.
    d. it makes DOEHRS data entry the most efficient.

67. (427) To ensure pumps will not be tampered with, who should you discuss the importance of air sampling with before placing your pumps in a fixed location?
    a. Workers.
    b. Base safety.
    c. Squadron commander.
    d. Workplace supervisor.

68. (428) Blank samples are prepared and shipped along with air samples to
    a. measure the effects of temperature and pressure changes during shipping.
    b. measure the effects of temperature and pressure changes during the sampling process.
    c. determine if any contamination occurred after calibrating the sampling pumps and before sampling began.
    d. determine if any contamination occurred from the time the media was opened until the time it reached the laboratory.

69. (428) How do you prepare a blank?
    a. Keep an unopened tube with the samples.
    b. Sample another worker away from the process.
    c. Open and immediately seal the media in the work area.
    d. Leave an opened tube in an area throughout sampling.

70. (428) When collecting breathing zone air samples the flow rate changed since you began sampling. As a worst-case measure, which flow rate observed should be used to determine volume collected?
    a. First.
    b. Lowest.
    c. Highest.
    d. Average.

71. (429) The scheduled work week has changed to 8 hours per day/6 days a week. Which reduction factor formula should be used to determine the equivalent occupational exposure limit-time weighted average (OEL-TWA)?
    a. Hourly.
    b. Daily.
    c. Weekly.
    d. Monthly.

72. (429) After determining the equivalent occupational exposure limit (OEL), you have to compare it to the sampling results based on the full exposure period. Using the Brief and Scala model, if the work shift was 10 hours a day, you divide the actual time you sampled by how much?
    a. 8.
    b. 10.
    c. 24.
    d. 40.

73. (430) In most cases when you receive air sampling results back from the laboratory you will need to calculate the time weighted average (TWA) and compare the results to the applicable occupational exposure limit (OEL). The laboratory results are in milligrams per cubic meter (mg/m^3); your OEL results are in part per million. In order to compare results, what *must* you convert your air sampling results to?
    a. M^3.
    b. mg.
    c. ppm.
    d. mg/m^3.

74. (430) After the results from mass/volume concentration air sampling are received you find the results are reported in grams. Before you can use the formula to determine mass/volume concentration, you will have to convert the results reported in grams into what measure?
    a. milliliters (ml).
    b. milligrams (mg).
    c. milligrams squares (m^2).
    d. No conversion required.

75. (431) *Field volume* refers to
    a. volume drawn through the sampling media.
    b. volume under field conditions.
    c. field atmospheric conditions.
    d. volume at 32 degrees Celsius (C).

76. (431) If you are sampling at a site that is separated from your base, it is prudent to calibrate the air-sampling pump
    a. at your home base.
    b. every 24 hours.
    c. repeatedly.
    d. at the site.

77. (432) If you sample for 7 hours of a 10-hour shift and can document that the worker is *never* exposed during the remaining three hours, you should calculate the time weighted average using which value?
    a. 3 hours.
    b. 7 hours.
    c. 8 hours.
    d. 10 hours.

78. (432) If you sample for 6 hours of an 8 hour shift and the worker stays in the area after sampling, you should calculate the time weighted average using which value?
    a. 4 hours.
    b. 6 hours.
    c. 7 hours.
    d. 8 hours.

79. (433) What *must* you calculate from the sampling and analytical error and your air sampling results to determine whether the time weighted average could be above the occupational exposure limit?
    a. Accuracy.
    b. Coefficient of variation.
    c. Upper confidence limit (UCL).
    d. Lower confidence limit (LCL).

80. (433) Which would it be prudent to do if the time-weighted average (TWA) is already above the occupational exposure limit (OEL)?
    a. Resample and recalculate the TWA.
    b. Compute the compliance factor.
    c. Calculate the lower confidence limit (LCL).
    d. Re-calculate the upper confidence limit (UCL).

81. (434) You should use a compliance factor to consider the effects of exposure to xylene, methyl chloride, and perchloroethylene because the chemicals
    a. react to each other.
    b. attack the same organ in the same way.
    c. produce irritation at high concentrations.
    d. cause the same illness in different organs.

82. (434) If air sampling showed that a worker is exposed to concentrations of 35 ppm xylene (occupational exposure limit (OEL), 100 ppm), 20 ppm methyl chloride (OEL, 50 ppm), and 25 ppm perchloroethylene (OEL, 50 ppm) and these chemicals have a similar toxicological effect what would be their total atmospheric concentration?
    a. 45 ppm.
    b. 80 ppm.
    c. 200 ppm.
    d. 280 ppm.

83. (435) When considering additive effects of chemicals, the occupational exposure limit (OEL) is exceeded if the compliance factor is which of the following?
    a. Less than one.
    b. Greater than one.
    c. Less than or equal to one.
    d. Greater than or equal to one.

84. (435) Using the provided concentrations 20 parts per million (ppm) xylene (occupational exposure limit (OEL), 100 ppm), 20 ppm methyl chloride (OEL, 50 ppm), and 20 ppm perchloroethylene (OEL, 50 ppm), what is the unity for the compliance factor?
    a. 0.4.
    b. 0.8.
    c. 1.0.
    d. 1.2.

Unit 4. Solid/Soil Sampling

AIR FORCE MEMBERS perform many processes and activities that can potentially release hazardous CBRN materials into the environment. These materials can also enter the environment from isolated incidents such as an airplane crash, natural disasters, or terrorist activities. Identification and quantification of soil contamination may be necessary to assess health risk and determine if clean-up actions are necessary.

436. Soil/solid sampling methodology

As with air and water sampling, a soil sampling methodology along with a sampling strategy is your plan of action that outlines how you will conduct your soil sampling event. A good methodology will ensure that sampling will be performed in an organized, methodical and repeatable process, and that the results will identify what material(s) contaminated the soil and the *extent* of contamination.

Soil sampling is conducted for two primary reasons: health risk assessment and regulatory compliance. Recall that the intent of OEHSA is to identify exposure pathways associated with OEH hazards that require additional data collection (i.e., sampling) for health risk assessment. If the exposure pathway environmental medium of concern is soil, then you may be required to perform sampling to determine exposure pathway completion or to assess PAR exposure. In addition, you may be required to identify potential OEH hazards associated with material in soil during an emergency response. Soil sampling for health risk assessment is typically performed to determine the extent of the contamination (i.e., boundaries of the contaminated area and concentration of contaminant) and determine if the contaminant poses a hazard to personnel. Sampling for regulatory compliance purposes (e.g., EPA soil remediation requirements) is handled by civil engineering (CE). However, it is possible there may be situations where you are involved in remediation sampling to identify the existence and level of any contamination after a cleanup process and to determine if any existing contamination continues to be a risk to personnel or the environment. There are many factors to consider when developing your sampling methodology such as where to sample, how to sample, what to sample for, types of soil, and how it can affect contaminant mobility. Each of these considerations will be discussed in this unit.

437. Soil/solid sampling devices

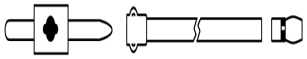
When taking soil samples, it is important to use the correct device(s) to retrieve the soil sample. Device selection is determined by several factors:

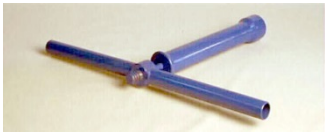
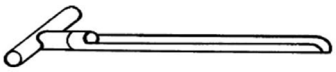
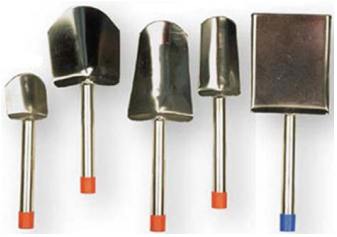
- Depth of sampling needed.
- Type of soil being sampled.
- Analytes of concern.
- Type of samples being collected (disturbed or undisturbed).

The following table lists common solid/soil sampling devices.

Name	Description	Image

Augers	• Augers are one of the main tools used for soil sampling. They screw into the soil and churn the soil to make it easier to sample.
	• Using augers to sample classifies the sample as disturbed, which means this type of sampling should not be used to sample for volatile organic compounds (VOC) because churning the soil will rapidly release VOCs into the air. Hand augers can reach depths of up to 4 feet, and gas-powered augers up to 12 feet.
	• There are two types of augers: bucket and screw:
	  • The bucket auger has several different types of interchangeable heads and is designed to take larger volumes of soil than the screw auger. The choice of head depends on the soil type.
	  • The screw auger bores holes in the soil and the sample is then collected with an alternate device such as a small hand shovel.
		
		Soil augers A, screw or worm auger; B, barrel auger; C, "Dutch" mud" auger

Tube samplers	• Tube samplers are used to collect disturbed or undisturbed samples. • Tube samplers are hollow metal tubes that are driven into the soil to collect the sample. • They provide the least disturbed collection method, therefore are preferred for collecting VOC samples. • The three types of tube samplers are Veihmeyer, Split Spoon, and Push Tube (described below).	See Veihmeyer tube sampler and split spoon tube sampler below.
Veihmeyer tube sampler	• A good core sampler for most types of soil and can reach depths of up to 10 feet. • To collect samples, drive the sold shaft to the desired depth and collect the sample from the bottom of the desired depth. • The best sampler for undisturbed soil samples taken at depths greater than 1 foot. • Its major limitation is that it cannot penetrate stony or rocky soil.	

Name	Description	Image
Split spoon tube sampler	• Has a split along the side for easy removal of sample. • Tube is hammered into the soil for sample collection to a depth based on the length of the spoon; usually 4 to 12 inches. • To retrieve the sample, unscrew the ends so the middle compartment can open. • This sampler is best used for samples at shallow depths of 1–12 inches. • For deeper samples, use an auger or mechanical drilling device prior to collecting with the split spoon.	
Push tube sampler	• This is a single-piece metal tube. • It is forcefully driven into the soil or sediment at the bottom of the borehole to collect an undisturbed subsurface sample. • It can be used for depths up to 25 feet.	
Trier sampler	• A trier sampler is a narrow tube with a T handle. The device is open on one side. • The device is used primarily for sampling loose soil on the surface or just under the surface. • To use, simply place the sampler in the soil and scoop up the sample. • The device is not recommended for compacted soil, clay, or rocky soil.	
Trowel, shovel, and scoop	• A trowel, shovel or scoop is used to fill containers, remove debris, dig trenches, and collect samples. • They can be either stainless steel or plastic. • These samplers are good to use for surface or shallow surface sample non-volatile compounds.	
Quick Silver Kit	• The Quick Silver Kit is a field sample collection kit. • The kit is a self-contained backpack with enough supplies to take solid, liquid, and/or wipe samples, and has been especially designed to avoid cross contamination. • The kit includes scoops, shovels, jars, and bags to assist in collection of soil sample. • All tools and consumables are conveniently packaged for ease of access and single use.	

With the exception of the Quick Silver kit and a shovel, soil sampling devices are not typically included as part of the BE equipment package. If the devices are not available, they may be obtained from the base Civil Engineering Environmental Flight.

438. Determining soil/solid sampling strategies

As previously stated, a sampling strategy is a road map. It details the entire sampling process from beginning to end. It includes the *methods* of selecting sample locations, the *manner* in which samples are collected, and the *handling* of the samples. The EPA DQO process is the best way to develop a sampling strategy; it establishes specific objectives for sampling and focuses data collection on meeting those objectives. Any data collection (sampling) should be tied to specific decisions or anticipated outcomes. For example:

- Is the contaminant of concern above background levels?
- Are contaminants present above regulated clean up criteria?
- Are human health risks unacceptable?

Adhering to a good sampling strategy will ensure the results are representative and usable for the intended purpose. Just as drinking water samples must be representative of the distribution system and not just the sample location, soil/solid samples need to reflect the site, not just one possible contaminated spot. As always, do not introduce bias into the sampling methodology or collection. When collecting soil samples, samples are **rarely** collected from the entire site. Instead, small, but representative samples of the site being investigated are collected. If properly collected, the results will reflect the concentration of the contaminants at the site and can be used to make decisions and conclusions about the entire site.

The act of collecting soil samples is a relatively straight forward process. However, a plan for carrying out the collection of the samples (sampling strategy) must be predetermined. This will direct the sample collection process, thus ensuring that representative samples and reliable, accurate results are obtained.

Developing the sampling strategy

A soil sampling strategy is developed when a complete or potentially complete exposure pathway involving soil has been identified, thus indicating that additional data is needed to fully assess the exposure hazards and risks. The USAFSAM *Laboratory Sampling Guide*, a reference that assists with developing sampling strategies, recommends the EPA DQO process when establishing a sampling strategy for collecting environmental samples. [1, 2]

The DQO process consists of the following seven steps:

- Step 1: State the problem.
- Step 2: Identify the decision or goal.
- Step 3: Identify information inputs to the decision.
- Step 4: Define the Boundaries.
- Step 5: Develop the decision rules and analytical approach.
- Step 6: Determine performance or acceptance criteria.
- Step 7: Develop the detailed sampling plan.

Step 1: State the problem

Before any other aspect of a sampling strategy can be determined, you should clearly identify the sampling objective.

- What is the reason for soil sampling?
- What is the anticipated COC relevant tithe OEH threat source?

Use the conceptual site model, existing reports, intelligence sources, experience, and professional judgment to describe the reason for the assessment.

Step 2: Identify the decision or goal

Establish a clear decision to determine why further data analysis or collection is needed. The following are examples illustrating this point:

- Does the OEH threat pose an acute or latent health risk to the PAR?
- Does an exposure pose an acceptable or unacceptable risk?
- Is the COC above background levels?
- Are contaminants present above regulated clean up criteria?
- Are human health risks unacceptable?

The sampling results will indicate intentional actions that will need to occur. These actions should be identified in this step. For example, suppose the following question is posed: "Is the oil stained soil in the middle of the living compound a contaminant source that is contributing to personnel feeling ill?" There are two possible outcomes, 1) the oily stain *is* a contaminate source contributing in personnel feeling ill, or 2) the oily stain *is not* a factor in personnel feeling ill. If the oily stain **is** a source of contaminant that is contributing factor, one action may be to remediate (remove) the contaminated soil to aid in preventing personnel from feeling ill, and another possible action could be to move the personnel away from the contaminated area. If the oily stain *is not* contributing to personnel feeling ill, then no action may need to be taken.

Step 3: Identify information inputs to the decision

This step is very comprehensive and in depth. Use interviews, site reconnaissance and observations to help determine the appropriate sampling types, methods, locations, sample collection equipment, and appropriate OEEL for comparison to sample results. This information will determine where and how samples are taken in order to obtain samples from appropriate exposure point concentrations.

Type of sample

A comprehensive sampling strategy should include a determination of whether to collect homogenized or composite samples.

Homogenized samples are obtained by collecting a uniform mixture of the soil you are sampling by mixing or blending the soil. In essence, this type of sampling creates an even distribution of the contamination that is in the soil and is representative of the total soil sample collected. All non-volatile soil samples should be homogenized to decrease chance of sampling error and increase the probability of representative samples. Homogenized sampling is not used for volatile organic compounds.

Once you have collected enough soil (from the same area), place your sample on a large sheet of aluminum foil, placed on top of a plastic tarp. Remove any debris (rock, twigs, etc.) and then use the following steps to homogenize your samples:

- Using a trowel or hand held shovel make a cone of sampled soil.
- Flatten cone.
- Quarter flattened cone.
- Mix soil by forming new cone.
- Repeat a minimum of 5 times.
- Using a clean shovel or spoon, place the soil into a sampling container.
- Label the sampling container.

Composite sampling takes individual discrete samples and mixes them together to create well-mixed average concentration sample for an entire sample area. It is the process of combining and homogenizing several individual soil samples. This provides an average contamination concentration

over a specified number of samples. Compositing dilutes high concentration of aliquots (portions).An aliquot is a subdivision of a section and results from an equal division of halving and fourths. This type of sampling is not recommended for volatile compounds.

For this type of sampling, use the same steps as for homogenized sampling; however, the difference is to first take samples from several different sections of the area you are sampling and then to prepare a homogenized sample. The results will provide you with an average concentration for the entire area you sampled. The steps for taking a composite sample are:

- Collect several soil samples from around the area you are sampling.
- Combine aliquots (divisions or parts) in a tub or plastic tarp.
- Follow homogenization protocol.
- Containerize required volume of sample and label the container.

Sampling collection method

Soil samples are obtained by manual sampling method. The human element is the key to the success or failure of manual sampling programs. Remember, the success of the sampling strategy is directly related to the care exercised in the sample collection. Optimum performance will be obtained using trained personnel. It is important to understand which sampling devices are best to use to collect the soil sample. For example, we discussed earlier Augers should not be used to collect a soil sample for VOCs because the auger churns the soil releasing possible VOCs into the air.

Sampling point locations

In most cases involving soil contamination, it will be obvious where to sample because you will be able to detect clues that will lead you to the area of contamination such as wet, oily, or discolored soil, dead vegetation, or an unpleasant odor. Examples of some of the types of releases and sampling opportunities you could encounter include, hazardous materials spill responses, and an intentional release of a CBRN material by terrorists. If contamination has been in the soil for a long time sampling locations may not be obvious. In these situations, your sampling plan should include sampling for areas further away from the site of actual or suspected contamination to determine the extent of the contamination.

Sampling designs

A sampling design can aid in determining the locations and numbers of samples to be taken. There are many designs to choose depending on the objective of your sampling. The following are the sampling design types [3,4]:

- Judgmental sampling.
- Simple random sampling.
- Stratified sampling.
- Systematic and grid sampling.
- Hot spot sampling.
- Advanced probabilistic-based sampling.

Judgmental sampling is the subjective selection of sampling locations at a site, based on historical information, visual inspection, obvious contamination, and best professional judgment. This type of sampling typically requires only a few samples to be taken and is used to identify contaminants present at high concentration areas and for emergency that require immediate sampling.

Simple random sampling is the most basic statistical approach and is usually applied when minimal site background information is available and visible signs of contamination are not evident during an initial site survey. This strategy uses the theory of random chance probabilities to choose representative sampling locations. The sample area is divided into equal grids and each location is selected independently of any previous chosen sample location. It is most effective when the number

of available sampling points is large enough to lend statistical validity to the random selection process. It is also used when there are no obvious “hot spots” or patterns of contamination.

Once the number of samples is determined, randomly plot the sampling locations on a grid. A map of the study area is overlain with a grid of an appropriate scale. The starting point of the grid should be randomly selected rather than located for convenience. This can be done by selecting four random numbers from a random number table. The first two numbers locate a specific grid square on the overlay. The second two identify a point within that grid square. This point is fixed on the map and the entire grid shifted so that a node on the grid coincides with the point selected. Using this technique avoids the questions that are often raised about biased sample locations. Figure 4–1 is an example of a simple random sampling grid.

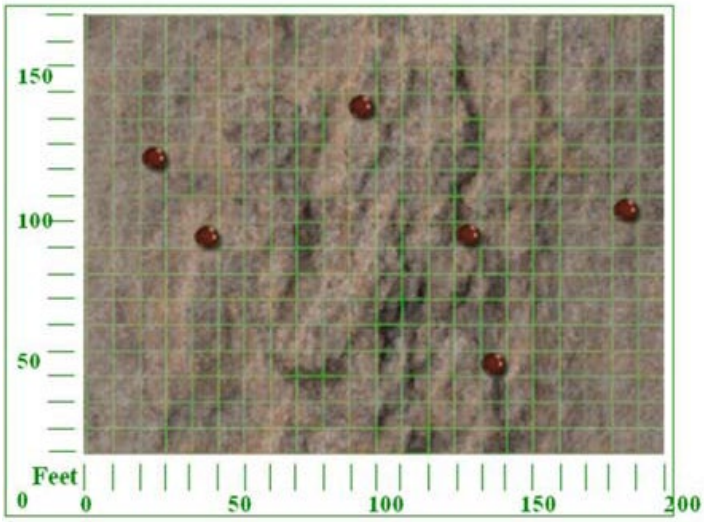


Figure 4–1. Simple random sampling grid.

Stratified random sampling is used to investigate large sites that encompass a number of soil types, topographic features, or land uses. In this strategy, the site is divided into different sampling areas or subgroups that are thought to be more homogenous. The division of the site is based on the assumption that each subgroup is more homogenous than the site as a whole. The site may be divided into subgroups based on pre-existing data and professional judgment. The data from each subgroup may be used to determine the mean or total contaminant concentration within the subgroup and make comparisons between the different subgroups. The data can also be combined to provide information about the entire site. Figure 4–2 is an example of a stratified random sampling grid.

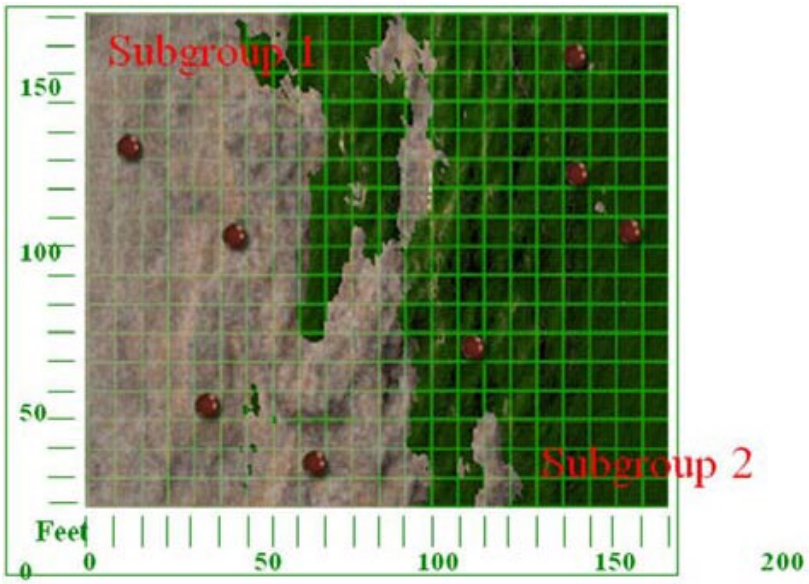


Figure 4–2. Stratified random sampling grid.

Systematic and grid sampling is sometimes referred to as systematic random sampling. These methods involve dividing the entire area to be sampled into grids and collecting samples at predetermined intervals on the grid (e.g., collect one sample every 30 x 30 feet. In systematic random sampling, the location of the first sampling point is selected at random and all subsequent sampling locations are determined using a systematic pattern from that point. The grid-based option is the best statistical sampling strategy for minimizing bias and providing complete site coverage, especially for large sites. This method is also effective in locating hot spots. The most basic grid system is a straight line between two points on which regularly spaced sampling locations are designated. However, most sampling requires a two-dimensional grid system for locating sampling points. Two types of two-dimensional grids that are used are square and triangle. This sampling strategy follows the basic guidelines as stratified and simple random sampling. Figure 4–3 is an example of a systematic grid.

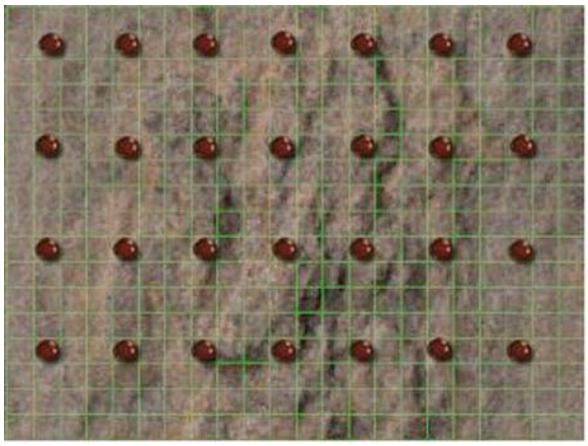


Figure 4–3. Systematic grid.

Hot spot sampling is used to sample small, localized areas that are characterized by high contaminant concentrations. In order to detect hot spots, a special systematic grid sampling approach is necessary. This type of sampling follows the same parameters as the systematic grid sampling approach; however, you will normally conduct hot spot sampling over a smaller area. Background data from events such as spills or leaks usually triggers the need for hot spot sampling, therefore, you should use the background data to select the sampling area and grid pattern. The sampling will identify

contaminated hot spots and the extent of the contamination. A triangular grid pattern increases the efficiency of the hot spot search. Figure 4–4 is an example of a triangular grid pattern.

Figure 4–4. Triangular grid pattern for hotspot sampling.

Advanced probabilistic-based sampling designs include ranked set sampling and adaptive cluster sampling.

- Ranked set sampling uses a two-phase sampling design that identifies sets of field locations, utilizes inexpensive measurements to rank locations within each set and then selects one location from each set for sampling. Ranked set sampling is useful when the cost of locating and ranking locations in the field is low compared to laboratory measurements.

- For adaptive cluster sampling, initial samples are taken using simple random sampling, and additional samples are taken at locations where measurements exceed some threshold limit.

Composite sampling is performed to measure the *average* concentration of a contaminant over a broad area. Multiple soil samples are physically mixed together (in a bucket for example) in an effort to form a single homogeneous sample to be analyzed. This provides an average contamination concentration for the area of concern. Composite sampling should generally only be performed when the sampling objective is to calculate an average soil contaminant concentration over a homogeneous area.

The USAFSAM *Laboratory Sampling Guide* provides a chart (duplicated below) to aid in selecting a soil sampling designed that best suits a situation.

If you are	And you have	Consider using	To
Performing a screening phase of an investigation of a relatively small-scale problem.	A limited budget and/or a limited schedule.	Judgmental sampling.	Assess whether further investigation is warranted that should include a statistical probabilistic sampling design.
Developing an understanding of when contamination is present.	An adequate budget for the number of samples needed.	Grid sampling.	Acquire coverage of the time period of interest.
Developing an understanding of where contamination is present.	An adequate budget for the number of samples needed.	Grid sampling.	Acquire coverage of the area of concern with a given level of confidence that you would have detected a

If you are	And you have	Consider using	To
			hot spot of a given size.
Estimating a population mean.	An adequate budget Budget constraints and analytical costs that are high compared to sampling costs Budget constraints and professional knowledge or inexpensive screening measurements to assess the relative amounts of the contaminant at specific field sample locations.	Systematic or grid sampling Composite sampling Ranked set sampling.	Also produce information on spatial or temporal patterns Produce an equally precise or a more precise estimate of the mean with fewer analyses and lower cost Reduce the number of analyses needed for a given level of precision.
Estimating a population mean or proportion.	Spatial or temporal information on contaminant patterns.	Stratified sampling.	Increase the precision of the estimate with the same number of samples, or achieve the same precision with fewer samples and lower cost.
Delineating the boundaries of an area of contamination.	A field screening method.	Adaptive cluster sampling.	Simultaneously use all observations in estimating the mean.
Estimating the prevalence of a rare trait.	Analytical costs that are high compared to sampling costs.	Random sampling and composite sampling.	Produce an equally precise (or more precise) estimate of the prevalence with fewer analyses and lower cost.
Attempting to identify population units that have a rare trait (for a finite population of units).	The ability to physically mix aliquots from the samples and then retest additional aliquots.	Composite sampling and retesting.	Classify all units at reduced cost by not analyzing every unit.
Attempting to identify population unit(s) that have the highest contaminant levels (for a finite population of units).	The ability to physically mix aliquots from the samples and then retest additional aliquots.	Composite sampling and retesting.	Identify such units at reduced cost by not analyzing every unit.

Adapted from Table 3–1 from EPA QA/G–5S, Guidance on Choosing a Sampling Design for Environmental Data Collection (Dec 2002).

Selecting an exposure limit

A critical part of Step 3 of the DQO process is selecting the appropriate OEL. The generally accepted practice is for you to select the most appropriate and current OEL adopted from established, recognized standards including, but not limited to:

- Those in AFIs and AFOSH Standards.
- Air Force Medical Services Agency (AFMSA) policy letters.
- Technical reports or guidance documents provided by USAFSAM.

- In deployment locations refer to the MEGs for soil in the USAPHC TG-230.
- In the absence of recognized standards, utilize your chain of command and the USAFSAM ESOH Service Center for guidance.

Step 4: Define the Boundaries

In this step, determine the exposed population, the number of samples, the physical boundaries from which representative exposure can be determined, and the smallest sampling unit on which a decision will be made. The selection of the sampling devices that were discussed earlier needs to be determined based on its ability to obtain the correct size and shape and orientation of the sample, in addition to meeting other performance goals specific by the sampling goals. Some factors to consider when completing this step:

- Time and resources constraints on the data.
- Military operational factors (sorties and convoy).
- Military objectives may impose restrictions (force protection).
- Industrial operations (shift work, 24-hour operations).
- Meteorological conditions (temperatures).
- Spatial boundaries (geographic limitations).

Step 5: Develop the decision rules and analytical approach

The main objective of this step is to come up with your decision rule, which consists of the parameter of interest action level and alternative actions. The selected result parameter and action level combined to develop the decision rule. The result parameter is the limit that will be used during your HRA: Are you interested in "average" conditions or "extreme, worst-case" conditions? The OEL selected in Step 3 can be used to predetermine the AL to be used to establish your decision rule. An example decision rule is as follows:

> ***If*** *the mean concentration in the surface 2 inches of soil area defined as 20 feet by 100 feet exceeds 1 ppb,* ***then*** *remove a 6 inch layer of soil,* ***else*** *leave the soil intact*.

Step 6: Determine performance or acceptance criteria

In this step, determine the desired confidence level in your results before collecting samples (e.g., 99, 95 90, 80, or 70 percent confident that a correct decision is being made). Identify the gray area (typically in AF operations this is the range between the AL and the OEEL).[3]

Step 7: Develop the plan for obtaining data

This step incorporates the outputs from steps 1–6 into a resource-effective sampling strategy that will meet or exceed the objectives. This step summarizes previous steps and outlines the field sampling strategy including:

- Number of samples.
- Sample design.
- General collection techniques.
- Sample matrix and quantity.
- Sample locations.
- Timing issues for sample collection, handling, and analysis.
- Analytical methods.
- Statistical sampling scheme.

Common pitfalls to avoid during sample plan development include:

- Nonrepresentative sampling.
- Instability or contamination of samples between sampling and analysis.
- Interferences and matrix effects in analysis,
- Inability to determine the relevant forms of the parameter being measured,
- Improper calibration, and (6) failure to blank-correct.

Documentation

The proper documentation of your samples is an important step in your sampling methodology. Details you should document include sampling site location, date/time of contaminant release (if known), date/time samples were collected, sample number, collector's name, description of the samples, possible sources of contaminant release, any identifying markings on containers and drums in the area, local weather at the sampling site, and the results of any on site monitoring.

Once your sampling methodology and strategy have been established, and you have determined what type of sampling equipment, devices, and supplies will be required, you should consider the below factors before you head out to conduct your sampling.

439. Collecting soil/solid samples

Data collection should be tied to specific decisions or anticipated outcomes. The following are some examples:

- Is the COC above background levels?
- Are contaminants present above regulated clean up criteria?
- Are human health risks unacceptable?

Knowing the types of soil that are in the geographical area you have to sample is important. How a contaminant interacts and moves within the soil are important considerations in the sampling strategy; it can assist in deciding which sampling device will be used to obtain the sample and how deep and how far out from the contamination area to sample. Along with the type of soil, knowing if a contaminant is soluble or insoluble can be helpful to you; soluble contaminants mix with water and travel through the soil better than insoluble contaminants. Other than the specific sampling device(s) you will use to collect your soil samples, some of the items you should bring out to the sampling site include a camera, maps, global positioning system, sampling forms, decontamination material/equipment, aluminum foil, plastic tarp/sheets, and any personal protective equipment you might need.

Once you arrive at the site/area where you will be sampling, you will collect either surface or subsurface samples (in some cases, both). If soil contamination is obvious, you should collect samples from the least contaminated areas first then work your way to the most contaminated areas. In addition, avoid cross contamination by disinfecting your sample collection devices and change gloves between each sample. Check first to determine sample collection device and cleaning requirements based on suspected contaminant; some only require soap and water, others such as polychlorinated biphyenyls (PCB) may require hexane or some other solvent. An alternative to cleaning is to use disposable collectors that are bagged after each use; disposal actions will depend on results of sampling.

Surface sampling

Surface soil sampling typically reaches depths of about 1 to 12 inches. Before you conduct surface sampling, it's important to first clear the sampling area of any debris such as leaves, twigs and trash down to the desired sampling depth. Next, make sure the equipment you use to clear the site is clean to prevent possible cross contamination of the soil sample. It's also a good idea to discard any of the materials touched by the debris removal equipment. Use a pre-cleaned stainless steel scoop to cut a

block of soil to the desired depth and sample volume width, and then collect the sample. Once the sample is collected, containerize and prepare the sample for shipment to the analytical laboratory.

Subsurface sampling

Subsurface sampling is used for depths from one foot or deeper. Just as for surface sampling, you should clear around the top of the area you will be sampling of any visible debris. When using subsurface sampling procedures, the specific sampling device (Veihmeyer, augers, etc.) used will dictate the correct procedures.

Other factors to consider before and when collecting soil and solid samples are as follows:

- Since many contaminants can quickly volatilize and disperse, collect samples as soon as possible after discovering or being notified there is actual or suspected soil contamination.
- If sampling was conducted because of an actual or suspected enemy attack, measures should be in place to have your samples analyzed by a direct reading instrument or to have them transported by the fastest method possible to an analytical laboratory.
- Determine the type of sampling strategy you will use to collect your samples (statistical or non-statistical sampling).
- Make sure you select/use the correct sampling device.
- Make sure your sampling device is clean prior to sampling.
- Be sure to decontaminate/clean your sampling device if you are sampling in multiple areas or if you are sampling for different contaminants (reduces cross contamination).
- Make sure you collect the correct amount of soil.
- Make sure you use the correct sampling containers and properly preserve your samples (if required).

Sieving

Sieving is the physical process of sorting samples through a sieve (screen) to remove debris and/or sort the soil sample by particle size. This type of sample preparation is mainly used for metals analysis and is conducted before analyzing the samples with an x-ray fluorescence (XRF) survey meter. Sieving can also be used to determine if a particle soil size is related to contaminant distribution. Sieving is not recommended for volatile compounds.

Since sieves come in different types and sizes, you should contact your analytical laboratory for guidance on which type and size sieve to use (see fig. 4–5). The following steps are used in the sieving protocol:

- Break up the soil with a trowel or hand held shovel.
- Remove any large debris (stones, rocks, worms, etc.).
- Crush entire sample.
- Use stainless steel screen for organics/Teflon for metals.
- Use the quartering process (see homogenized samples) to collect the sample.
- Containerize required volume of sample and label the container.

Figure 4–5. Soil sieves (fhwa.dot.gov).

Volatile organic compounds sampling

The guiding principal to keep in mind with VOC sampling is to maintain the sample in an intact form from the time of collection to analysis if possible. Once you determine you will be taking VOC soil samples you should attempt to take your samples and have them analyzed as quickly as possible to minimize volatilization of contaminants. For this reason, it's always a good idea to have several sampling devices dedicated for VOC sampling in your environmental sampling equipment and supply inventory.

If you recall, the tube sampler is the preferred method for collecting soil samples for VOCs. Ideally, the sample is collected in the tube, sent to the lab, and then analyzed in the same tube. This minimizes air contact and subsequent loss of vapors, which is a major concern when sampling for VOCs. Figure 4–6 is an example of one type of tube sampler used for VOC sampling.

Figure 4–6. Tube sampler for VOCs.

Regardless of what type of sampling, there are some situations where “control samples” along with your regular soil samples will be also collected. Control, or background, samples are collected from clean areas near the area where you collected your contaminated (or suspected contaminated) soil samples and are used as baseline data. The results of the control samples are compared to the contaminated sample results. This is particularly important when determining accurate radiation levels; control sample results are subtracted from the contaminated sample results.

Most of the soil samples you collect, send them to a laboratory for analysis; you should contact the laboratory in advance to find out sampling parameter such as types of sampling containers and preservation techniques, if applicable. If you are uncertain about any of the above sampling considerations, you should contact your servicing analytical laboratory for specific guidance.

440. Field analyzing soil/solid samples

Field analysis of soil/solid samples provides on-site measurements of contaminants of concern, limiting the number of samples that need to be collected and sent to an off-site laboratory for costly and time-consuming analysis. Field analysis can also define where to focus and/or collect bulk soil samples by indicating where possible contamination exists.

The table below provides an overview of common equipment used for field analysis/screening. Each listing includes a brief description and photograph. Refer to the respective user manual for additional information on a specific device.

Name	Description	Images
Portable Gas Chromatograph(GC)/ Mass Spectrometer (MS) HAPSITE with head space	• Analyzes for Volatiles. • Provides on-scene detection, identification and quantification of toxic industrial chemicals and chemical warfare agents. • Greater sensitivity to nerve and blister agents, identifies and measures numerous VOCs as well as identifies compounds in unknown mixtures. • Its sensitivity provides capability for detecting contaminants of concern at levels below other detectors’ threshold levels. • The HAPSITE used in combination with the Headspace Sampling System provides the capability to perform soil analysis for quantitative results in the field.	

Name	Description	Images
Fourier-Transfer Infrared Spectroscopy (FT-IR) HAZMAT ID	• Analyzes for Non-Volatiles, Explosives. • It identifies substances by matching the chemical absorption rate using infrared spectroscopy. • Only identifies unknown substances, it cannot quantify them. It verifies the presence or absence. • Identifies the constituent when there is 10 percent or more of the substance being analyzed. • It will not identify: o Substances with ionic bonds. o Elemental substances such as metals. o Dilute water solutions. o Individual components of a mixture that are <10% of the mixture. o Cannot definitively identify biological agents (IDs as a protein).	
Toxic Vapor Analyze (TVA)–1000	• Analyzes for organic or inorganic. • This analyzer uses either a flame ionization detector (FID), or a photoionization detector (PID), or *both* types of detectors to sample and measure concentration of gases. • Benefits: o Cost-effective packaging. o Detector response ratios can help characterize compounds. o Enhanced analytical capability derived from simultaneous detection.	
XRF	• Analyze for Metals. • There are three options for analysis of metals in soil samples, including in-situ, ex-situ bagged samples, and ex-situ samples prepared in XRF cups. • Clean the analyzer window with a soft cloth or disposable wipes after each analysis, otherwise soil may accumulate on the detection window.	
ADM 300 Radiation Meter with Probes	• Analyzes for Radiation (alpha, beta, gamma, and x-ray. • Multi-functional survey instruments are rugged and reliable and designed for use in all environments.	

Name	Description	Images
Hand-Held Assay (HHA)	• Analyzes for chemical warfare agents. • The HHA is a simple, antibody - based assay (test) used to presumptively identify biological warfare agents. HHAs are inexpensive, reliable, and easy to use. • One-time use capability designed to presumptively identify up to 10 agents, one agent at a time. • HHAs are not designed to be the sole method of identification and are not for diagnostic use. • Not normally used for soil samples but it is used for solids such as powders.	

Before using any equipment, it is important to know (or have a good idea) what materials will be sampled and be familiar with the selected equipment (including its capabilities and limitations). If taking bulk soil samples in addition to using field-analyzing equipment, ground readings of the area should be taken. These results should be documented before taking any bulk soil samples. Taking initial field readings will help narrow down the location and levels of soil contamination. In addition, obtained field readings should be compared to the correct OEL—the units of measurement for the field readings and the OELs should be the same.

Soil gas sampling is one type of common field analysis done by BE personnel. This analysis is used to indicate whether there are VOCs in the soil. In general, the procedures for soil gas sampling for VOCs are as follows:

- A ⅜ inch hole driven into ground.
- Stainless steel probe or Teflon tubing inserted into ground/hole.
- Hole is sealed at top (around probe or tubing) using modeling clay.
- Gas is sampled by pulling air through air pump.
- Samples can be collected in a Tedlar bag or Tenax sorbent tube and screened with a PID/FID.

When using a PID and FID, some factors that could influence the sampling results are soil temperature, soil adsorption capacity, sampling instrument response factor, and time the bore hole has been opened.

Background readings are useful for two reasons. First, they indicate if there is any other significant contamination in the area. Second, any background readings should be subtracted from the contamination readings to give a true indication of actual contamination levels.

441. Interpreting soil sample results

After the sampling strategy has been completed and the samples collected, the results are compared to the relevant standard for interpretation. This is done by comparing the sampling results to the selected OEL and determining if the result exceeds the applicable standard. In the absence of an OEL, the results can be interpreted by specifying the presence or absence of the contaminant. Whether comparing to an OEL or determining the presence of contamination, the results will be used to make OEH decisions and recommendations effecting personnel and the environment. When comparing results to a standard, several considerations need to be made:

- Ensure the sample and standard have the same exact spelling.
- Ensure the correct units of measurement for both sample and standard are used (convert units of sample to match sample, if needed).

- Ensure the results are compared to the correct type of standard.
- Ensure the correct laboratory analysis method was conducted.
- Ensure the correct calculations are used (if sample calculations are needed).
- Properly document sample results in accordance with the latest standard operating procedures/data management system.

References

[1] AFRL, *"USAFSAM Laboratory Sampling Guide,"* 11 May 2012.

[2] EPA, "Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G–4," February 2006.

[3] USAF, *Occupational and Environmental Health Site Assessment,* April 2012.

[4] EPA, Guidance on Choosing a Sampling Design for Environmental Data Collection, EPA QA/G–5S, 2006.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

436. Soil/solid sampling methodology

1. What is the importance of having a good soil/solid sampling methodology?

2. Soil sampling is conducted for what two primary reasons?

437. Soil/solid sampling devices

1. Why is an auger not used to sample for VOCs?

2. Why are tube samplers a good sampling device to collect VOCs?

3. Trier samplers are primarily used to sample what type of soil?

438. Determining soil/solid sampling strategies

1. How can you ensure the data from your soil sampling is representative and usable for the intended purpose?

2. Cite some obvious signs of soil contamination.

3. What type of soil sampling strategy uses the theory of random chance probabilities to choose representative sampling locations?

4. If you needed to investigate large sites that encompass a number of soil types, topographic features, or land uses, which type of sampling should you perform?

5. For unknown contamination, what actions can you take to determine what analytes to sample?

6. What type of sampling is use to sample for metals before analyzing with an x-ray fluorescence survey meter?

7. Where and why are background soil samples collected?

439. Collecting soil/solid samples

1. Where should you collect samples if soil contamination is obvious?

2. What effect does soluble contaminates have on soil?

440. Field analyzing soil/solid samples

1. Cite the advantage to taking field readings of the soil you will be sampling.

2. When using a PID/FID, what are some factors that could influence the sampling results?

441. Interpreting soil sample results

1. What are soil sample results used for?

2. What are a few things you need to take into consideration when comparing results to a standard?

Answers to Self-Test Questions

436

1. It will ensure your sampling will be performed in an organized and methodical process.
2. Health risk assessment and remediation.

437

1. Augers churn the soil which can rapidly release VOCs into the air.
2. They provide the least disturbed collection method.
3. Loose soil on or just under the surface.

438

1. By adhering to a good sampling strategy.
2. Wet, oily, or discolored soil or dead vegetation; an unpleasant odor.
3. Simple random sampling.
4. Stratified random sampling.
5. Use your investigative skills and direct reading sampling equipment to get an idea what type of CBRN material might have contaminated the soil.
6. Sieving sampling.
7. Near the area where you collected your contaminated soil samples; used as baseline data for comparison to the contaminated sample results.

439

1. From the least contaminated areas first.
2. Soluble contaminants mix with water and travel through soil better than insoluble contaminants.

440

1. It will help narrow down the location and levels of contamination in the soil.
2. Soil temperature, soil adsorption capacity, sampling instrument response factor, and time the borehole has been opened.

441

1. To make OEH decisions and recommendations effecting personnel and the environment.
2. (1) Ensure the sample and standard have the same exact spelling.
   (2) Ensure you are using the correct units of measurement for both sample and standard (convert units of sample to match sample, if needed).
   (3) Ensure the results are compared to the correct type of standard.
   (4) Ensure the correct laboratory analysis method was conducted.
   (5) Ensure the correct calculations are used (if sample calculations are needed).
   (6) If you are certain the adjacent areas around the site where you are taking field readings contain no contamination.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

85. (436) Remediation sampling is conducted to determine
    a. the extent of contamination before any cleanup is conducted.
    b. if any contamination exists after a cleanup process.
    c. the need for personnel protective equipment.
    d. which personnel have been exposed.

86. (436) What is an important factor to consider when developing a sampling methodology?
    a. Topography.
    b. Time of day.
    c. Where to sample.
    d. Weather conditions.

87. (437) What are the two types of augers?
    a. Bucket and screw.
    b. Trowel and shovel.
    c. Split spoons and push tube.
    d. Veihmeyer tube and trier sampler.

88. (437) Which sampling device has a *major* limitation of not being capable of penetrating stony or rocky soil?
    a. Trier sampler.
    b. Push tube sampler.
    c. Veihmeyer tube sampler.
    d. Split spoon tube sampler.

89. (438) If a soil sample is mixed or blended to create an even distribution of the contamination that is in the soil, what type of sample has been collected?
    a. Uniform.
    b. Composite.
    c. Homogenized.
    d. Total.

90. (438) Which type of sampling strategy should be used when there is minimal site background information available and there are no visible signs of contamination?
    a. Hot spot.
    b. Simple random.
    c. Systematic grid.
    d. Stratified random.

91. (438) What type of sampling strategy would be used to investigate large sites that encompass a number of soil types, topographical features, or land uses?
    a. Hot spot.
    b. Simple random.
    c. Systematic grid.
    d. Stratified random.

92. (438) What type of grid pattern increases the efficiency of hot spot soil sampling?
    a. Square.
    b. Diagonal.
    c. Triangular.
    d. Rectangular.

93. (439) It is important to know how a contaminant interacts within the soil because it
    a. lets you know how much of the sample to collect.
    b. can help you determine the extent of contamination in and around the area.
    c. lets you know how deep and how far out from the contamination area to sample.
    d. can help you determine the type of direct-reading instrument to use to collect samples.

94. (439) Which type of sample can be used to determine if a particle size is related to contaminant distribution?
    a. Homogeneous.
    b. Distribution.
    c. Composite.
    d. Sieving.

95. (439) What is the *major* concern when sampling for volatile organic compounds?
    a. Collecting the correct amount of soil.
    b. Properly preserving the sample at the collection site.
    c. Minimizing air contact and loss of vapors with the soil sample.
    d. Ensuring the sample is analyzed within 24 hours of collection.

96. (440) What field analysis device is *best* used to verify presence or absence?
    a. Hazardous Air Pollutants on Site (HAPSITE®).
    b. Hazardous material (HAZMAT) identification (ID).
    c. Toxic Vapor Analyze (TVA)–1000.
    d. X-ray fluorescence (XRF).

97. (440) What field analysis device can be used to sample for metals?
    a. Hazardous Air Pollutants on Site (HAPSITE®).
    b. Hazardous material (HAZMAT) identification (ID).
    c. Toxic Vapor Analyze (TVA)–1000.
    d. X-ray fluorescence (XRF).

98. (440) The advantage of collecting soil gas samples in the field is it will
    a. indicate if there are any volatile organic compounds in the soil.
    b. define the migration pattern of the contaminants in the soil.
    c. indicate if the soil is soluble or insoluble.
    d. indicate the porosity of the soil.

99. (441) After sampling results have been obtained, how are they interpreted?
    a. They are documented in Defense Occupational and Environmental Health Readiness System (DOEHRS) and sent to the major command (MAJCOM).
    b. They are compared to the selected occupational exposure limit (OEL).
    c. They are compared against previous results.
    d. They are interpreted by the laboratory.

100. (441) Which of these is *not* a consideration when comparing analysis results to a standard?
    a. Ensure the correct laboratory analysis method was conducted.
    b. Ensure the results are compared to the correct type of standard.
    c. Ensure all individuals potentially affected are listed in supportive documentation.
    d. Ensure the correct units of measurement for both the sample and standard are being used.

Student Notes

Glossary of Abbreviations and Acronyms

°	degree
µg	microgram
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	acute exposure guideline level
AF	Air Force
AFI	Air Force instruction
AFRL	Air Force Research Laboratory
AFMAN	Air Force manual
AFMSA	Air Force Medical Services Agency
AFOSH	Air Force Office of Safety and Health
AFTTP	Air Force tactics, techniques, and procedures
AIHA	American Industrial Hygiene Association
AL	action level
ANSI	American National Standards Institute
AOC	area of concern
ASAGE	Automated Sampling Guide
ASTDR	Agency for Toxic Substance and Disease Registry
BE	bioenvironmental engineering
BEE	bioenvironmental engineer
BEI	Biological Exposure Indices
BWA	biological warfare agent
C	ceiling limit; Celsius
CBRN	chemical, biological, radiological, and nuclear
CDC	career development course; Centers for Disease Control and Prevention
CDS	Civil Defense Simultest
CE	civil engineering
CEGL	continuous exposure guidance level
CFR	Code of Federal Regulations
CO	carbon monoxide
COC	contaminants of concern
CONUS	continental United States
CR(VI)	hexavalent chromium
CSM	conceptual site model

CV	coefficient of variation
DCS	deployable cartridge sampler
DLS	Department of Laboratory Sciences
DOD	Department of Defense
DOEHRS	Defense Occupational and Environmental Health Readiness System
DOT	Department of Transportation
DPD	diethyl-p-phenylenediamine
DPS	deployable particulate sampler
DQO	data quality objectives
DRI	direct-reading instruments
DW	drinking water
E. coli	Escherichia coli
EAP	exposure assessment priority
EEGL	emergency exposure guidance level
EL	exposure limit
EM	emergency management
EMI SIG	Emergency Management Issues Special Interest Group
EPA	Environmental Protection Agency
ERPG	Emergency Response Planning Guidelines™
ESOH	environmental, safety, and occupational health
F	fraction
FAC	free available chlorine
FC	fecal coliform
FID	flame ionization detector
FRB	field reagent blank
FT-IR	Fourier-transform infrared
GC	gas chromatograph
GF	glass fiber
HAPSITE®	Hazardous Air Pollutants on Site
HAZMAT	hazardous material
Hg	mercury
HHA	Hand-Held Assay
HPC	heterotrophic plate count
hr	hour
HRA	health risk assessment
HSS	headspace sampling system
IAQ	indoor air quality
IATA	International Air Transport Association

ID	identification; identifier
IDLH	immediately dangerous to life or health
IHMOD	industrial hygiene model
IOM	Institute of Occupational Medicine
IPE	individual protective equipment
IRIS	Integrated Risk Information System
K	Kelvin
L	liter
LCD	liquid crystal display
LCL	lower confidence limit
LEL	lower explosive limit
LER	longitudinal exposure record
LOD	limit of detection
lpm	liters per minute
m^3	cubic meter
MAC	maximum allowable concentration
MCE	mixed cellulose ester
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MEG	military exposure guideline
mg	milligram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
min	minute
ml	milliliter
mm	millimeter
MRL	minimal risk level
MS	mass spectrometer
NAAQS	National Ambient Air Quality Standards
NCEL	new chemical exposure limit
NIOSH	National Institute for Occupational Safety and Health
NMAM	National Institute of Occupational Safety and Health Manual of Analytical Methods
NRC	Nuclear Regulatory Commission
NSN	national stock number
NTP	normal temperature and pressure
OARS	Occupational Alliance for Risk Science
OEH	occupational and environmental health

OEHSA	occupational and environmental health site assessment
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration
OTM	Occupational Safety and Health Administration technical manual
P/A	presence/absence
PAC	protective action criteria
PACAF	Pacific Air Forces
PAR	population at risk
PCB	polychlorinated biphenyl
PEL	permissible exposure limit
pH	potential of hydrogen
PH	public health
PID	photoionization detector
PM	particulate matter
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
REL	recommended exposure limit
RF	radio frequency
RM	risk management
SAE	sampling and analytical error
SAM	sampling and analysis monitoring
SCAPA	Subcommittee on Consequence Assessment and Protective Actions
SDS	safety data sheet
SDWA	Safe Drinking Water Act
SEG	similar exposure group
SPEGL	short-term public emergency guidance level
STEL	short-term exposure level
TCC	total combined chlorine
TEEL	temporary emergency exposure limit
TERA	Toxicology Excellence for Risk Assessment
TG	technical guide
TLV®	threshold limit value
TRC	total residual chlorine
TSCA	Toxic Substances Control Act

TVA	Toxic Vapor Analyze
TWA	time-weighted average
TWA_{STEL}	time-weighted average short-term exposure limit
UCL	upper confidence limit
UEI	unit effectiveness inspection
UN	United Nations
USACHPPM	United States Army Center for Health Promotion and Preventive Medicine
USAF	United States Air Force
USAFCENT	United States Air Forces Central Command
USAFE	United States Air Forces in Europe
USAFSAM	United States Air Force School of Aerospace Medicine
USAFSAM/OEA	United States Air Force School of Aerospace Medicine Analytical Services Division
USAPHC	United States Army Public Health Command
USAPHC-E	United States Army Public Health Command-Europe
UV	ultraviolet
VOC	volatile organic compound
W	watt
WEEL	workplace environmental exposure level
WPAFB	Wright-Patterson Air Force Base
XRF	x-ray fluorescence
yr	year

Student Notes

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