AFRL-SA-WP-SR-2016-0023

U.S. Air Force School of Aerospace Medicine Laboratory Sampling and Analysis Guide

Maj Crystalyn E. Brown

November 2016

Air Force Research Laboratory
711th Human Performance Wing
School of Aerospace Medicine
Occupational & Environmental Health Dept
2510 Fifth St., Bldg 840
Wright-Patterson AFB, OH 45433-7913

NOTICE AND SIGNATURE PAGE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

Qualified requestors may obtain copies of this report from the Defense Technical Information Center (DTIC) (http://www.dtic.mil).

AFRL-SA-WP-SR-2016-0023 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

//SIGNATURE//	//SIGNATURE//
DAVID R. CARPENTER, PhD Senior Technology Consultant	WENDY E. ODDEN, COL, USAF, BSC Chair, Occupational & Environmental Health

This report is published in the interest of scientific and technical information exchange, and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
15 Nov 2016	Special Report	November 2013 – October 2016

4. TITLE AND SUBTITLE
U.S. Air Force School of Aerospace Medicine Laboratory Sampling and Analysis Guide

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Maj Crystalyn E. Brown

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USAF School of Aerospace Medicine
Department of Occupational and Environmental Health/OEA
2510 Fifth St., Bldg 840
Wright-Patterson AFB, OH 45433-7913

8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL-SA-WP-SR-2016-0023

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.

13. SUPPLEMENTARY NOTES
Cleared, 88PA, # 2014-0577, 18 Nov 2014.
Supersedes AFRL-SA-WP-SR-2014-0019 (same title) and AFRL-SA-WP-SR-2012-0008, *Laboratory Sampling Guide* (11 May 2012)

14. ABSTRACT
This sampling guide is designed to aid base-level Bioenvironmental Engineers in submitting industrial hygiene, environmental health, and radiological samples to the U.S. Air Force School of Aerospace Medicine (USAFSAM), Occupational and Environmental Health Department, Analytical Services Division. This guide provides information on the collection, handling, and analysis of samples submitted to the Analytical Services Division laboratories at Wright-Patterson AFB, OH. It also provides guidance for Pacific Air Forces locations using USAFSAM Detachment 3 laboratories and for Air Force Central Command locations using the U.S. Army Public Health Command-Europe laboratories.

15. SUBJECT TERMS
Occupational health, environmental health, radiation, dosimetry, air sampling, water sampling, soil sampling, Occupational and Environmental Health Site Assessment (OEHSA), industrial hygiene, health risk assessments, site assessments, radioanalysis, Defense Occupational and Environmental Health Readiness System (DOEHRS), customer support, analytical method, sample plan development, collection volumes, sample media, reporting limits, Automated Sampling Guide (ASAGE), field blanks, quality assurance, turnaround time, sample submission forms, AF Form 2753

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Col Wendy E. Odden
U	U	U	SAR	195	19b. TELEPHONE NUMBER *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

This page intentionally left blank.

TABLE OF CONTENTS

Section **Page**

LIST OF FIGURES

Page

LIST OF TABLES

Page

This page intentionally left blank.

FOREWORD

This guide provides specific technical information to assist BE personnel in sample collection, lab analysis, and results interpretation. This guide does not address direct reading sampling and instrumentation.

The U.S. Air Force School of Aerospace Medicine, Occupational and Environmental Health Department, Analytical Services Division (USAFSAM/OEA) Laboratory Sampling Guide is designed to provide a customer friendly reference. This guide supersedes AFRL-SA-WP-SR-2014-0019 USAF SCHOOL OF AEROSPACE MEDICINE LABORATORY SAMPLING AND ANALYSIS GUIDE (15 May 2014). The guide is designed in Adobe Acrobat Reader 10 Portable Document Format with embedded hyperlinks to external websites, email addresses, download links, and internal bookmarks for ease of use. External **links** and internal **bookmarks** are indicated by blue text. Clicking the **bookmarks** will take you directly to the reference section of the Sampling Guide.

Disclaimer

The Analytical Services Sampling and Analysis Guide is provided in uncontrolled (customer use) format. Due to the wide geographic distribution and turnover in Air Force personnel, USAFSAM does not maintain a list of recipients and automatically provide updated copies. The contents of the Sampling Guide are subject to change based on method revisions, updates, or changes. The Analytical Services Division is not responsible for any sampling error incurred by the customer. Any mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Please routinely visit Analytical Services on the Environmental, Safety, and Occupational Health (ESOH) Service Center website [restricted access] to ensure you are using the current version of this guide.

Please address all analytical questions and inquiries to the Customer Service section in the Analysis Support Branch (OEAS). Direct all sampling strategy and policy questions to the Environmental, Safety, and Occupational Health (ESOH) Service Center, or reference the Automated Sampling/Analysis Guide (ASAGE).

CONTACTING USAFSAM ANALYTICAL SERVICES DIVISION

	USAFSAM/OEA WRIGHT-PATTERSON AFB, OH	USAFSAM TPML KADENA AB, JPN
TELEPHONE	*All Labs @ WPAFB* **DSN: 798-3435** **Comm: 937-938-3435** *Monday – Friday* 0800 – 1600 Eastern ESOH Service Center (24/7) DSN: 798-3764 1-888-232-ESOH (3764)	**DSN: 315-632-8275** **Comm: 011-81-611-732-8275** *Monday – Friday* 0730 – 1630 Japan Std Time
EMAIL	USAFSAM/OEA Customer Service esoh.service.center@us.af.mil	18AMDS.SGPL.AnalyticalLab@us.af.mil
INTERNET	Analytical Services Website* ESOH Service Center Website	Share Point Site*
SHIPMENT ADDRESSES	***Chemistry Lab*** USAFSAM/OEA Attn: Chemistry Lab 2510 Fifth Street, Bldg 840, W327N Wright-Patterson AFB, OH 45433 ***Radioanalytical Lab*** USAFSAM/OEA Attn: Radioanalytical Lab 2510 Fifth Street, Bldg 840, W331 Wright-Patterson AFB, OH 45433 ***Dosimetry Lab*** USAFSAM/OEA Attn: Dosimetry Lab 2510 Fifth Street, Bldg 840, W329B Wright-Patterson AFB, OH 45433	*APO* USAFSAM TPML/AD Attn: Sample Receiving Unit 5213 Bldg 853 APO AP 96368-5213 *Commercial* TPML USAFSAM AD Unit 5213 Bldg 853 Kadena AB Okinawa Japan 904-0020

***Restricted access.**

SECTION 1: INTRODUCTION TO ANALYTICAL SERVICES

1.0 Introduction

This sampling and analysis guide is designed to support base-level Bioenvironmental Engineers (BEs) in submitting industrial hygiene, environmental health, and radiological samples to the U.S. Air Force School of Aerospace Medicine (USAFSAM), Department of Occupational and Environmental Health Analytical Services Division (OEA).

Overseas guidance is provided in Appendix A for Pacific Air Forces (PACAF) locations using USAFSAM TPML laboratories and Appendix B for U.S. Air Forces Central (AFCENT) locations using the U.S. Army Public Health Command-Europe (USAPHC-Europe) laboratories. Radiation dosimetry details in this guide are limited to shipping and handling information; for specific guidance on radiation dosimetry, refer to Air Force Manual (AFMAN) 48-125, *Personnel Ionizing Radiation Dosimetry* [1].

1.1 Summary of Changes

This guide has been substantially revised and should be completely reviewed. Major changes include clarification of laboratory services and all sample submission procedures. Section 2, Occupational Health Sampling and Analysis, includes discussions on media shelf life, exposure assessment strategies and censored data analysis. Calculation examples moved to Appendix C. Sample collection and calibration train instructions moved to Appendix D. Section 3, Sampling and Analysis for Selected Hazards, provides guidance regarding more prevalent workplace exposures y base-level BEs encounter, and Section 5, Radioanalytical Sampling and Analysis, provides the most current sample submission procedures for wipes and foreign soils. Websites supplementary to this guide were added to Appendix E.

1.2 Mission Statement

The mission of OEA is to serve the best interests of the USAF and the individual warfighter by providing analytical chemistry and related consultative support for USAF-wide occupational, environmental, and radiation health surveillance.

Analytical Services ensures that customer quality and timeliness needs are met through in-house and subcontract laboratory services. The laboratory maintains a robust in-house quality assurance (QA) program, including audits of subcontract laboratories. The laboratory provides consultative support regarding sample collection, analysis, data interpretation, and reliable data warehousing of historical sample results.

1.3 Analytical Services Organizational Structure

The Analytical Services Division is organized into two branches and six sections as indicated by the organization chart in Figure 1. All analytical questions and inquiries should be addressed to the Customer Service section in the Analysis Support Branch (OEAS). All sampling strategy and policy questions should be directed to the ESOH Service Center.

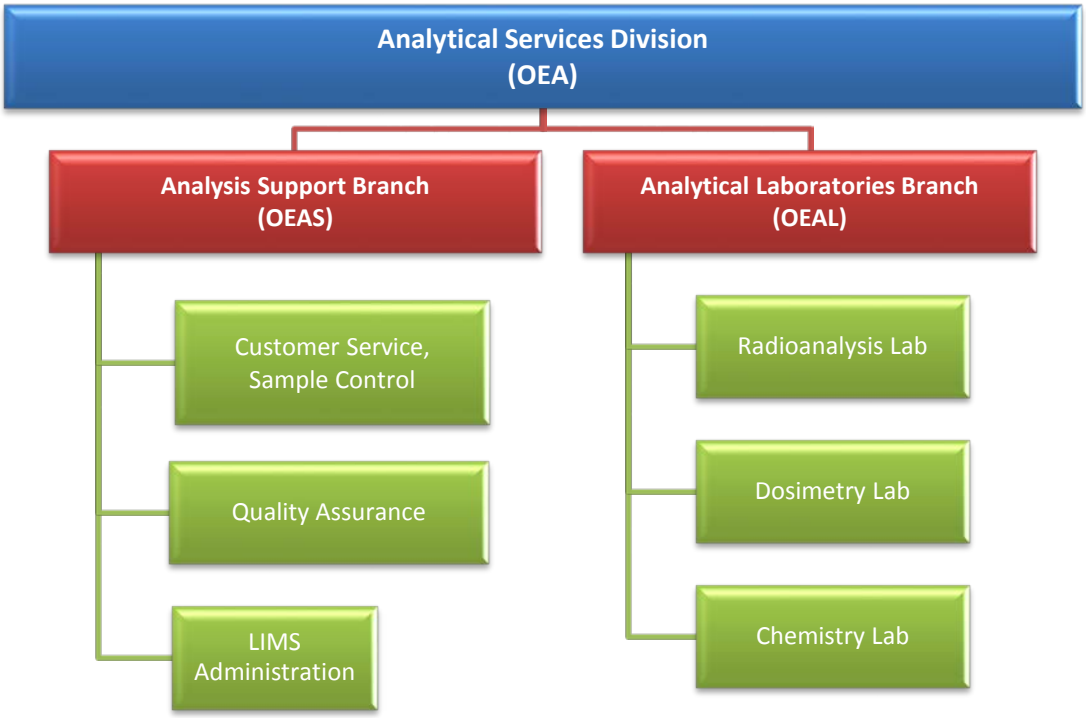


Figure 1: Analytical Services Organizational Structure

1.4 Summary of Services

OEA provides the following laboratory services:

- Radioanalysis Lab
- Radiation Dosimetry Lab
- Chemistry Lab, including industrial hygiene and environmental chemistry

OEA may be able to accommodate other requests either through qualified commercial laboratories or through in-house method development, if the projected sample load is significant. New analytical methods are time consuming and usually require 6 months to a year or more to complete.

1.5 Quality Assurance Policy

OEA is committed to providing the highest quality and legally defensible analytical data in a timely and efficient manner. The validity and reliability of all the information generated are ensured by strict adherence to documented quality control (QC) and quality assurance (QA) protocols throughout the entire sample receipt, processing, preparation, testing, and reporting process.

1.6 Accreditations

OEA maintains accreditation by third party organizations to both national and international standards (Table 1). The scope of testing for these accreditations covers environmental, occupational health, and radiation dosimetry. A complete list of Industrial Hygiene Laboratory Accreditation Program (IHLAP) and Environmental Lead Laboratory Accreditation Program (ELLAP) accredited fields of testing can be obtained by visiting the American Industrial Hygiene Association (AIHA) Laboratory Accreditation website. The complete list of equipment the Radiation Dosimetry Lab is accredited to process can be accessed by visiting the National Volunteer Laboratory Accreditation Program (NVLAP) website.

Table 1: Analytical Services Laboratory Accreditation Summary

IH/ENVR Chemistry Laboratory	
Accrediting Body	AIHA
Accreditation	IHLAP ELLAP
Lab ID	101490 (WPAFB); 101802 (TPML, Kadena AB, Japan)
Radioanalytical Laboratory	
Accrediting Body	Coming Soon
Accreditation	N/A
Lab ID	N/A
Radiation Dosimetry Laboratory	
Accrediting Body	National Voluntary Laboratory Accreditation Program (NVLAP)
Accreditation	ISO/IEC 17025:2005
Lab ID	100548-0 (WPAFB)

1.7 Funding

There is no direct cost to base-level BEs for the use of USAFSAM Analytical Services. USAFSAM/OEA is centrally funded through Defense Health Programs (DHP) and baseline funding is used to cover the cost of in-house and subcontracted analysis.

USAFSAM Analytical Services is not funded to provide routine or compliance drinking water analysis; however, a blanket purchase agreement (BPA) has been established with commercial laboratories that are certified in drinking water analysis for most of the lower 48 states. If necessary, base-level personnel may request use of the BPA through a signed memorandum of agreement. This process does not provide funding for drinking water analysis; however, it does permit the bases to receive drinking water analytical services at our subcontracted pricing.

If you desire USAFSAM to be directly funded for your drinking water requirements, please discuss with your major command BE and the Air Force Medical Operations Agency.

1.8 Subcontract Analysis

If subcontract services are required, please contact OEA Customer Service prior to sample collection (e.g., during the planning phase) for approval/coordination of commercial lab analysis. Without prior coordination, there will be a significant delay in analysis. Prior coordination ensures the analyte being requested is on contract and funds are available for analysis.

If an analyte is not on contract, request special authorization and funding through USAFSAM/OEA Workflow. The request must contain a detailed summary of the project (e.g., sample matrix, analytical method desired, number of samples, estimated collection dates, goal of the project, etc.).

Customer Service requests installations to AVOID submitting non-critical samples for contracted analysis during the timeframe of *15 September to 15 October* for end of fiscal year closeout. By delaying these submissions, Customer Service will be able to balance and reconcile funding accounts in a timely manner.

1.9 Automated Sampling Guide / Customer Support

Analytical Services provides several means of support to address sampling questions (Table 2). The Automated Sampling Guide (ASAGE) [restricted access], an online application to aid in industrial hygiene and environmental health sample plan development, is also linked on the USAFSAM laboratory's website [restricted access]. ASAGE is designed to be the first stop, self-service site to address basic industrial hygiene and environmental sampling and analysis questions that provides method-specific details including handling, stability, media type, and reporting limits based on the analyte of concern.

ASAGE will list all available methods for a given analyte and indicate the preferred in-house method. ASAGE includes additional methods available either in-house or provided by our subcontract laboratories; however, please pre-coordinate with Customer Service to ensure the method standards or funding is available.

Beyond ASAGE, Laboratory Customer Service and ESOH Service Center personnel are available for telephone consultation. For technical questions, if our Customer Service professionals cannot answer your question(s), you may be referred to the appropriate analyst or function chief within the laboratory for additional information.

Table 2: Customer Support Services

CUSTOMER'S NEED	CUSTOMER SERVICE DSN 798-2523	ESOH SERVICE CENTER DSN 798-3764	ASAGE
Selecting appropriate analytical method	X	X	X
Requesting rush analyses	X		
Technical Information on analyses	X		
Reprint of historical results	X		
Sample collection	X	X	X
Shipping guidance	X		X
Sample processing/final report status	X		
Sample plan development		X	
Appropriate OEEL recommendations		X	
Sample collection volumes/flow rates		X	X
Reporting limits	X		X
Analytical Error	X		

1.10 Customer Satisfaction

Analytical Services values you as a customer. Our staff is dedicated to providing quality service. OEA Customer Service may send an electronic customer satisfaction survey after your project is complete. If you receive a survey link, please take the time to complete it. The Laboratory Quality Assurance Team reads and discusses each survey. If necessary, they'll initiate corrective or preventive action.

If you do not receive an electronic customer satisfaction survey and you would like to complete one, please contact OEA Customer Service or access it at this link: USAFSAM/OE Customer Satisfaction Survey.

Customers are welcome and encouraged to arrange a tour of our laboratory facilities when visiting USAFSAM. To arrange a tour, please contact OEA Customer Service. The key to good service is communication. Please keep us informed by phone or e-mail of any changes in your sampling dates, number of samples, or requirements. In turn, OEA will keep you informed of changes or problems as they arise.

1.11 Turnaround Time (TAT) Goals

Analytical Services strives to provide results in a timely and efficient manner. Laboratory turnaround time (TAT) is defined as the time from receipt of samples at the laboratory performing the analysis to the release of analytical data. In the event the laboratory is unable to meet the published TATs, we will contact you with an explanation and a new projected TAT. Table 3 lists TAT in business days. Please note the labs do not operate on federal holidays.

Table 3: USAFSAM Analytical Turnaround Times (TAT)

Laboratory	WPAFB, OH (days)	Kadena AB, JPN (days)
Industrial Hygiene	**10 (10-20 subcontracted)**	**20**
Environmental	**10-20**	**20**
Radioanalytical	**25-60**	**N/A**
Dosimetry	**5 – Monthly Reports 10 – Quarterly Reports**	**N/A**

1.12 Priority Requests

The laboratory strives to meet base-level requests for quick turnaround times in the event of acute health risk or extreme mission impact. At a minimum all rush analysis requests must be coordinated with Customer Service ***prior to*** shipping samples. This is especially important if the circumstances make contract analysis necessary.

The laboratory priority request form, available on the USAFSAM laboratory's website [restricted access], is required for all rush analysis requests. Requests will not be considered without the completion of this form. A formal review of the lab's capacity, capabilities, customer's time requirements, certification requirements, logistics, method hold times, and subcontract funding (if applicable) is completed when approving priority requests. This form is applicable to the chemistry and radioanalytical labs.

1.13 Sample Submission Procedures

Please follow the steps outlined in Figure 2, Sample Submission Flowchart. Following the correct sample submission process will ensure timely sample processing, eliminate significant delays, and ultimately ensure you receive results when you need them. If samples are collected or documented incorrectly, we will make every effort to obtain the necessary information to convert the invalid sample into a valid sample.

OEA can no longer accept the AF Form 2750, AF Form 2753 or the 495 envelope as valid submission forms.

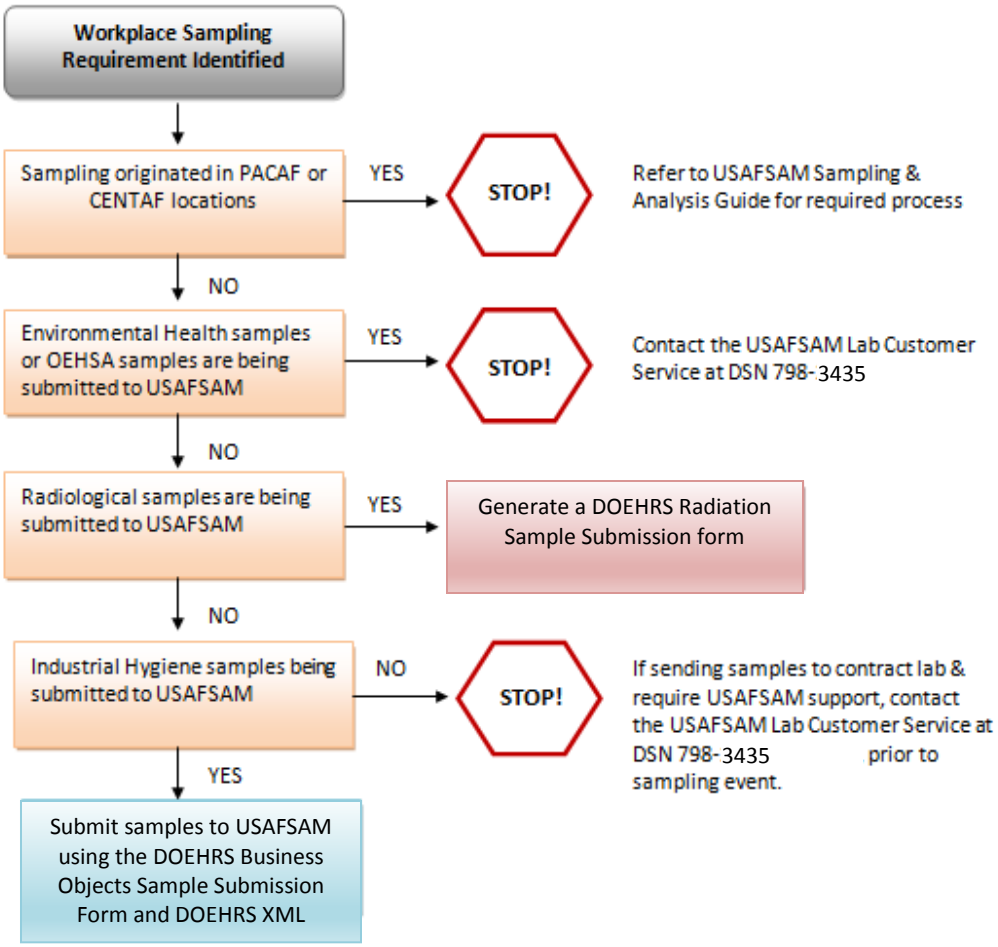


Figure 2: Sample Submission Flowchart

A sample submission form must accompany each sample shipment. Without a form, the laboratory may reject the shipment or be forced to significantly delay analysis. Seal the submission form in a waterproof, zip-lock bag for protection during the shipping process (especially for shipments that contain liquids). Always use indelible ink (never pencil) for all submission form markings. Any DOEHRS data errors made on the submission form must be corrected in DOEHRS and the submission form reprinted. Errors to the POC or other fillable sections must be crossed out with a single line, initialed, dated, and rewritten or you can choose to start over with a new form.

The primary industrial hygiene sample submission form is the DOEHRS Business Objects Transactional Report Sample Submission form . If the DOEHRS submission form is unavailable, the USAFSAM (locally developed) alternate submission form may be used. 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 if you require an alternate submission form. Refer to Appendix F for DOEHRS sample submissions procedures.

The 495 envelope may only be used to transport radiation wipe samples. Radiological sample submissions must be accompanied with the DOEHRS sample submission form. Refer to the DERG – Radiation Sample Submission Form on the ESOH Service Center for DOEHRS sample

submissions procedures. A USAFSAM developed 2753 is available for use only when DOEHRS is unavailable.

1.14 Shipping and Handling Procedures

Customers may use the 711th Federal Express (FedEx®) account to ship samples to USAFSAM, AFTER coordinating with OEA Customer Service. Use of the 88th AB Wing or the now-closed, former USAFSAM FedEx® accounts is strictly forbidden. USAFSAM is charged a stiff penalty of shipping costs plus 150% if customers use an unauthorized account. This diverts funds from sample analysis.

For prompt delivery of priority or time-sensitive samples, the most expedient method is FedEx® priority overnight. (Please **DO NOT** ship first delivery as it is an unnecessary extra expense. Customer Service receives priority and first delivery samples at the same time, so it will not expedite samples any faster.) If FedEx® is not available at your location, you may ship samples at the base's expense using a different carrier, but please consider sample stability and hold times if shipping by any means other than overnight.

Deliver hand-carried samples to USAFSAM prior to 1400 hours Monday through Friday to ensure they are processed into the Laboratory Information Management System. Refer to Table 4 below for additional guidance on sample shipping methods.

Table 4: Sample Shipping Methods

- **With long holding times** - **Not requiring refrigeration**	- **For immediate or emergent analysis** - **With short hold times** - **Must be refrigerated**
Can be sent by	***Must be sent by***
➢ Commercial Carrier - USAFSAM FedEx® Acct - Local Acct thru UPS®, DHL® Worldwide, etc. ➢ Hand Carry ➢ Traffic Management Office (TMO) ➢ U.S. Postal Service	➢ Overnight service via Commercial Carrier - USAFSAM FedEx® Acct - Local acct thru UPS®, DHL Worldwide®, etc. ➢ Hand Carry
Check with your chosen carrier to ensure delivery date!	

1.14.1 Hazardous Materials

Hazardous materials are articles or substances that are capable of posing a risk to health, safety, property, or the environment. A list of hazardous materials can be accessed from the International Air Transport Association Dangerous Goods Regulations Manual [2]; 49 CFR Part 172, Section 101 *Hazardous Materials Table* [3]; or local TMO. The shipper must comply with any regulatory requirements such as proper labeling and packing. All labels and forms must be complete, legible, and accurate. The shipper must be trained and certified to ship hazardous materials.

The U.S. Department of Transportation (DOT) provides regulations governing the transport of hazardous materials under the Hazardous Materials Transportation Act of 1974. The applicable

requirements of the regulations are found in 49 CFR Parts 171 through 177. The shipper should particularly note DOT regulations in the following areas:

- Marking and Labeling – 49 CFR part 172 [3]
- Placarding – 49 CFR part 172 [3]
- Monitoring – 49 CFR part 172 [3]
- Packaging – 49 CFR part 173 [4]
- Transportation by Rail – 49 CFR part 174 [5]
- Transportation by Air – 49 CFR part 175 [6]
- Transportation by Vessel – 49 CFR part 176 [7]
- Transportation on Public Highways – 49 CFR part 177 [8]

1.14.2 Dry Ice

Dry ice is the most used hazardous material for shipments. Dry ice belongs to 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. A good sturdy fiberboard box is acceptable. Polystyrene is generally unacceptable outer packaging.

1.14.3 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 transportation by the carrier.

1.14.4 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.

Many temperature-sensitive samples received are shipped in normal containers that were not designed for temperature control. In these instances, samples were received at room temperature and were no longer valid for compliance sampling.

Do not ship on Fridays or right before holidays; OEA is unable to accept Saturday or holiday deliveries for routine shipments.

1.14.5 Routine Shipments

For routine air sample shipments (i.e., no special shipping/handling requirements), samples should be placed in a plastic bag then in a cardboard box (Figure 3). Pack the samples securely to avoid any rattle or shock damage. Packaging material (bubble wrap, foam peanuts, etc.) can be

added to limit sample mobility within the box. The sample submission paperwork should be inserted into the box and not inside the same plastic bag as the samples. In addition, an XML file should be emailed to Customer Service (see Figure 3).

The plugs used to cap air cassettes and sorbent tubes often fall off during shipping. Using tape to seal the plugs can increase the chance the samples will still be capped when they arrive at the lab and reduce the potential for contaminant loss and cross-contamination. Care should be taken to ensure the tape is contaminant free (e.g., do not use tape with toluene in the adhesive if you are looking for toluene).

Priority samples delivered after duty hours on weekdays, weekends, or holiday delivery ***must*** be coordinated with Customer Service in advance of the requested delivery date.

Figure 3: Sample Packaging and Shipping

Additional contaminant/analytical method specific shipping and sample preservation requirements can be found by referring to the individual method, ASAGE, or by calling Customer Service.

1.14.6 Labeling Requirements

All samples submitted for lab analysis shall be properly labeled with a unique identifier (i.e., DOEHRS sample ID). Sample IDs shall contain no more than 13 characters and each physical sample ID shall correspond to an ID on the sample submission paperwork. Following strict QC protocols, the lab is required to receive customer approval prior to modifying any IDs on submission paperwork/physical samples even if it is an obvious transcription error. All discrepancies in sample IDs must be resolved prior to the lab proceeding with analysis. Incorrectly labeled samples will delay analysis and extend TAT. Sample ID labels should be placed on sample cassettes or tubes. ID's placed on the plastic bag a sample is stored in may fall off during shipment, especially in a cooler with ice. If this happens and samples cannot be identified by the lab, samples will be cancelled.

1.15 Base-Level QA/QC Procedures

Please complete a detailed quality control (QC) before shipping samples to the laboratory. The QC process includes a review of sample collection dates, volumes, IDs, media, requested analyte/analytical method, and base contact information . For each physical sample, there should be a corresponding sample identification (ID) on the sample submission paperwork. The quality control process includes a review of sample collection dates, volumes, IDs, media, requested analyte/analytical method, base contact information as applicable, and is a recommended addition to flight sampling standard operating procedures (SOP)

Appendix G contains a template QC checklist for reference. The template is designed as an example industrial hygiene QC protocol; however, additional QC protocols for radiation and environmental samples may be developed and included in your base-level sampling standard operating procedures.

1.16 Chain of Custody

A formal chain of custody is normally required only when the analytical results will be evidence in litigation. If you require this level of "chain of custody," please contact Customer Service for detailed discussions on sample labeling, packing, and shipping procedures. Samples that do not require refrigeration and are not time sensitive should be sent by the *U.S. Postal Service using Registered Mail with a Return Receipt Request* to ensure a proper chain of custody.

1.17 Sample Receipt and Processing

Upon receipt, the OEA Customer Service staff will review the samples and associated paperwork. After verifying the samples' integrity, the staff will process them into the Laboratory Information Management System and assign a unique laboratory work order number. You will be informed by lab personnel of any deviation from requirements (holding time exceeded, temperature not met, etc.) that may compromise the analytical results. If the condition of the submitted sample does not allow the generation of valid analytical data (i.e., use of incorrect sampling media or the hold time has been exceeded), the lab may inform you that the work order has been canceled.

Sample submissions requesting multiple analytical methods will often be split into multiple work orders and reported separately as each individual method is completed. For example, a single shipment containing five hexavalent chromium samples and five metal samples will be separated into two different work orders. This is due to the samples being analyzed in separate in-house laboratories. Two separate reports will be provided as soon as each work order is complete.

1.18 Reporting

Final reports will not be released until reviewed and verified by the appropriate Technical Manager, Function Chief, or their authorized designee. Final reports are typically sent via e-mail to the individuals identified on the sample submission paperwork. Reports may be sent to multiple individuals by listing additional names in the comments section of the DOEHRS sample submission form. At the same time, sample results will be uploaded into DOEHRS via the XML. Copies of archived reports may be obtained by submitting a written request or e-mail to Customer Service.

Levels of Reporting. Analytical Services provides several levels of laboratory reports, including:

- *Level 1*: **This is the standard laboratory report provided by USAFSAM to most customers.** This is a report consisting of the analytical results for the associated methods, cover page, case narrative, and scanned analysis request form. Higher level lab reports are only provided on an as-needed basis.
- *Level 2*: This is a Level 1 report that includes the batch quality control sample results.
- *Level 3*:This is a Level 2 report that includes most aspects of the analytical run, such as instrument calibration data, tune data, prep logs, analysis logs, and instrument quality control data.
- *Level 4*: This is a Level 3 report that includes the raw data for the analyses involved. The raw data include the printouts from the instruments, such as chromatograms.

Disclaimers: The lab recognizes that there are field situations when samples cannot be taken according to required sampling methods. In such cases, the laboratory will usually analyze the sample if taken on appropriate sampling media and report results possibly accompanied by one of the example disclaimer statements listed in the comments section of the final report:

- INSUFFICIENT AIR VOLUME: The sampled air volume is less than recommended for this method.
- QUESTIONABLE FLOW RATE: The flow rate differs from the recommended method's rate.
- BLANKS NOT SUBMITTED: No field blank was submitted as required by the analytical method.

PLEASE NOTE THAT ANY SAMPLES RECEIVED ON INCORRECT MEDIA OR OUTSIDE THE HOLD TIME WILL NOT BE ANALYZED.

Regardless of the lab analyzing the sample, it is particularly important to pay attention to any comments included in the narrative of the final report. Any issues that occurred with sample shipment, receiving, analysis, or QC will be annotated in the comments section and could jeopardize the validity of a result for a health risk or compliance assessment.

1.19 Chemical and Biological Warfare Agents

Do not send samples known to be contaminated with chemical or biological agents.

Samples suspected to be contaminated with or collected from areas suspected to have been previously contaminated with chemical or biological agents ***must*** be **SCREENED** and found to be **NEGATIVE** prior to shipment to USAFSAM. The negative screening results should be clearly documented on the sample submission paperwork accompanying the samples.

USAFSAM is not designed to handle suspected chemical or biological warfare samples. Bases should refer to the Laboratory Response Network (LRN) managed by the Centers for Disease Control and Prevention for a listing of national (biological warfare) and LRN-C (chemical warfare) Level 1 laboratories. The LRN is designed to develop, maintain, and strengthen an integrated national and international network of laboratories that can respond quickly to the needs for rapid testing, timely notification, and secure messaging of results associated with acts of biological and chemical terrorism.

1.20 Bibliography

Refer to the bibliography for a list of publications that provide information about other areas of interest to USAFSAM customers, such as regulatory requirements and sample collection techniques. These sources include, but are not limited to, other USAFSAM Technical Guides and pertinent regulatory documents.

1.21 DOEHRS Tutorials

All DOEHRS screen shots and tutorials are contained in Appendix F. For quick access to a related tutorial, click the DOEHRS icon throughout the guide to be directed to the applicable section in the appendix. The DOEHRS tutorials in this guide assume a basic understanding of DOEHRS and are designed to aid in specific sampling discussions. For basic user guidance, refer to the DOEHRS Support Office [restricted access] website.

For issues relating to DOEHRS or the DOEHRS Sample Submission Form, contact the DOEHRS Support Office at 937-938-3764, DSN 798-3764, or email: esoh.service.center@us.af.mil.

1.22 Definitions

Appendix H contains a list of definitions.

1.23 Analysis of Breathing Oxygen

Technical Order (TO) 42B6-1-1, Quality Control of Aviator's Breathing Oxygen, 6 March 2012, states that breathing air tests after incidents affecting flying personnel will be submitted to one of the laboratories listed in Table 5 [9]. For assistance with shipping bottles to the applicable fuels laboratory, check with your local POL unit.

Table 5: Fuels Laboratory Contact Information

Aerospace Fuels Laboratory (FP2070) AFPA/PTPLA 2430 C St, Bldg 70, Area B, Wright-Patterson AFB, OH 45433-7632 Commercial (937) 255-2106 DSN: 785-2106	**Aerospace Fuels Laboratory** (FP2075) AFPA/PTPLE 1747 Utah Ave., Bldg 6670 Vandenberg AFB, CA 93437-5220 Commercial (805) 606-6263 DSN: 276-2756	**Aerospace Fuels Laboratory** (FP2080) AFPA/PTPLF RAF Mildenhall, UK., Bldg 725 APO AE 09459 Commercial 44-1-638-54-2043 DSN 314-238-2043/3797/5757
Aerospace Fuels Laboratory (FP2083) AFPA/PTPLG Bldg 854 Unit 5161 Kadena AB, Okinawa, JA APO AP 96368-5162 Commercial 011-81-611-734-1602/3394/0322 DSN: 315-634-3394/1602/0322	**76 MXSS/MXDTAA** Attn: Chemical Sciences Section 3001 Staff Drive/STE I-63 Tinker AFB, OK 73145-3038 Commercial: (405) 736-2135 DSN: 336-2135	

1.24 USAFSAM Sampling and Analysis Process

The sampling and analysis process involves identifying the size, scope, and type of sampling that is required. As stated in section 1.9, Laboratory Customer Service and ESOH Service Center personnel are available for telephone consultation. Refer to Figure 4 for a detailed look at the USAFSAM sampling and analysis process.

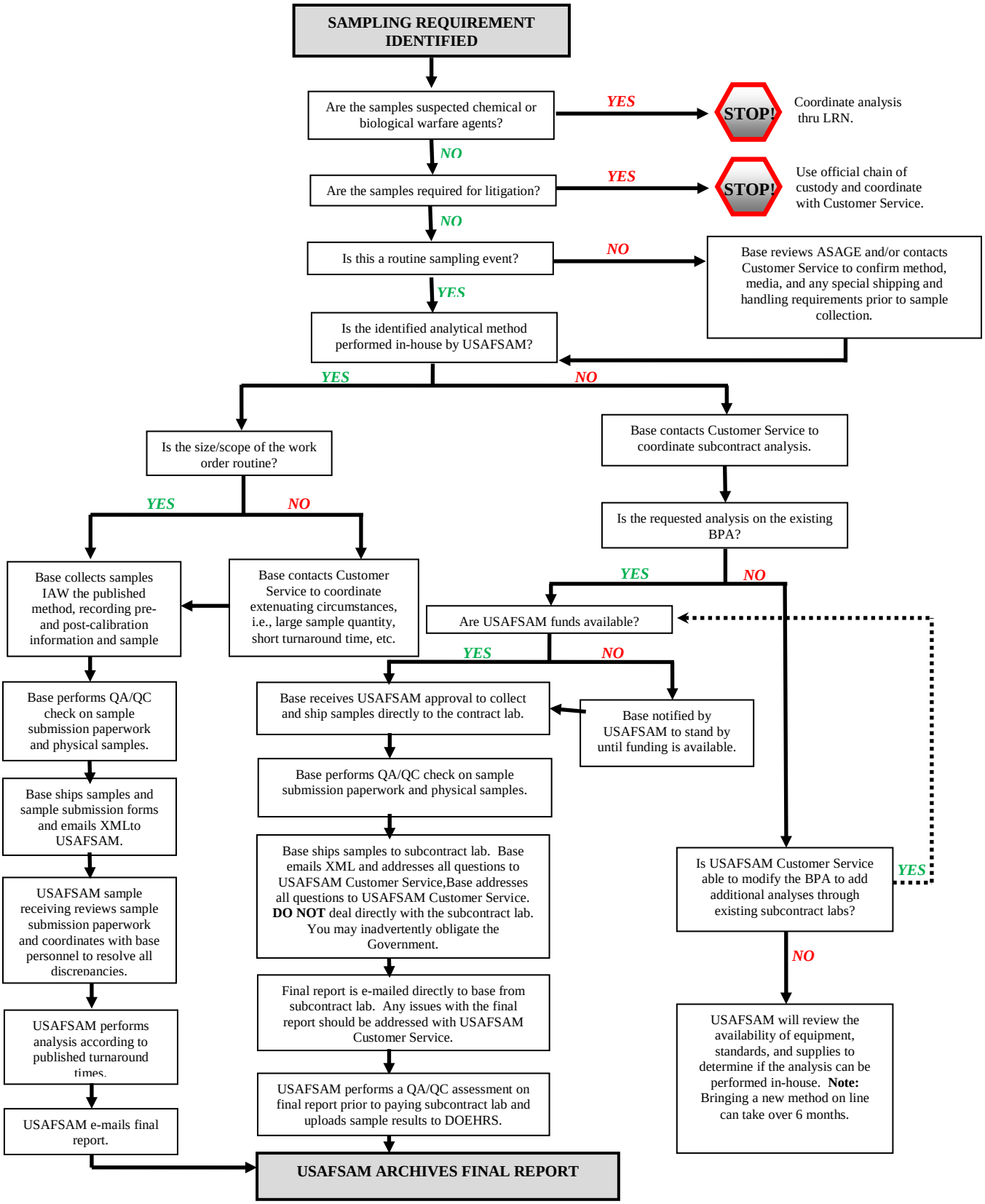


Figure 4: USAFSAM Sampling and Analysis Flowchart

SECTION 2: OCCUPATIONALHEALTH SAMPLING & ANALYSIS

2.0 Occupational Health Sampling

Occupational health samples are generally collected in conjunction with a health risk assessment (HRA) of hazards generated in the industrial workplace. Samples are typically collected referencing American Conference of Governmental Industrial Hygienists (ACGIH®) and OSHA exposure criteria and are personal samples with a pump attached to an actual employee. Occupational health samples may also be collected in non-industrial workplaces to assess the migration of contaminants from adjacent industrial processes (e.g., fuel operations, generator exhaust, hazardous material storage area), or simply be present around the workplace.

2.1 Industrial Hygiene Services

USAFSAM Analytical Services provides a wide-range of in-house analytical services through the Chemistry Lab. Table 6 provides a complete list of these services.

Table 6: Industrial Hygiene Analytical Services Available

Analytical Capability			WPAFB	Kadena AB, JP
Gas Chromatography	Mass Spectrometry	GC/MS	X	-
	Flame Ionization Detector	GC/FID	X	X
	Flame Photometric Detector	GC/FPD	X	-
	Nitrogen Phosphorous Detector	GC/NPD	X	-
	Electron Capture Detector	GC/ECD	X	-
Inductive Coupled Argon Plasma	Optical Emission Spectrometry	ICP/OES	X	X
	Mass Spectrometry	ICP/MS	X	X
High Performance Liquid Chromatography	Ultraviolet Detector	HPLC/UV	X	-
	Fluorescence	HPLC/FL	X	-
Atomic Absorption Spectrometry		AA	-	X
Ion Chromatography		IC	X	X
Gravimetric Analysis		GV	X	-

2.2 Industrial Hygiene Sample Plan Development

The first step in a successful sampling event is developing a complete sampling strategy. The ESOH Service Center has developed a comprehensive Sampling Strategy Planner and Narrative Field Note Taker to help simplify this task as well as facilitate gathering the required information for DOEHRS input. These tools can be found in the Air Sampling DERG on the ESOH Service Center website. At a minimum, a sampling plan should start by answering the following six questions.

2.2.1 Question 1: What is the sampling objective?

Why is the sampling being conducted and what is the desired outcome? Will the results be compared to a published occupational and environmental exposure limit (OEEL)? Are you looking for deviations from an established baseline? Has there been a change in operations, equipment, or materials driving the sampling event? *'What is the purpose of sampling?'* is the single most important question and ***MUST*** be answered prior to sampling. Bottom line: what do you intend to do with the quantitative results listed on the final report? Typical purposes for an exposure assessment include:

- Health risk assessment and management
- Compliance determination
- Management of programs that are implemented by comparison with an exposure limit
- Health complaint or air quality problem
- Future epidemiologic studies
- Task or contaminant investigation for determination of exposure control strategies
- Worker compensation/toxic tort case
- Evaluation of future changes in the workplace (i.e., introduction of a new chemical)

2.2.2 Question 2: Where are you sampling?

Identify expected exposure sites. Include where chemicals are stored, transported, and used at the site and what ventilation and airflow patterns exist. Identify the buildings, rooms, and work centers where the potential hazard will be generated.

2.2.3 Question 3: What are you sampling?

This is based on available information. What are the potential chemical hazards? Refer to available safety data sheets (SDSs). 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)? Note: If there is high probability that sampling will need to be conducted, it is recommended to request a physical copy of the SDS of the actual product being used at the time of sampling. This will eliminate any issues with outdated information from SDS databases.

2.2.4 Question 4: What type of sample will you collect?

For compliance sampling, OSHA requires that an employee's exposure be measured by any combination of long-term or short-term samples that represent the employee's actual exposure. There are three basic types of sample collection techniques: personal samples, breathing zone, and area monitoring. While they are all acceptable, personal samples provide the best information in determining an employee's actual exposure.

Personal Samples. This is the preferred method of evaluating worker exposure to airborne chemicals. The sampling pump and collection device are directly attached to the employee and worn continuously during all work and rest operations. "Attach the sample collection device (use a tube holder for glass sampling tubes) to the shirt collar or as close as practical to the nose and mouth in the employee's breathing zone (i.e., in a hemisphere forward of the shoulders within a radius of approximately six to nine inches)" [10].

Area Monitoring. The sampler is placed in a fixed location in the work area (also referred to as "general air"). The samplers can be used to measure emissions from process equipment or background levels of an environmental agent. They may not be used for OSHA permissible exposure limit (PEL) compliance.

2.2.5 Question 5: Who are you sampling?

This is based on knowledge of the potential exposure sites and the various job requirements at the site. What job classifications or specific individuals should be considered for monitoring?

Maximum Risk Employee. Workers with the greatest potential exposure should be considered for compliance sampling. Samples collected from maximum risk employees should not be used to characterize the exposure profiles of similar exposure groups (SEGs), as bias would be introduced. 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. Worst-case monitoring data must be interpreted carefully because data do not reflect the "true" exposure profile and, therefore, might not reflect the actual health risk for workers in a given SEG.

Random Sampling of a Similar Exposure Group. Random sampling of a SEG is the appropriate method to defining exposure profiles. Random sampling means that the sampling day and the individual from the SEG to be sampled should be selected as randomly as possible. Picking specific workers within an SEG for sampling due to perceived exposures introduces bias and is discouraged. 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. Table 7 gives the required sample size **n** of a random sample drawn from a group of size **N** that ensures with 90% confidence that at least one individual from the highest 10% exposure group is contained in the sample.

Table 7: Random Sampling of an SEG[a]

Size of Group N	Number of Required Samples
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

[a]Table 3.1 from NIOSH Occupational Exposure Sample Strategy Manual [11].

2.2.6 Question 6: What is the sample duration?

Sample duration may vary from a few seconds to 8 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 OEEL 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 below factors in determining the appropriate sample duration.

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

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. Maximum sampling times aim not to collect too much mass of contaminant to avoid sorbent breakthrough or filter overloading.

For example, charcoal tubes may need to be changed more frequently to prevent breakthrough. The breakthrough time of a charcoal tube is a function of the air concentration of the contaminant being sampled, the sample flow rate, and the humidity of the environment being sampled. Breakthrough time is also a function of the type, amount, size, and packing configuration of the charcoal in the tube and competition for sorbent sites by other contaminants present in the air. Similar limits on sampling time apply to filters and impingers to prevent overloading. Judgment should be exercised in changing sampling media of any type often enough to sample a sufficient volume of air to quantify the sample without the occurrence of breakthrough.

Type of OEEL to Which the Sampling Results Will Be Compared. Samples collected over the time period for which the OEEL is defined provide the best estimate of the time-weighted average (TWA) employee exposure. Each type of OEEL imposes different sample duration requirements:

Ceiling (C) Standard. Samples collected to determine compliance with ceiling limits are usually taken as a series of 15-minute samples during periods of maximum expected exposure. Samples taken for comparison with ceiling limit OEELs are best taken in a non-random fashion, during periods of maximum expected concentrations. A minimum of three measurements should be taken during each work shift sampled. The highest of all the measurement results is the best estimate of the employee's exposure for that shift. Direct reading instruments are ideal for ceiling measurements,

Short-Term Exposure Limit (STEL). STEL samples should be taken over a 15-minute period. STEL samples should also be taken in a non-random fashion during periods of maximum expected concentration.

8-hour Time-Weighted Average OEELs. Evaluate the potential for employee overexposure through partial or full shift air sampling. Full shift samples should be taken to evaluate TWA exposures whenever possible and must be used when determining compliance with OSHA PELs. Full shift sampling is defined as a minimum of the total time of the shift less 1 hour (i.e., 7 hours of an 8-hour shift or 9 hours of a 10-hour work shift). However, no more than 8 hours of sample can be used in the 8-hour TWA-PEL calculation (refer to discussion on extended work shifts below). Figure 5 provides a diagram of available 8-hour TWA measurements and can be further broken down into:

- *Full Period Single Sample Measurement.* The sample is taken for the full period of the standard. This would be 8 hours for an 8-hour TWA standard.

- *Full Period Consecutive Samples Measurement.* Several samples (equal or unequal time duration) are obtained during the entire period appropriate to the standard. The total time covered by the samples must be 8 hours for an 8-hour TWA standard.

- *Partial Period Consecutive Samples Measurement.* One or several samples (equal or unequal time duration) are obtained for only a portion of the period appropriate to the standard. For an 8-hour TWA standard, this would mean that the sample or samples cover about 4 to less than 8 hours. Several samples totaling less than 4 hours (as eight 30-minute samples) would probably be best described as grab (short-term) samples for the purposes of analysis.

- *Grab Samples Measurement.* Grab samples are taken at random intervals over the period of time for which the standard is defined. Each sample collection is less than 1 hour each, generally only minutes to seconds.

Extended Work Shifts. For employees working shifts longer than 8 hours, there are two approaches to determining the workers' 8-hour TWA.

- *8-hour Continuous Sample.* Sample the worst continuous 8-hour work period of the entire extended work shift.

- *8-hour Non-Contiguous Sample.* Collect multiple samples over the entire work shift. Sampling is done so that multiple personal samples are collected during the first 8-hour work period and additional samples are collected for the extended work shift. Unless you are dealing with lead, the employee's exposure in this approach is calculated based upon the worst 8 hours of exposure during the entire work shift. Using this method, the worst 8 hours do not have to be contiguous.

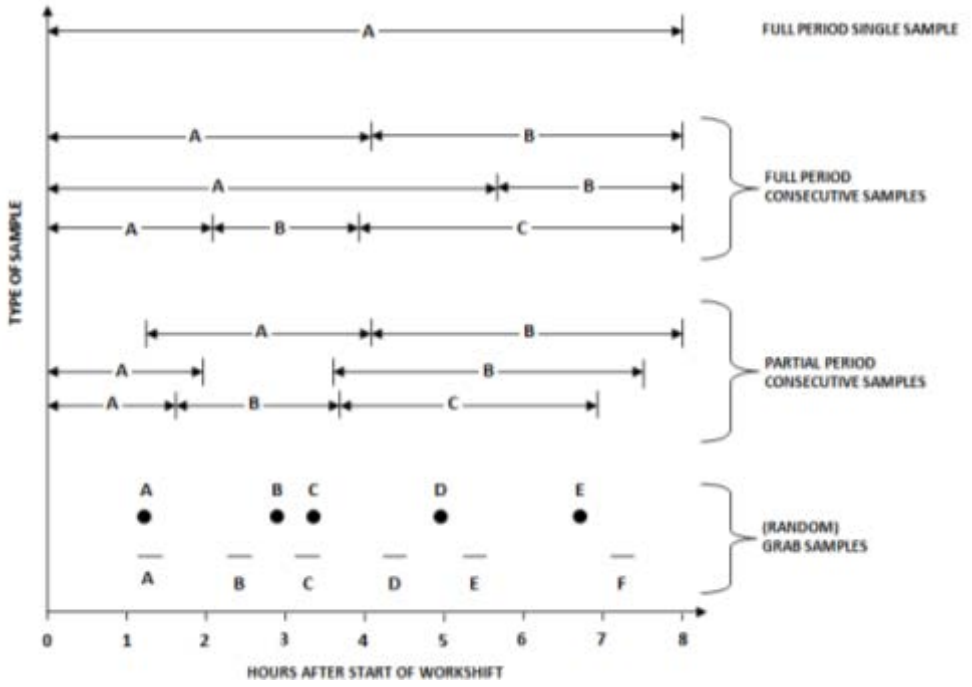


Figure 5: Types of Personal Samples
(Figure 3.1 from NIOSH Occupational Exposure Sampling Strategy Manual) [11]

2.3 Exposure Assessment Strategy

The exposure assessment strategy is part of the overall Department of Defense and AF exposure assessment models. This strategy is step five within the AF model described in Air Force Instruction (AFI) 48-145, *Occupational and Environmental Health Program*, Figure 4.1 [12]. The recommendation for three and then potentially for three additional samples (a total of six) is for processes that warrant an air sampling characterization. These recommendations are not intended for processes that are either so short in duration or present so little risk as to not warrant air sampling when evaluated in relation to other risk-prioritized exposure assessment needs.

2.3.1 Exposure Assessment Model

The AIHA Exposure Assessment Strategies Committee has developed an Excel spreadsheet with 12 algorithms/models developed from the book *Mathematical Models for Estimating Occupational Exposure to Chemicals* [13]. The Excel spreadsheet is called "IH Mod" and can be downloaded for free from the committee's website. Prior to the use of any model, users should become familiar with the limitations and applicability of the model to the assessment application.

- If the model results in < 50% of the OEEL, then the exposure should be acceptable.
- If the model results in ≥ 50% of the OEEL, then perform screening sampling.

Refer to Appendix I for the exposure assessment model flowchart.

2.3.2 Statistics… Going Beyond Upper and Lower Confidence Limits (UCL/LCL)

To calculate statistics in DOEHRS, the software requires at least six samples. This supports AIHA's recommendation that six or more measurements should be taken to characterize an exposure profile as a starting minimum. For many processes with moderate to high variability, fewer than six measurements usually leaves a great deal of uncertainty about the exposure profile.

For detailed discussions on statistics and exposure profiles, refer to Appendix J, Censored Data Analysis.

2.3.3 Screening Sampling

Take three representative random samples. The samples should capture all exposures for the work shift and consider similar target organs from various hazards. The samples should be as "random" as possible. Research indicates that most industrial hygienists cannot accurately identify the "worst case" exposures. Intentional bias of the sampling data through an attempt to select "worst case" or "best case" data will actually make the exposure assessment less protective of the worker rather than more protective. If only a few workers are performing the task, then sample all of them. The use of direct reading instruments (DRIs) for inhalational exposures is strongly encouraged.

a. If any of the three UCLs ≥ OEEL, the exposure profile is unacceptable, enact controls.

OR

b. If all three UCLs < 10% of the OEEL, then the exposure profile is acceptable.

OR

c. If any of the three UCLs ≥ 10% of the OEEL but none exceed the OEEL, then the exposure profile is uncertain. Execute full characterization or preemptively enact controls.

2.3.4 Full Characterization

Take three more representative random samples (still encourage DRIs). First, calculate 95th percentile of all six (or more) data and compare to the OEEL to categorize the exposure profile using the flowchart.

Next, complete verification. In general, exposure profiles should be reviewed and verified against the documented determinants of exposure during routine industrial hygiene surveillance. The frequency for surveillance, and therefore verification of exposure profiles, is prescribed in AFI 48-145[12]. However, more attention should be given to exposure profiles where the data are sparse, or have high variability, such as a geometric standard deviation that exceeds 3.0.

Even when such profiles are deemed acceptable, the variability suggests a process that is not well defined. For unacceptable exposure profiles, the data should be verified annually. Unacceptable profiles may be for processes awaiting engineering controls or processes where all feasible engineering controls still cannot reduce exposures to acceptable levels.

Unless demanded by regulation, it is not necessary to repeat a sampling campaign when none of the determinants of exposure have changed. The results will only reconfirm what is already known and waste resources that could have been directed toward uncertain exposure profiles. It is important to maintain surveillance over unacceptable exposure profiles and keep the commander's attention on those hazardous processes that could cause harm to workers and mission.

2.4 Analytical Methods

Most analytical methods used by the Chemistry Lab for industrial hygiene are published by NIOSH and OSHA. Since OSHA does not require specific analytical methods, unless stated in a stressor-specific standard, any method (i.e., American Society for Testing and Materials (ASTM), scientific literature, journal articles, etc.) can be used for compliance sampling as long as it meets NIOSH criteria of accuracy within ±25% at the 95% confidence level.

For a listing of preferred in-house analytical methods, please refer to the USAFSAM Automated Sampling Guide [restricted access] or call OEA Customer Service.

2.4.1 OSHA Sampling and Analytical Methods

An alphabetical list of chemicals as well as a list of chemical abstract service (CAS) numbers that have either a validated or partially validated OSHA method can be accessed on the OSHA Index of Sampling and Analytical Methods.

2.4.2 NIOSH Manual of Analytical Methods (NMAM)

The NMAM may be searched by chemical name, Chemical Abstracts Service (CAS) number, or method number. In addition to individual analytical methods, the NMAM provides guidance on quality assurance, method evaluation, biological monitoring, aerosols, and special measurement considerations. The front page of each NIOSH method summarizes sampling and measurement parameters and gives estimates of limit of detection, working rage, precision, and interferences (Figure 6).

CHEMICAL NAME **METHOD #**

FORMULA Molecular Weight Chemical Abstracts Service # RTECS #

Method numbers are the same as those in the 3rd edition. Evaluation (Full, Partial, Unrated, N/A) is assigned as described in Method Classification of these "blue pages." Issue date reflects current version (e.g., August 15, 1994) and previous 3rd edition versions, if any.

OSHA : These exposure limit values are
NIOSH: those in effect at the time of
ACGIH: printing of the method.

PROPERTIES: Boiling/melting points, equilibrium vapor pressure, and density help determine the sample aerosol/vapor composition.

SYNONYMS: Common synonyms for the substance. These are all listed alphabetically in the Index of Names and Synonyms ("yellow pages" in this Manual).

SAMPLING

SAMPLER: Brief description of sampling EQUIPMENT

FLOW RATE: Acceptable sampling range, L/min

VOL-MIN: Minimum sample volume (L); corresponds to Limit of Quantitation (LOQ) at OSHA PEL

-MAX: Maximum sample volume (L) to avoid analyte breakthrough or overloading

BLANKS: Each set should have at least 2 field blanks, up to 10% of samples, plus 6 or more media blanks in the case of coated sorbents, impinger solutions, or other special samplers.

ACCURACY

Data are for experiments in which known atmospheres of the substance were generated and analyzed according to the method. Target accuracy is less than 25% difference from actual concentration over the range of the method.

MEASUREMENT

TECHNIQUE: The measurement technique used

ANALYTE: The chemical species actually measured

A summary of the measurement EQUIPMENT, SAMPLE PREPARATION, and MEASUREMENT steps appearing on the second page of the method is given here.

CALIBRATION: Summary of type of standards used

RANGE: Range of calibration standards to be used; from LOQ to upper limit of measurement (Note: More concentrated samples may be diluted in most cases to fall within this calibration range.)

ESTIMATED LOD: Limit of detection (background + 3)

PRECISION ($_r$): Experimental precision of spiked samplers

APPLICABILITY: The conditions under which the method is useful, including the working range in mg/m^3 (from the LOQ to the maximum sampler loading) for a stated air volume are given here.

INTERFERENCES: Compounds or conditions which are known to interfere in either sampling or measurement are listed.

Figure 6: Layout of Front Page of NIOSH Methods (Summary provided from the NMAM) [15]

2.5 Sample Media

Personal sampling media typically falls into three categories: filters, solid sorbent tubes, and passive monitors. Less commonly, impingers and bubblers are used. It is important to annotate the type of media used during each sampling event. Prior to sampling, ensure the media is ***not*** expired. For questions regarding media shelf life, contact the manufacturer. The Chemistry Lab cannot extend a media shelf life. The physical state of the contaminant being sampled should be considered when determing a sampling media. It is important to choose the proper sampling media to collect all phases of the contaminant of interest. For example, some isocyanate protocols require a two-stage sampling approach. The first stage contains an untreated polytetrafluoroethylene (PTFE) (Teflon) filter to collect the aerosol phase and stage two holds a treated glass fiber filter (GFF) to capture the vapor phase.

2.5.1 Filters

Filter sampling is used to evaluate potential airborne particulate hazards, such as dusts, fumes, and mists (Figure 7). For filter sampling, a pump is used to actively pull a known volume of air through a filter appropriate for the hazard. After the particulate matter has been deposited on the filter, the concentration (mass) of the analyte of interest can be determined by analytical methods. Filter pore size is important (i.e., a 0.8-µm pore size creates more resistance than a 5-µm pore, creating increased velocity, impact, and efficiency).

Care should be taken not to overload the cassette. An overloaded cassette can easily be identified by loose particulates that move freely when the filter is inverted. If the filter is overloaded the lab will make every attempt to consider cassette wall deposits during the analytical preparation though the final result may be only an estimated concentration. A record of this observation will be present in the case narrative of the report.

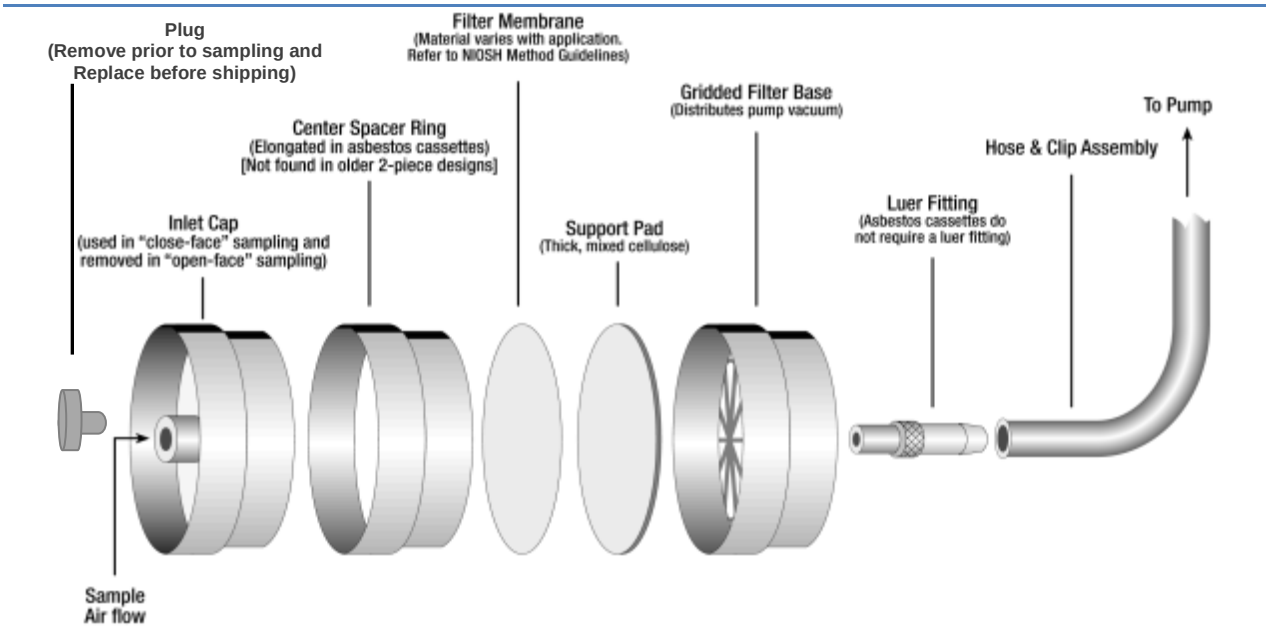


Figure 7: Air Sampling Filters (Courtesy of SKC Inc.)

There are several types of filters used for airborne hazard sampling. The type of filter required for a specific analyte and analytical method is given in ASAGE. Table 8 shows examples of a few types of filters and their use:

Table 8: Types of Air Sampling Filters (Courtesy of SKC Inc.)

Filter Type	Typical Uses	
GFF	Isocyanates, Oil Mists, Pesticides	
Polyvinyl Chloride (PVC)	Particulates, Silica, Hexavalent Chromium, Metals	
Mixed Cellulose Ester (MCE)	Metals, Particulates, Fibers, Asbestos	
PTFE	Alkaline Dust, Oil Mist, Hydrogen Sulfide	
Quartz	Diesel Particulate, Elemental Carbon	

2.5.2 Solid Sorbent Tubes

Many gases and vapors are collected using solid sorbent tubes (Figure 8), which usually consist of a glass tube containing two sections of a solid adsorbent material. When air is actively pulled through the tube, airborne gases and vapors are adsorbed by the first sorbent section while the second section serves as a backup in case analyte breakthrough occurs. If directional arrows are present on the sampling tubes indicating the proper air flow, the arrow should be pointed toward the pump. Hint: the smaller portion of the sorbent material (backup sorbent layer) is always closer to the pump.

Prior to laboratory analysis, the sorbent material is removed from the sampling tubes and the analytes of interest are extracted and analyzed. The first and second sections of the sorbent tube are analyzed separately to monitor breakthrough. *Breakthrough* describes a condition in which the mass of a collected gas or vapor in the backup section is greater than 10% of the mass in the front section. This means that a significant quantity of the contaminant may not have been collected. The calculated concentration, therefore, is of questionable validity. High temperature and high humidity will increase the likelihood breakthrough will occur. The analytical lab will typically flag final results if breakthrough is suspected.

Sorbent tubes are designed to be used in the vertical position. If a sorbent tube is hung on an employee horizontally, sorbent material may fall to one side of the tube and allow airflow to pass more readily, reducing the absorption efficiency of the tube. There are several types of solid sorbent tubes used for gas and vapor sampling. The type of sorbent tube required for a specific analyte for each test is given in ASAGE. Table 9 shows examples of a few types of sorbent tubes and their uses:

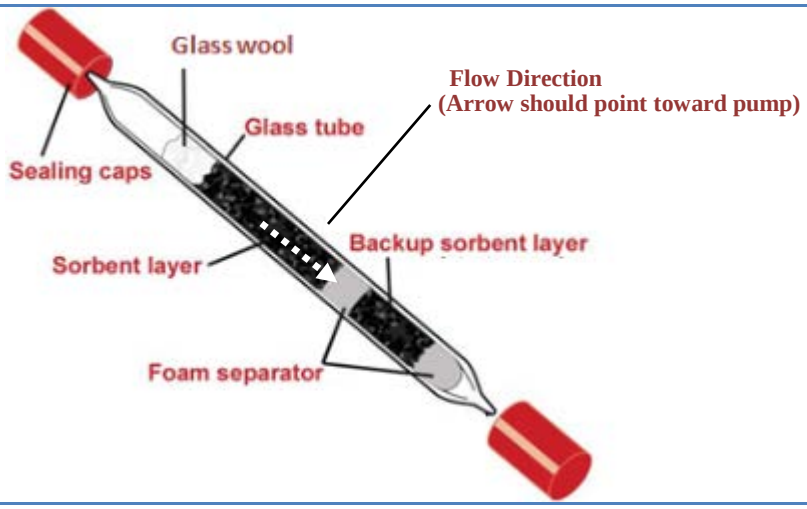


Figure 8: Air Sampling Solid Sorbent Tubes (Courtesy of SKC Inc.)

Table 9: Types of Solid Sorbent Tubes (Courtesy of SKC Inc.)

Tube Type	Typical Uses
Anasorb® 747	Methyl Ethyl Ketone, Ethylene Oxide
Charcoal Tube	Organic Solvents
Molecular Sieve	Nitrogen Oxides
XAD®-2	Pesticides, Polynuclear Aromatic Hydrocarbons, Amines
XAD®-7	Glycols, Cresols, Phenol
Silica Gel	Aliphatic Amines, Methanol, Aldehydes, Acid Mist
Chromosorb 106	Napthalene

2.5.3 Diffusive Samplers

Diffusive samplers, also known as passive monitors or badges, do not require a sampling pump (Figure 9). They are small plastic enclosures filled with a granular solid sorbent such as activated charcoal that has an affinity for organic gases and vapors. One section of the enclosure is open to the air.

Organic gases and vapors in the air that pass through the opening by diffusion are adsorbed, or trapped, by the sorbent material. Diffusion is the passage of molecules through a semi-permeable barrier. It occurs because molecules tend to move from an area of high concentration to an area of low concentration. If the ambient concentration of a particular gas or vapor is greater than the concentration inside the monitor, then the gas or vapor molecules will diffuse across a barrier into the monitor and be collected by a sorbent material. The rate of diffusion is determined by the manufacturer of the device.

Monitoring begins when the device's cover is removed; the time is recorded. The worker wears the monitor in his or her breathing zone. When sampling is complete, the monitor is removed and resealed and the time is recorded. ***Note:*** Only a few select passive monitors and analytical methods have been published and approved by OSHA. In many cases there are no OSHA or NIOSH methods to reference to ensure the reliability of data when using passive samplers.

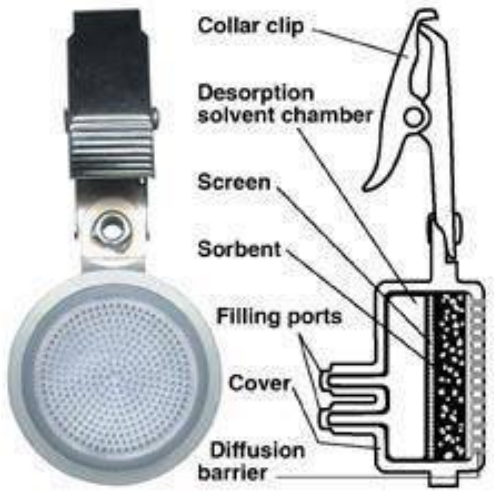


Figure 9: Air Sampling Passive Monitors (Courtesy of SKC Inc.)

Generally, to use a passive monitor, air movement at 25 ft/min across the face of a passive sampler is necessary for proper sampling. This condition is normally met during personal sampling on a mobile worker, but not during area sampling in calm air. When air is stagnant at the face of a passive monitor, "starvation" occurs because the boundary zone is depleted of fresh contaminant molecules. The resulting slowdown in the diffusion process decreases the effective sampling rate and produces an erroneous low measurement of concentration. Alternatively, excessively turbulent air will also disrupt normal diffusion rates, and therefore the use of axial fans or work in hoods should be given consideration when using diffusive samplers
. Table 10 shows examples of a few types of passive monitors and their uses:

Table 10: Types of Passive Monitors (Courtesy of SKC Inc.)

Passive Monitor	Typical Uses	
SKC UME^{X}	Formaldehyde	
SKC 575-001 **SKC 575-002**	Specific Organic Solvents (Check applicability)	
SKC Ultra®	Organic Solvents	
3M™ 3500 **3M™ 3520**	Specific Organic Solvents (Check applicability)	

2.5.4 Media Shelf Life

NOTE: Section 2.5.4, Media Shelf Life, Tables 11-13, provides an overview of shelf life based on prevalent media types.

For more specific SKC information, go to http://www.skcinc.com/certificates.asp. This website is a reference you can use to view SKC certificates for media expiration dates by Lot Number. Scroll down the page until you see "Sorbent Certificate of Analysis."

Table 11: Stable Media Shelf Life

Manufacturer	Product	Expiration (if applicable)	Notes
Millipore HAWP04700	MCEF	None	Currently there is no expiration date associated with this product.
SKC 226-01	ANASORB CSC	YES, arbitrary[a]	The tubes have a 5-year expiration date ascribed to them. The date is somewhat arbitrary and (in a private communication) is based not on scientific but inventory control. If the product was centrally managed the supplier would be willing to send a new Certificate of Analysis (or equivalent), which would allow the product to be used without comment.
SKC 225-8-01-1	PVC Filters	None	Currently there is no expiration date associated with this product.
SKC 225-1827	Quartz Filters	YES	The expiration date is arbitrary and could be extended if the volume warranted interaction with the supplier.
Supelco 20358	ORBO	Recently removed[b]	The vendor has recently removed the expiration date. Recently the vendor has removed expiration dates from many of their ORBO type products.

[a]Based on SKC communications dated Friday, December 20, 2013, 10:18 a.m.
[b]Based on Supelco communications dated Friday, September 27, 2013, 12:30 p.m.

Table 12: Prepared Media Shelf Life

Manufacturer	Product	Expiration (if applicable)	Notes
SKC 225-8204	Pre-Weighed PVC	YES[a]	On media that are open ended with caps and not glass sealed, the vendor has a shelf life that ranges from 2 to 3 years. That was actually based on some data that show, over time, backgrounds can increase. This expiration date should be adhered to.
OMEGA ISOCHEK	Isocyanate Sampler	YES[a]	10 mo, ambient. SKC had discussions with Omega. Omega selected the expiration dates based on its knowledge of the filter media and also discussions with the manufacturers of the filter media. This expiration date should be adhered to.
SUPELCO	Asset Isocyanate Sampler	Yes[b]	24 mo, ambient. The product is new and additional evaluation may extend the expiration date.
SKC 226-119	DNPH Treated SG	YES[a]	Stored in freezer. Due to the reactivity of the media and the presence of carbonyl compounds in the workplace, the expiration date should be adhered to.

[a]Based on SKC communications dated Friday, December 20, 2013, 10:18 a.m.
[b]Based on Supelco communications dated Friday, September 27, 2013, 12:30 p.m.

Table 13: Badge Media Shelf Life

Manufacturer	Product	Expiration (if applicable)	Notes
SKC – UMEX 500-100	Formaldehyde Badge	YES	Freezer.
3M Badge 3500	Organic Vapors	YES, 18 mo, based on validation study[a]	Per the manufacturer –"All of the 3M diffusion monitors have an 18-month shelf life. As mentioned, this is based on the formaldehyde and ethylene oxide monitors. I am not aware of any reason to have a shelf life on the organic vapor monitors, but I believe all were given 18 months to be consistent." Without extensive (and expensive) validation studies, this expiration date should be adhered to.
3M Badge 3721	Formaldehyde	YES, 18 mo, based on validation study[a]	Same as above.
3M Badge 3551	Ethylene Oxide	YES, 18 mo, arbitrary[a]	Same as above.

[a]Based on 3M e-mail communications dated Tuesday, November 19, 2013, 4:36 p.m.

2.6 Sample Blanks

There are two types of sampler blanks: field and media blanks.

Media Blanks. The purpose of media blanks is to check for "preexisting" presence of the contaminant (media background). 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. Field blanks should be handled in the same manner as the actual field samples, except that 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. There, they should be opened and immediately capped. 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.

How Many Blanks Should I Submit?

You must consult the specific analytical method being used to understand the number of blanks and type of blanks required. If the analytical method is not specific on the number of blanks to submit, consider the following during planning:

The OEA IH laboratory strongly recommends the following sampling strategy with regard to field and media blank submission:

- A minimum of one field blank per sampling method/media, per sample batch with a 10% field blank submission rate overall.
    - EXCEPTION: Asbestos sample collection requires a minimum of two field blanks regardless of the number of samples collected, followed by a 10% blank submission rate for batches with greater than 10 samples.
- A minimum of one media blank per sampling method/media, per sample batch with a 10% media blank submission rate overall.
    - EXCEPTION: Formaldehyde sampling on Passive Dosimeters (UMEX) requires a minimum of three media blanks per sampling set regardless of the number of samples collected, followed by a 10% blank submission rate for batches with greater than 10 samples.
    - EXCEPTION: Hexavalent Chromium sampling on PVC filters requires a minimum of three media blanks per sampling set regardless of the number of samples collected, followed by a 10% blank submission rate for batches with greater than 10 samples.

OSHA Technical Manual Section II: Chapter 1(IV) only addresses the use of field blanks. The manual states, "Field blanks are required for each requested analysis and for each lot number of sampling media" [10]. OSHA suggests using one blank for up to 20 samples, except for asbestos, which always requires two blanks [10].

The AIHA publication *The Occupational Environment: Its Evaluation, Control, and Management* discusses the use of field blanks and transport. A minimum number of sample blanks is not identified [14].

The NMAM, Chapter D, General Considerations for Sampling Airborne Contaminants, requires you to consult the specific analysis method for the number and type of blanks required.

How do I perform blank sample corrections?

The Chemistry Lab ***does not*** blank correct results when contaminants are detected on media blanks. To learn how to blank correct your samples, go to Appendix C, Section C3. Blank results should be logged into DOEHRS just like a field sample. USAFSAM Customer Service will upload blank results into DOEHRS along with raw sample results. You will then need to go into DOEHRS and blank correct any sample results that may require it.

Do I use the field or media blanks for corrections?

This is depends on which guidance that you want to follow as to what type of answer you will receive.

- The OSHA Technical Manual does not discuss the blank correction process. It only recommends that blanks be collected [10].

- The AIHA publication *The Occupational Environment: Its Evaluation, Control, and Management* suggests using the field blank for corrections [14]. Basically, subtract the mass of the contaminant on the field blank from the mass found on the actual sample. Then divide by the air volume sampled to determine the mass concentration of the contaminant. Analytical methods typically list a permissible mass limit for field blanks. If the contaminant mass on the field blank exceeds the permissible mass limit, the airborne concentrations on the actual sample become questionable.

- The NMAM, Glossary of Abbreviations, Definitions, and Symbols (IV), starting on page A-3, defines both field and media blanks. Below are the definitions, which include guidance for blank corrections [15]:

    - Field Blank: A sampler handled exactly the same as the field samples, except no air is drawn through it. Used to estimate contamination in preparation for sampling, shipment and storage prior to measurement, **but not actually subtracted from sample readings (see media blank)**.

    - Media Blank: An unexposed sampler, not taken to the field or shipped, **used for background correction of sample readings or for recovery studies.** This is why the media blank is used in example calculations, Appendix C.

2.7 Application of OEELs to Unusual Ambient Conditions

The objective of industrial hygiene air sampling is to obtain the best estimate of the true airborne concentration the employee is exposed to at the sampling site. Analytical laboratories generally report the *mass* of the contaminant found on a filter or charcoal tube. The lab then uses the customer-provided sample volume to calculate the airborne concentration at the sampling site.

Care should be taken in comparing this lab-provided sample result to applicable OEELs when sample site temperatures and pressures are substantially different than those at normal temperature and pressure (NTP) conditions (25°C and 760 torr). Refer to the following guidelines below when comparing sampling results obtained under unusual atmospheric conditions to OEELs:

Aerosols. For aerosols, compare the mass per unit of actual volume (not adjusted to NTP) to the OEEL. Volumes reported to the lab should be the air sample volume collected at site temperature and pressure without adjustment. Since most aerosol OEELs are published in terms of mass of the chemical substance in air by volume (mg/m^3), the units reported by the lab (also mg/m^3) will match those in published OEELs. No conversions are necessary.

Gases and Vapors. For gases and vapors, most OEELs are established in terms of parts of vapor or gas per million parts of contaminated air by volume (ppm). As mentioned earlier, most analytical laboratories generally report results in mg/m^3. To compare gas and vapor results to the OEEL, follow the procedures defined by ACGIH and outlined in Appendix C (Unit Conversions), Section C8.

> ***Step 1***. Determine the exposure concentration, expressed in terms of mass per volume, at the sampling site using the sampling volume not adjusted to NTP conditions.
>
> ***Step 2***. If required, convert the OEEL to mg/m^3 (or other mass per volume measure) using a molar volume of 24.45 L/mole and equation (16) below, where 24.45 equals the molar volume of air in liters at NTP conditions. The molecular weight of various contaminants of concern can be obtained from the NIOSH Pocket Guide to Chemical Hazards [16].
>
> ***Step 3***. Compare the exposure concentration to the OEEL, both in units of mass per volume.

SECTION 3: SAMPLING & ANALYSIS FOR SELECTED HAZARDS

3.0 Sampling and Analysis for Selected Hazards

This section provides additional sampling and analysis guidance for more prevalent workplace exposures assessed by base-level BEs These are analytical areas that are currently trending high for the BE career field and generate the most questions and/or concerns.

3.1 Dusts, Mineral Dusts, Particulates, and Fibers

Dusts, mineral dusts, particulates, and fibers overview:

- "Respirable silica" is not an official analysis method or term. Analysis is performed for crystalline silica. Do not request "respirable silica" when a cyclone is used because it is implied that the sample is respirable. The preferred term on the sample submission paperwork and the XML should be quartz, cristobalite, and tridymite.

- N7500 can identify quartz, cristobalite, and tridymite. OSHA ID-142 can identify cristobalite and tridymite only. Our recommendation is to use N7500 if you suspect or have confirmed crystalline silica (e.g., quartz, cristobalite, or tridymite). **OSHA ID-142 would most often be accomplished if collecting samples side-by-side with an OSHA inspector.**

- All dusts containing fibers (e.g., fiberglass, etc.), but free of asbestos, should be analyzed by phased contrast microscopy (PCM) (N7400 B-counting rules). If asbestos is suspected or confirmed, personal air samples should be analyzed with PCM (N7400 A-counting rules). Area samples can be either N7400 or N7402. Typically, clearance sampling requires N7400.

- All dust not related to the above hazards should either be N0500 (total dust) or N0600 (respirable dust) based on workplace variables.

- When workers are exposed to coal dust require a bulk of the coal to determine the presence/percentage of anthracite or bituminous coal dust **AND** percent crystalline silica. Collect two separate bulk samples because the characterization of coal and crystalline silica is completed at two separate laboratories. Bulk sample is not required if characterization of the coal lot is already known.

3.1.1 Crystalline Silica, SiO_2 (Quartz)

The following is a single example of analysis results for SiO_2 where only NIOSH 7500 was requested. This will provide a concentration in (mg/m^3) that can be compared directly to the OSHA PEL. The percentage of each silica component is no longer applies.

NIOSH 7500 (only)	Concentration		Reporting Limit (µg)
	µg	mg/m^3	
Cristobalite	<5	<0.012	5
Quartz	<5	<0.012	5
Tridymite	<10	<0.025	10

Interpretation of Respirable Silica results:

The OSHA PEL is based on total respirable silica. As shown in the table above, lab results will be reported as quartz, cristobalite, and tridymite forms of silica. The results will need to be added to determine the total respirable silica.

3.1.2 Asbestos Identification

Bulk, Polarized Light Microscopy (PLM). PLM with dispersion staining is used to analyze bulk samples. PLM is usually very specific, but some non-asbestiform silicate amphiboles, such as fibrous tremolite, can compromise its specificity. PLM analysis reports an asbestos percentile range due to the subjective and inaccurate nature of the estimation.

Air, Phased Contrast Microscopy. PCM is the most common method of analysis for airborne asbestos samples. PCM is only relatively accurate due to its dimensional counting rules and optical resolution limitations. Fibers will be counted as asbestos if their length-to-width ratio is 3 to 1 and the fibers are longer than 5 µm. Because some fibers may fall within the asbestos fiber parameters and be considered "OSHA fibrous," non-asbestos fibers will be counted as asbestos.

Air, Electron Microscopy. Transmission electron microscopy (TEM) and scanning electron microscopy (SEM) are the two electron microscopy techniques commonly used for asbestos analysis. Their major advantages are their ability to count smaller fibers than PCM and to identify the type of fiber. Their major disadvantages are high costs (10-20 times PCM), tedious analysis, and lengthy result turnaround time. The asbestos exposure standard was developed with PCM data; hence, there is no relevant standard with which to compare the TEM or SEM results, and SEM has no accepted standard method.

3.1.2.1 TEM Asbestos Hazard Emergency Response Act (AHERA) vs. NIOSH

AHERA or NIOSH (Table 14)? Depends on why you are sampling. The AHERA TEM air clearance monitoring requires 13 samples to be collected. Five samples should be collected inside the contained area. Five samples should be collected outside the contained area. Two field blanks should be opened for 30 seconds (one inside containment and one outside containment). One unopened lab blank should be submitted.

Even though 13 samples are required to be collected, AHERA does allow for a "screening" in which only the five inside samples are analyzed, but you have to collect at least 1200 liters of air for each sample. The Environmental Protection Agency (EPA) permits this initial screening test to save analysis costs in situations where the airborne concentration is expected to be sufficiently low. If you collect less than 1200 liters of air, you are required to submit all 13 samples for analysis (40CFR763, Subpart E) [18]. If you collect clearance samples, mark **"clearance"** on the submission form for each clearance sample to ensure you receive TEM AHERA analysis.

Table 14: AHERA vs. NIOSH

AHERA	NIOSH
Clearance Monitoring	**Worker Exposure**
Results in f/mm^2	Results in f/cc
EPA defined size: **≥0.5 µm long; ≥5:1 aspect ratio**	OSHA-defined size: ≥5 µm long; ≥3:1 aspect ration
Flow rate: <10 liters per minute (Lpm)	Flow rate: 0.5 to 16 Lpm
Minimum Volume: **1200 liters (for screening)** **560 liters**	Minimum Volume: 48 liters

3.1.2.2 Asbestos Bulk Sampling

Typically, USAFSAM does not fund analysis relating to the identification of asbestos-containing material (ACM). USAFSAM only funds analysis of bulk samples directly related to employee exposure and health risk assessments. In accordance with AFI 32-1052, *Facility Asbestos Management* [19], base Civil Engineering (BCE) is required to verify whether presumed ACM and flooring material contain asbestos by completing an asbestos survey in accordance with 40 CFR Part 763, Subpart E (sampling methods are specified in paragraphs 763.85-87) [18].

Your installation asbestos management plan, developed by BCE, is required to document requirements for budget estimates and contractor asbestos analysis and abatement. BCE funding for ACM identification should be addressed in the base asbestos management plan.

Additional Air Sampling Guidance to Consider (Table 15):

- ✓ Use a 2- mm cassette for all breathing zone exposure monitoring.
- ✓ An MCE filter membrane with a pore size of 0.8 µm or 1.25 µm must be used. Recommend ordering and using only 0.8-µm filters that have been factory prescreened for background fibers.
- ✓ The sampling flow rate must be between 0.5 and 2.5 L/min. Use 2.5 L/min for standardization unless circumstances deem otherwise. For monitoring area concentrations, use between 1 and 16 L/min. If high flow area sampling is to be done, recommend using 12 L/min for standardization.
- ✓ Do all asbestos sampling open face. The 25-mm cassette must have a 50-mm extension cowl that is electrically conductive.
- ✓ During sampling, static charges can accumulate on the cassette cowl that will reduce the sample's fiber concentration efficiency. Ideally, the complete cassette body should be the black conductive type and grounded by wire to some metal fixture, i.e., plumbing, railing, electrical outlet, etc. Realistically, grounding a breathing zone sample is impractical, but it still helps to use a conductive cowl with a black conductive filter base connected to conductive tubing. The black stripe in clear plastic tubing is graphite, which makes the tubing conductive. It is particularly important to ground high-volume, long-duration samples, which have the greatest potential for building up static charges. Area sampling with an AC voltage hi-flow pump that has a grounded plug makes it easy to ground the cassette cowl to the pump's frame.

Sample Shipments. Do not ship sampled cassettes in packing that has high electrostatic charges on its surfaces because it can cause fiber migration from the filter to the cassette walls during shipment. Don't use polystyrene "peanuts"; use only crushed or shredded paper or plastic "blister" sheeting.

Table 15: Asbestos Sampling

Matrix	Method	Collection Media	Comments
Air	NIOSH 7400 ***A Rules***	0.8-µm MCE, 25-mm, conductive cowl on cassette	Primarily used for estimating asbestos concentrations, but does not differentiate between asbestos and other fibers. Use in conjunction with NIOSH 7402 for assistance in identification of fibers.
Air	NIOSH 7400 ***B Rules***	0.8-µm MCE, 25-mm, conductive cowl on cassette	B-counting rules are more appropriate for measurement of specific non-asbestos fiber types, such as fibrous glass, refractory ceramic fibers, and carbon fibers. The upper diameter limit in this method prevents measurements of non-thoracic fibers.
Air	NIOSH 7402	0.8-µm MCE, 25-mm, conductive cowl on cassette	Used to determine asbestos fibers in the optically visible range and is intended to complement the results obtained by PCM (NIOSH 7400). N7400 should be run first, and any results over the reporting limit can then be run with N7402.
Bulk	EPA 600/R-93/116	Wide mouth glass jar	Should only be used in conjunction with an HRA.
Settled Dust (Wipe Sample)	ASTM D6480-99	Ghost Wipe	Should only be used in conjunction with a health risk assessment. **Note: Wipe analysis for asbestos is not available in-house or on contract. However, dust or mass micro-vacuum methods are available at our commercial labs. Contact Customer Service prior to sampling for instructions.**

3.1.3 Composite Materials

During aircraft maintenance and crash and recovery operations, workers can be exposed to fibrous and non-fibrous composite particulates. For composite materials, the recommended methods are shown in Table 16. For additional information, refer to the latest *Advanced Composite Materials Base-Level Guide* available on the ESOH Service Center website.

Table 16: Composite Material Sampling

Matrix	Method	Collection Media	Comments
Air	NIOSH 7400 B Rules	0.8-µm MCE, 25-mm, conductive cowl on cassette	B-counting rules are more appropriate for measurement of specific non-asbestos fiber types, such as fibrous glass and refractory ceramic fibers. Do not use for composite fibers. The upper diameter limit in this method prevents measurements of non-thoracic fibers. Ensure the samples are clearly marked "for fibers other than asbestos" and specify the type of fiber if known.
Air	NIOSH 0500	Pre-weighed, 5-µm PVC, 37-mm cassette	NIOSH 0500 is recommended to determine total particulates not otherwise regulated. Pre-weighed PVC filters ordered from the manufacturer are the recommended media. Match weight media may also be used if pre-weighed media is not available.
Air	NIOSH 0600	Pre-weighed, 5-µm PVC, 37-mm cassette with cyclone	NIOSH 0600 is recommended to determine respirable particulates not otherwise regulated. Pre-weighed PVC filters ordered from the manufacturer are the recommended media. Match weight media may also be used if pre-weighed media is not available.

3.1.4 Respirable, Thoracic, Inhalable, and "Total" Particulates

Particulate samples may represent the respirable, thoracic, or inhalable fractions of the particulates (Figure 10) or the nominal "total" particulates. Each particulate fraction requires a different sampling device. Care should be taken to determine which particulate fraction an OEEL refers to and to ensure that the correct sampling method and device are used. In DOEHRS, only one inspirability should be selected and only when performing particulate testing. Please DO NOT select an inspiribilty for any other hazards. It can interfere with the XML upload into LIMS and delay sample analysis.

Respirable Particulates. Respirable particles penetrate to the pulmonary region containing the respiratory bronchioles, alveolar ducts, and alveolar sacs across which gas exchange occurs and generally are considered to be 5 µm or less in aerodynamic diameter. Respirable dust is collected using a clean cyclone (Figure 11) at a flow rate recommended by the cyclone manufacturer to achieve the predetermined collection efficiencies.

Sampling is usually done with a cyclone upstream of the filter to preselect the fraction of particles of each size that pass through (i.e., penetrate) the cyclone and are collected on the filter. Several types of cyclones are available commercially including the 10-mm plastic cyclone and the aluminum cyclone. The flow rate through the cyclone is critical to obtaining the correct aerosol distribution. The manufacturer should be consulted for the currently recommended flow rate to conform to the respirable aerosol size distribution. When sampling with a cyclone, remember the following tips:

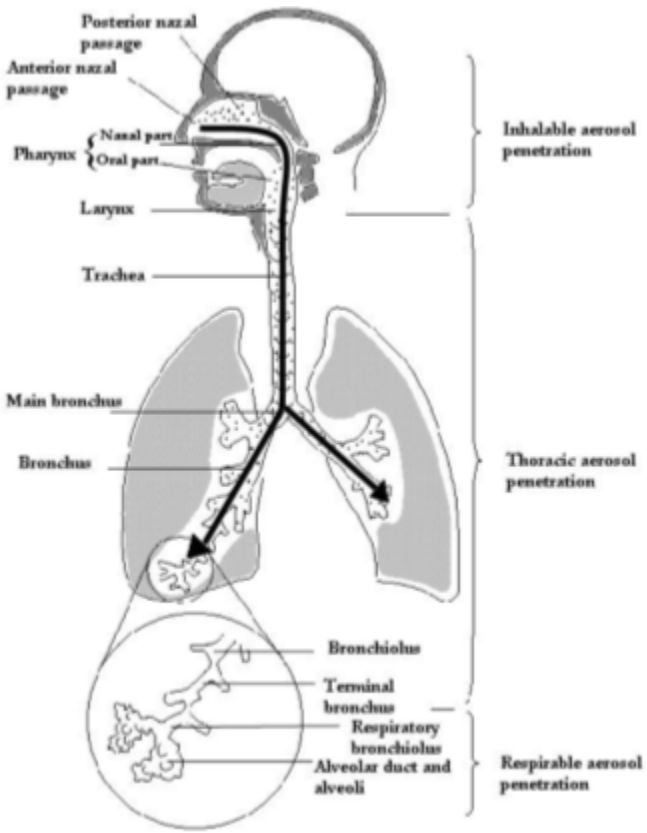


Figure 10: Respirable, Thoracic, and Inhalable Particulates (EPA Figure 4-1, APTI 435: Atmosphere Sampling Course)

- ✓ Prior to using a cyclone, remove the grit cap and vortex finder and inspect the cyclone interior. If the inside is visibly scored, discard the cyclone, since the dust separation characteristics of the cyclone might be altered.
- ✓ Following the manufacturer's recommendations, clean the interior of the cyclone to prevent re-entrainment of large particles. Clean all parts of the cyclone, including the interior of the grit pot, with mild soapy water. The cyclone can be wiped with a clean dust-free tissue, air dried, blow dried, or wiped with isopropyl alcohol.
- ✓ Sampling trains using cyclones require the use of a 1-liter "calibration jar"; refer to the manufacturer's recommendations for detailed calibration instructions.
- ✓ When sampling for the respirable fraction of particulates, the cyclone should not be inverted when attached to the filter cassette. Larger particles are collected in the grit chamber during sampling; inverting the cyclone can cause the larger particles to fall out of the grit chamber and onto the filter, resulting in erroneously high results.
- ✓ Cyclones absolutely must be removed from filter cassettes prior to sending the samples to the lab.

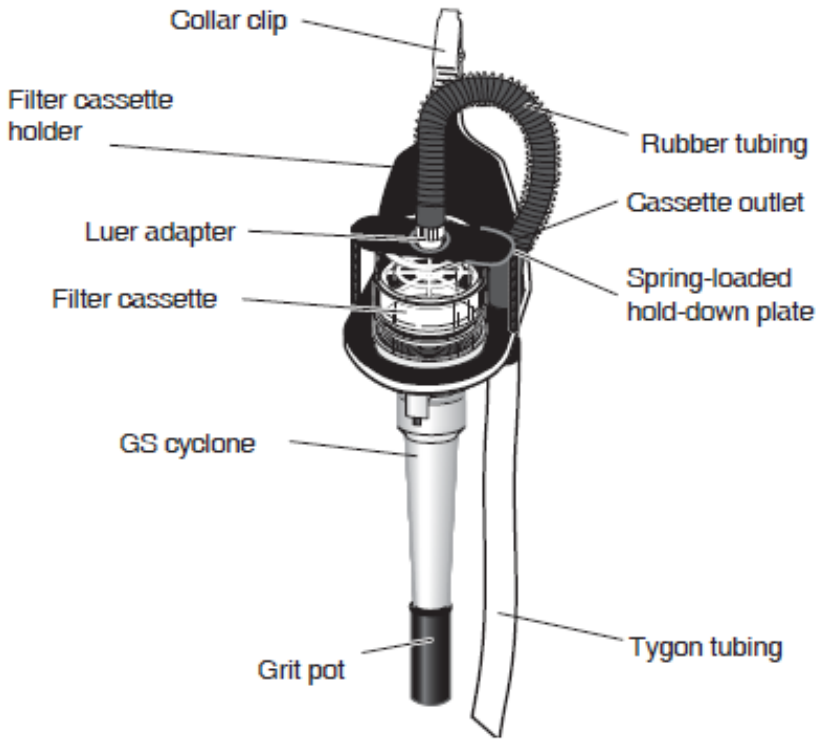


Figure 11: Typical Cyclone Assembly (Courtesy of SKC Inc.)

Thoracic Particulates. Thoracic particles are dust that can enter the tracheobronchial region and generally are smaller than 10 µm. Currently, there are no published standards that require thoracic aerosol sampling. However, with international agreement on what this fraction is with respect to the size distribution, such OEELs may soon follow. The only personal sampler for thoracic aerosols is the GK2.69, offered by BGI Incorporated. When such devices are used, the manufacturer should be consulted to determine the correct flow rate to collect a thoracic aerosol size distribution.

Inhalable Particulates. Inhalable particulates are the fraction of total workplace aerosol actually entering the respiratory tract. Some TLVs are set for inhalable fractions. Three inhalable aerosol samplers are widely available including the Institute of Occupational Medicine (IOM) sampler (Figure 12), the button sampler (both distributed by SKC, Inc.), and the conical inhalable sampler distributed by BGI, Inc. The IOM sampler operates at 2 L/min, the button sampler at 4 L/min, and the conical inhalable sampler at 3.5 L/min. As more OEELs are set for inhalable aerosols, other samplers will probably be introduced.

When such devices are used, the manufacturer should be consulted to determine the correct flow rate to collect an inhalable aerosol size distribution. Follow the manufacturer's recommendations for sending filters to the laboratory. For the IOM, remove the cassette from the sampler and place the manufacturer's cover on the cassette. The loaded filter in the cassette without the IOM body can be protected properly in the transport clip and cover. Send the cassette in the clip to the laboratory. The Chemistry Lab will clean and return all transport clips, covers, and inhalable particle sampler bodies received by the lab to the customer. For additional information on inhalable particles and beryllium, refer to the USAFSAM *Base Level Guide for the Occupational Exposure to Beryllium* [20].

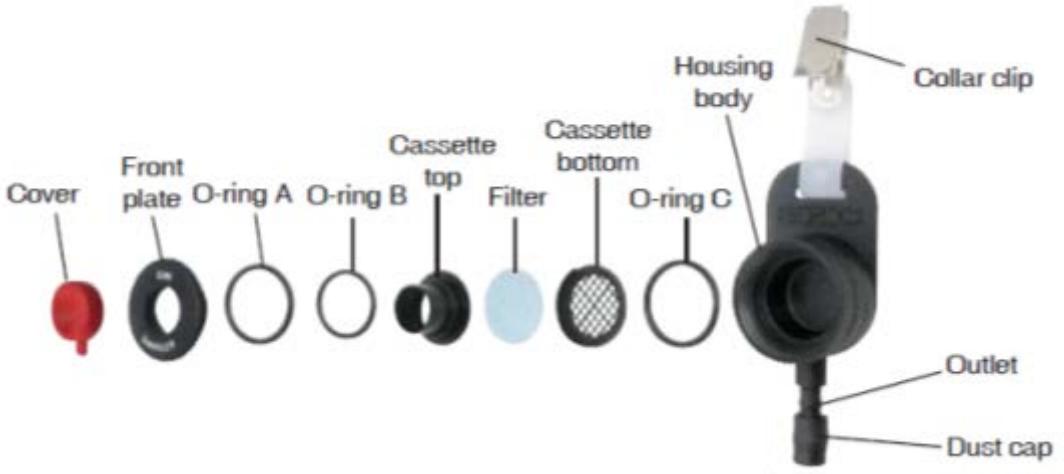


Figure 12: IOM Sampler Assembly
(Courtesy of SKC Inc.)

When sampling with an IOM, remember the following tips:

- ✓ Follow the manufacturer's recommendations for shipping the sampler to the laboratory. After sampling, remove the cassette from the sampler and place the cover on the cassette. The loaded filter in the cassette without the IOM body can be protected in the transport clip and cover (Figure 13). Send the cassette in the clip to the laboratory.
- ✓ IOM field blanks should be treated in the same manner as the samples. Blanks should be placed in the cassette and transport cover.
- ✓ All media will be cleaned and returned by the laboratory. Allow 2 to 4 weeks for media to be shipped back to the customer.
- ✓ IOM calibration requires the use of the calibration adapter. Refer to the manufacturer's information for additional details.

Figure 13: IOM Transport Clip
(Courtesy of SKC Inc.)

"Total" Particulates. For total particulate sampling results, the estimate is that 60% of the particles available in the airstream are ultimately respirable. All OSHA PELs for "total" particulates are sampled with a closed faced 37-mm filter cassette. Studies have shown that this sampling method collects fewer particulates than an inhalable sampler.

Gravimetric Analysis. NIOSH 0500 for total particulates and NIOSH 0600 for respirable particulates both use gravimetric analysis (Table 17). Gravimetric analysis involves drawing a known volume of air through a filter of known initial weight, then reweighing the filter to determine the mass captured. The average particulate concentration is the difference in beginning mass and ending mass divided by the volume of air sampled. Particulate samples collected for gravimetric analysis by NIOSH 0500 or 0600 MUST be collected on pre-weighed or matched-weight PVC filters. Care should be taken to not overload the filter.

- ✓ *Matched weight.* Matched weight refers to two filters that are matched in weight and loaded into a cassette in a strictly controlled lab environment. The top filter collects contaminants and the bottom filter serves as a control. After sampling, both filters are removed and weighed individually; the difference between weights is the sample weight. The mass of particulates sampled is the difference between the collection filter and the control filter.

- ✓ *Pre-weighed.* Pre-weighed filters are weighed to within 5 decimals; the filters are preloaded into cassettes in a strictly controlled lab environment. The cassettes are marked with weight and lot number. The mass of the particulates sampled is the ending mass minus the pre-weighed mass. Pre-weighed media is the Chemistry Lab's preferred media for gravimetric analyses. This media is usually easily identified by a large label on the filter cassette listing the filter weight.

Table 17: Respirable and Total Particle Sampling

Matrix	Method	Collection Media	Comments
Air	NIOSH 0500 (Total)	5.0-µm, 37-mm pre-weighed PVC filter, *or* 5.0-µm, 37-mm matched-weight PVC filter	Lab is unable to analyze samples collected on media other than matched or pre-weighed filters. Pre-weighed PVC filters are the preferred media.
Air	NIOSH 0600 (Respirable)	5.0-µm, 37-mm pre-weighed PVC filter, *or* 5.0-µm, 37-mm matched-weight PVC filter *and* cyclone (10-mm nylon cyclone or aluminum cyclone)	Pre-weighed PVC filters are the preferred media. See manufacturer's guidance for calibration of cyclone assembly. Cyclone should be inspected prior to use. If cyclone is visibly scored, do not use. Refer to manufacturer's literature for proper sampling flow rates. Do not invert the sampler assembly at any time; this may deposit oversized material from the cyclone body onto the filter. Cyclones should be removed prior to sending cassettes.

3.1.5 Employee Exposure within Coal Plants

There is little published literature that provides guidance to the BE community for assessing employee exposure to coal dust and silica (SiO_2) at local coal plants. In addition, analysis is not performed at USAFSAM, and contract analysis is required. Although there are several hazard types (chemical and physical) you may be required to evaluate, this section will only focus on coal dust and silica (SiO_2) exposure sampling, analysis, and results interpretation as they relate to coal plant employees. Final sampling strategy requirements are the responsibility of the base BE flight.

3.1.5.1 Coal Dust Silica (SiO2) Respirable Fraction

One of the concerns in coal plants is the exposure to particulates containing silica, see section 3.1.1. The percentage of silica no longer applies, use the current OSHA PEL for total respirable silica.

3.1.5.2 Coal Characterization

The second concern is the exposure to coal. To assess worker exposure to coal, a bulk coal sample must be analyzed by polarized light microscopy/materials characterization (PLM/MC) to determine the makeup of the coal (e.g., anthracite or bituminous coal). Personal air samples must also be collected via NIOSH 0600, see section 3.1.4.

3.1.6 Hardwood Dust

NIOSH and OSHA do not recommend wood dust respirable sampling for compliance, per Standard Interpretation between NIOSH and OSHA, April 22, 1993. There are two acceptable methods (N0500 and OSHA PV2121). The methods are slightly different in procedure (environmental conditions, etc.) but should be comparable to each other. OSHA Compliance Officers will use PV2121, but almost everyone else in the BE community will use N0500 (only method listed in NIOSH Pocket Guide). N0500 is the preferred method and is performed in-house at the USAFSAM lab. Note that OSHA PV2121 is not available on contract. N0500 is recommended for wood dust exposure unless you are doing confirmatory compliance sample next to an OSHA inspector. Since PV2121 is not on contract, contact Customer Service during the planning phase for options.

3.2 Metals in Air

Analytical Services can perform metals in air analysis at USAFSAM using NIOSH 7300 for the 23 metals listed below (Table 18). Additional analytes may be available through contract support upon request; contact Customer Service for additional information. With the exception of a low level reporting limit for beryllium, all analyses are conducted by inductively coupled argon plasma optical emission spectrometry unless otherwise specified by the customer.

▪ **Aluminum** ▪ **Antimony** ▪ **Arsenic** ▪ **Barium** ▪ **Beryllium**	▪ **Cadmium** ▪ **Chromium** ▪ **Cobalt** ▪ **Copper** ▪ **Iron** ▪ **Lead**	▪ **Magnesium** ▪ **Manganese** ▪ **Molybdenum** ▪ **Nickel** ▪ **Selenium** ▪ **Silver**	▪ **Strontium** ▪ **Thallium** ▪ **Tin** ▪ **Titanium** ▪ **Vanadium** ▪ **Zinc**

Table 18: Metals in Air Sampling

Matrix	Method	Collection Media	Comments
Air	NIOSH 7300	0.8-µm MCE *or* 5.0-µm PVC, 37-mm cassette	Indicate type of media used on sample submission paperwork. May use pre-weighed or matched-weight PVC media to obtain both particulate (NIOSH 0500 or 0600) and metal (NIOSH 7300) results from a single cassette.
Air	Modified NIOSH 7300 for Inhalable Beryllium	IOM sampler with 25-mm MCE filter, *or* button aerosol sampler, 25-mm MCE filter	**"OSHA ID-125G" must be selected on the submission form to obtain analysis for the lowest available reporting limit.** **Please indicate on the paperwork if the source of contamination is suspected to be high-fired beryllium.** Allow 2 to 4 weeks for IOM and button samplers to be cleaned and returned. Provide return address on sample submission paperwork.

3.2.1 Metals in Air (Media)

Metal air samples can be collected on either PVC or MCE media. It is important to indicate the type of media used on the paperwork sent to the lab. Laboratory control samples will be prepared on the same media used during sample collection.

3.2.2 Metals in Air (Screening)

The lab can analyze multiple metals on a single filter up to a full metal screen including all 23 metals listed above. To correctly populate a DOEHRS Sample Submission Form with all 23 metals, each metal must be individually identified as a process hazard and listed on the sample submission form and XML. The lab will no longer accept the comment "Please conduct a full metal screen" placed in the comment field. ***Note:*** For best results and to reduce the potential for interference, the list of requested metals should be limited based on knowledge of the industrial process.

3.2.3 Metals in Air (Compounds/Oxides)

NIOSH 7300 can be used to determine concentrations of compounds in air using the equation in Appendix C (*i.e., $BaCl_2$, CuO, Fe_2O_3, MgO, MnO, $PbCrO_4$, and $SrCrO_4$).* Please note that some metal compounds and oxides are not soluble in the acids used for digestion (i.e., aluminum oxide, high-fired beryllium) and may be underestimated if only analyzed as the metal. Please contact the laboratory to discuss analysis options if you suspect these compounds are present in your sample.

Titanium dioxide (N7300) and sodium hydroxide (N7401) are available through subcontract support; however, these analytes must be collected individually and cannot be analyzed with other analytes.

3.2.4 Metals in Air (Chromium)

USAFSAM recommends measuring hexavalent chromium exclusively with NIOSH 7605. NIOSH 7300 can only provide total chromium results. For details on hexavalent chromium sampling, refer to Section 3.3 in this guide.

3.2.5 Metals in Air (Welding)

The key to assessing welding risk is understanding workplace-specific content of welding rods, coatings, filler metals, and base materials/alloys. Work closely with workplace supervisors and welders to determine applicable hazards at your location. Samples outside of the 23 analytes listed in this section will be subcontracted and must be collected separately.

When sampling for welding fumes, the filter cassette must be placed inside the welding helmet to obtain an accurate measurement of the employee's exposure. If, however, the welding helmet cannot be used as a sampling environment, the personal sampling pump cassette can be attached in the breathing zone at collar level.

The resulting information can be used as a screening tool: "the air outside the helmet was (not) at a level of concern; therefore, the air inside the welding helmet was (not) at a level of concern." Welding fumes samples are normally taken using 37-mm filters and cassettes; however, if these cassettes will not fit inside the helmet, 25-mm filters and cassettes can be used. Care must be taken not to overload the 25-mm cassette when sampling.

3.2.6 Metals in Air (Special Notice)

All samples for mercury (Air on a tube: NIOSH 6009 / Particulates: OSHA ID-145) or tungsten (OSHA ID-213) must be collected individually. The analyses are also subcontracted.

3.2.7 Metals In Air (Copper Fumes/Dusts)

When sampling copper fumes and/or dusts, such as at a CATM range for frangible bullet firing or for welding operations, the appropriate sampling method is NIOSH 7300. NIOSH and AFIOH studies have verified NIOSH 7300 as the sampling method for military ranges. DO NOT request NIOSH 7029, as this method does not distinguish between fumes and dusts; it distinguishes between soluble and insoluble copper salts, which is not applicable for CATM range or welding operations.

3.3 Hexavalent Chromium

NIOSH 7605 is exclusively recommended for hexavalent chromium Cr(VI) sampling Table 19). **Cr (VI) samples MUST be collected on PVC filters.**

For best results, samples should be stored and shipped refrigerated. Samples are stable for 2 weeks at room temperature and 4 weeks if refrigerated.

Hexavalent chromium hazards should be documented in DOEHRS by selecting "CHROMIUM(VI)." This is the analyte that should be listed under "Display Hazard Name" on the Discoverer Viewer sample submission form sent to the lab when requesting NIOSH 7605.

Care should be taken to not overload the cassette during dusty operations (i.e., mechanical sanding of painted aircraft parts). For additional guidance on hexavalent chromium, refer to the USAFSAM *Hexavalent Chromium Technical Guide* [21].

Table 19: Hexavalent Chromium Sampling (CrVI)

Matrix	Method	Collection Media	Comments
Air	NIOSH 7605	5.0-µm PVC, 37-mm cassette	Samples MUST be collected on PVC media. MCE filters physically dissolve in the laboratory desorption process. This creates a thick fluid that cannot be filtered or run through the chromatography column, which makes them impossible to analyze.
Bulk	Modified NIOSH 7605	Plastic or glass container	Should only be used in conjunction with an HRA.
Settled Dust (Swipe)	Modified NIOSH 7605	5.0-µm PVC filter only	Samples MUST be collected on PVC media. Refer to the swipe procedures below and the *Occupational Hygiene: Contamination Control and Housekeeping Guide* for additional information [22].

3.4 Swipe Sampling

Guidance on the swipe sample collection varies based on the contaminant and analytical method. Below is the lab's recommended collection procedures based on popular analytes. For media other than those shown in Table 20, coordinate with OEA Customer Service prior to sample collection to ensure the lab will be able to accommodate the request. Additional swipe sample guidance can be found in *Occupational Hygiene: Contamination Control and Housekeeping Guide* [22].

Table 20: Swipe Sampling

Matrix	Method	Media	Analyte(s)			
Settled Dust (Swipe)	EPA 6010C	Ghost Wipes	**Only Lead and Beryllium**			
Settled Dust (Swipe)	EPA 6010C	MCE Filters; Whatman 541	Aluminum Antimony Arsenic Barium Beryllium Cadmium	Chromium[a] Cobalt Copper Iron Lead Magnesium	Manganese Molybdenum Nickel Selenium Silver Strontium	Thallium Tin Titanium Vanadium Zinc
Settled Dust (Swipe)	Modified NIOSH 7605	PVC Filters; Whatman 541	Hexavalent Chromium (CrVI)			

[a]Total chromium.

Wipes used for the Environmental Lead (Pb) Laboratory Accreditation Program must meet ASTM E1792 specifications. Ghost Wipes meeting these ASTM requirements are available through the Chemistry Lab by placing an order through Customer Service. Ghost Wipes should be used for sampling to meet ASTM specification and all ELLAP requirements.

Metal Screens. The lab can analyze multiple metals on a single MCE swipe sample up to a full metal screen including all 23 metals listed in Section 3.2. To correctly populate a DOEHRS Sample Submission Form with all 23 metals, each metal must be individually identified as a process hazard. The lab will no longer accept the comment "Please conduct a full metal screen" placed in the comment field. ***Note:*** For best results and to reduce the potential for interference, the list of requested metals should be limited based on knowledge of the industrial process.

Swipe Collection Procedures. The following basic procedures may be referenced when collecting swipe samples:

- ✓ ***Media***. Ghost Wipes may be ordered by contacting Customer Service; generally the media will arrive the next business day. All other media should be ordered through local supply channels.
- ✓ ***Gloves***. Clean disposable gloves should be worn when handling the filters. The gloves should not be powdered. A new set of clean impervious gloves should be used for each sample to avoid contamination of the filter by previous samples (and the possibility of false positives) and to prevent contact with the substance.
- ✓ ***Sketch***. If multiple samples are to be taken at the worksite, prepare a rough sketch of the area to be sampled. Usually use a 1-ft^2 or 100-cm^2 template.
- ✓ ***Vials***. Prepare a sufficient number of vials, each labeled with a unique number, for the projected sampling needs. If vials are not available, plastic bags may be used. Record the sample vial number and the location where the sample is taken.
- ✓ ***Sample Area***. Depending on the purpose of the sample, it may be useful to determine the surface loading of the contamination (i.e., in micrograms of analyte per area). For these samples, it is necessary to record the area of the surface wiped (i.e., 100 cm^2). This would not be necessary for samples taken to simply show the presence of the contaminant.
- ✓ ***Preparing the Media***. Remove the filter from the carrying container with clean PTFE-coated tweezers or plastic tweezers. Do not use metal tweezers to handle the filters as they may deposit trace metals onto the filters. Samples should be taken wet for MCE filters (dampen but do not saturate with deionized water). If using pre-moistened wipes, there is no need to wet the media. For hexavalent chromium, wipes should be collected dry as the water will allow any metal interferences to interact with the Cr(VI), thereby affecting the results. ***Do not*** sample using the blue separator sheets commonly found in commercially available MCE and PVC media.
- ✓ ***Swiping***. Firm pressure should be applied when wiping. Start at the outside edge and progress toward the center, making concentric squares of decreasing size. Fold the filter with the contaminant side inward and repeat. Without allowing the filter to come into contact with any other surface, fold the filter with the exposed side inward. Place the filter in a sample vial or zip-lock bag, cap or seal, and place a corresponding sample number and the location on the diagram. Include notes with the sketch giving any further description that may prove useful when evaluating the sample results (i.e., a description of the surface sampled, such as pencil, doorknob, safety glasses, lunch table, inside respirator, employee names, etc.). ***Note:*** do not write on the filters. All sample labeling should be done on the individual sample vials or zip-lock bags.

- ✓ ***Blanks***. At least one blank filter treated in the same fashion, but without wiping, should be submitted for each sampled area.

For additional swipe collection procedures, refer to OSHA W4001 for hexavalent chromium and NIOSH 9100 for lead. ***However***, only the media listed in the table above should be used when sending samples to the USAFSAM Chemistry Lab.

3.5 Jet Fuels and Other Naphthas

NIOSH 1550 is the preferred in-house method for the analysis of various types of hydrocarbon mixtures called "naphthas" including petroleum ether, rubber solvent, petroleum naphtha, petroleum distillates mixtures, VM&P naphtha, mineral spirits, kerosene, coal tar naphtha, and Stoddard solvents (Table 21).

Be sure to ask specifically for what you are sampling (e.g., JP-8, kerosene, etc.). N1550 is not capable of distinguishing between VM&P naphtha, kerosene, or JP-8 because these naphthas are hydrocarbon mixtures with overlapping compounds. If NIOSH 1550 is the only thing listed on the sample submission paperwork, your workorder will be delayed until OEA Customer Service is able to obtain which specific naphtha you would like reported.

The CAS and synonyms are all over the board for naphtha mixtures. Typically, they are not the same and are dependent on a specified boiling point range. All naphtha results are calculated using an area sum of the range of compounds expected from the requested naphtha. Due to the similarity between kerosene and JP-8, they have very similar instrument responses, and although it is not the standard practice of the laboratory to analyze for both, results have been found to be within 5% of each other.

The laboratory does keep a variety of common naphthas on hand for analysis (e.g., kerosene, mineral spirits, petroleum ether, petroleum distillates, JP-8, Stoddard solvents, VM&P naphthas, and PD-680. **There is no need to provide a bulk sample for those analytes. For all other naphthas, submit a 5-mL bulk sample of the naphtha from your base.**

Alternatively, a base may request "total hydrocarbons." The TLV is actually listed as kerosene/jet fuels, as total hydrocarbon vapor. So if you wanted to evaluate as total hydrocarbon vapor, then you would just ask for "total hydrocarbons." The difference is that the result is calculated using the area of hexane instead of JP-8.

The official sampling strategy for JP-8 is outlined in the Interim Base-Level Guide for Exposure to Jet Fuel and Additives, AFRL-SA-WP-SR-2012-0002 [23]. Remember, there is no need to sample for the complete list of compounds because NIOSH 1550 does not distinguish between the different naphthas. Which naphtha is requested should depend on what is being used by the worker being monitored. If one is working with JP-8, then that is the analyte of interest.

What is the difference with 200 mg/m^3 vapors and 5 mg/m^3 for aerosols?

The 200 mg/m^3 standard for vapors is derived from the ACGIH TLV for kerosene/jet fuels as total hydrocarbon vapor and the 5 mg/m^3 is derived from the ExxonMobil OEL for kerosene and middle distillate fuel aerosols.

How do you sample for JP-8 in cold climates (aerosols)?

The sampling for aerosols is difficult because there is no standard/validated method to assess exposures, as the properties vary depending on which process you are evaluating (cold starts vs. fueling/defueling vs. fuel transport), and there is definitely a GAP in exposure assessments strategy and guidance. If sampling for a JP-8 as a liquid aerosol, one could use a mass-based method like NIOSH 0500 or 0600, but as that media changes temperature, you lose a fraction of the aerosol due to evaporation. A charcoal tube would eliminate the loss as a vapor, but the sampling dynamics (i.e., pump velocity and tube diameter) will influence your capture efficiency and may prevent collecting enough aerosols. So when evaluating aerosols, you are, in most cases, going to underestimate the exposure. There is a potential to use a particle counter to evaluate the exposure, but it is not going to be able to specify (identify) what caused that count.

Table 21: Jet Fuels and Naphtha Sampling

Matrix	Method	Collection Media	Comments
Air	NIOSH 1550	Anasorb CSC, Coconut Charcoal, 50/100 mg sorbent	Submit 5-mL bulk sample with air samples (if necessary). Package bulk sample separately to prevent cross-contamination. Identify specific naphtha to be analyzed on sample submission forms. Jet fuels (NIOSH 1550) and benzene (NIOSH 1501) may be sampled on a single tube.

Multiple contaminants can often be analyzed from a single sorbent tube if the analytical technique and desorption are the same. The lab routinely receives duplicate samples collected for benzene and JP-8 on separate sorbent tubes. Benzene by NIOSH 1501 and JP-8 by NIOSH 1550 can be collected on a single sorbent tube since they are both analyzed by GC/FID with carbon disulfide desorption. The only available analytical method in DOEHRS for both JP-8 and benzene is listed as NIOSH 1501. However, if NIOSH 1501 is selected in DOEHRS, bases should list NIOSH 1550 for benzene in the comments section of the sample submission form as well.

3.6 Isocyanates

The Iso-Chek® sampling protocol is the recommended sampling method for isocyanates including the monomer and oligomer form of the isocyanates listed in Table 22 below. Iso-Chek® uses a two-stage filter arrangement that results in the separation of vapor from aerosol (Figure 14).

Stage one contains an untreated PTFE filter to collect the aerosol phase and stage two holds a glass fiber filter impregnated with 9-(N-methylaminomethyl) anthracene (MAMA) for the vapor phase of isocyanates. The required flow rate is 1 L/min with a maximum volume of 15 liters. This is important to note since it will drive a high filter change-out frequency, i.e., every 15 minutes. Very low concentrations (less than 1 ppb) may be sampled at 2 L/min for 30 minutes.

Asset samplers are an alternative method of collecting isocyanates. They have a hold time of 28 days and do not require refrigeration. They are also not restricted to 15 minute samples like ISO-CHEK's.

Table 22: Isocyanates Available Using the Iso-Check® and Asset Sampler Protocols

Isocyanate	Form of Isocyanate	DOEHRS Hazard Name
1,6-HDI	1,6 Hexamethylene Diisocyanate Monomer	Hexamethylene Diisocyanate Monomer
	1,6 Hexamethylene Diisocyanate Oligomer	Hexamethylene Diisocyanate Oligomer
MDI	Methylene Diphenyl Diisocyanate Monomer	Methylene Bisphenyl Isocyanate (MDI)
	Methylene Diphenyl Diisocyanate Oligomer	Methylene Diphenyl Diisocyanate Oligomer
IPDI	Isophorome Diisocyanate Monomer	Isophorone Diisocyanate
	Isophorome Diisocyanate Oligomer	Isophorone Diisocyanate Polymer
2,4-TDI	2,4 Toluene Diisocyanate Monomer	2,4 Toluene Diisocyanate
	2,4 Toluene Diisocyanate Oligomer	2,4-Toluene Diisocyanate Oligomers
2,6-TDI	2,6 Toluene Diisocyanate Monomer	Toluene-2,6-Diisocyanate
	2,6 Toluene Diisocyanate Oligomer	2,6 Toluene Diisocyanate Oligomer

When collecting isocyanate samples using the Iso-Chek® protocol (Table 23), follow the step-by-step procedures prepared by the Omega Specialty Instrument Co. and included in the original sampling supply kit from the manufacturer. The sampling procedures may also be accessed online through the SKC or the Omega Specialty Instrument Co. When collecting isocyanate samples using Asset samplers (Table 23), use instructions provided by the contract laboratory.

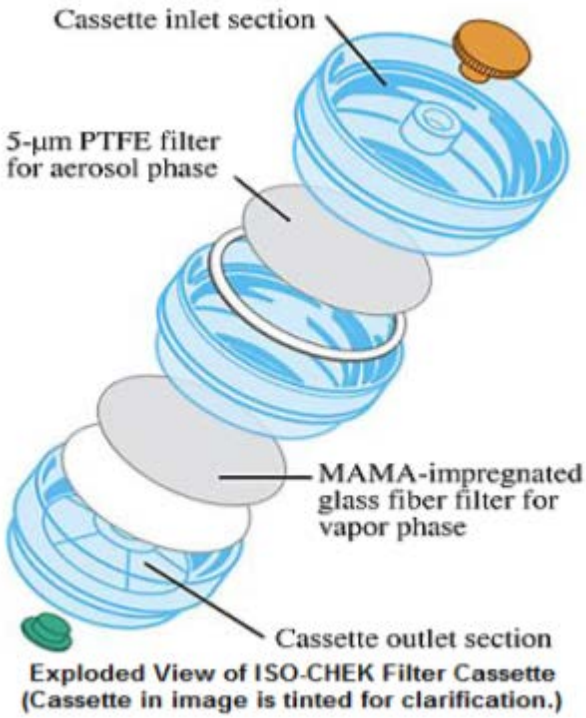


Figure 14: Iso-Check® Cassettes (Courtesy of SKC Inc.)

Table 23: Isocyanate Sampling

Matrix	Method	Collection Media	Comments
Air	**ISO-CHEK®,** *1,6-HDI, MDI, IPDI, 2,4-TDI, 2,6-TDI*	Dual filter cassette, 5.0-µm PTFE filter, MAMA-impregnated GFF Sample kits can be ordered from SKC (225-9023 or 225-9023A)	Transfer PTFE filter to the reagent jar immediately after sampling and protect sample from light (wrap in aluminum). Be sure to order the Iso-Chek® kit that includes derivatizing solution. Store cold and ship with gel packs to the lab as soon as possible. **Unrefrigerated samples are stable for 7 days; refrigerated samples are stable for 7 to 10 days.**
Air	Asset Sampler *1,6-HDI, MDI, IPDI, 2,4-TDI, 2,6-TDI*	Supelco Asset Isocyanate Sampler	When ready to sample, contact USAFSAM Customer Service to request samplers. Customer service will need: POC, address, commercial phone number, and number of samplers required. The samplers will be provided by the subcontract lab.

Note: Isocyanate sampling has a very high sample collection and submission error rate. Attention to detail and strict adherence to the protocol are required to ensure the validity of sample results. Below are key points to remember when sampling using the Iso-Chek® protocol:

- ✓ Bases should request the Iso-Chek® protocol and list the specific isocyanate desired (i.e., 1,6-HDI, MDI, etc.) on sample submission paperwork. The default analytical report will include both monomer and oligomer fractions. If you have determined your sampling requires just the monomer or oligomer fraction, you may specify that on the sample submission paperwork as well.
- ✓ Be sure to order Iso-Chek® kits that include the derivatizing solution (SKC 225-9023 or 225-9023A).
- ✓ Unplug and connect the cassette to a sample pump calibrated to 1 L/min.
- ✓ Take a 15-minute sample.
- ✓ Immediately after sampling, open the cassette and remove the PTFE filter with forceps (filter closest to air inlet). Do not remove the washer-style support pad from the cassette.
- ✓ Match the cassette ID number with the reagent jar number; place the filter in the prepared jar containing the methoxy-2-phenyl-1 piperazine reagent in toluene.
- ✓ Keep the fiberglass filter in the cassette.
- ✓ Re-plug the cassette; wrap it in foil to protect the sample from light.
- ✓ Label both the cassette and corresponding reagent jar with the same DOEHRS sample ID.
- ✓ A field blank should be prepared in the same manner, with the PTFE filter removed and placed in the reagent jar.
- ✓ Store collected samples in the refrigerator until ready for shipping.
- ✓ Ship all jars *and* cassettes to the laboratory as soon as possible (same business day). The manufacturer's original shipping container works well for sending field samples to the laboratory.

- ✓ DOT regulations require that material able to absorb the solvent be packed with the jars in case of a leak. The blue foam in the original shipping packaging meets this requirement. DOT regulations also require that the package be placed in another cardboard box prior to shipment. Use the 40 CFR 173.4 labels provided by the manufacturer to ship the package.
- ✓ To extend sample stability, ship samples with gel packs within a cooler or Styrofoam container. Refrigerated samples are stable for 7 to 10 days. Contact Customer Service *prior* to shipping samples if they will arrive at the lab within 48 hours of the hold time expiring.
- ✓ Do not ship samples on Fridays or right before holiday weekends. USAFSAM/OEA is not able to accept routine Saturday or holiday deliveries. Refrigerated samples shipped overnight on Friday will not be received by the lab until Monday morning.

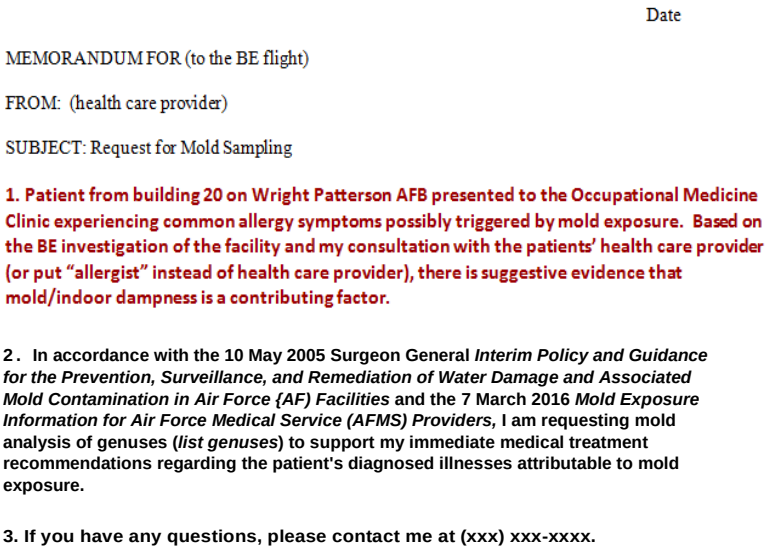
3.7 Mold Sampling

Periodically, Analytical Services receives a request to conduct mold sampling in conjunction with an occupational illness investigation. Mold sampling is generally not recommended.

- ➢ Microbial sampling and analysis have significant limitations and may not be a predicator of indoor air related health problems. There are currently no industry or legal standards for acceptable microbial concentrations in buildings.

- ➢ Sampling should only be accomplished as the result of consultation with the patient's physician/health care provider, occupational medicine physician, or allergist in order to provide information that supports a specific clinical diagnosis or aids in medical treatment.

In the rare event sampling is required, analysis will be subcontracted. Sampling media will be provided by the subcontract labs. Have the patient's physician complete the mold request letter/memorandum (see Figure 15) and forward it to OEA Customer Service. Once OEA Customer Service receives the request letter, our staff will contact the BE flight to discuss sampling and analysis options. Please ensure the BE contact information is included. If this letter doesn't apply, suggest reevaluating the need for mold sampling and analysis.



Date

MEMORANDUM FOR (to the BE flight)

FROM: (health care provider)

SUBJECT: Request for Mold Sampling

1. Patient from building 20 on Wright Patterson AFB presented to the Occupational Medicine Clinic experiencing common allergy symptoms possibly triggered by mold exposure. Based on the BE investigation of the facility and my consultation with the patients' health care provider (or put "allergist" instead of health care provider), there is suggestive evidence that mold/indoor dampness is a contributing factor.

2. In accordance with the 10 May 2005 Surgeon General *Interim Policy and Guidance for the Prevention, Surveillance, and Remediation of Water Damage and Associated Mold Contamination in Air Force {AF) Facilities* and the 7 March 2016 *Mold Exposure Information for Air Force Medical Service (AFMS) Providers*, I am requesting mold analysis of genuses (*list genuses*) to support my immediate medical treatment recommendations regarding the patient's diagnosed illnesses attributable to mold exposure.

3. If you have any questions, please contact me at (xxx) xxx-xxxx.

Figure 15: Example Mold Sampling Request Memo

SECTION 4: ENVIRONMENTAL HEALTH

4.0 Environmental Health Samples

Environmental health samples are collected to assess ambient environmental conditions (i.e., sand in New Mexico, smog in Los Angeles, radon in Colorado), industrial operations located either inside or outside the area of concern (AOC), or conditions that affect large portions of the AOC. A variety of sampling techniques could be used to sample environmental concerns (24+ hour air samples, soil, surface, and drinking water). The techniques will be based on the contaminants and are up to the discretion of the risk assessor. Environmental health samples are assigned to a location; personnel are linked to the possible exposure through the location.

4.1 Environmental Health Analytical Services

Analytical Services meets the demand for environmental health analytical services both through in-house Chemistry Lab capabilities and through a network of contracted commercial labs. These capabilities span the full spectrum of commercially available analytical techniques. The contract can often be modified to meet the emerging and new technology demands of the field. For a general idea of the commercial services available, you may reference the sampling guides for the three major contract labs used by USAFSAM including Test America, Bureau Veritas North America (BVNA), and Eurofins Eaton Analytical. **These links are provided as a general reference ONLY; Customer Service *must* be contacted to address any questions and will make the final determination regarding the use of a commercial lab.** A few of the more common analytical methods are referenced in each of the applicable sections below including drinking water, surface and ground water, air, and soil sampling.

4.2 Use of Commercial Labs

USAFSAM/OEA is DHP funded to cover environmental health sampling on a limited basis. **As mentioned in Section 1 of this guide, the use of a commercial lab *must* be coordinated with Customer Service *prior* to sample collection.** Commercial labs often require the customer use a lab-supplied sampling kit and chain of custody (COC). Customer Service will walk the customer through the sampling process from sample kit/supply delivery, collection, shipping, and receipt of final results. While the DOEHRS Business Objects Sample Submission Form is the preferred COC for in-house occupational health analyses, a COC provided by the commercial lab may be required for environmental health sample submissions. Customer Service will coordinate COC requirements with the base.

4.3 Federal Regulations

While BEs no longer collect environmental compliance samples, it is beneficial to understand the basic federal regulations governing environmental compliance and associated sampling and analysis. Having an understanding of the governing standards will aid in the development of an appropriate environmental health risk assessment sampling strategy. Federal environmental legislation (Table 24) that includes sampling and analysis is largely covered under five main acts: Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Resource Conservation and Recovery Act (RCRA), Clean Air Act (CAA), and the Toxic Substances Control Act (TSCA). References to the EPA analytical methods are found in each applicable section below. For a compiled index of National Environmental Methods, refer to ASAGE or the collaborative

National Environmental Methods Index hosted by the U.S. Geological Survey Water Resources Discipline, the EPA Office of Water, and the Center for Integrated Data Analytics. Each piece of legislation is discussed in detail in the following sections.

Table 24: Federal Environmental Legislation

Environmental Media	CWA	SDWA	RCRA	CAA	TSCA
Waste Water, Sewage Sludge	X		X		
Ground Water		X	X		
Drinking Water		X			
Storm Water	X				
Soil, Sludge			X		X
Solid Waste			X		X
Waste Oil			X		
Air				X	

4.3.1 Clean Water Act

CWA establishes the basic structure for regulating discharges of pollutants into waters of the United States and regulating quality standards for surface waters. Under the CWA, the EPA has implemented pollution control programs such as setting wastewater standards for industry. They have also set water quality standards for all contaminants in surface waters. The CWA made it unlawful to discharge any pollutant from a point source into navigable waters unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges. The analytical methods promulgated under the authority of Section 304(h) of the CWA are sometimes referred to as the "304(h)" or "Part 136" methods. The methods measure chemical and biological pollutants in media such as wastewater, ambient water, sediment, and biosolids. A complete listing of CWA methods can be found on the EPA Clean Water Act Analytical Methods website.

4.3.2 Safe Drinking Water Act

SDWA was established to protect the quality of drinking water in the United States. The law focuses on all waters actually or potentially designed for drinking use, whether from above ground or underground sources. The act authorizes the EPA to establish minimum standards to protect tap water and requires all owners or operators of public water systems to comply with these primary (health-related) standards. Water systems must use EPA-approved analytical methods when analyzing samples to meet federal monitoring requirements or to demonstrate compliance with drinking water regulations. A list of approved methods for the analysis of drinking water samples can be obtained from the EPA Drinking Water Analytical Methods website.

4.3.3 Resource Conservation and Recovery Act

RCRA, which amended the Solid Waste Disposal Act, regulates the management of solid and hazardous waste to protect public health and the environment. This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also requires substances identified as hazardous wastes be tracked with a "cradle-to-grave" manifest system. EPA Publication SW-846 is the official compendium of analytical and sampling methods for hazardous waste characterization that have been evaluated and approved for use in complying with the RCRA regulations. For BE operations, SW-846 methods can be used not for compliance

but rather to characterize solid and potentially hazardous waste in association with an environmental HRA.

4.3.4 Clean Air Act

CAA is the comprehensive federal law that regulates air emissions from stationary and mobile sources. Among other things, this law authorizes EPA to establish National Ambient Air Quality Standards (NAAQS) to protect public health and public welfare and to regulate emissions of hazardous air pollutants. The 1990 amendments to the CAA list 187 toxic air pollutants not previously regulated under the NAAQS. Asbestos demolition and renovation also fall under the CAA umbrella. A list of approved air toxic analytical methods can be found on the EPA Ambient Monitoring Technology Center and the Inorganic (IO) Compendium Methods page.

4.3.5 Toxic Substances Control Act

TSCA gives the EPA the broad authority to regulate the manufacture, use, distribution, and disposal of chemical substances and is intended to protect the public from unknown development of dangerous new chemicals. TSCA addresses the production, importation, use, and disposal of specific chemicals including polychlorinated biphenyls (PCBs), chlorofluorocarbons, asbestos, radon, and lead-based paint. Test methods for PCBs can be found in the TSCA.

4.4 Sample Plan Development and the Data Quality Objectives (DQO) Process

The EPA DQO process can be a useful tool to develop an environmental sampling plan. The DQO process establishes specific objectives for an environmental study and focuses data collection and analysis to meet those objectives. The DQO process achieves two major objectives: it ensures that the type, quantity, and quality of data collected are appropriate for the decision at hand, and it eliminates the collection of unnecessary, redundant, and overly precise data. The DQO process is defined in the *Guidance for the Data Quality Objectives Process*, EPA QA/G-4, and in Figure 16.

4.4.1 DQO 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 environmental risk assessment. During this step, also identify available BE resources for sampling and the primary decision makers (i.e., commanders, public health, flight medicine, etc.). Give a concise description of the environmental health threat and exposure pathway. Summarize existing information into a conceptual site model including previous sampling information, preliminary estimates, and process descriptions. A conceptual site model should be a three-dimensional “picture” of site conditions at a discrete point in time (snapshot) that conveys what is known or suspected about the facility, releases, release mechanisms, contaminant fate and transport, exposure pathways, potential receptors, and risks. Refer to the Occupational and Environmental Health Site Assessment (OEHSA) *Documentation and Data Management Technical Guide* on the ESOH webpage for additional details [restricted access].

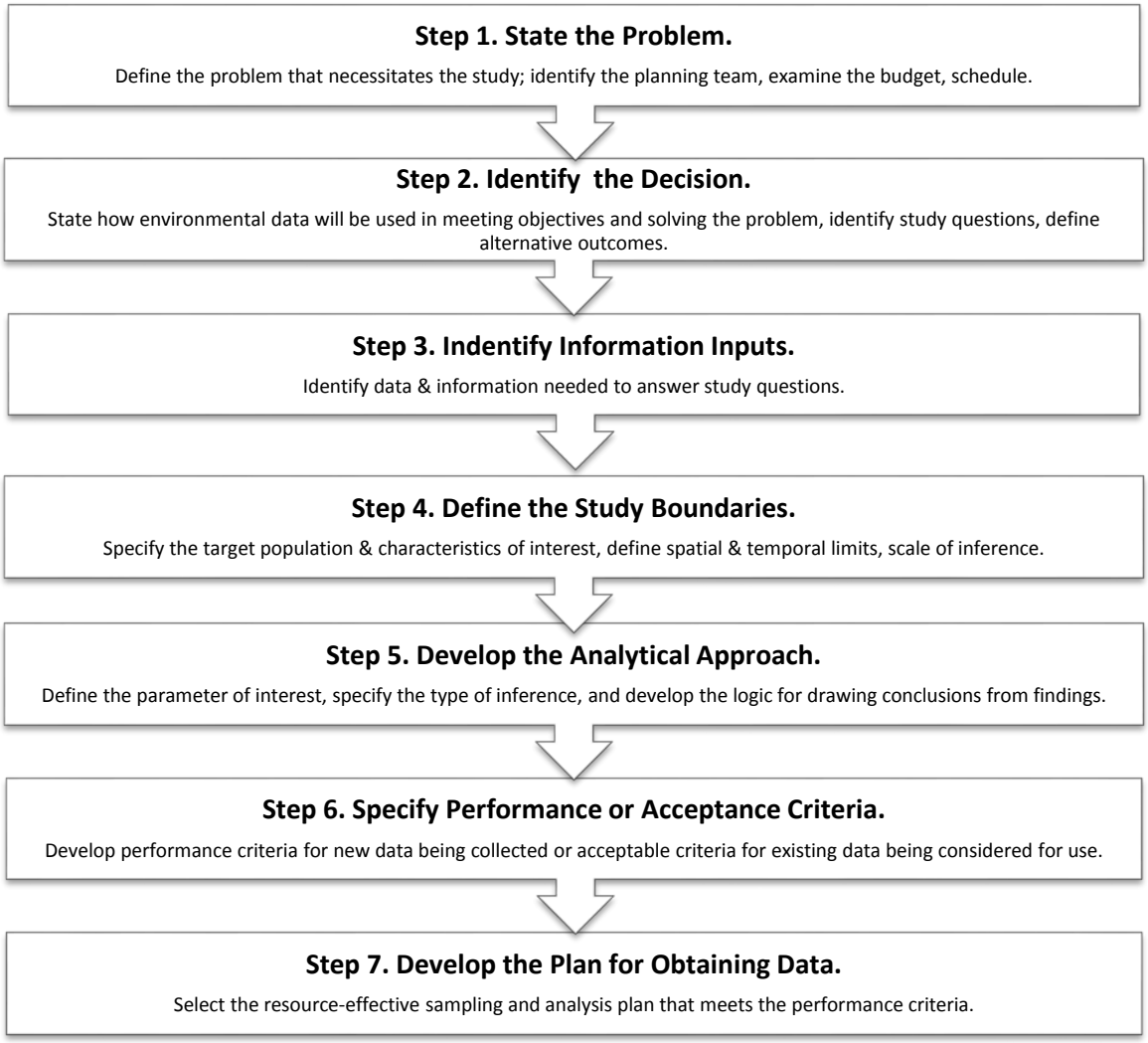


Figure 16: Sample Plan Development and the DQO Process

4.4.2 DQO Step 2: Identify the Decision

In step two of the DQO process, the goal of the study is identified. Specifically for sampling and analysis, what do you intend to do with the analytical results? State the questions you intend to answer with qualitative and/or quantitative results. Consider alternative outcomes and courses of action based on varying sampling results.

4.4.3 DQO Step 3: Identify Inputs to the Decision

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, and required detection limits. Risk assessment standards are mentioned below. Additional information regarding matrix specific analytical methods and sample collection equipment are discussed elsewhere in this document.

Researching applicable risk assessment standards is typically a critical part of this step. Below is a list of available environmental risk assessment standards and toxicological information to aid in this process:

- ✓ *Agency for Toxic Substance and Disease Registry (ASTDR) Minimal Risk Levels (MRLs)*. ASTDR MRLs are probably the best guide for community exposure. ASTDR derives MRLs for noncancer 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.

- ✓ *U.S. Army Technical Guide 230, Environmental Health Risk Assessment and Chemical Exposure Guidelines for Deployed Military Personnel*. These standards are based on toxicological studies and can assist in making a risk-based decision during deployments and while in-garrison. Values in these tables are associated with threshold effects relative to the health effects of the given chemical. Technical Guide 230 addresses chemical hazards to include chemical warfare agents, acutely toxic industrial chemicals, and a wide array of general environmental pollutants. The guide does not address biological or nuclear/radiation hazards. There is a Reference Document (Rd) 230 that provides details associated with the methods, scientific rationale, and assumptions behind the established military exposure guidelines.

- ✓ *U.S. EPA National Ambient Air Quality Standards*. NAAQS regulate air quality while in-garrison, and exposures should be documented. These regulations may not apply while deployed; however, the information can be used to guide the health risk assessment. NAAQS are divided into clean air primary standards and secondary standards. Primary standards are designed to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards are established to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. NAAQS have been established for six principal criteria pollutants including nitrogen dioxide, ozone, sulfur dioxide, particulate matter (PM), carbon monoxide, and lead.

- ✓ *EPA Maximum Contaminant Levels (MCLs)*. MCLs are standards that are set by the EPA for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed in public water systems under the SDWA. MCLs ensure that drinking water does not pose a short-term or long-term health risk. EPA sets MCLs at levels that are economically and technologically feasible.

- ✓ *ACGIH Threshold Limit Values and OSHA Permissible Exposure Limits.* These regulations are enforceable in-garrison and compliance is mandatory. While OSHA regulations are not enforceable in some deployed locations, it is important to consider OSHA PELs and ACGIH TLVs when assessing the exposures from local environmental and industrial activities. It is important to remember these standards were promulgated on the basis of an 8-hour/day, 5-day/week work week for employees conducting the task generating the hazard. These values may not be appropriate for general populations but may provide valuable information during the environmental health risk assessment.

- ✓ *EPA Integrated Risk Information System (IRIS)*. IRIS is a human health assessment program that evaluates risk information on effects that may result from exposure to environmental contaminants. The IRIS database contains information for more than 550 chemical substances containing information on human health effects that may result from exposure to various substances in the environment. IRIS provides reference doses for non-carcinogenic toxicity and slope factors (carcinogenic potency factors) for carcinogens.

4.4.4 DQO Step 4: Define the Study Boundaries

It is important to clearly define the AOC to be sampled including spatial boundaries (number of acres, miles of shoreline, gallons of pond water, etc.) and temporal boundaries (seasonal variances, volatilization rate, etc.). 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 and generally where samples will be collected and the time frame when the samples should be taken. Select a sampling device based on its ability to (1) obtain the correct size, shape, and orientation of the samples and (2) meet other performance goals specified by the planning team.

4.4.5 DQO Step 5: Develop a Decision Rule

The main objective of step five of the DQO process is to select a result parameter and action level. These two should then be combined to develop the decision rule (see Table 25).

Result Parameter. The sample results parameter is the parameter (mean, median, or upper confidence limit) that will be used with the HRA – are you interested in "average" conditions or "extreme, worst case" conditions. The statistical parameter (mean, median, percentile) selected in step five can be based on what the action level (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.

Table 25: Result Parameters and Their Applicability to a Decision Rule[a]

Parameter	Definition	Appropriate Conditions of Use
Mean	Average	Estimate central tendency, comparison of 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	May be preferred to estimate central tendency if the population contains some values are less than the limit of quantitation. However, the median is not a good choice if more than 50% 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.

[a]Adapted from Table 5-1 from EPA QA/G-4, Guidance for the Data Quality Objectives Process [24].

Action Level. Define the AL, either using predetermined AL from fixed standards such as a published drinking water MCL or using a more conservative investigation-based AL, i.e., 1/10 the OEEL. 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. An example of a decision rule is as follows:

If the mean concentration in the surface 2 inches of soil area defined as 20 ft by 100 ft exceeds 1 ppb, then remove a 6-inch layer of soil, else leave the soil intact.

4.4.6 DQO Step 6: Specify Performance or Acceptance Criteria

Identify sources of error (i.e., sampling error, analytical error, etc.). Determine the desired confidence level in your results before collecting samples (i.e., 99, 95, 90, 80, or 70% 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).

4.4.7 DQO 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:

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

Common pitfalls to avoid during sample plan development include (1) non-representative sampling, (2) instability or contamination of samples between sampling and analysis, (3) interferences and matrix effects in analysis, (4) inability to determine the relevant forms of the parameter being measured, (5) improper calibration, and (6) failure to blank-correct.

4.5 Probability-Based vs. Judgmental Sampling Designs

There are two classes of sampling designs to consider: probability-based and judgmental Table 26). The former is sometimes called statistical designs and the latter directed sampling information. The two classes have very different properties. Strong statistical conclusions are available with probability-based designs but not with judgmental designs. Use of professional expertise and/or historical knowledge about the site can improve development of statistical and judgmental sampling designs. Key questions to be considered are:

- ✓ Is the objective of the sample to estimate an average or to find a hot spot?
- ✓ Is there a reference or background population that can be used as a comparison to the target population?
- ✓ Will sampling sites be chosen ahead of time or in the field based on visual or other evidence and, if the latter, what are your criteria for selection?
- ✓ Is the AOC homogeneous or is it heterogeneous in nature needing stratification or division into approximately homogeneous areas?
- ✓ Can samples be composited?

Table 26: Probability-Based Versus Judgmental Sample Designs[a]

	Probability-Based	Judgmental
Advantage	✓ Provides ability to calculate uncertainty associated with estimates ✓ Provides reproducible results within uncertainty limits ✓ Provides ability to make statistical inferences ✓ Can handle decision error criteria	✓ Can be less expensive than probabilistic designs ✓ Can be very efficient with knowledge of the site ✓ Easy to implement
Disadvantage	✓ Random locations may be difficult to locate ✓ An optimal design depends on an accurate conceptual site model	✓ Depends upon expert knowledge ✓ Cannot reliably evaluate precision of estimates ✓ Depends on personal judgment to interpret data relative to study objectives

[a]Adapted from Table 2-1 from EPA QA/G-5S, Guidance on Choosing a Sampling Design for Environmental Data Collection [25].

4.5.1 Judgmental Sampling

In judgmental sampling, the selection of the number, location, and timing of sampling collection is based on knowledge of the feature or condition under investigation and on professional judgment (Figure 17). Conclusions about the target population are limited and depend entirely on the validity and accuracy of professional judgment; probabilistic statements about parameters are not possible. Expert judgment may also be used in conjunction with other sampling designs to produce effective sampling for defensible decisions.

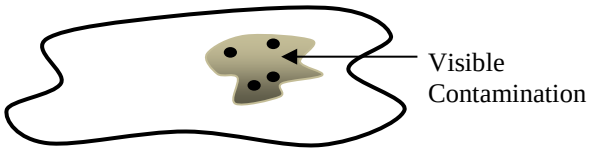


Figure 17: Judgmental Sampling

4.5.2 Simple Random Sampling

In simple random sampling, particular sampling units (i.e., locations, time, etc.) are selected using random numbers, and all possible selections of a given number of units are equally likely (Figure 18). For example, a simple random sample of a set of drums can be taken by numbering all the drums and then, using a random number generator, selecting the drums to be sampled. This method is easy to understand, and the equations for determining sample size are relatively straightforward. An example is shown in Figure 18. This figure illustrates a possible simple random sample for an area of soil. Simple random sampling is most useful when the population of interest is relatively homogeneous, i.e., no major patterns of contamination or "hot spots" are expected.

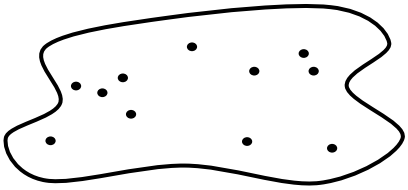


Figure 18: Simple Random Sampling

4.5.3 Stratified Sampling

In stratified sampling, the target population is separated into non-overlapping strata or subpopulations that are known or thought to be more homogeneous (relative to the environmental medium or the contaminant) so that there tends to be less variation among sampling units in the same stratum than among sampling units in different strata (Figure 19). Strata may be chosen on the basis of spatial or temporal proximity of the units or on the basis of preexisting information or professional judgment about the site or process. Advantages of this sampling design are that it has potential for achieving greater precision in estimates of the mean and variance and that it allows computation of reliable estimates for population subgroups of special interest.

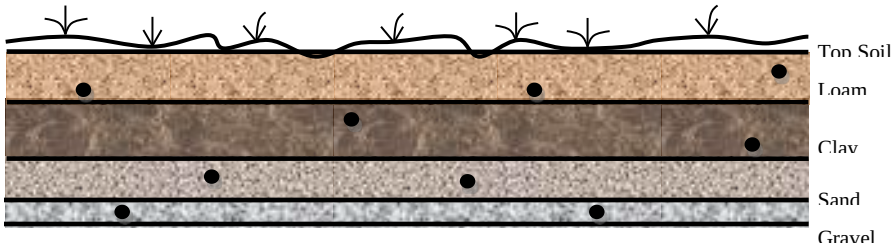


Figure 19: Stratified Random Sampling

4.5.4 Systematic and Grid Sampling

In systematic and grid sampling, samples are taken at regularly spaced intervals over space or time (Figure 20). An initial location or time is chosen at random, and then the remaining sampling locations are defined so that all locations are at regular intervals over an area (grid) or time (systematic). Systematic and grid sampling is used to search for hot spots and to infer means, percentiles, or other parameters and is also useful for estimating spatial patterns or trends over time. This design provides a practical and easy method for designating sample locations and ensures uniform coverage of a site, unit, or process.

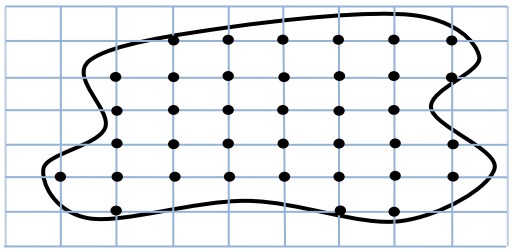


Figure 20: Systematic and Grid Sampling

4.5.5 Advanced Probabilistic-Based Sampling Designs

Two 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. In adaptive cluster sampling, *n* samples are taken using simple random sampling, and additional samples are taken at locations where measurements exceed some threshold value. For additional information on these two advanced sampling designs, refer to EPA QA/G-5S [25].

4.5.6 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 (Figure 21). 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 or temporal variability is not needed.

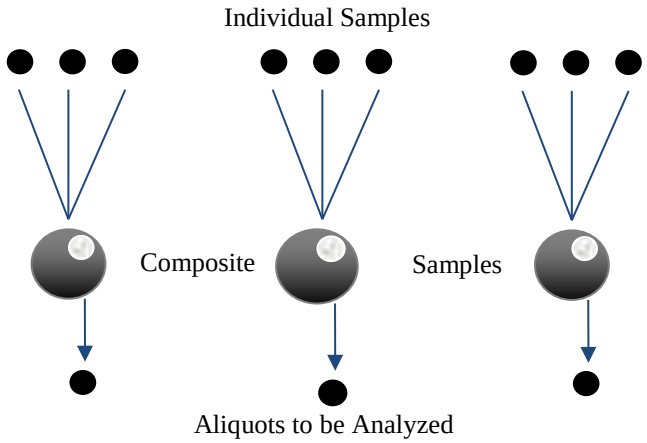


Figure 21: Composite Sampling

4.5.7 Choosing a Sampling Design

Table 27 summarizes the various sampling designs and can be used to select a design based on site-specific requirements.

Table 27: Choosing a Sampling Design[a]

If you are…	And you have…	Consider using…	In order 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 hot spot of a given size
Estimating a population mean	An adequate budget	Systematic or grid sampling	Also produce information on spatial or temporal patterns
	Budget constraints and analytical costs that are high compared to sampling costs	Composite sampling	Produce an equally precise or a more precise estimate of the mean with fewer analyses and lower cost
	Budget constraints and professional knowledge or inexpensive screening measurements to assess the relative amounts of the contaminant at specific field sample locations	Ranked set sampling	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

[a]Adapted from Table 3-1 from EPA QA/G-5S, Guidance on Choosing a Sampling Design for Environmental Data Collection [25].

4.6 Visual Sample Plan Software

When probability-based sampling designs are desired, one resource available to assist BEs is the Visual Sample Plan (VSP®) software program developed cooperatively between the Department of Energy, EPA, Department of Homeland Security, the Centers for Disease Control and Prevention, and the United Kingdom; VSP® is available for free download at http://vsp.pnnl.gov/. VSP® is a software tool that supports the development of a defensible sampling plan based on statistical sampling theory and statistical analysis of sample results to aid in decision making. VSP® is suited for larger scale sampling events and has many sampling design and statistical analysis modules focused on soils, sediments, surface waters, streams, groundwater, and buildings. The underlying software methodology employs the DQOs discussed in this guide.

4.7 Quality Control Samples

Background Samples. Background samples are collected at or near the AOC in areas not influenced by site contamination. It demonstrates the ambient concentrations of a substance from both naturally occurring and anthropogenic non-site sources. Background samples are collected from each media of concern: soil, sediment, surface water, groundwater, 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 Quality Control Samples. A number of field quality control samples should be taken during environmental health sampling. The specific quantity of quality control 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. A general discussion on the type of QC samples is included in Table 28 and below:

- ✓ *Trip Blanks.* Trip blanks (also known as field reagent blanks) 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 due to the potential for preservative decomposition when sampling kits are stored under deployment conditions.
- ✓ *Equipment Blanks.* 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 analyte 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.* 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 for many analytical methods.

- ✓ *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.

Table 28: Project Quality Control Checks[a]

QC Check	Information Provided
Blanks	
Bottle Blank	Cleanliness of sample bottles
Field Blank	Transport, storage, and field handling bias
Reagent Blank	Contaminated reagent
Rinsate or Equipment Blank	Contaminated equipment
Method Blank	Response of an entire laboratory analytical system
Replicates, Splits, etc.	
Field Collocated Samples	Sampling + measurement precision
Field Replicates	Precision of all steps after acquisition
Field Splits	Shipping + interlaboratory precision
Laboratory Splits	Interlaboratory precision
Laboratory Replicates	Analytical precision
Analysis Replicates	Instrument precision

[a]Adapted from Table 5, EPA QA/G-5, Guidance for Quality Assurance Project Plans [26].

4.8 Implementation: Selecting Equipment and Conducting Sampling

Sampling Equipment: The tools, devices, and methods used for sampling contaminants will vary with the form, consistency, and location of the matrix to be sampled. The following sections provide a brief summary of types of sampler devices available for air, water, and soil. These are by no means an inclusive list of all commercially available sampling equipment; rather, they are a brief summary of possible options. For a detailed discussion on selecting a suitable sampling device, refer to ASTM Standard D6232-08, *Standard Guide for Selection of Sampling Equipment for Waste and Contaminated Media Data Collection Activities* [27]. Equipment selection criteria should include consideration for:

- ✓ Chemical compatibility
- ✓ Physical compatibility
- ✓ Sample volume capability
- ✓ Ease of operation
- ✓ Ability to be decontaminated
- ✓ Single use or reusable
- ✓ Cost

Sample Preservation: Sample preservation methods and maximum holding times associated with different analyses need to be taken into consideration to ensure proper analysis. Preservation of the samples is accomplished by pH control, chemical addition, temperature control, or a combination of the above methods. The preservation of the samples may be required if immediate analysis of the sample is not possible. When using chemical additive for preservation, invert the container several times after filling to ensure adequate mixing of the preservative with the sample. The preservation methods and recommended sample holding time should be checked before sampling for any analyte.

In most cases, sampling containers already containing the required preservative can be supplied by the lab. *Do not rinse* these containers prior to filling, and do not allow overflowing. With some sampling containers there are preservative that ***must*** be added to the sampling container ***after*** the sample has been collected. The preservative will be provided by the lab in a separate vial or container with the sample container. Please ensure the correct sequence of sampling and preservation is followed.

Holding Times: The maximum holding times are established by the published method. These holding times are based on the use of recommended sample containers and preservation techniques. Please contact the lab before shipping samples if the lab will receive the samples with less than 48 hours to meet holding times.

Sample Storage: In general, the shorter the time that elapses between collection of samples and its analysis, the more reliable the analytical results. Remember to adhere to particular parameter storage requirements; typically, most samples require storage at 4°C.

4.9 Drinking Water Sampling

Installation BEs are responsible for funding and executing routine drinking water compliance sampling as directed by AFI 48-144, *Drinking Water Surveillance Program* [28]. Base-specific monitoring frequencies, analytical methods, and laboratories should be documented in detail in the local sampling, analysis, and monitoring (SAM) plan. The regulatory agency ***must*** certify a laboratory before it may analyze drinking water samples for compliance monitoring.

Local contracting mechanisms and funds should be used to obtain analytical services of a certified lab. In the event a local contract is not established, the USAFSAM commercial lab BPA may be available. The commercial labs utilized by USAFSAM are certified in most states on many fields of testing. Contact Customer Service if your base is unable to establish a local contract and requires the use of the USAFSAM commercial lab BPA for emergent sampling requirements.

General drinking water sampling guidance is provided in the sections below. Refer to the base-specific SAM plan and the USAFSAM report *Drinking Water Surveillance Technical Guide* [29] [limited access] for additional details regarding drinking water sampling and analysis. The regulatory agency should also be for compliance sampling guidance.

4.9.1 Drinking Water General Sample Collection Considerations

It is important that good sampling techniques be followed to ensure representative samples are sent to the laboratory for analysis. Proper selection, collection, identification, and shipment of samples must occur to ensure the reliability of all Air Force drinking water programs.

Example Sampling Procedures. The following are examples of common utility sampling locations and some of the basic nuances to sampling these locations.

- ✓ *Sampling from Accessible Water Taps:* Remove the aerator, if present; aeration will remove volatile organic compounds (VOCs) from the sample. Maintain a steady flow of water until the water temperature is constant, and then hold the sample container under the discharge at an angle so that the sample flows down the inside wall of the sample container. This also minimizes aeration. Fill the container(s) to the fill line (if present) or to the top of the container lip.

- ✓ *Sampling from Fire Hydrants:* Sampling from a hydrant is usually not recommended but may be required in the event of a water main break or repair. If sampling at a hydrant is required, remove the small cap from the low-pressure side, adjust the flow down to a manageable level for sample collection, and collect the sample as if from a tap.
- ✓ *Sampling from Water Towers:* Sampling from a water tower is usually only required in rare situations and possibly during water contingency monitoring to establish baseline characteristics. If sampling is required, allow the water to run for at least 20 to 30 minutes to clear the plumbing leading to the sample port before sampling. If there is no sampling port, then a pump should be used. Lower the pump into the water reservoir to depth(s) prescribed by the routine sampling plan or by the person in charge of the investigation.

4.9.2 Drinking Water Analytical Methods

As mentioned previously, sampling and analytical regulatory requirements should be thoroughly documented in the SAM plan. A few common SDWA analytical methods are listed in Table 29 that, in addition to regulatory compliance, may be used as a screening method in conjunction with a general HRA or an OEHSA. Check with the lab for container and preservative requirements and analytical method(s) to be used prior to sampling. In addition, sampling interferences, laboratory methods, and known matrix effects may require specific project preservations to be developed. A sampling plan should be prepared and reviewed with the laboratory prior to starting any sampling operation.

Table 29: General Drinking Water Analytical Methods

Contaminant	Method	Container	Comments
VOCs	EPA 524	Amber vial, Teflon-lined septum	Recommended container size is 40-120 mL glass vial with PTFE-faced silicon septum, preserve with hydrochloric acid (HCl) to pH<2, cool to 4°C, no headspace. If chlorine is present, add ascorbic acid prior to HCl addition. Hold time is 14 days.
Semi-VOCs	EPA 525	Amber vial, Teflon-lined septum	Recommended container size is 1-L amber bottle, reduce residual chlorine by adding sodium sulfite, preserve with HCl to pH<2, cool to 4°C, no headspace.
Anions	EPA 300	Plastic or glass jar	Recommended container size is 100 mL, cool to 4°C. Holding time is 28 days.
Metals	EPA 200.7 EPA 200.8	Plastic or glass jar	Recommended container size is 500 mL, preserve with nitric acid to pH<2, cool to 4°C. Preserved samples are stable for 6 months. For determination of dissolved metals, samples should be filtered on-site prior to preservation with nitric acid. If not possible, samples need to get to the lab ASAP for filtering. Indicate on paperwork whether or not samples were field filtered.
Pesticides			
Organophosphorus	EPA 507	Glass jar	Recommended container size is two 1-L glass bottles. Residual chlorine should be reduced by adding 50 mg/L of sodium sulfite. Adjust pH<2 by adding HCl, cool to 4°C. Hold time is 14 days.
Organochlorine	EPA 508	Glass jar	Recommended container size is two 1-L glass bottles. Residual chlorine should be reduced by adding 50 mg/L of sodium sulfite. Adjust pH<2 by adding HCl, cool to 4°C. Hold time is 14 days.

4.10 Surface and Groundwater Sampling

If a complete exposure pathway is present, it may be necessary to sample surface, ground, and/or storm water. Assess these water sources from a health perspective, i.e., *"Is storm water run-off a potential source of OEH threats due to industrial operations and does it affect personnel in the AOC?"*

4.10.1 Surface and Groundwater General Sampling Considerations

Surface water sampling can include any body of water that rests or flows over land, including streams, rivers, lakes, ponds, creeks, lagoons, estuaries, surface impoundments, or coastal waters. Samples can be collected at surface level or at a prescribed depth interval. Sampling points should be established at the locations where distinct changes in pH, temperature, dissolved oxygen, or conductivity indicate the possible presence of contaminants. When sampling from a nonpoint source, it is important to consider special properties and precautions when developing a representative sampling design, including stratification, current, storm events, time of year, circulation, velocity, turbidity, and salinity.

Actual sampling situations encountered in the field may vary according to the site. The most important goal of surface water sampling is to collect a representative sample of the appropriate horizons or phases present in the liquid and that meets the DQOs. Surface water can be collected as a grab or as a composite sample. Samples that require VOC analysis should be submitted to the laboratory as a grab sample rather than a composited sample to minimize the potential loss of the volatile contaminant.

Groundwater monitoring wells, underground injection wells, and industrial wells are potential sources of groundwater samples. Evacuation or purging of the water column in a monitoring well is required prior to sample collection to remove the standing water column and induce groundwater flow from the surrounding formation into the well.

4.10.2 Surface and Groundwater Sampling Equipment

Surface and groundwater sampling equipment includes, but is not limited to, laboratory-cleaned sample bottles, automatic samplers, bacon bombs, weighted bottle samplers, bailers, dippers or "pond samplers," drum thief, Kemmerer samplers, submersible pumps, peristaltic pumps, piston pumps, and liquid grab samplers. Decontamination of existing and new equipment is required prior to use in the field. Table 30 summarizes possible liquid sampling equipment options. The table also provides the names of additional guidance documents that can be referenced for detailed instructions on equipment use. Consider the following factors when selecting a sampling device:

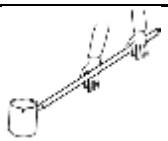
Surface Water

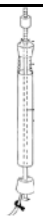
- ✓ Will the sample be collected from shore or from a boat?
- ✓ From what depth should the sample be collected?
- ✓ What is the overall depth and flow direction of the river or stream?

Groundwater

- ✓ Type of well and depth of well
- ✓ Diameter of well casing
- ✓ Expected recharge rate of well

Table 30: Liquid Sampling Equipment Selection Guide[a]

Sampling Device	Image	Device-Specific Guidance	Sample Type	Comments
Automatic Sampler		ASTM D6538 EISOPQA Manual (USEPA 1996b)	Shallow (25 in), discrete or composite	Auto samplers are available to collect samples for VOA and provide a grab or composite sample and may be unattended. Need power source/battery. Commonly used at wastewater treatment plants. Must be knowledgeable of compatibility of waste and sampler components.
Bacon Bomb		USEPA 1984 USEPA 1994c	Depth, discrete	For parameters that do not require a PTFE sampler. Recommended for sampling of lakes, ponds, large tanks, or lagoons. May be difficult to decontaminate and materials of construction may not be compatible with sample matrix.
Bailer		ASTM D4448 USEPA 1992c USEPA 1994c	Depth, discrete	Bailers are not recommended for sampling groundwater for trace constituent analysis due to sampling-induced turbidity [30,31]. Unable to collect samples from specific depths (unless a point-source bailer is used). Available in a variety of sizes as either reusable or single-use devices. May be chemically incompatible with certain matrices unless constructed of resistant material.
COLIWASA		ASTM D5495 ASTM D5743 ASTM D6063 USEPA 1980	Shallow, composite	Reusable and single-use models available. Inexpensive. Glass type devices may be difficult to decontaminate. Collects undisturbed sample. For mixed solid/liquid, media will collect semi-liquid only. Not for high viscosity liquids.
Dipper (or "pond sampler")		ASTM D5358 ASTM D5013 USEPA 1980	Shallow, composite	For sampling liquids in surface impoundments. Inexpensive. Not appropriate for sampling stratified waste if discrete characterization needed.
Drum Thief		ASTM D6063 ASTM D5743 USEPA 1994b	Shallow, composite	Usually single use. If made of glass and reused, decontamination may be difficult. Limited by length of sampler, small volume of sample collected, and viscosity of fluids.

Kemmerer Sampler		Depth, discrete	Recommended for lakes, ponds, large tanks, or lagoons. May be difficult to decontaminate. Materials may not be compatible with sample matrix but all PTFE construction is available. Sample container exposed to media at other depths while being lowered to sample point.
Liquid Grab Sampler		Shallow, discrete, composite - suspended solids only	For sampling liquids or slurries. Can be capped and used to transport sample. Easy to use. May be lowered to specific depths. Compatibility with sample parameters is a concern.

[a]Images and table adapted from Table 9, EPA530-D-02-002, RCRA Waste Sampling Draft Technical Guide [32].

4.10.3 Surface and Groundwater Analytical Methods

Table 31 lists common analytical methods applicable to surface and groundwater sampling. In-garrison, the installation NPDES permit will list specific sampling and analytical monitoring requirements including frequency, sample location, sampling method, and QC requirements. While the NPDES compliance sampling requirements are managed by CE, this is a good place to start if no information is known about potential surface water contamination.

Table 31: Surface and Groundwater Analytical Methods

Contaminant	Method	Container	Comments
VOC Screen	EPA SW 8260	Glass vial, Teflon-lined septum	Recommended container size is 40 mL (2), preserve with HCl to pH<2, cool to 4°C, no headspace. Two vials per sample.
Metals	EPA SW6010 EPA SW6020	Plastic or glass jar	Recommended container size is 500 mL, preserve with nitric acid to pH<2, cool to 4°C. Preserved samples are stable for 6 months.
Pesticides			
Organophosphorus Pesticides	EPA SW8141	Amber glass, Teflon-lined cap	Recommended container size is two 1-L samples. Hold time is 7 days, cool to 4°C.
Organochlorine Pesticides	EPA SW8081/8082	Amber glass, Teflon-lined cap	Recommended container size is two 1-L samples. Hold time is 7 days, cool to 4°C.

4.11 Soil Sampling

Soil samples are collected for a variety of reasons including chemical, physical, toxicological, and biological analysis. Due to the inherent variability of soils, collection techniques should be evaluated and chosen for each sampling site and each sampling purpose. Choosing the most appropriate sampling device and technique depends on 1) purpose of the sampling, 2) the location of the soil, and 3) the characteristics of the soil.

4.11.1 General Soil Sampling Considerations

Both sample depth and area are considerations in determining appropriate sample volume. Depending on the analytes being investigated, samples are collected at the surface (0-3 in.), extended surface (0-6 in.) and/or at one-foot depth intervals. Non-water soluble contaminants such as dioxin and PCBs are often encountered within the first six inches of soil. Water-soluble contaminants such as metals, acids, ketones, and alcohols will be encountered at deeper depths in most soils except clays. Contaminants in solution, such as PCPs in diesel fuel and pesticides in solvents, can penetrate to great depths (i.e. down to bedrock), depending on soil type. The following is a description of the types of samples that may be collected:

- ✓ *Cores*- vertical discrete grab samples. Most appropriate for historical contamination information or dredging decisions at heavily contaminated areas.
- ✓ *Scoops and Dredges*- Surface (top two to four centimeters) sediment grab samples. Most appropriate for benthic, sediment oxygen demand (in-situ), recent ambient conditions and recent contaminant investigation.
- ✓ *Scoops and Dredge Composites*- surface sediment composite samples. May be used to reduce costs for specific conditions/situations such as ambient or specific historical data. In general, however, discrete sampling is preferred if resources are available.

4.11.2 Soil Sampling Equipment

Soil sampling devices should be of sufficient quality not to contribute contamination to samples (i.e. painted surfaces which could chip off into the sample). Additionally, the sampling equipment should be either easily decontaminated, or cost-effective if considered to be single use only. Soil sampling equipment includes, but is not limited to, augers, core samplers, dredges, scoops, shovels, trowels, split barrel samplers, and triers. Table 32 summarizes possible soil sampling equipment options. The table also provides the name of additional guidance documents that can be referenced for detailed instructions on equipment use.

Table 32: Soil Sampling Equipment Selection Guide[a]

Sampling Device	Image	Device-Specific Guidance	Sample Type	Comments
Auger		ASTM D1452 ASTM D4700 ASTM D6063 Mason 1992 USEPA 1993c	Surface or depth, disturbed	Easy and quick for shallow subsurface samples but not recommended for VOA. Requires considerable strength and labor and destroys soil horizons.
Miniature core sampler		ASTM D4547 ASTM D6418	Discrete	Used to retrieve samples from surface soil, trench walls, or subsamples from soil cores. O-rings on plunger and cap minimize loss of volatiles and allow device to be used to transport sample. Designed for single use. Cannot be used on gravel or rocky soils. Must avoid trapping air with samples.

Ponar dredge		ASTM D4387 ASTM D4342 USEPA 1994e	Bottom surface, rocky or soft, disturbed	One of the most effective samplers for general use on all types of substrates (silt to granular material). May be difficult to repeatedly collect representative samples. May be heavy.
Scoop, shovel, and trowel		ASTM D5633 ASTM D4700 ASTM D6063	Surface, disturbed, selective	Usually for surface soil and solid waste samples. Available in different materials and simple to obtain. Easy to decontaminate and rugged. May bias sample because of particle size. May exacerbate loss of VOCs.
Split barrel sampler		ASTM D1586 ASTM D4700 ASTM D6063	Discrete, undisturbed	May be driven manually or mechanically by a drill rig with trained personnel. May collect a sample at depth. A liner may be used in the device to minimize disturbance or for samples requiring VOA.
Trier		ASTM D5451 ASTM D6063	Surface, relatively undisturbed, selective	Recommended for powdered or granular materials or wastes in piles or in bags, drums, or similar containers. Best for moist or sticky materials. Will introduce sampling bias when used to sample coarse-grained materials.
Thin-walled tube		ASTM D1587 ASTM D4823 ASTM D4700	Surface or depth, undisturbed	Useful for collecting an undisturbed sample (depends on extension). May require a catcher to retain soil samples. Inexpensive, easy to decontaminate. Samples for VOA may be biased when sample is extruded.

[a]Images and table adapted from Table 9, EPA530-D-02-002, RCRA Waste Sampling Draft Technical Guide [32].

4.11.3 Soil Sampling Analytical Methods

Table 33 lists common analytical methods that may be beneficial if laboratory analysis of soil is required in conjunction with a health risk assessment.

Table 33: Soil Sampling Analytical Methods

Contaminant	Method	Container	Comments
VOC Screen	EPA SW8260	Glass, Teflon-lined cap	Recommended container size is 125 mL, cool sample to 4°C, sample hold time is 14 days.
Metals	EPA SW6010 EPA SW6020	Plastic or glass jar	Samples are stable for 6 months, keep samples cool to 4°C, recommended container size is 125 mL.
Pesticides			
Organophosphorus Pesticides	EPA SW8141	Glass, Teflon-lined cap	Recommended container size is 250 mL, cool sample to 4°C, hold time is 7 days.
Organochlorine Pesticides	EPA SW8081/8082	Glass, Teflon-lined cap	Recommended container size is 250 mL, cool sample to 4°C, hold time is 14 days.

4.12 Air Sampling

Environmental air sampling methods are typically categorized by the air or emission source or by the type of pollutant measured. A few of these categories include indoor air samples, ambient air samples, stationary source samples, and soil vapor samples.

- ✓ *Indoor air sampling* is conducted in all types of living and workplace environments, including industrial facilities, office buildings, and homes. OSHA, NIOSH, and EPA methods are typically referenced for collecting indoor air samples.

- ✓ *Ambient air sampling* is conducted in outdoor locations, usually in the vicinity of known or suspected sources of air pollutants at ambient temperature, pressure, and humidity. Typical locations for ambient air sampling include soil remediation sites and manufacturing facilities. Ambient air sampling can also be conducted to assess nuisance particulate sources spreading over a large geographical region such as automotive traffic on a highway or the air quality of a city.

- ✓ *Stationary source sampling* is also mainly conducted outdoors, but may also occur at indoor locations in industrial settings. Stationary source samples are collected from a single point source of emissions, such as an exhaust stack. Typical locations for source testing include industrial boilers, various manufacturing facilities, and power plants. Regulatory agencies that have developed methods or guidelines for ambient and stationary source testing include the EPA, California Air Resources Board, Department of Toxic Substances Control, and various Air Quality Management Districts.

- ✓ *Soil vapor samples* may be used for investigations of possible soil and groundwater contamination. Analysis of these whole air samples can occur both in the field and using reach-back laboratories. Since analytical methods have yet to be published specifically for soil vapor, ambient air methods are typically used.

Air pollutants are categorized by the regulations controlling them and their chemical and physical properties. National air standards divide air pollutants into two categories including criteria pollutants and hazardous air pollutants.

4.12.1 Criteria Pollutants

The NAAQS list six criteria pollutants with established national regulatory limits including nitrogen dioxide, sulfur dioxide, carbon monoxide, lead, ozone, and PM. Particulate matter is further defined by EPA as total suspended particulates (TSP), $PM_{2.5}$, and PM_{10}. Note: these definitions differ from the ACGIH respirable, thoracic, and inhalable fractions.

- ✓ *TSP* – total suspended particulates is suspended matter in air including solid and low vapor pressure liquid particles. TSP accounts for all suspended particulates, with no preference to size selection. The size range is typically 0.01 µm to 100 µm and larger.

- ✓ *PM_{10}* – particles with a diameter less than 10 µm that pose a health risk because they can be inhaled and accumulate in the respiratory system. Particles with diameters between 2.5 and 10 µm are referred to as "coarse." Sources of coarse particles include crushing or grinding operations and dust from paved or unpaved roads.
- ✓ *$PM_{2.5}$* – particles with a diameter less than 2.5 µm, referred to as "fine" particles, and are believed to pose the largest health risk. Because of their small size, fine particles can lodge deeply into the lungs. Sources of fine particulates include all types of combustion and some industrial processes.

4.12.2 Hazardous Air Pollutants

Hazardous air pollutants, some of which have national, state, or local regulatory limits, include 187 compounds. Hazardous air pollutants, which are usually collected using whole air sampling, can be divided into the following categories based on their chemical composition and physical properties:

✓ Non-volatiles (metals and heavy organics, etc.)	Boiling Point > 300°C
✓ Semi-VOCs (SVOCs)	Boiling Point 120-300°C
✓ VOCs	Boiling Point <120°C

4.12.3 General Air Sampling Considerations

Particulates. Air sampling for particulates typically involves capturing the particles on filters using either a high-volume or low-volume sampling pump. The mass of particles on the filter is then determined. The filter can be furthered analyzed for specific analytes if desired (i.e., lead, chromates, etc.).

Non-volatiles and SVOCs. Air sampling for non-volatiles and most SVOCs usually involves trapping the compounds on solid (charcoal tubes), liquid media (impingers), or filters, then extracting or desorbing the media for analysis. Refer to the occupational health section of this guide for additional information on sampling with solid sorbent material and filters.

VOCs. VOCs may be collected on solid sorbent material or by conducting whole air sampling. In whole air sampling, samples are collected and analyzed in the gaseous phase. This method is best suited for volatile, non-polar compounds and fixed gases. Some SVOCs with boiling points as high as 170°C can be collected using whole air sampling, depending on the temperature and reactivity of the sample matrix and the sampling media.

4.12.4 Air Sampling Equipment

The two most commonly used media for whole air sampling are metal canisters and bag samples (Table 34).

Table 34: Air Sampling Equipment Selection Guide

Sampling Device	Image	Device-Specific Guidance	Sample Type	Comments
Sorbent Tube		EPA TO 17	Active sorbent tube sampling	Used for the determination of VOCs in ambient air using active sampling onto sorbent tubes.
Summa® Canister		EPA TO 15 EPA TO 14A	Whole air VOC samples	Stainless steel vacuum canister. Rugged and does not require the use of a pump.
Fused Silica-Lined Summa® Canisters		EPA TO 15 EPA TO 14A	Whole air reactive organic compounds	These canisters have been treated with an inert silica glass lining that extends holding times for polar or oxygenated compounds and sulfur-containing compounds.
Gas Bags		EPA TO 15 EPA TO 14A	Whole air VOC samples	Two layers of film sealed at the edges with a valve on one side. Sample will require special handling (fragile) and a pump for collection.
Particulate Sampling Systems		Manufacturer's guidance	Filter	Refer to manufacturer's guidance for use of federal reference samplers and other particulate sampling systems (Deployable Sampler System (DPS) Sampling Kit shown to the left). Filters should be pre-weighed prior to sampling.

Metal Canisters. Stainless steel canisters, made less reactive by depositing a pure chrome-nickel oxide on the interior surface, are popular for whole air sampling. The Summa® canister is a common (but trademark) term used to refer to an air sampling canister. Air sampling canisters may also be referred to as a "SilcoCan®" or "MiniCan®." Canisters are generally referred to as a "ppb sampling device."

Canisters come in a variety of sizes including 400 cc, 1 liter, and 6 liters. These metal canisters use passive sampling, in which a vacuum is used to draw air into a stainless steel canister. The canisters can be used to collect TO-15 analytes, as well as fixed gases like methane, carbon monoxide, carbon dioxide, oxygen, and nitrogen. The canisters are cleaned and analyzed for cleanliness prior to use and may be cleaned and reused many times. Holding times for most analytes in summa canisters have shown to be stable for up to 30 days. Canisters can be taken as a grab sample (< 5 minutes) or as an integrated sample (taken over a longer period of time, usually 30 minutes to 24 hours). Integrated sampling using a canister requires a flow controller to regulate the rate at which the sample enters the sampling container.

Canisters are completely evacuated prior to use. During sampling, a valve is opened and air is drawn into the canister through the inlet until the canister pressure has equilibrated with that of the source being sampled. The vacuum/pressure gauge is used to monitor the canister pressure and indicates when there is an air flow problem or when sampling is complete. Canister rentals are available through USAFSAM contract labs. Contact Customer Service to arrange shipment.

Bag Samples. Flexible bags for the collection of whole air samples are available in several different plastic materials including Tedlar®, Teflon®, Mylar®, etc. Sample bags consist of two layers of film sealed together at the edges with a sampling valve on one side. Sample bags are generally referred to as a "ppm sampling device." Care should be taken when sampling for trace contaminants, since VOCs may be present in sampling bags in ppb concentrations. Conditioning bags prior to use by purging with nitrogen further reduces contaminants.

Once a sample bag has been used, however, it cannot be reused for low concentration (sub-ppm) sampling because the sample bag may absorb VOCs, which can off-gas at a later time. Sample bags come in a variety of sizes from >1 liter to 30 liters. The holding time for most compounds in sample bags varies depending on the compound, but is significantly less than that for canisters: typically 1 day or less for sulfur compounds and 3 days for other compounds. Sample bags are less expensive and easy to handle and transport, but require the use of a pump, have a short hold time, and are fragile.

Proper sample bag material selection depends on matching the particular film characteristics with the compound to be sampled, the concentration level, and the time between sample collection and analysis. Currently Tedlar® bags are the most commonly used bags in the Air Force; however, in 2009 DuPont announced its plan to phase out support for Tedlar® film in the sample bag market. The Kynar® bag is one alternative if Tedlar® bags become unavailable. Kynar® bags have low VOC and sulfur background. Contact Customer Service if you require assistance selecting the appropriate sampling bag for your unique situation.

4.12.5 Air Sampling Analytical Methods

Table 35 lists popular analytical methods that may be beneficial if laboratory analysis of air samples is required in conjunction with an HRA.

Table 35: Air Sampling Analytical Methods

Contaminant	Method	Media	Comments
VOC Screen	EPA TO-17	Triple-bed tube (Supelco Carbotrap®)	Keep samples cold. Tubes must be ordered from the lab and must be used within 30 days.
	EPA TO-15	Summa® canister or Tedlar® bag	Keep samples cold. Summa canister hold time is 30 days, Tedlar bag is 3 days. Six-liter summa canisters are recommended for lower concentration samples (ambient air) and 1-liter summa canisters for higher concentration samples (soil gas, flares, etc.). Summa canister rentals may be coordinated by calling Customer Service.
$PM_{2.5}$ **PM_{10}** **TSP**	EPA Compendium Method IO-2	Various filters	Recommended when a federal reference method is required. Filters must be pre-weighed within 30 days of the sampling period. Refer to system manufacturer's operating instructions for sampling details.
	SKC DPS Kit AirMetrics TAS AirMetrics MiniVol	Various 47-mm filters	The DPS and the AirMetrics TAS and MiniVol are not federal reference samplers.[a] Filters must be pre-weighed prior to sampling. Refer to system manufacturer's operating instructions for sampling details.
Metals	Modified NIOSH 7300 EPA Compendium Method IO-3	2- mm MCE filter Various 47-mm filters	A variety of methods including ICP-OES and ICP-MS may be used to determine chemical species and may be used in conjunction with PM monitoring.
Asbestos	TEM by EPA Level I-III		TEM method divided into three levels of analysis. Level I is morphology and visual selected area electron diffraction (SAED) pattern recognition, Level II adds elemental analysis, Level III adds some zone axis SAED and elemental analysis
	ISO 10312		Ambient air determination of asbestos fibers, direct transfer transmission electron microscopy method. Sampled with elutriator or direct air sampling.
	AHERA TEM		Normally used for building clearance, additional grid openings for sensitivity
	ASTM D6281-96 TEM		ASTM version of ISO 10312

[a]Particle air samplers may be coming through the career field modernization effort; alternatively, they may be available through equipment request to USAFSAM or the U.S. Army Public Health Command.

4.13 Identification of Unknown Materials

The USAFSAM contract labs are capable of performing qualitative material characterizations of unknown bulk solid materials using the methods indicated in Table 36. To ensure quality data to support identification, it is extremely important to provide as much information as possible when submitting samples. Examples include shipping documentation, container labels, safety data sheets (SDS), communication memos, or historical documents. Also helpful is information regarding the location, including type of industrial activity, types of machinery, or other materials located at the scene. USAFSAM is ***NOT*** capable of handling unknown samples suspected of containing chemical warfare, biological agents, or explosives.

Table 36: Identification of Unknown Bulk Materials

Method	Container	Comments
PLM/MC	Wide mouth glass jar	Polarized light microscopy/materials characterization. Uses optical properties to identify larger particles.
TEM/MC	Wide mouth glass jar	Transmission electron microscopy/materials characterization. Morphology, SAED, and energy dispersive spectroscopy (EDS). Uses elemental chemistry and crystallinity to identify very small particles – less than 10 µm.
SEM/MC	Wide mouth glass jar	Scanning electron microscopy/materials characterization. Uses morphology and elemental chemistry to identify larger particles from dusts or bulks.
SEM/EDS	Wide mouth glass jar	Scanning electron microscopy/energy dispersive spectroscopy. Uses elemental analysis of individual particles to provide qualitative as well as quantitative results as desired.

4.14 Occupational and Environmental Health Site Assessments

The OEHSA Technical Guide outlines general sampling considerations in Chapter 7. The tables provided in the tech guide are *simply guidance* on sampling tools and techniques to characterize the background or baseline levels; this guidance ***must*** be adjusted as appropriate to accommodate local conditions. OEHSA sampling requirements can span the spectrum of environmental sampling possibilities, crossing mediums (i.e., air, water, soil) requiring varying analytical methods (i.e., EPA, ASTM, NIOSH).

In most cases, OEHSA sampling generally will start with direct reading instruments. When the determination to conduct lab sampling is made, a decision to the appropriate analytical method must be made. When the analyte and media are known, an analyte-specific method should be chosen. If no information or limited information is known about an AOC, the general screening sampling methods for soil, surface water, drinking water, and air as discussed in the previous sections of this guide may be useful as a starting point for the environmental HRA.

4.15 Statistics and the Data Quality Assessment (DQA)

As defined by the EPA, a DQA is the scientific and statistical evaluation of environmental data to determine if they meet the planning objectives of the project and thus are the right type, quality, and quantity to support their intended use. Summarizing environmental data and choosing the right statistical method is a large task and one that is currently not supported in DOEHRS for environmental sampling. For detailed guidance on performing a DQA for environmental sample results, refer to the EPA document *Data Quality Assessment: Statistical Methods for Practitioners (EPA QA/G-9S)* [33]. By using DQA, a reviewer can answer four important questions:

1. Can a decision (or estimate) be made with the desired level of certainty, given the quality of the data?
2. How well did the sampling plan perform?
3. If the sampling strategy is used again for a similar study, would the data be expected to support the same intended use with the desired level of certainty (i.e., is there repeatability)?
4. Is it likely that sufficient samples were taken to enable the reviewer to see an effect if it was really present?

SECTION 5. RADIOLOGICAL SAMPLING & ANALYSIS

5.0 Radioanalytical Services

There are multiple reasons why a radiological sample may be collected for laboratory analysis. It is critical that the BE have a clear understanding of the purpose of a sample. Your analysis requirements must then be effectively communicated to the laboratory to ensure a proper analysis is performed and that results meet your needs. Once results are received, the results must be effectively interpreted. If any part of this process is not carried out effectively, then both time and resources are wasted. The purpose of this radiation section is to assist AF personnel in conducting this process.

5.1 Significant Changes/Updates

The following are significant changes from the 2012 edition of the sampling guide.

5.1.1 Wet Swipes

Wet swipes are only required for liquid scintillation cocktail (LSC) analysis. All other samples should be dry wiped. Wet swipes will draw the contaminant into the filter paper, reducing our counting efficiency from 33% to 6%.

5.1.2 Soil Sampling & Analysis

To ensure compliance with all requirements outlined in 7 CFR Part 330 – Federal Plant Pest Regulations; General; Plant Pests; Soil, Stone, and Quarry Products; Garbage and 7 CFR Part 301 – Domestic Quarantine Notices, you must contact OEA Customer Service prior to collection and shipping any soil samples to USAFSAM for analysis. For all samples considered "foreign soils," the USAFSAM laboratory will provide sampling containers, labels, and shipping directions.

5.1.3 Quality Control Samples

Two QC samples are required for each set of 20 samples (e.g., field blanks and field duplicates).

For example, 50 swipes submitted would require three blanks and three duplicates. A field blank consists of a sample media that is treated exactly the same way as the samples but taken from an area known to be free of contamination. A field duplicate is a sample taken at the same location twice. If it isn't possible to take the required QC samples, notify the laboratory Customer Service prior to sample collection.

Samples received without the proper QCs will be rejected.

5.1.4 Sample Submission Form

AF Forms 2753 & 495 are no longer accepted as a submission form. Use DOEHRS Radiation Sample Submission form for submitting samples to the USAFSAM Radioanalytical Laboratory. Refer to the DERG – Radiation Sample Submission Form on the ESOH Service Center. If the DOEHRS form is unavailable, use the WPAFB 2753. Additional tips to remember include:

- AF 495 may be used as an envelope.
- Do not submit more than one sample in a container or they'll be rejected.
- "All" is not an analysis method. ID isotopes of concern. When in doubt, contact OEA Customer Service for assistance.
- The Radioanalytical Laboratory cannot analyze for noble gases, i.e., Kr-85
- Do not submit routine samples for isotopes with half-lives less than 30 days.

5.1.4 Bioassay Samples

It is highly recommended to contact OEA Customer Service prior to collecting any bioassay samples, including baseline samples. Due to the complex nature of bioassay samples, we would prefer to assist you in determining analysis requirements rather than providing you poor results. Be prepared to answer the following questions: what is the requirement for sampling, how many samples will be collected, what is the exposure (isotope) max level workers can be exposed, when are workers being exposed, how frequently are workers being exposed.

5.2 Radiation Sampling Plan Development

There are multiple steps in accomplishing successful sampling (Figure 22).

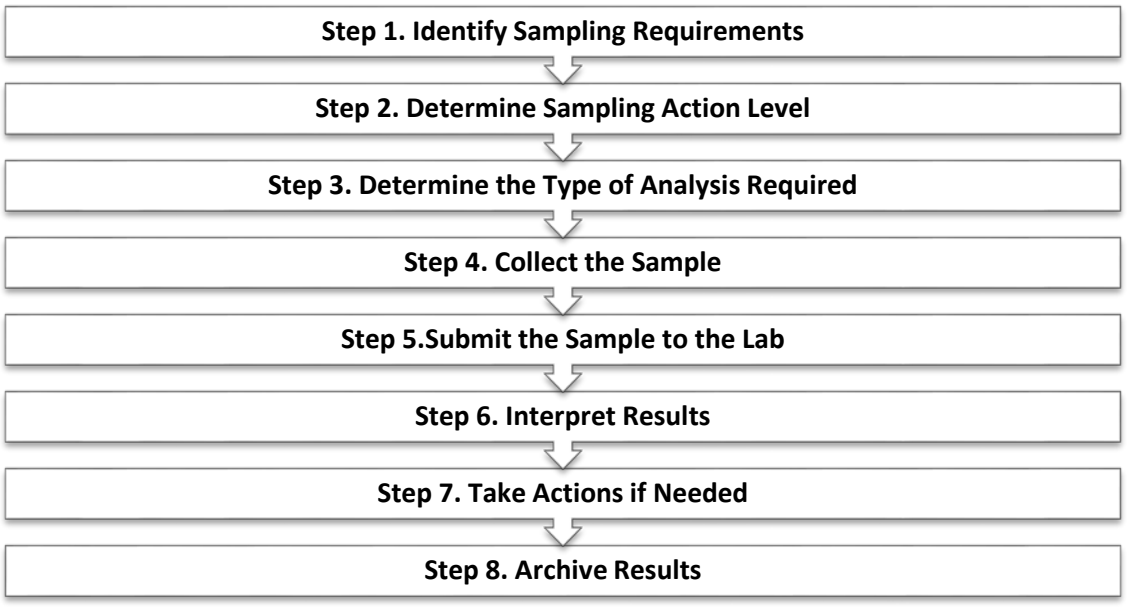


Figure 22: The Complete Radiological Sample Collection Process

5.3 Identifying Sampling Requirements

The first step in the radiological sample process is to determine the need to sample and the requirements associated with the sample. There are numerous reasons for collecting a radiological sample. Some of the most common reasons in the AF include permit compliance, hazard assessment, contamination identification, waste disposal/characterization, shipping requirements, and exposure monitoring. It is important that the reason for the sample be known before it is collected, as it will be the primary driver of the collection method and analysis performed. Table 37 and the following paragraphs discuss typical AF sampling requirements and associated action levels.

5.3.1 Sealed Sources for Permit Compliance

AF radioactive material permits will often specify that the sealed sources be surveyed on a routine basis. The following are requirements for a typical USAF permit. **(Review your actual permit for individual requirements.)**

- **Frequency of Sampling:** This is typically every 6 months unless the certificate of registration from the U.S. Nuclear Regulatory Commission (NRC) states a different interval.

- **Sealed Source Device Registry Number (SSDR).** For a device to be considered a sealed source by the NRC, it is typically assigned an SSDR. This certifies that it has passed a battery of tests to ensure that it will not leak. As part of this registry, the device will be assigned a sampling interval. The value can typically be found in your permit application, which usually requires copies of the SSDR for devices. If not available and not specified in your permit, you should contact the manufacturer or the Radioisotope Committee to obtain a copy of the SSDR.

- **Leak Testing Methods.** Leak testing methods can be specified by the manufacturer, by TO, or by a locally generated procedure. They typically involve swipe sampling specific areas of the device to determine if the material has leaked. In some cases, a swab may be used instead of a swipe for small enclosures. BEs should have written procedures for leak testing. If the procedure was submitted as part of your application then the procedure is part of your permit and is mandated. Additional sampling requirements may be specified in your permit.

- **Transfers.** If you receive a new source and do not have a certificate from a transferor indicating that a leak test has been made within a specified interval, the source shall be leak tested within 30 days of receipt. The source shall not be used or transferred unless leak test results are less than ***0.005 microcuries (µCi)***. If the leak test results are 0.005 µCi or greater, contact the Radioisotope Committee Secretariat for assistance. A source that has contamination below this limit may still be a concern.

Table 37: Typical Radiological Sampling Requirements & Action Levels

Reason for Sampling	Guidance/Requirements	Action Level	Notes
Permit Compliance	AF Radioactive Material Permit Sealed Source Device Certificate	See AFI 48-148 for requirements	Required for: Alpha sources >10 µCi Beta sources >100 µCi
Generally Licensed Device	Manufacturers' labels or no less than 6 months	See AFI 48-148 for requirements	There are some exceptions for this requirement. See AFI 40-201 Attachment 2.
Waste Characterization	10 CFR 61 AF Radioactive Recycling and Disposal (AFRRAD) Requirements	Identification of all isotopes; quantification level is not well defined; contact AFRRAD for guidance	Analysis should be sufficient to ensure that limits specified in 10 CFR 61 are met or to meet the requirements of AFRRAD.
Internal Dose Assessment	AFI 48-148; 3.5	Required for any individual who may receive greater than 2% of the annual limits of intake (ALI)	Investigation required for 25% of the ALI in a qtr. A baseline measurement must be conducted before any routine monitoring is started. Monitoring is typically quarterly but can be monthly.
Contamination Control	AFI 48-148 Table A4.2 (from Reg Guide 1.86) Local procedures may supersede	Other values for humans and emergencies can be found in NCRP Report 161 or may be locally mandated.	Typically, removable contamination is measured with a swipe sample. Fixed contamination is typically measured with a handheld instrument. Even if below limits, contamination can be indicative of problems.
Permit Termination Final Status Survey	AFI 40-201 10 CFR 20.1402 Multi-Agency Radiation Survey & Site Investigation Manual (MARSSIM) (NUREG 1575)	25 mrem /yr	Limits will be specified in your decommissioning plan. Limits will be based upon limiting the dose to members of the public to less than 25 mrem annually from any remaining material.
Environmental Assessment	MARSSIM	15 – 25 mrem/yr Or other limit beyond the scope of this document	
Transportation	49 CFR 173.443(a) Table 11	ALARA and 2200 dpm/100 cm^2 Beta 220 dpm/100 cm^2 Alpha	Note: Typically this limit can be demonstrated by performing a swipe and measuring with a handheld instrument. However, permitted materials, if the permit is being terminated, require a final leak test. 40-201 3.11.6.4.

- **Sealed Sources Not Requiring Testing.** Sealed sources need not be tested if they contain only hydrogen-3 or a radioactive gas, if the half-life of the isotope is 30 days or less, or if they contain no more than 10 µCi of beta- and/or gamma-emitting material or not more than 10 µCi of alpha-emitting material.

- **Sealed Sources in Storage.** Sealed sources need not be tested if they are in storage and are not being used. However, when they are removed from storage for use or transferred to another person, and have not been tested within the required test interval, they shall be tested before use or transfer. No sealed source shall be stored for a period of more than 2 years without being tested for leakage and/or contamination.

5.3.2 Generally Licensed Devices (GLDs)

AFI 40-201, *Managing Radioactive Materials in the US Air Force*, specifies the sampling requirements for GLDs [34]. All GLDs must be tested for leakage on a routine basis except the following:

- Devices containing only krypton
- Devices containing only tritium
- Devices containing not more than 100 µCi of other beta- and/or gamma-emitter or 10 µCi of alpha-emitter and devices held in their initial shipping container prior to installation

The frequency of testing will be specified on the device label but cannot exceed 6 months. As with permits, the removable contamination from GLD cannot exceed 0.005 µCi.

5.3.3 Waste Characterization

The isotopes and quantities of any radioactive material must be identified before disposal. Refer to 10 CFR 61, your base Radiation Safety Officer (RSO), and the AFRRAD office for guidance. The contact information for the AFRRAD office is below:

AFRRAD (ABW/CEV)
1450 Littrell Road
Wright-Patterson AFB, OH 45433
Comm: 937-257-2010; DSN: 787-2010
Email: AFRRAD@wpafb.af.mil
https://afkm.wpafb.af.mil/community/views/home.aspx?Filter=OO-MS-MC-05

5.3.4 Internal Dose Assessment

For personnel who may be exposed to unsealed radioactive sources that may result in an uptake of more than 2% of the allowable limit, internal dose monitoring is required. Internal dose monitoring typically consists of submission of urine samples and/or fecal samples for analysis.

- *Annual Limits on Intake.* ALI are specified in 10 CFR 20 Appendix B. Operations involving unsealed quantities of radioactive materials should be evaluated to determine if 2% of the ALI may be exceeded. This can be done theoretically or by using bioassay monitoring.

- *Bioassay Monitoring.* Bioassay monitoring may be required to assess exposures during radiological incidents as well. Bioassay monitoring is beyond the scope of this guide. If you believe that you have an operation that may require monitoring or evaluation, contact Customer Service for guidance.

5.3.5 Contamination Control

It is sometimes necessary to determine if an unsealed source has contaminated a surface or piece of equipment. Any time work with unsealed sources is conducted, an assessment should be made of the possibility of transfer of contamination and procedures should be implemented to identify any such contamination. Such contamination is usually identified using handheld instruments and swipes.

5.3.6 Permit Termination

AFI 40-201 requires that a final survey be conducted when a permit is terminated. The purpose of the survey is to ensure that no radioactive materials remain.

5.3.7 Environmental Assessment

To protect members of the public, environmental surveys may be conducted on AF installations to assess radioactive contamination. Environmental surveys should include a detailed sampling and analysis plan that specifies laboratory samples to be taken. Refer to the Data Quality Objectives discussion in Section 2 of this guide for additional guidance.

5.3.8 Transportation

Samples aren't needed when transporting radioactive materials. Swipes can usually be measured on site to meet transportation requirements. However, permits may require samples before a source is transferred or immediately after it is received. These must be processed by the lab.

5.4 Determine Action Level

Before a sample is submitted, assign an AL to each sample. The AL is determined by the installation RSO. After speaking with your RSO, if you still require assistance to determine an AL, contact OEA Customer Service. Not all samples require an AL; some samples may only be a measure of risk. An example would be determining presence/absence in field sampling.

5.5 Determining the Type of Analysis

The type of analysis required for a sample will be determined by the radionuclide and specific sampling requirements. It is important to ensure that the type of analysis requested will meet the regulatory requirements or will allow for an accurate health risk assessment. Samples can be analyzed using a variety of methods. It is important that you request the proper sampling method to obtain the results you desire. Analytical Services has a wide range of in-house radioanalytical capabilities.

5.5.1 Gross Alpha/Beta Counting

In gross alpha and beta counting, your sample is placed on a metal disc. The disc is then placed in a volume of gas and counted. The instrument can differentiate between alphas and betas but not between different isotopes. No isotope identification is possible. This method is typically used as a screening tool but can be used to quantify some isotopes in samples that may only contain a single isotope. This is the preferred method for single isotope analysis if the radionuclide emits an alpha or beta particle.

5.5.2 Liquid Scintillation Counting

In liquid scintillation counting, your sample is placed in a solution that emits light when exposed to radiation. This method can be used to measure low energy beta emitters. Typically the method is used to measure H-3, Ni-63, and C-14.

5.5.3 Alpha Spectrometry

In alpha spectrometry, your samples are prepared by chemical separation. The sample is digested (dissolved into a liquid) to make it into a solution. This solution is then chemically separated. The element of interest is separated from all others present as much as possible. This purified solution is then placed on a small metal disc and then measured in an alpha spectrometer. An alpha spectrometer then counts the number of alpha particles and their energies emitted. Using these data, the activity of alpha-emitting isotopes of that element can be quantified.

5.5.4 Gamma Ray Spectrometry

Gamma ray spectrometry uses high purity germanium detectors to measure the number and energy of gamma rays emanating from your sample. Energies from 50 keV to roughly 2 MeV can be measured with current lab capability. Using the energies of the emitted gammas, an unknown isotope can be identified. By using the yield and number of gammas emitted, the activity of each radioactive isotope in the sample can be identified.

Gamma ray spectrometry should be requested when you have a sample with an unknown isotope present. It should also be used for determining the activity concentration of each gamma- emitting isotope in a sample.

- *Precautions*. When determining activity present in a sample, the assumption is made that the activity is uniformly distributed throughout the sample. In the event this is not the case, the actual activity present in the sample may be over- or underreported. If you suspect that a sample may contain non-uniform activity, then you should contact Customer Service for further guidance.

- *Disadvantages*. It requires long measurement times. The detectors and equipment are quite expensive to purchase and maintain. Interpretation of the spectrum for reporting requires a significant amount of time and expertise. TAT may be extended for this type of analysis.

5.5.5 Recommended Analysis Based on Sample Type

Table 38 outlines recommended analysis based on sample type and isotope of concern. Contact the lab if you plan to use something else.

Table 38: Recommended Radioanalyses for Different Types of Samples

Item	Source	Analysis to Request	Typical Media
Chemical agent monitors	Ni-63	LSC	Whatman paper (or eq) or cotton swab on wooden stick
X-ray fluorescence	Cd-109	Gamma Spec	Whatman paper (or eq)
Alpha check source (ADM 300)	Th-232	Gross Alpha/Beta	Whatman paper (or eq)
Beta/gamma source (ADM 300)	Cs-137	Gross Alpha/Beta	Whatman paper (or eq)
Illuminated military eq(new)	H-3	LSC	Request Tritium kit from lab
Illuminated military eq(old)	Ra-226	Gross Alpha/Beta	Whatman paper (or eq)

5.6 Radionuclides of Interest

The following section discusses several radionuclides of interest to AF operations.

5.6.1 Tritium

Tritium (H-3) is an isotope of hydrogen and can be found in self-luminous lights, emergency exit signs, lensatic compasses, as a trace element in many types of biomedical research, and as a component of some nuclear weapons. Typically, tritium is analyzed using liquid scintillation counting. Direct reading instruments are available but rarely part of the BE shop equipment package.

5.6.2 Carbon-14

Carbon-14 (C-14) is commonly used in research laboratories, although it has a few non-laboratory applications in the AF as well. It is also produced naturally in the atmosphere. Like tritium, C-14 is readily absorbed by living systems and becomes evenly distributed in the body. The most common pathway to exposure is direct inhalation in the workplace, in the environment, and by ingestion of foodstuffs that have incorporated C-14 by photosynthesis. Like tritium, C-14 is a very low energy beta emitter and is analyzed using liquid scintillation counting.

5.6.3 Strontium-90 and Strontium-89

Strontium is an important component of fallout from nuclear weapons. Sr-90 may be found in the workplace, where it is used in certain types of gauges, for industrial and medical radiation purposes, and in certain types of research. Of the various isotopes of strontium, Sr-90 is the most important because of its long half-life (28 years). It has a short-lived daughter, Y-90, that emits high energy beta particles. Sr-90 is a relatively high energy beta emitter. Sr-90 is analyzed by using gross beta counting. For more precise measurements, please contact OEA Customer Service for further information.

5.6.4 Cesium-137 and Cesium-134

Cesium is a fission product. Cs-137 is found in the environment due to fallout from nuclear weapons. It may be found in the workplace in the form of sealed sources used for irradiation and industrial radiography purposes. The primary hazard from Cs-137 is external exposure. Cs-137 is a high energy gamma emitter and beta emitter and has a relatively long half-life. Cs-134 is a beta and gamma emitter as well with a much shorter half-life of 2 years and is typically found in much lower concentrations than Cs-137. Cs-137 and Cs-134 are typically analyzed using gamma spectrometry in media other than swipes/filters. In swipes/filters, it is analyzed by gross beta counting. If specific concentrations are required, please contact the lab to discuss requirements.

5.6.5 Iodine-131 and Iodine-133

Iodine-131 is found in the nuclear medicine departments of most large hospitals and as an effluent from nuclear facilities. The thyroid is the critical organ where iodine concentrates. Of the various radioisotopes of iodine, I-131 is the most important, followed by I-129 and I-133. I-131 has several important exposure pathways to personnel. In the workplace, direct inhalation or ingestion is of primary concern. I-129 is primarily a beta emitter. I-129 and I-133 are both beta and gamma emitters. Iodine compounds are typically quite volatile, and care must be taken to account for this when sampling.

5.6.6 Cobalt-60, Manganese-54, Cobalt-58, Zinc-65, Iron-55, and Iron-59

Co-60, Mn-54, Co-58, Zn-65, Fe-55, and Fe-59 are activation products normally associated with the operation of nuclear reactors, or they can be produced in an accelerator. Each nuclide may be found in the workplace as a check or calibration source and, in the case of Co-60, in large irradiation and industrial radiography sources and medical teletherapy sources. All these sources are normally sealed, with the only potential for exposure being external radiation or a source of leak. These are all gamma emitters and are typically analyzed using gamma spectrometry.

5.6.7 Radium-226 and Radium-228

A common isotope encountered in military projects is radium. This isotope has been used extensively since the turn of the century to produce self-luminous dials and is often found on many of the dial faces of older aircraft. It has also been used in the form of small sealed sources for radiation cancer therapy and radiography. Radium is a naturally occurring radionuclide and, as a result, may be found in high concentrations in some soils, drinking water, and some foods.

Worker exposures include external radiation, ingestion of loose contamination and, under unusual circumstances, inhalation of aerosols. Radium is an alpha and beta emitter. Radium can be measured in soil with gamma spectrometry, typically by measuring the progeny of radium. The sample is sealed in an airtight can and radium progeny are measured after 30 days of buildup time in the can. Thus, analyzing for radium can be a time-consuming process. Radium swipes are measured by gross alpha counting. Radium in bioassays is measured by alpha spectrometry.

5.6.8 Radon

Radon is a naturally occurring noble gas. Radon is a decay product of radium, which is a decay product of uranium. Radon is constantly produced in soil and building materials where uranium exists. Because the gas is inert and has a 3.8-day half-life, radon can diffuse through the soil, where it enters the atmosphere or groundwater. Radon in the atmosphere decays back into particulate daughters that adhere to dust particles. These aerosols may then be inhaled or deposited on foodstuffs and ingested.

The average annual dose to members of the general public from man-made and natural radiation sources is 620 mrem. Of this, 230 mrem is attributed to inhaled radon progeny. The AF Radon Assessment and Mitigation Program is designed to assess significant exposures to radon in the workplace and residences of AF personnel and mitigate those measured to be greater than 4 pCi/L. Primary concern from radon is the alpha emission from its daughter products; however, radon is also a gamma emitter. Sampling for radon is accomplished using direct reading instruments and electrets. Contact the lab for further guidance.

5.6.9 Thorium-232

Thorium-232 (Th-232) is a naturally occurring isotope of thorium. Thorium is a common material used in many commercial and military applications. It has been used as an optical lens coating, in gas mantles, in thoriated tungsten welding rods, in fluorescent lamp starters, and as a component of magnesium-thorium alloys (magthor). These alloys have been used extensively in the skins of many aircraft and missiles, as well as in engine components. Thoriated alloys are often used in areas requiring high heat resistance and high tensile strength. Th-232 is naturally occurring and thus any thorium metal will be radioactive. Thorium is also naturally present in soil and water. Thorium is an alpha and gamma emitter. Thorium can be measured either via gamma spectrometry or alpha spectrometry.

5.6.10 Uranium

Uranium is a radionuclide that occurs naturally in the earth's crust. It has a half-life of $4.5x10^9$ years. Naturally occurring isotopes include U-238, U-235, and U-234. Mined uranium is processed to create uranium enriched in the isotope U-235, which then is used as fuel in modern nuclear power plants and naval nuclear vessels.

The by-product of uranium enrichment is U-238, which has a lower concentration of U-235 than in naturally occurring uranium. This by-product is also called depleted uranium. Depleted uranium has been used extensively in the military as counterweights, armor, and armor-piercing munitions. It also was used commercially as a glaze and colorant for ceramics, jewelry and glasses, and as a mildly radioactive shielding material.

Exposure to uranium in the workplace can include external exposure from handling munitions and counterweights and, under more unusual conditions, ingestion or inhalation of uranium contamination. Examples of sites where loose contamination may be present include target ranges or battle areas where depleted uranium penetrators have been used. Non-enriched and depleted uranium is a chemical hazard and not a radiological hazard. Enriched uranium can be a radiological hazard. U-238, U-235, and U-234 are measured using both gamma spectrometry and alpha spectrometry, with alpha spectrometry being the preferred method.

5.6.11 Plutonium-239 and Plutonium-238

Plutonium is not a naturally occurring element. Pu-239 is used in nuclear weapons. Pu-238 is used primarily as a heat source in radioisotopic thermoelectric generators to provide power in extremely remote environments. Pu-238 powered radioisotopic thermoelectric generators have been used successfully to power such deep space satellites as Cassini and Galileo. Pu-239, Pu-238, and Pu-240 are typically analyzed using alpha spectrometry

5.7 Swipe Samples

Analytical results will be inaccurate unless careful attention has been given to sampling procedures. The following instructions provide detailed, step-by-step procedures for collecting swipe samples for radioanalyses.

5.7.1 Swipe Collection Procedures (Non-Tritium Sources)

Swipes, also known as smears or wipes, provide a semi-quantitative measure of removable activity. They are collected by wiping an area using a filter paper while applying moderate pressure. The area of concern for smear surveys will usually be 100 cm^2. Current surface contamination guidelines are specified in terms of this area size. If the surface is thickly coated with particulate material, such as rust or dirt, a sample of the particulate material should be collected as a separate sample instead of attempting to use a smear.

Use this collection procedure for surveys of small penetrations such as cracks or anchor-bolt holes. All smears are placed in an individual container to prevent cross-contamination while awaiting analysis. It is unlikely that outside surfaces, exposed to wind and rain, will have significant levels of removable surface activity. Swipes for removable surface activity are not appropriate for use on soil.

Materials:

- Filter paper discs (Whatman® No. 41 or equivalent), 4.25 cm or less in diameter. Anything larger cannot be analyzed and will be cancelled. Cotton tip applicator is used to access remote areas only in accordance with (IAW) AF TO 11H4-8-5-1. The filter papers are standard non-medical items and may be obtained by using a Whatman catalog, catalog no. 1001-042. The Whatman Company can be reached at 1-800-Whatman. ***Do not use swipe papers with "sticky" backs.***
- Sample container (e.g., envelope, bag, or AF Form 495) (1 per sample), pencil, and pen
- Gloves
- Tape measure or 100-cm^2 template

Procedures:

- Protective equipment: Wear protective gloves when sampling. If it is suspected that samples may be grossly contaminated, change gloves between each swipe to prevent cross-contamination. When sampling, avoid touching the sample surface as much as possible.
- QC samples: For each batch of 20 samples (or less), collect QC samples. The required QC samples are a field blank and a field duplicate.
- Place a small "x" IN PENCIL ONLY on the outer edge of the filter paper on the side that is to touch the radioactive source or area being tested for contamination.

- In a slow back and forth "s" motion applying moderate pressure, swipe an area of 100 cm^2. Repeat the process at a 90-degree angle direction using the same swipe. If a cotton tip is used, swipe as much of the area that may be contaminated as possible using moderate pressure up to 100 cm^2.
- Place **unfolded** disc (or cotton tip stick) in the container (applicator sticks may be broken if necessary to fit the envelope). Leave the container unsealed. Do not tape, glue, or staple it shut.
- Enter data into DOEHRS and generate a radiation sample submission form through Business Objects.
- Place the submission form and separately bagged samples plain envelope for mailing. The use of cardboard or metal mailing tube is not necessary. DO not use AF Form 495 as a mailing envelope.

5.7.2 Swipe Collection Procedures for Tritium

Because tritium is volatile, it is important that it be contained immediately after sampling to get an accurate result. For this reason, the swipe must be placed immediately in a special vial. These vials are provided by the lab. **Call OEA Customer Service for the necessary sampling materials, swipes, and liquid scintillation cocktail (LSC) vials.**

Materials:

- Filter paper discs (Whatman® No. 41 or equivalent), 4.25 cm or less in diameter. Cotton tip applicator sticks may be used for swipe samples of Cs-137 sources taken in accordance with AF TO 11H4-8-5-1. The filter papers are standard non-medical items and may be obtained by using a Whatman catalog, catalog no. 1001-042. The Whatman Company can be reached at 1-800-Whatman. ***Do not use swipe papers with "sticky" backs***.
- Scintillation vials, 1 per sample
- Deionized water
- Container (1 per sample), pencil, and pen
- Gloves
- Tape measure or 100-cm^2 template

Procedures:

- Protective equipment: Wear protective gloves when sampling. If it is suspected that samples may be grossly contaminated, change gloves between each swipe to prevent cross-contamination. When sampling, avoid touching the sample surface as much as possible.
- QC samples: For each batch of 20 samples (or less), collect QC samples. The required QC samples are a field blank and a field duplicate.
- Moisten the swipe lightly (use a spray water bottle) and wipe an area of 100 cm^2 by gently rubbing (moderate pressure) two times. It is not necessary to place an "x" on the swipe.
- Place the swipe immediately into the provided, pre-filled LSC vial. Enter sample information into DOEHRS and generate the sample submission form through business objects, marking the top of the scintillation vial with the same base sample number used on the form. NOTE: DO NOT MARK THE SIDE OF THE VIAL.
- Place the lid on the LSC vial.
- Return both used and unused vials to the laboratory in the shipping container provided.

5.8 Biological Samples (Bioassay)

Bioassay samples are used to assess the extent of internal exposures to radioactive materials. By measuring the amount of radioactive material leaving the body, an estimate can be made of the radioactive material taken into the body and a dose estimate can be made. Bioassay sampling and interpretation is a complex science.

It is highly recommended to contact OEA Customer Service prior to collecting any bioassay samples, including baseline samples. OEA would prefer to assist you in determining analysis requirements rather than providing you poor results. Be prepared to answer the following questions: what is the requirement for sampling, how many samples will be collected, what is the exposure (isotope) max level workers can be exposed, when are workers being exposed, how frequently are workers being exposed.

Bioassay monitoring can either be conducted on a routine basis or a non-routine basis. All individuals who are routinely monitored should have a baseline sample collected. The baseline sample is used to assess if the individual may have had any previous exposures and to identify typical levels of naturally occurring isotopes present. Routine results are then compared to baseline results to help identify any change. Personnel who may be unexpectedly exposed to >2% of the occupational limit in a single exposure should consider a baseline sample as well.

5.8.1 Nasal Swabs

Nasal swabs are used as a non-quantitative screening tool to assess whether an inhalation (and to a lesser extent an ingestion) of radiological material has occurred. Nasal swabs are not indicated under normal occupational monitoring conditions. It is important to note that nasal swabs are only an indicator of an inhalation exposure and cannot be used to quantitatively assess the amount of contamination inhaled. It should only be used as a positive indicator of inhalation but cannot be used as a negative indicator of inhalation.

For a nasal swab to provide meaningful data, the sample must be collected within *1 hour* of the termination of exposure in both nostrils (one swab per nostril). There is no need for a *pre-exposure* or *baseline* nasal swab.

Materials:

- A cotton-tipped applicator, FSN 6640-00-729-6484, moistened with water is recommended. If these are not available, any moistened cotton swab may be substituted.
- Deionized water
- Gloves

Procedures:

- Protective equipment: Wear protective gloves when sampling. If it is suspected that samples may be grossly contaminated, change gloves between each swab to prevent cross-contamination. When sampling, avoid touching the sample surface as much as possible. Additional protective equipment may be required if sample is taken at a contamination control station; however, samples should only be taken in areas free of airborne contamination.

- Use a separate applicator for each nostril. Gently rub the tip around the inside of the nasal passages. It is not necessary to swab more than just the first quarter to half inch of the nasal passage. Patients must not have recently cleaned, irrigated, or otherwise disturbed material in the nasal passageways since the suspected exposure.
- After taking the sample, place each applicator in a culture tube or bag and then place the tube or bag in an envelope. Do not use tubes with culture media. Label sample with identifying information: name, rank, Social Security number (SSN), home base, and organization. Note that each swab (one per nostril) is a separate sample, with its own sample number and completed DOEHRS generated sample submission form.
- When completing the sample form, be sure to indicate the isotope of concern and the requested analysis.

5.8.2 Urine Samples

Urine analyses are the most common type of in-vitro bioassay technique. Urine samples are used to assess inhalation or ingestion intakes of soluble forms of many radionuclides. The sensitivity of the technique in measuring an intake is dependent on when the sample was collected post intake, as well as the specific solubility (chemical form) of the radionuclide and the exposure pathway, i.e., ingestion versus inhalation.

The timing of urine samples can be critical for maximum sensitivity. It is important that you contact OEA Customer Service for guidance if you suspect an exposure. In general, urine samples should be collected within the first week after a suspected exposure for maximum sensitivity. Further sampling may be required under the guidance of the laboratory.

Materials:

- 24-hour urine container, 3.0 Lite, (Cs (40) Curtin Matheson Scientific Catalog #282-252), or a new collapsible, square, 1-gallon cubetainer (FSN 6640-00-117-7855) and a new disposable funnel. If neither container is available, contact Customer Service.

Procedures:

- Instruct the person on the following procedures: Discard the first morning void and collect all other voids during the next 24 hours, including the first void the following morning. Collect the specimen in a non-contaminated area. Use caution to avoid surface contamination of the collection container. Wash hands prior to capturing each void. Collect all urine over a 24-hour period. Keep the container sealed between each void. Multiple containers may be used if needed.
- A normal 24-hour total urine volume is 1000-2000 mL. Do not add any chemical or reagent as a preservative. The sample may be kept cooled during collection to control odor and bacterial growth but it is not required.
- Properly identify each sample container with name, SSN, and collection start and stop dates/times. Submit a completed DOEHRS generated sample submission form with the sample. Ship to the lab as soon as possible.

5.8.3 Fecal Samples

Fecal analyses are considered the most sensitive means of in-vitro bioassay to detect inhalation or ingestion intakes of insoluble radionuclides, particularly transuranics such as americium, plutonium, thorium, and uranium. As with urine samples, the sensitivity of the technique is highly dependent on the specific chemical form of the nuclide, as well as the route of exposure.

Even more important is the time between a suspected exposure and sample collection. Since insoluble compounds pass through the gastrointestinal tract rapidly post exposure, you should contact OEA Customer Service immediately if a suspected exposure occurs. Typically, fecal samples should be collected within 5 days following a suspected acute intake.

Materials:

- 1-gallon plastic bags
- Cardboard box

Procedures:

- Label 5-10 plastic bags with the individual's name and SSN.
- All fecal matter should be collected over a 24-hour period. Instruct the individual to collect the specimen in a non-contaminated area, using care to avoid surface contamination of the collection bags. This will include washing hands prior to capturing the specimen.
- Defecate directly into a 1-gallon new plastic bag. Either zip-lock or twist tie closure is acceptable.
- Seal the bag and store in a cardboard box or other sturdy container.
- Repeat for all episodes in a 24-hour period, placing each sampling in the same cardboard carton. The sample may be kept cool or frozen during collection to control odor and bacterial growth.
- Once complete, place all sample bags in a larger plastic bag and seal.
- Properly identify the sample with name, SSN, and collection start and stop date and time. Submit a completed DOEHRS generated sample submission form with the sample.
- Samples should be frozen before shipment, time permitting, to control odors.

5.8.4 Breathing Zone Air Samples

The most direct measure of exposure to particulate radioactivity is a breathing zone air sample. The method uses a personal air sampling pump calibrated to a known flow rate (commonly 2 L/min) and fitted with a submicron membrane (i.e., 0.7 μm) air filter cartridge mounted near the individual's breathing zone.

Materials:

- Personal air sampling pump & air filter cartridge

Procedures:

- Follow manufacturer's instruction for maintenance, calibration, and operation of the personal air sampling pump.

- When the individual is prepared to enter a contaminated area, place a new filter cartridge on the pump. Suspend the filter, open faced, near the individual's breathing zone (retain the cover of the filter cartridge for reuse after sampling).
- Turn on the pump, recording the initial flow rate and time activated.
- When the individual exits the area, record the sampler flow rate and turn off the sampler. Record the total sampling time, average flow rate over the sampling period, and, if provided, the integrated sample volumes.
- Remove the filter cartridge from the sampler with caution to avoid external contamination of the cartridge and filter. Replace the top cover of the cartridge to protect the filter media.
- Prepare a field blank sample. The blank sample should accompany the actual sample during all phases of the sampling except actual collection.
- Place the cartridge in a small envelope or box. The outer envelope should be marked with name, SSN, collection start and stop times and dates, average flow rate, and calculated or measured integrated sample volume. Include a brief history or reason for sampling, the submitting base, the base sample number, and all other identifying information. Submit a completed DOEHRS generated sample submission form with the sample.

5.9 Soil Samples

Soil sampling procedures depend on the purpose of the sampling program. In all cases, careful selection of control (background) samples associated with the sampling site is required to allow interpretation of results.

Equipment. The selection of proper sampling equipment (Table 39) is important to ensure that samples are collected effectively and efficiently. Sampling equipment generally consists of a tool to collect the sample and a container to hold the collected sample. Sampling tools are selected based on the type of soil, sample depth, number of samples required, and training of available personnel. The selection of a sampling tool may also be based on the expected use of the results.

For example, if a soil sample is collected to verify the depth profile used to develop the calibration for *in-situ* gamma spectrometry, it is important to preserve the soil core. Table 39 lists several examples of tools used for collecting soil samples, situations where they are applicable, and some advantages and disadvantages involved in their use.

Containers. Sampling containers are generally not a major concern for collecting surface soil samples as long as they contain the sample. Large zip-lock bags are recommended. These containers are fairly economical; provide easy access for adding and removing samples; and resist chemicals, breakage, and temperature extremes. Glass containers are also acceptable, but they are fragile and could break during shipment. The following are common sample containers:

- Soil jars, 1-gallon, screw cap, Cs, 8125-01-227-6038
- Bag, plastic, interlocking seal, 12x12, 8105-00-837-7757
- Bag, plastic, interlocking seal, 8x8, 8105-00-837-7755

Sample Size. Sample size should be consistent with the requirements of the analytical method. The following minimum quantities are necessary for analysis:

- Gamma spectrometry plus gross alpha and/or gross beta: 2 kg of soil (approximately 1-ft^2 area 3 inches deep)

- Gross alpha and/or gross beta: 100 grams

Table 39: Radiological Soil Sampling Tools and Typical Uses

Equipment	Application	Advantages/Disadvantages
Tier	Soft surface soil	Inexpensive; easy to use and decontaminate; difficult to use in stone or dry soil
Scoop or trowel	Soft surface soil	Inexpensive; easy to use and decontaminate; trowels with painted surfaces should be avoided
Bulb planter	Soft soil, 0-15 cm (0-6 in.)	Easy to use and decontaminate: uniform diameter and sample volume; preserves soil core; limited depth capability; can be difficult to decontaminate
Soil coring device	Soft soil, 0-60 cm (0-24 in.)	Relatively easy to use; preserves soil core; limited depth capability; can be difficult to decontaminate
Thin-wall tube sampler	Soft soil, 0-3 m (0-10 ft)	Easy to use; preserves soil core; easy to decontaminate; can be difficult to remove cores
Split spoon sampler	Soil, to bedrock	Excellent depth range; preserves soil core; useful for hard soils; often used in conjunction with drill rig for obtaining deep cores
Shelby tube sampler	Soft soil, to bedrock	Excellent depth range; preserves soil core; tube may be used for shipping core to lab; may be used in conjunction with drill rig for obtaining deep cores
Bucket auger	Soft soil, 7.5 cm - 3 m (3 in. - 10 ft)	Easy to use; good depth range; uniform diameter and sample volume; may disrupt and mix soil horizons greater than 15 cm
Hand-operated power auger	Soil, 15 cm - 4.5 m (6 in. -15 ft)	Good depth range; generally used in conjunction with bucket auger; destroys soil core; requires two or more operators; can be difficult to decontaminate

Purpose of Soil Sampling. It is important to understand the purpose of a soil sample in selecting the appropriate sampling method. The two most common reasons for collecting soil samples are to measure surface deposition or to measure total activity in soil.

Surface Deposition. Surface deposition is of primary interest in response scenarios. Surface deposition is often used to estimate airborne concentrations, external dose rates, and the total activity released and validate predictive models (i.e., Hazards Assessments and Prediction Center models). Surface deposition is the total amount of radioactive material deposited over a fixed surface area.

When collecting these types of samples, the depth of soil collected is not important. Samples should not be deeper than the first few centimeters of soil depth. All surface materials should be included in the sample. This includes vegetation, rocks, or other debris that could have material deposited on them. It is important, though, to pick a flat area that is as free of debris as possible. Additionally, it is important to pick an area that is representative. The sample should be collected in an area away from buildings or other obstructions that could significantly alter wind patterns.

Total Soil Activity. Measurement of total soil activity is usually of concern during environmental remediation and assessment operations. The activity per unit mass of soil is used to estimate the level of contamination at a location. The level of contamination can then be used to estimate potential doses. These types of samples are usually conducted after periods long enough past deposition that all of the radiological material has been incorporated into the soil matrix. The material is no longer concentrated primarily on the surface. For this reason, it is important to not add extra mass to the sample that is likely not contaminated. When performing such sampling, it is typical to discard any surface debris when sampling or to collect it and analyze it separately.

5.9.1 Surface Deposition Soil Sampling Using the Trench Method

To collect a representative soil sample, choose soil that is relatively dry, except for sediment, and is in a flat, open area. Do not sample under trees, bushes, or other overhanging objects. Avoid windrows or areas next to roads. If the area to be sampled is covered with vegetation, leaves, etc., treat that portion as a separate vegetation sample.

Each group of soil samples should include a field blank sample that is collected exactly as the other samples. Field blanks should be collected in an area that is known to be free of contamination but otherwise has similar conditions (e.g., same type of soil, vegetation, etc.).

Materials:

- Quartz/gallon size sealable bags
- Hammer, if soil is compacted
- Sampling frame, 10 x 10 cm
- Work gloves
- Flat trowel
- Tape measure
- Disposable gloves

Procedures:

- To avoid contamination, place plastic bags on the ground; lay the clipboard, instruments, and tools on the bags.
- On the sample form, record the GPS reading, location, time, date, and other descriptive information.
- Put on work gloves over disposable gloves.
- Survey the site using an appropriate survey meter, taking readings approximately 1 meter (3 feet) (if appropriate) and at 2.5 cm (1 inch) above ground. Record the readings.
- Use an indelible ink pen to record the sample number on the sample container.
- Be careful not to disturb the sample collection area while digging the trench.
- Using a trowel, dig a trench 45 cm long x 15 cm wide x 15 cm deep (18 x 6 x 6 in.). Fashion a vertical surface that is as straight as possible (Figure 23 below).

- Place the open end of the sampling frame against the edge of the trench from a 10-cm x 10-cm (4 x 4-in.) square sample area. Press or tap (if hard) the cutter edge into the soil to stops (2 cm deep).
- Slide the flat trowel under the sampling frame, pick up the sample, and slowly dump it into a sealable bag. Check that the sample number is on the container.
- If a sampling frame is not available, measure a 10-cm x 10-cm area. Using any digging tool, collect the soil to a depth of 2 cm as evenly as possible. If additional volume is needed, collect adjacent 10-cm x 10-cm areas until sufficient volume is obtained.
- Any debris, vegetation, rocks, or other non-soil material should be removed by hand from the sample. For surface deposition, the debris should be submitted as a separate sample for analysis.
- Record the depth taken and surface area on the sample form.
- Clean the sampling equipment with water.

5.9.2 Total Activity Soil Sampling Using the Trench Method

To collect a representative soil sample, choose soil that is relatively dry, except for sediment, and is in a flat, open area. Do not sample under trees, bushes, or other overhanging objects. Avoid windrows or areas next to roads. If the area to be sampled is covered with vegetation, leaves, etc., treat that portion as a separate vegetation sample.

Materials:

- Gallon size sealable bags
- Hammer, if soil is compacted
- Sampling frame, 10 cm x 10 cm
- Work gloves
- Flat trowel
- Tape measure
- Disposable gloves

Procedures:

- To avoid contamination, place plastic bags on the ground; lay the clipboard, instruments, and tools on the bags.
- On the sample form, record the GPS reading, location, time, date, and other descriptive information.
- Put on work gloves over disposable gloves.
- Survey the site using an appropriate survey meter, taking readings approximately 1 meter (3 feet) (if appropriate) and at 2.5 cm (1 inch) above the ground. Record the readings.
- Use an indelible ink pen to record the sample number on the sample container.
- Be careful not to disturb the sample collection area while digging the trench,
- Using a trowel, dig a trench 45 cm long x 15 cm wide x 15 cm deep (18 x 6 x 6 in.). Fashion a vertical surface that is as straight as possible (Figure 23 below).
- Using a small trowel or other digging implement, collect the soil to a depth of 6 inches. Alternate depths may be used if needed. The depth of samples may be specified in survey plans.
- Slide the flat trowel under the sampling frame, pick up the sample, and slowly dump it into a sealable bag. Check that the sample number is on the container.

- Any debris, vegetation, rocks, or other non-soil material should be removed by hand from the sample. For total activity, the debris may be discarded or submitted as a separate sample for analysis.
- Record the depth taken and surface area on the sample form.
- Clean the sampling equipment with water.

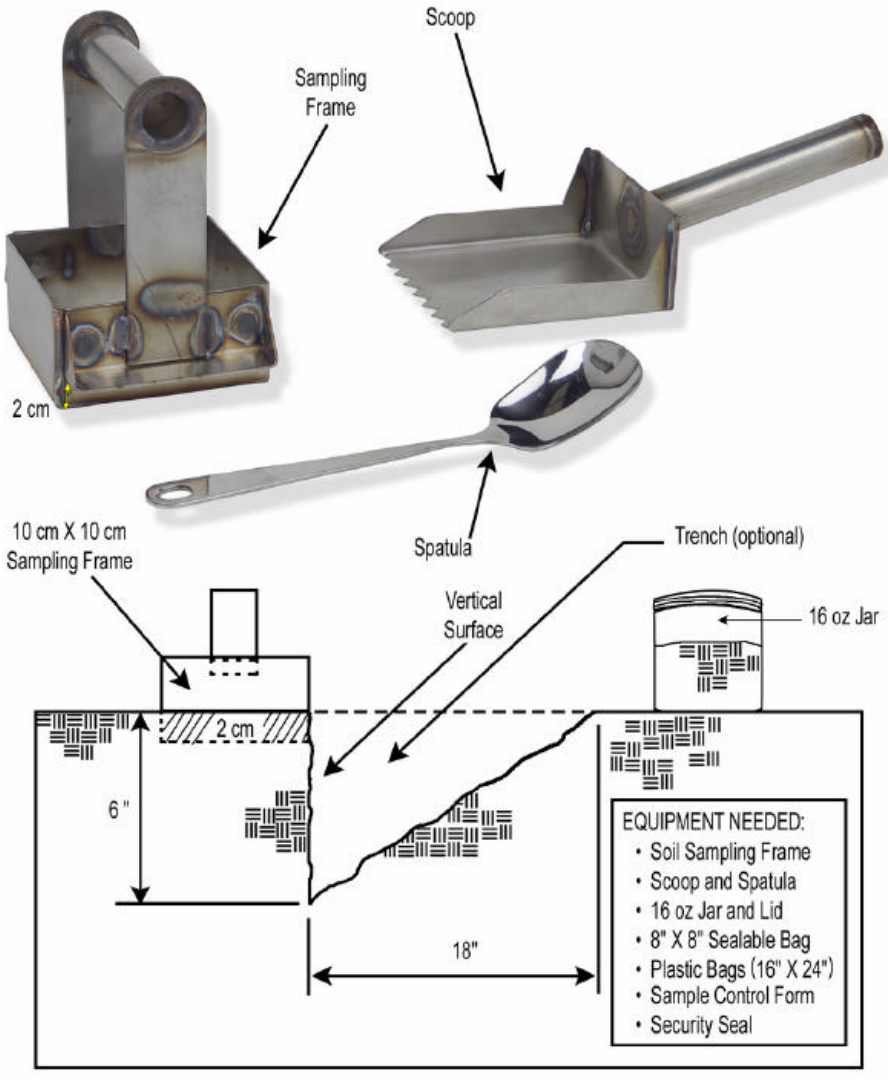


Figure 23: Soil Sampling Frame for Radiological Samples

5.9.3 Surface Deposition Core Sampling

The procedure described here is designed to obtain samples that will measure the total amount of an initially airborne contaminant that has fallen out in a given area. The core method is typically faster in soft soils, although it is often not as accurate as the trench method. Contact the ESOH Service Center for sampling instructions.

5.9.4 Incremental Core Sampling

A depth profile is only useful for finding the relative vertical distribution of the radionuclide. Since only 100-300 cm^2 of surface area at one spot is sampled when taking depth increments, the integrated deposit is not necessarily representative of the area. The trench method is more time consuming and more difficult than taking core samples. Therefore, researchers rarely sample and composite more than two samples per trench and rarely take duplicate profiles. However, if care is taken, there will be very little cross-contamination and the data collected in terms of the depth profile will be more accurate. Contact the ESOH Service Center for sampling instructions.

5.10 Surface Water Sampling

Surface water refers to streams, rivers, lakes, ponds, etc. The term does not necessarily imply that the sample is collected from a shallow depth. Sampling locations will depend upon the objectives of the sampling program. For example, the objective may simply be to meet the requirements of regulatory agencies. Nevertheless, the purpose of water sampling is generally:

- ✓ To characterize the water quality. Samples may be taken in the mainstream of rivers, lakes, etc.
- ✓ To estimate the exposures to the public. In this case, the sampling sites will be at the point of exposure, i.e., recreational areas, public water supply intake, etc.
- ✓ To perform a long-term trend analysis. The sample may then be taken at locations where long-term historical information is available.

5.10.1 Rivers, Streams, Creeks

In general, samples are required at points where the contaminant is well mixed and has the greatest cross-section homogeneity. It is impossible to get representative samples near an out-fall (i.e., the release point). Indeed, mixing of the contaminant may not occur for substantial distances downstream. This is especially true for large, slow-moving rivers.

The best locations to sample are downstream of turbulence. The higher the water velocity, the greater the turbulence will be. Therefore, sampling should be downstream of falls, whitewater, or riffles where possible. Influxes of water into the stream/river being sampled can introduce heterogeneity into the cross-sectional concentrations. As such, sampling should not be performed near the confluence with tributaries or point sources such as out-falls of industrial and municipal effluents.

Background samples are typically taken upstream of the facility discharge. Care must be exercised when this is done in rivers near the coast. Samples should be taken far enough upstream to avoid tidal influences. Sampling in or near estuarine waters can be extremely difficult because the differences in temperature and density between fresh and salt water can result in substantial stratification.

Where the stream is relatively narrow, i.e., less than 20 feet across, and the water well mixed, one sampling point should suffice: at mid-depth in the center of the stream. If the sample must be collected from the bank rather than midstream, it is best to collect the sample from the bank on the outside of a bend where the flow is greatest.

For larger and less well mixed rivers, composite areal (as opposed to temporal) will be required. This will involve at least one sample collected just below the surface, a sample from mid-depth, and a sample collected just above the bottom.

It is often recommended that three to five vertical composites be collected for a sample at a given position along a stream or river. Sometimes it is specified that these points be equidistant across the river. This may be fine in many cases, but the sampling points should reflect the river's volumetric flow.

5.10.2 Lakes and Ponds

These bodies of water experience less mixing and have a greater tendency to stratify than streams and rivers. As a result, a larger number of samples will be required. In a small impoundment or pond, a single vertical composite at the deepest point may be satisfactory. In a natural pond, this will usually be near the center. For a manmade body of water, the deepest point would be near the dam rather than the center. With lakes and large impoundments, several vertical composites will be required. They might be taken on a single or multiple transect or on a grid.

5.10.3 Surface Water Sampling Procedures

Sampling will usually be done from a boat, but it is sometimes possible to sample from the shore (or a bridge). Wading is to be avoided where possible. The only time wading is acceptable is in shallow, swiftly moving streams. In such a case, the samplers should make every effort to avoid disturbing the sediments. They should also move upstream after entering the water and before sampling.

Dipping. The sample container itself can be simply submerged in the water. The container opening should be pointing upstream and the whole process should be done carefully while disturbing the water as little as possible. Note, the container should be submerged; it should not be possible to collect surface debris. Obviously, this cannot be done in very shallow bodies of water.

Subsurface Samplers. Subsurface grab samplers are available that use a technique very similar to that just described. In these devices, a sealed bottle attached to a pole is lowered in the water to the appropriate depth. A control rod attached to the bottle cap is used to open the bottle and, after the bottle is filled, seal it.

Sample Containers. Collect a minimum of 2 liters, with the entire sample provided in one container. Use a plastic container, if at all possible. Suggested types include:

- ✓ Bottle, screw cap, collapsible, square, 1-gallon capacity, 12/pkg, FSN 6640-00-117-7855
- ✓ Bottle, screw cap, collapsible, square, 1-quart capacity, 12/pkg, FSN 6640-00-117-8042

Sample site selection:

- Choose an area that is open, not sheltered by trees or high brush, if possible.
- Consider the purpose of sampling when selecting a location, i.e., intake for drinking water, areas of access for farm animals.
- Avoid areas where surface debris could inhibit sampling.
- Avoid areas of high turbidity or high sediment, if possible.
- Inlet/outlet areas of water treatment plants may both need to be sampled. Samples from still water areas may also be required.
- Take sample from midstream, if possible.
- When a lake or reservoir is sampled, the sample should represent water that makes up the largest portion of the reservoir. Operating from bridges, docks, or boats may facilitate open-water collections.
- Avoid stirring up sediment and including it in the sample. Sample upstream if it is necessary to wade into the water. Sampling buckets should not be allowed to sink to the bottom.

Procedures:

- On the sample form, record the GPS reading, location, time, date, and other descriptive information.
- Use an indelible ink pen to record the sample number on the collection container.
- If the funnel and bucket have been previously used, they should be as clean as reasonably achievable.
- Set the sample container in a stable location on the ground with the funnel inserted in the opening.
- Stand downstream of bridges or structures.
- Lower the bucket into the main channel of stream, disturbing sediments and aquatic vegetation as little as possible.
- Collect a 3.5-liter (1-gallon) bucket of water and pour it into the sample container until the water in the container is within 2 cm (1 inch) of the top.
- Rinse the funnel and bucket with clean water.
- Dry the container with an absorbent towel.

5.11 Potable Water

When collecting from wells, the well casing or well bore must be purged of 3-5 volumes of standing water. As a rule, this may take 30 minutes. At a minimum, the nearest domestically used well down gradient from the discharge or contaminant source of interest should be sampled.

Materials:

- Bottle, screw cap, collapsible, square, 1-gallon capacity, 12/pkg, FSN 6640-00-117-7855

Procedures:

- When collecting water from a tap, the tap should be directly connected to a main water line and should not be connected to a water storage tank.
- Remove aerator and strainers prior to sampling.
- Allow the cold water tap to run at least 2-3 minutes prior to sampling.
- Collect a minimum of 4 liters, with the entire sample provided in one container. Use a plastic container, if at all possible.
- To avoid cross-contamination, be sure to clean all sampling equipment with distilled water prior to acquiring additional samples.

- Preservative must be added to the sample no later than 5 days after the collection to ensure that the sample has pH 2 or less. To ensure that this requirement is accomplished, it is recommend that the sample be shipped next day air. Additionally, that lab should be notified that the sample is coming. If this is not possible, add 5 mL of concentrated nitric acid per liter of sample. This applies to all samples, except radon-222 and H-3, in water that are collected in plastic or glass and sent to the laboratory.

The USAFSAM laboratories do not maintain accreditation for safe drinking water analysis. Each state has its own accreditation requirements for SDWA. If you need to perform SDWA for radiological materials, then you should identify a local laboratory that is accredited in your state to perform the analysis. If you require assistance with sample procedures or identifying an accredited lab, contact Customer Service.

5.12 Vegetation and Foodstuffs

Although vegetation is not routinely obtained for analyses, collection of such samples should be made when the potential for food chain contamination exists. Vegetation growing on contaminated soil should be sampled and analyzed. Several kilograms of vegetation may be needed depending on the analytical sensitivities for the radionuclides of interest. The minimum sample volume is 3 liters of densely packed sample and should be double plastic bagged or packed in a 1-gallon wide-mouth plastic jar with screw cap. In the event foodstuffs require collection, contact Customer Service for proper procedures.

5.13 Air Sampling

Filters and Flow Rates. The most frequently employed filter in environmental air sampling is the glass fiber filter. It is popular because it can maintain a low-pressure drop even at the high flow rates and large dust loadings associated with environmental air sampling. The lower the pressure drop, the lower the workload on the air mover and, as a rule, the more accurate the flow meter reading. Cellulose (or paper) filters may also be used but are often less desirable.

- It is generally desirable to maintain a velocity across the face of the filter on the order of 20-50 meters per minute (keep in mind when calculating the face velocity that the effective sampling area is less than the overall size of the filter). Maintaining such velocities is especially important with cellulose filters, since a substantial decrease in collection efficiency can occur at low velocities. High velocities are inappropriate with membrane filters due to the associated high-pressure drop.
- If the flow rate decreases by more than 20% over the sampling period, it will be necessary to change the type of filter being used, reduce the flow rate, change the filter more frequently, or switch to a pump with a constant flow regulator.

Sampling Times. Refer to Appendix C, Section C12 for calculation example. It is important that the times and dates for the beginning and end of each sampling period be as close as possible for all the sampling locations (including background). *It is critical that the sample time and flow rate or total sample volume be included on the sample form for all air samples.*

Sampling Duration. The minimum required sample time will be dependent upon the minimum detectable activity of the analysis method, the action level for the sample, and the flow rate. For

unknown samples and during emergency response scenarios, a collection time of 1 hour is recommended but a minimum time of 20 minutes is typically required for most analysis methods. As a rule of thumb, a collection time of 20-60 minutes can be used with the Radeco if the nuclide is unknown.

Sample Collection. During collection, the sample should be disturbed as little as possible. This can be difficult if there is a strong wind, rain, snow, or below freezing temperatures. It is recommended that quick disconnect couplings be used with the filter holder/sampling head. If this is done, the entire sampling head (with the used filter and/or cartridge) can be transferred into a sealed plastic bag without the need to remove the filter in the field. A fresh sampling head is used to replace the old one.

Materials:

- AC generator (optional)
- Low-volume air sampler
- Sampling tripod
- Sealable plastic bags
- Extension cord
- Forceps
- Sampling head
- Fuel
- Cellulose filters
- Cartridge
- Gloves

Procedures:

- Position the generator far enough away from the sampler and downwind so that exhaust fumes are not picked up by the sampler.
- Position the assembled sampling apparatus with air intake facing the source of the suspected airborne radioactive material release. Wind is a factor. Wind direction determines where you might set up your air samplers, but you still want the apparatus pointed toward the source.
- The face of the sampler should be at breathing zone height, approximately 1.5 meters (5 feet).
- To avoid effects of structurally induced turbulence, whenever possible the horizontal distance between the sampler and any structure should be equal to twice the height of the obstruction.
- Place a small "x" IN PENCIL ONLY on the outer edge of the "exposed" side of the filter paper. Carefully place the filter onto the sample head or sampling unit. Discard any damaged filter media (perforations, tears, folds, etc.).
- Avoid excessive tightening of the sample heads to prevent possible damage to the gasket. Turn the unit on and wait approximately 5 minutes before recording the initial flow rate. Determine the initial flow rate on the rotameter and record the flow rate and start time on the sample form.
- Run the sampler for the collection period.
- Prior to turning the sampler off, determine the ending flow rate.
- Turn off the sampler and record the ending flow rate and the time off on the sample form.
- Put on gloves.
- In a clean area if possible, using forceps remove the particulate filter carefully and place in a sealable plastic bag. Seal the bag. Decontaminate the forceps with clean water and dry. DO NOT FOLD FILTERS.

- Insert the sample filter ***unfolded*** into a plastic bag and then into an outer envelope for shipment. The outer envelope should be marked with the submitting base, the base sample number, and all other identifying information.
- Record any sign of damage to the filters, i.e., color or texture and any sign of a deteriorating gasket indicated by blurring of the margins of the filter.
- Ensure the DOERHS Radiation Sample Submission Form accompanies the sample and includes the start and stop date and time, total sampling time, and volume of air sampled in cubic meters, corrected for standard conditions.

5.14 Other Materials

The Radioanalytical Lab performs radionuclide analysis on other types of samples such as industrial materials, biota, and/or chemicals. Specific instructions may be obtained by contacting Customer Service.

5.15 Special Considerations for Radiological Sample Shipping and Handling

5.15.1 Preservation

The specified analysis and the chemical characteristics of the radionuclide to be analyzed, as well as the objectives of the survey, determine sample preservation considerations. The purpose of preserving a sample is to maintain the sample in the condition needed for analysis between the time the sample is collected and the time that the sample is analyzed. Sample preservation should be coordinated with the analytical laboratory.

Many of the radiochemical species of interest behave like trace metals, and the preservation of water samples is easily achieved by acidification [35,36]. This prevents metallic species from depositing on the walls of the container. **It is the USAFSAM laboratory's policy that samples should not be preserved in this manner before shipment.** Any liquid samples should be shipped expeditiously to the lab for analysis. The sample will be preserved upon receipt. If shipment will take longer than 5 days to reach the lab, the sample should be preserved. Contact Customer Service for guidance.

The ***exceptions*** to this rule include:

- ✓ Samples for H-3 and C-14 analysis should never be preserved.
- ✓ Samples for analysis of isotopes with volatile oxidized forms (e.g., ^{129}I, ^{131}I) should not be preserved with oxidizing acids. Add either sodium bisulfite or sodium metabisulfite as a holding reductant for iodine to the preserved sample. Then add acid to a pH of 1 or less. Again, it is recommended that such samples be preserved upon receipt at the lab.
- ✓ For samples that may have organic compounds that could react with the acid, other methods of preservation should be evaluated.

5.15.2 Holding Time

Shipment to the lab should be expedited to minimize decay and/or surface plating before analysis. The lab should be consulted for any liquid sample that will require greater than 5 days to ship to the lab.

5.15.3 Temperature Control

None of the current methods used in the lab require temperature control. For urine samples, standard refrigeration should be used to control odors and bacteriological growth. Fecal samples should be frozen to control odor.

5.15.4 Packaging and Transporting Samples

All samples sent for analysis should be properly packaged before shipment. Visually inspect each sample container for indications of leaks or defects in the sample container.

- If needed, wipe individual sample containers with a damp cloth or absorbent paper to remove any exterior contamination.
- Place liquid sample containers inside individual plastic bags to reduce the chance for cross-contamination and to contain the sample in case of leakage or breakage. Also include sufficient absorbent material to contain the liquid samples in case of leakage or breakage.
- Package sample containers to prevent breakage by immobilizing and isolating each sample container using packing material; this is especially important in cold weather, when plastic containers become brittle and water samples may freeze.
- Include the original, signed chain-of-custody form listing the samples in each package, i.e., if possible, avoid having multiple packages covered by a single chain-of-custody form.

SECTION 6. REFERENCES

1. U.S. Air Force. Personnel ionizing radiation dosimetry. Washington, DC: Department of the Air Force; 2016 Feb 22. Air Force Manual 48-125.
2. International Air Transport Association. Dangerous goods regulations, 55th ed. Montreal: IATA; 2014.
3. National Archives and Records Administration. Hazardous materials table, special provisions, hazardous materials communications, emergency response information, training requirements, and security plans. Washington, DC: NARA; 2013. 49 CFR 172.
4. National Archives and Records Administration. Shippers—general requirements for shipments and packagings. Washington, DC: NARA; 2013. 49 CFR 173.
5. National Archives and Records Administration. Carriage by rail. Washington, DC: NARA; 2013. 49 CFR 174.
6. National Archives and Records Administration. Carriage by aircraft. Washington, DC: NARA; 2013. 49 CFR 175.
7. National Archives and Records Administration. Carriage by vessel. Washington, DC: NARA; 2013.49 CFR 176.
8. National Archives and Records Administration. Carriage by public highway. Washington, DC: NARA; 2013.49 CFR 177.
9. TRI-COR Industries, Inc. Technical manual: quality control of aviator's breathing oxygen. Wright-Patterson AFB, OH: Air Force Petroleum Agency; 2012 Mar 6. Technical Order 42B6-1-1.
10. Occupational Safety & Health Administration. Personal sampling for air contaminants. In: OSHA technical manual (OTM). Section II: Chapter 1. Washington, DC: OSHA; 2014. Directive No. TED 01-00-015 [TED 1-0.15A].
11. Leidel NA, Busch KA, Lynch JR. Occupational exposure sampling strategy manual. Cincinnati: National Institute for Occupational Safety and Health; 1977 Jan. DHEW (NIOSH) Publication No. 77-173.
12. U.S. Air Force. Occupational and environmental health program. Washington, DC: Department of the Air Force; 2014 Jul 22. Air Force Instruction 48-145.
13. Keil CB, Simmons CE, Anthony TR, eds. Mathematical models for estimating occupational exposure to chemicals, 2nd ed. Fairfax, VA: AIHA Press; 2000.
14. Anna DH, ed. The occupational environment: its evaluation, control, and management, 2nd ed. Falls Church, VA: American Industrial Hygiene Association; 2011.
15. National Institute for Occupational Safety and Health. NIOSH manual of analytical methods (NMAM®), 4th ed. Atlanta, GA: NIOSH; 2003:25,26;A-3,5,7. DHHS (NIOSH) Publication 2003-154.
16. National Institute for Occupational Safety and Health. NIOSH pocket guide to chemical hazards. Atlanta, GA: NIOSH; 2005. DHHS (NIOSH) Publication No. 2005-149. Retrieved 7 November 2011 from http://www.cdc.gov/niosh/npg/.
17. Occupational Safety & Health Administration. Toxic and hazardous substances, TABLE Z-3. Washington, DC: OSHA; 1997. 29 CFR 1910.1000. Retrieved 10 April 2013 from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9994.
18. National Archives and Records Administration. Subpart E – Asbestos-containing materials in schools. In: Code of Federal Regulations. Washington, DC: NARA; 1987. 40 CFR 763.
19. U.S. Air Force. Facility asbestos management. Washington, DC: Department of the Air Force; 2014 Dec 24. Air Force Instruction 32-1052.
20. Batten TW. Base level guide for the occupational exposure to beryllium. Wright-Patterson AFB, OH: U.S. Air Force School of Aerospace Medicine; 2012 Mar. Report No. AFRL-SA-WP-SR-2012-0007.
21. U.S. Air Force School of Aerospace Medicine, Risk Analysis Division. Hexavalent chromium technical guide [Limited access].Wright-Patterson AFB, OH: U.S. Air Force School of Aerospace

Medicine; 2011 Nov. Retrieved 1 February 2014 from https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=625&admin.
22. U.S. Air Force School of Aerospace Medicine, Occupational and Environmental Health Assessment Section. Occupational hygiene: contamination control and housekeeping [Limited access]. Wright-Patterson AFB, OH: U.S. Air Force School of Aerospace Medicine; 2011 Jul. Retrieved 1 February 2014 from https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=494&admin.
23. Hinz JP, Sonntag DM, Clarke BM. Interim base-level guide for exposure to jet fuel and additives. Wright-Patterson AFB, OH: U.S. Air Force School of Aerospace Medicine; 2011 Dec. Report No. AFRL-SA-WP-SR-2012-0002.
24. U.S. Environmental Protection Agency. Guidance for the data quality objectives process: EPA QA/G-4. Washington, DC: EPA; 2000 Aug. Report No. EPA/600/R-96/055.
25. U.S. Environmental Protection Agency. Guidance on choosing a sampling design for environmental data collection: EPA QA/G-5S. Washington, DC: EPA; 2002 Dec. Report No. EPA/240/R-02/005.
26. U.S. Environmental Protection Agency. Guidance for quality assurance project plans: EPA QA/G-5. Washington, DC: EPA; 2002 Dec. Report No. EPA/240/R-02/009.
27. ASTM International. Standard guide for selection of sampling equipment for waste and contaminated media data collection activities. West Conshohocken, PA: ASTM; 2008 Jan. ASTM D6232-08.
28. U.S. Air Force. Drinking water surveillance program. Washington, DC: Department of the Air Force; 2014 Sep 21. Air Force Instruction 48-144.
29. Gooden WJ. Drinking water surveillance technical guide [Limited access]. Wright-Patterson AFB, OH: U.S. Air Force School of Aerospace Medicine; 2015 Aug. Report No. AFRL-SA-WP-SR-2015.
30. U.S. Environmental Protection Agency. Sediment classification methods compendium. Washington, DC: EPA; 1992 Sep. Report No. EPA 823-R-92-006. Retrieved 1 February 2014 from http://water.epa.gov/polwaste/sediments/cs/upload/classmethods.pdf.
31. Puls RW, Barcelona MJ. Low flow (minimal drawdown) ground-water sampling procedures. Retrieved 1 February 2014 from http://www.epa.gov/superfund/remedytech/tsp/download/lwflw2a.pdf. Washington, DC: U.S. Environmental Protection Agency; 1996 Apr. Report No. EPA/540/S-95/504.
32. U.S. Environmental Protection Agency. RCRA waste sampling draft technical guidance: planning, implementation, and assessment. Washington, DC: EPA; 2002 Aug. Report No. EPA530-D-02-002.
33. U.S. Environmental Protection Agency. Data quality assessment: statistical methods for practitioners: EPA QA/G-9S. Washington, DC: EPA; 2006 Feb. Report No. EPA/240/B-06/003.
34. U.S. Air Force. Managing radioactive materials in the US Air Force. Washington, DC: Department of the Air Force; 2014 Sep 17. Air Force Instruction 40-201.
35. U.S. Environmental Protection Agency. Handbook of RCRA ground-water monitoring constituents: chemical and physical properties. Washington, DC: EPA; 1992 Sep. Report No. EPA 530-R-92-022. Retrieved 1 February 2014 from http://nepis.epa.gov/Exe/ZyNET.exe/2000DXQ7.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C91thru94%5CTxt%5C00000004%5C2000DXQ7.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.
36. U.S. Environmental Protection Agency. Preparation of soil sampling protocols: sampling techniques and strategies. Washington, DC: EPA; 1992 Jul. Report No. EPA/600/R-92/128. Retrieved 1 February 2014 from http://www.epa.gov/OUST/cat/mason.pdf.

APPENDIX A: PACIFIC COMMAND (PACAF)

A1. General Information

Theater Preventative Medicine Laboratory (TPML) is a forward-based detachment of USAFSAM located at Kadena AB, Japan. TPML is a member of the 711th Human Performance Wing at Wright-Patterson AFB, OH, servicing PACAF/PACOM operations. The TPML Analytical Division's mission is to perform lab analysis on a variety of media to support environmental and occupational hygiene programs. TPML's Analytical Division services include:

- Industrial Hygiene Analyses
- Environmental Analyses
- Drinking Water Analyses
- Bulk Materials
- Hazardous Waste
- Toxicity Characteristics Leachate Procedure
- Assistance Finding Specialized Analytical Options
- DHL Express Shipping Available Upon Request
- ESAM Budget Advisement
- Analytical Contract Laboratory Capabilities:
  - Japanese Commercial Laboratories
  - Korean Commercial Laboratories
  - U.S. Navy and U.S. Army Laboratories
  - U.S. Stateside Contract Commercial Labs

TPML will accept sample submissions on the DOEHRS sample submission forms or using the TPML sample submission forms included in this guide. If you have any questions on how to complete the form, please call Customer Service. A list of in-house TPML services is included on the following page.

A2. TPML Funding

TPML is funded to cover the cost of in-house and contract analysis of Air Force industrial hygiene, environmental health, and drinking water analyses. In addition, TPML offers a fee-for-service program for non-Air Force Surgeon General funded programs. A surcharge of 100% is added for 24-hour priority requests and 50% surcharge for 72-hour priority requests. In addition, a 10% service charge is added for contract laboratory testing. Contact TPML to obtain current pricing information as well as a list of contract laboratory point of contacts.

Det 3, USAF School of Aerospace Medicine
Analytical Division Unit 5213, Box 10
APO AP 96368-5213

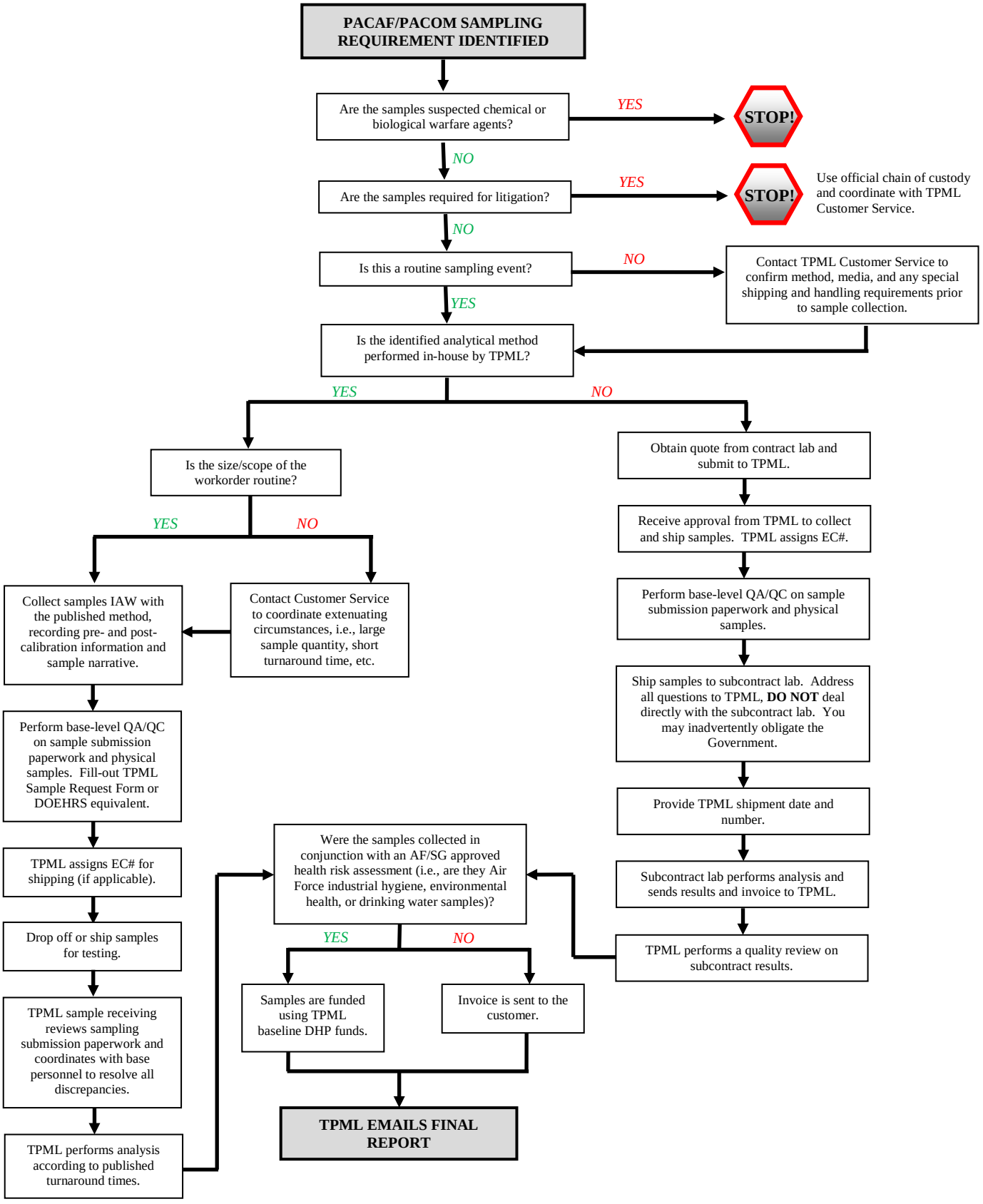
ANALYTE	METHOD	MATRIX
Acidity	EPA 305.1	Water
Alkalinity	EPA 310.1	Water
Ammonia	US-696D-82X	Water
Anion Panel	EPA 300.0	Water
Bromide	EPA 300.0	Water
Chloride	EPA 300.0	Water
Conductivity	EPA 120.1	Water
Chromium VI	EPA 218.6	Water
Chromium VI	EPA 218.6	Salt Water
Chromium VI	NIOSH 7605	Air
COD	EPA 410.4	Water
Color	EPA 110.2	Water
Copper	EPA 200.7	Drinking Water
Flashpoint	SW 1010	Haz Waste Non-solid
Fluoride	EPA 300.0	Water
Hardness	EPA 200.7	Water
Lead	SW846 / 7000A	Paint
Lead	SW846 / 7000A	Swipe
Lead	SW846 / 7000A	Soil
Lead	EPA 200.7	Drinking Water
Langelier Saturation	Modified	Water
Mercury	EPA 245.2	Water
Mercury	EPA 245.2	Bulk
Mercury	EPA 245.2	TCLP

ANALYTE	METHOD	MATRIX
Metals in Water (20 analytes)	EPA 200.7	Water
Non Potable Water Prep	EPA 200.2	Water
Metals in Air (20 analytes)	NIOSH 7300	Air
Metals in Bulk (20 analytes)	EPA 6010B	Bulk
Bulk Prep	SW846	Bulk
Metals in TCLP (7 analytes)	SW 6010/7470	Bulk
TCLP Prep	SW 1311	Bulk
Metals, RCRA (Total) (7 analytes)	EPA 6010B	Bulk
Nitrate	EPA 300.0	Water
Nitrite	EPA 300.0	Water
Nitrate + Nitrite	EPA 300.0	Water
Orthophosphate	EPA 365.3	Water
PCB - Water	EPA 608/8082	Water
PCB - Oil	EPA 600/4-81-045	Oil
PCB - Soil	EPA 8082 (modified)	Soil
PCB - Swipe	EPA 8082 (modified)	Swipe
pH	EPA 150.1	Water
Phosphorous, Total	EPA 365.2	Water
TDS	EPA 160.1	Water
TSS	EPA 160.2	Water
Silica	US-696H-82W	Water
Solids (Total Residue)	EPA 160.2	Water
Sulfate	EPA 300.0	Water
Turbidity	EPA 180.1	Water

TPML, USAF School of Aerospace Medicine
Analytical Division
Unit 5213, Box 10
APO AP 96368-5213
DSN 315-632-8349

REQUEST FOR LABORATORY SERVICES							
Project Information							
Date of Request							
Name Of Requester							
E-mail							
Organization							
Address Line 1							
Address Line 2							
Phone Number							
Fax							
Client Sample Number							
MIPR Number							
Sample Information							
Sample Type							
Installation							
Location/Source							
Collected By							
Date/Time Collected							
Preservatives							
pH / Temperature							
Sample Category							
(Hazardous Waste, Drinking Water, Waste Water, Asbestos, PCB, Lead, Industrial Hygiene, etc.)							
Turn-Around-Time							
Routine (28 Days)							
72 Hours (50% Surcharge)							
24 Hours (100% Surcharge)							
Chain of Custody							
Relinquished By/Time/Date			Relinquished By/Time/Date				
Relinquished By/Time/Date			Relinquished By/Time/Date				
Relinquished By/Time/Date			Relinquished By/Time/Date				
Relinquished By/Time/Date			Relinquished By/Time/Date				
Relinquished By/Time/Date			Relinquished By/Time/Date				
Special Instructions							

Analyses Requested (X all that apply)					
DW Inorganics		**WW Inorganics**		**WW Metals**	
Total Dissolved Solids		Acidity		Aluminum	
Conductivity		Alkalinity		Antimony	
Nitrate		Ammonia as N		Arsenic	
Fluoride		Bromide		Barium	
Chloride		Chloride		Beryllium	
Sulfate		Chromium VI		Boron	
Langelier Index		COD		Cadmium	
Aluminum		Color		Calcium	
Antimony		Conductivity		Chromium	
Arsenic		Fluoride		Cobalt	
Barium		Hardness		Copper	
Beryllium		Nitrate + Nitrite		Iron	
Boron		Nitrite		Lead	
Cadmium		Nitrate as N		Magnesium	
Calcium		ortho-Phosphorus		Manganese	
Chromium		Silica		Mercury	
Copper		Sulfate		Molybdenum	
Iron		Total Dissolved Solids		Nickel	
Lead		Total Phosphorus		Selenium	
Magnesium		Total Suspended Solids		Silver	
Manganese		Turbidity		Sodium	
Mercury		**Bulk & HW**		Strontium	
Nickel		Flash Point		Thallium	
Selenium		pH		Vanadium	
Silver		Lead (Bulk)		Zinc	
Sodium		TCLP-Metals			
Thallium		**Other Analyses/Special Instructions:**			
Zinc					
Organics					
PCB (Bulk)					
PCB (Oil)					
BTX					



APPENDIX B: AIR FORCE CENTRAL COMMAND (AFCENT)

B1. General Information

Sampling support for the bases in the area of responsibility is primarily provided by the U.S. Army Public Health Command- Europe (USAPHC, formerly CHPPM-EUR). AFCENT BE personnel should refer to the *USAFCENT Deployed Bioenvironmental Engineering (BE) Guide*. It is best to sample on Sunday or Monday and ship immediately so that it is received before the weekend. This reduces the likelihood of exceeding holding times and storage temperatures. USAPHC-Europe recommends you first contact FedEx, DHL Worldwide, and UPS to determine which carrier serves your particular location.

B2. USAPHC-Europe Procedures

Consult the USAPHC-Europe DLS Customer Guide to determine media and container selection, holding times, and sample preparation issues. If emailing your questions or concerns, please use the DLS Customer Hotline email [usachppmeur.dlshotline@amedd.army.mil]. This hotline is available to all DLS staff members and is checked several times during the day.

A Request for Services form ***must*** be completed ***prior*** to sending samples to USAPHC-Europe. For the most current copy of USAPHC-Europe forms, refer to the DLS Customer Guide. Fax forms to the Customer Service Division (CSD) at DSN 314-486-7054. This same process can be used to order sample kits. CSD can provide sampling containers with the exception of IH media. Always provide your civilian mailing address and phone number if possible, as they try to send all sampling kits and reports via commercial couriers (this cost is covered by the memorandum of agreement AFCENT has with USAPHC-Europe).

Wait for the division chief (either Organic or Inorganic) to accept (or reject) your request via email. If there is a scheduling problem, they will work with you and may change your collection and submission date. CSD will notify you when the request is accepted. If your request for services is accepted, complete CSD Form 2 or 3 to send with your sample. If USAPHC-Europe is unable to conduct the requested analyses, contact the AFFOR BE to find another lab to conduct the analysis or a sampling method that USAPHC-Europe will support.

Package and ship your sample via contract carrier. Include the CSD Form 2 or 3 with your sample.

To assist the TMO Office or U.S. Army Combat Cargo Officer in verifying shipments to USAPHC-Europe DLS (U.S. Forces owned), please insert the Department of Defense Address Activity Code (DODAAC) in the commercial address as follows:

USAPHC-Europe (Department of Laboratory Sciences)
DODAAC – WK4UPX
Kirchberg Kaserne Gebaude 3809, Raum 110
D-66849 Landstuhl, Germany
Phone (Civilian): 06371-86-7052

Email the carrier tracking number (or air bill information) to the DLC Customer Hotline email so they can track the sample. Please provide the airway bill number for DHL and FedEx and the TCN and Mission number for AMC shipments so they can track them. Historically, TNT and UPS have not met their contractual requirements regarding shipping times and handling and should be used with caution.

USAFSAM may also be able to provide sample analysis support in the event USAPHC-Europe is unable to meet your analytical needs. Contact the AFCENT BE to formally request use of USAFSAM services.

Notify the AFCENT BE or AFFOR BEM immediately of any exposures that exceed an occupational and environmental action level or exposure standard.

APPENDIX C: INDUSTRIAL HYGIENE EQUATIONS

C1. Flow Rate Reporting

The difference between the pre- and post-calibration flow rates should be equal to or less than 5%. If the difference is greater than 5%, check your pump battery has a valid charge. If the battery is charged and the value is still >5% (0.05), the pump may need to be serviced. If the difference between the flow rates is greater than 5%, the sampling event should be re-accomplished.

DOEHRS uses the lower flow rate (either pre-use or post-use flow) to calculate and report air sample volumes. By using the lower flow rate, the concentration of the analyte(s) reported by the laboratory will conservatively overestimate the airborne concentration in the sampling environment. DOEHRS uses the equation below to determine the flow rate difference; any difference greater than 5% will automatically be flagged in the pre/post calibration screen in DOEHRS.

Flow Rate Difference

$$\frac{(\boldsymbol{pre - calibration\ flow\ rate}) - (\boldsymbol{post - calibration\ flow\ rate})}{\boldsymbol{pre - calibration\ flow\ rate}} \times \mathbf{100} \quad (1)$$

Example:
You have just completed air sampling and finished your post-use flow check. The pre-use calibration flow was recorded as 3.05 L/min and the post-use flow check was recorded as 2.89 L/min. Determine the flow rate difference for your sampling event.

$$\frac{(3.05\ \text{L/min}) - (2.89\ \text{L/min})}{3.05\ \text{L/min}} \times 100 = 5.25\% > 5\%$$

In this example, since the flow rate difference is >5% the sampling event should be re-accomplished.

C2. Determining Sample Flow Rate and Volume

C2.1 Sample Volumes When Concentrations Are at or Near the OEEL

When the sample concentration is estimated to be at or near the OEEL, the flow rate and sample volume can be obtained from the analytical method. When these parameters are used under normal sampling conditions:

- The test result should be accurate for the sample being collected.
- The detection limit for the analytical measurement system (the instrumentation and the method used for testing) can be met.
- The possibility of sample breakthrough is minimized.

With a known flow rate and sample volume, the air sampling time can be calculated using the following equation:

Sample Collection Time

$$\textbf{Air Sampling Time } (min) = \frac{\textbf{Volume } (L)}{\textbf{Flow Rate } (L/min)} \quad (2)$$

C2.2 Deviations from Recommended Volume and Flow Rate

Sampling situations may arise where departures from the recommended sample flow rates and air collection volumes are necessary. When such departures are required, they should be done only when based on an approved sampling plan. Departures from recommended guidance may be necessary if:

- *High Concentration.* The concentration of the analyte in question is expected to be high. An air collection volume at or near the lower limit of the recommended range should be used in this situation.
- *Dusty Environment.* Filter sampling in dusty areas is required. A lower than recommended total air collection volume should be used when sampling in this environment.
- *Low Level Detection.* The concentration of the analyte in question is expected to be much lower than the OEEL. An air collection volume at or near the upper limit of the recommended range should be used. For low level detection, the minimum air collection volume to obtain an adequate concentration of the desired analyte can be calculated using the reporting limit (RL) and the following formula:

Minimum Air Volume

$$\textbf{Minium Air Volume } = \frac{\textbf{RL}}{(\textbf{OEEL}) \times (\textbf{Desired Fraction})} \quad (3)$$

Example:
You wish to confirm welders in the NDI shop are not exposed to beryllium above 10% of the AF AL (0.0002 mg/m^3) during welding operations. The laboratory RL for beryllium is 0.05 µg and you intend to sample at 3 L/min. Determine the minimum sample volume and collection time.
Note: *Pay particular attention to your units.*

$$\text{Minium Air Collection Volume (L)} = \frac{(0.005\ \mu g) \times \left(\frac{1\ mg}{1000\ \mu g}\right) \times \left(\frac{1000\ L}{1\ m^3}\right)}{\left(0.0002 \frac{mg}{m^3}\right) \times \left(\frac{1}{10}\right)} = 250\ L$$

$$\text{Minium Air Sampling Time (min)} = \frac{250\ L}{3\ \frac{L}{min}} = 84\ min$$

C3. Blank Corrections

If contaminant is detected greater than the RL on media blanks, the field sample results should be blank corrected. Remember only consider media blanks -- ***NOT*** field blanks. There are three scenarios to consider:

- All media blanks have reported levels above the RL. Average the reported contaminant mass for all the media blanks. This average will be subtracted from each field sample reported contaminant mass prior to calculating sample results and TWAs.
- None of the media blanks reported levels above the RL. No corrections should be made.
- Some of the media blanks have reported levels above the RL. Average the reported contaminant mass for only those media blanks that reported levels above the RL and correct your field samples.

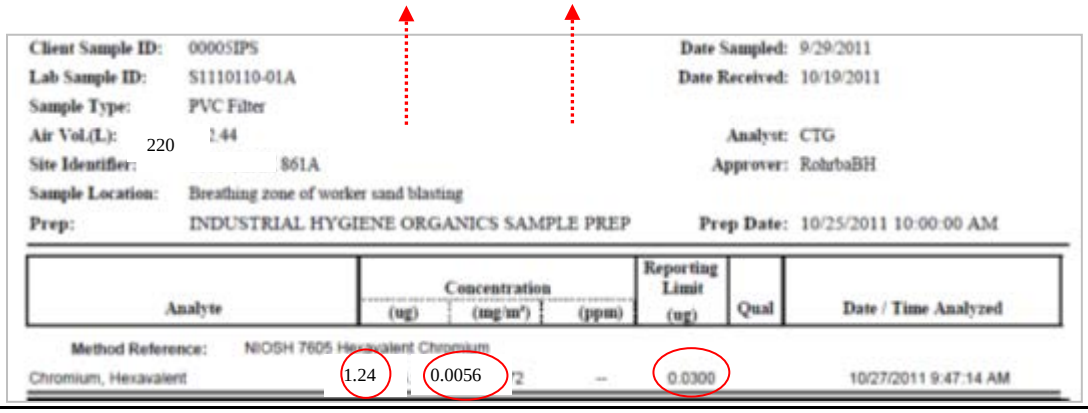
Blank Corrections

$$\textbf{Blank Corrected Result}\left(\frac{mg}{m^3}\right) = \frac{[\textbf{Field Sample Result}\ (\mu g)] - \textbf{avg}[\textbf{Media Blank Results}\ (\mu g)]}{\textbf{Sample Volume}\ (L)} \times \frac{1000\ L}{1\ m^3} \times \frac{1\ mg}{1000\ \mu g} \quad (4)$$

Example:
You collected hexavalent chromium air samples in your structural maintenance shop using NIOSH 7605. You sampled using PVC filters with a collection time of 110 minutes and volume of 220 liters for each filter. The lab's reporting limit is 0.03 µg. Determine the blank corrected sample results given the following information from the lab:

Where do you find the information to the right on a lab report…? See the example below.

Field Sample Results (µg)	Field Sample Results (mg/m^3)	Media Blank Results (µg)
1.24	0.0056	0.65
2.67	0.0121	0.95
1.76	0.0080	-
0.75	0.0034	-



Client Sample ID: 00005IPS
Lab Sample ID: S1110110-01A
Sample Type: PVC Filter
Air Vol.(L): 220 144
Site Identifier: 861A
Sample Location: Breathing zone of worker sand blasting
Prep: INDUSTRIAL HYGIENE ORGANICS SAMPLE PREP
Date Sampled: 9/29/2011
Date Received: 10/19/2011
Analyst: CTG
Approver: RohrbaBH
Prep Date: 10/25/2011 10:00:00 AM

Analyte	Concentration (ug)	Concentration (mg/m³)	Concentration (ppm)	Reporting Limit (ug)	Qual	Date / Time Analyzed
Method Reference: NIOSH 7605 Hexavalent Chromium						
Chromium, Hexavalent	1.24	0.0056	--	0.0300		10/27/2011 9:47:14 AM

1. Average the media blank results over the RL: $\frac{0.95\ \mu g + 0.65\ \mu g}{2} = 0.8\ \mu g$

2. Subtract the calculated average from each field sample results.

   1.24 µg - 0.8 µg = 0.48 µg
   2.67 µg - 0.8 µg = 1.87 µg
   1.76 µg - 0.8 µg = 0.96 µg
   0.75 µg - 0.8 µg = (-0.05)…< Reporting Limit of 0.03 µg, default to reporting limit value

3. Use the corrected mass to calculate the sample result.

$$\text{Blank Corrected Sample Result } \left(\frac{\text{mg}}{\text{m}^3}\right) = \frac{1.24\ \mu\text{g} - 0.8\ \mu\text{g}}{220\ \text{L}} \times \frac{1000\ \text{L}}{1\ \text{m}^3} \times \frac{1\ \text{mg}}{1000\ \mu\text{g}}$$
$$= 0.0022 \left(\frac{\text{mg}}{\text{m}^3}\right)$$

Corrected Sample Mass (µg)	Sample Volume (L)	Sample Result (mg/m^3)
0.48	220	0.0022
1.87	220	0.0085
0.96	220	0.0044
<0.03	220	<0.0001

C4. Time-Weighted Average Calculations

To properly calculate an employee's TWA exposure, professional judgment is necessary to decide what assumptions should be made regarding the exposure during unsampled work periods. For example, if the work shift is 8 hours and sampling was conducted for 7 hours and 15 minutes, you can either assume a zero exposure for the unsampled period or assume that the exposure is equal to the TWA over the sampled period.

TWAs are calculated using the equations below:

TWA Calculations

$$TWA_{8h} = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{480\ min}$$ ← 8-h TWA calculations when the employee exposure during the unsampled portion of the shift is assumed to be zero. (5)

$$TWA_{15\ min} = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{15\ min}$$ ← 15-min TWA-STEL calculations when the employee exposure during the unsampled portion of the operation is assumed to be zero. (6)

$$TWA = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{T_1 + T_2 + \ldots + T_n}$$ ← 8-h TWA or 15-min STEL calculations when the employee exposure during the unsampled portion of the shift is assumed to be equal to the average exposure of all sampled portions of the shift. (7)

***Example**:*

You would like to calculate the 8-hour TWA for your structural maintenance personnel from the example presented in the previous example. You have determined the employee's exposure during the unsampled portion (lunch) of the work shift to be equal to zero. Given the information below, calculate the 8-hour TWA.

Sample Result (mg/m^3)	Collection Time (min)
0.0022	110
0.0085	110
0.0044	110
<0.0001	110

$$TWA_{8h} = \frac{\left(\frac{0.0022\ mg}{m^3}\right)(110\ min) + \left(\frac{0.0085\ mg}{m^3}\right)(110\ min) + \left(\frac{0.0044\ mg}{m^3}\right)(110\ min) + \left(\frac{0.0001\ mg}{m^3}\right)(110\ min)}{480\ min}$$

$$TWA_{8h} = < 0.0035\ mg/m^3$$

C5. Sampling and Analytical Error

Sampling and analytical error (SAE) is a term used to account for the total error of a method. The SAE is a summation of the sampling, analytical, and pump errors. OSHA refers to these errors as the coefficient of variation (CV_T). NIOSH does not use the term CV_T, but rather uses the term overall precision (S_{rT}). **For the purpose of these calculations, the OSHA CV_T and the NIOSH S_{rT} are equivalent.** For a precise estimation of error, the S_{rT} or CV_T value should be obtained from the laboratory that performed the analysis. If the lab does not deviate from the published method, the estimated S_{rT} can be found on the first summary page of most NIOSH methods under the accuracy section.

OSHA and NIOSH Sampling and Analytical Error
95% Confidence Interval

OSHA Methods		***NIOSH Methods***	
$SAE = CV_T \times 1.645$	$\longrightarrow$ *Since* $CV_T = S_{rT}$... $\longrightarrow$	**$SAE = S_{rT} \times 1.645$**	(8,9)

Where:
SAE = Sampling and Analytical Error
CV_T = Total Coefficient of Variation (OSHA)
S_{rT} = Overall Precision (NIOSH)
1.645 = Statistical constant

***Example**:*
You would like to calculate the SAE for the hexavalent chromium samples collected in the example on page 125. Your samples were analyzed by the Chemistry Lab using NIOSH 7605 (CrVI).

Start by referencing your final report from the lab and note the analytical method. If the lab deviates from the published method, it will be annotated in the report. In this case, the Chemistry **Lab does not modify NIOSH 7605, so the S_{rT} value listed on the first page of the NIOSH method can be used to calculate the SAE.** Referencing NMAM 7605, you notice the S_{rT} equals 0.07:

Hexavalent Chromium Sampling Event → SAE = 0.07 X 1.645 = 0.12

If the lab deviates from the published procedure in the NMAM or OSHA method, AIHA requires the lab determine the method uncertainty (U) for the modified method. The lab must also provide the method uncertainty when there is no published S_{rT}, such as NIOSH 7300 for metals.

The laboratory publishes annual N7300 measurement uncertainties (uncertainty and bias) on our Kx website [restricted access].

The base may request U and B from the Chemistry Lab. These values can be used along with the air sampling pump's coefficient of variation (CV_P) to determine the SAE. The CV_P should be obtained from the manufacturer's specifications; if unknown, an estimate of 0.05 can be used.

SAE Using Laboratory Method Uncertainty

$$\boldsymbol{SAE = \sqrt{(CV_A)^2 + (CV_P)^2}\, X\, 1.645} \quad (10)$$

$$\mathbf{CV_A = \frac{\frac{U}{2}}{100+B}} \quad (11)$$

Where:
CV_P = Pump Coefficient of Variation, if unknown use 0.05
CV_A= Analytical Coefficient of Variation
U = Method Uncertainty (reported by lab)
B = Method Bias (reported by lab)

Example:
You have just completed lead sampling following NIOSH 7300. You refer to the final report and notice the reference method shows "NIOSH 7300 MOD" indicating the lab has slightly deviated from the NIOSH publication. Determine the SAE associated with this sampling event.

In this scenario, the lab can provide the method U and the B. After requesting U and B, the lab reports U = ±10.8% and B = -0.6%. The air sampling pump manufacturer lists the coefficient of variation as 4.0%; you can now calculate the SAE for the sampling event:

$CV_A = \frac{\frac{10.8}{2}}{100+(-0.6)} = 0.054$ $\qquad$ $CV_P = 0.04$

SAE = $\sqrt{(0.054)^2 + (0.04)^2}$ X 1.645 = 0.111, or ±11.1%

C6. Upper and Lower Confidence Limits

Sampling and analytical errors shall be incorporated into sample results to obtain the lowest value of the true exposure (with a stated degree of statistical confidence) and also the highest value of the true exposure (also with a degree of statistical confidence).

Confidence limits are values at each end of the confidence interval, which is the probable range of the true value. The lower value is called the lower confidence limit (LCL) and the upper value is the upper confidence limit (UCL). The LCL and UCL are each termed one-sided because the main concern is with being confident that the true exposure is either less or greater than the OEEL. These terms are often applied with a 95% statistical confidence limit and expressed as $LCL_{95\%}$ and $UCL_{95\%}$. The $LCL_{95\%}$ and $UCL_{95\%}$ are calculated differently depending upon the type of sampling method used.

Confidence limits can be used to classify the measured exposure into one of four categories shown in Figure C-1:

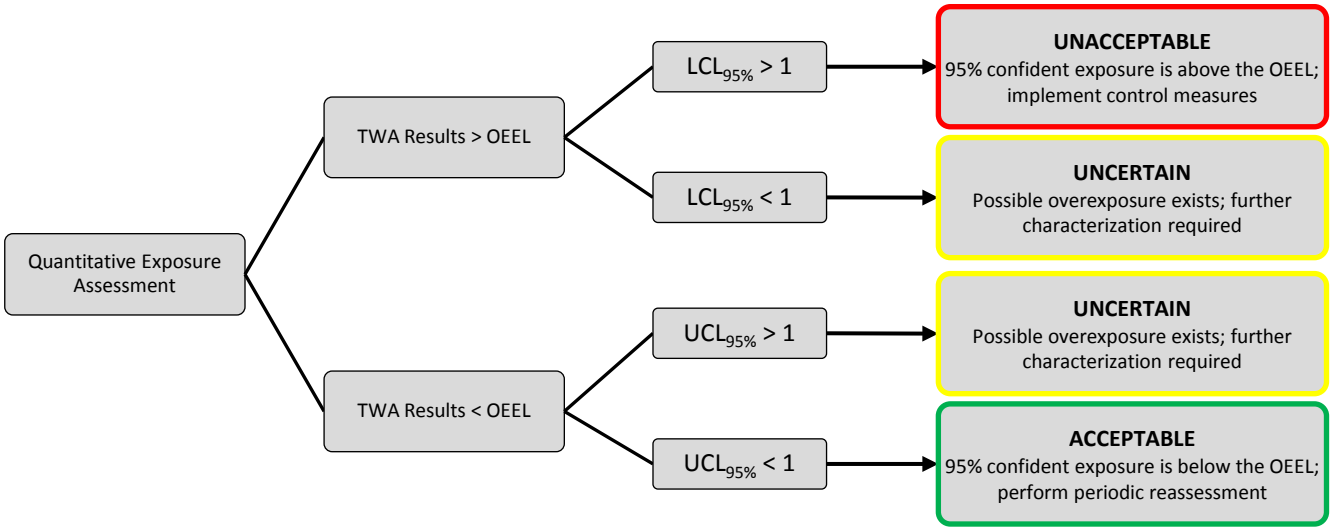


Figure C-1: Upper and Lower Confidence Limits

$LCL_{95\%}$ and $UCL_{95\%}$

$$Y = \frac{X}{OEEL} \quad (12)$$

Exposure Severity
X is the full-period sampling result and Y is the exposure severity.

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

$$UCL_{95\%} = Y + SAE \quad (13)$$

Full-Period, Continuous Single Sample
X is the full-period sampling result and Y is the exposure severity.

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

$$UCL_{95\%} = Y + \frac{SAE\sqrt{(T_1X_1)^2 + (T_2X_2)^2 + \cdots + (T_nX_n)^2}}{PEL\,(T_1 + T_2 + \cdots + T_n)} \quad (14)$$

Full-Period, Consecutive Sampling
$X_1, X_2, \ldots X_n$ is the n consecutive concentrations in a work shift and their corresponding time durations are $T_1, T_2, \ldots T_n$

Example:
Referring to the example on page 121, determine if the hexavalent chromium exposure is acceptable, uncertain, or unacceptable. The applicable OEEL was determined to be 0.005 mg/m^3. The SAE was previously determined to be 0.12.

Recall from earlier the consecutive concentrations, corresponding time durations, and resulting TWAs:

Sample Result (mg/m^3)	Collection Time (min)	TWA (mg/m^3)
0.0022	110	0.0035 mg/m^3
0.0085	110	
0.0044	110	
<0.0001	110	

Since the TWA result is less than the OEEL (0.0035 mg/m^3 < 0.005 mg/m^3), next calculate the UCL:

$$UCL_{95\%} = \frac{0.0035\ \text{mg/m}^3}{0.005\ \text{mg/m}^3} + \frac{0.12\sqrt{(110 \times 0.0022)^2 + (110 \times 0.0085)^2 + (110 \times 0.0044)^2 + (110 \times 0.0001)^2}}{0.005\ \text{mg/m}^3\,(110 + 110 + 110 + 110)} = 0.70$$

The $UCL_{95\%}$ (0.70) < 1, so you are 95% confident the exposure is less than the OEEL and classified as **acceptable**.

C7. Temperature and Pressure Corrections

Air volume is directly affected by temperature (T) and pressure (P) and corrections must be made when an air sampling pump is calibrated at one location and sampling is conducted a different location with substantially different T and P conditions. To prevent the required use of a correction factor, if at all possible the sampling pump should be calibrated in the field. If calibration in the field is not possible, then the indicated flow rate at the time of sampling must be corrected using equation (15) below. The equation below should only be used for rotameter sampling pumps (the most popular field instrument used for air sampling).

In general, temperature and pressure corrections should only be used when a significant shift has occurred between the calibration and field conditions. According to both NIOSH and OSHA a deviation of more than ±5% of the calibration value is considered to be a significant shift. In other words, a flow rate should be corrected if measured conditions exceed calibration conditions by 5% or greater using equation below.

Note: Most new commercially available air sampling pumps ***automatically*** correct for variations in temperature and pressure to deliver a constant flow rate. Refer to the manufacturer's literature to determine if your pump has this capability. If this is the case, the equation is not necessary.

Flow Corrections for Temperature and Pressure

$$Q_{Field} = Q_{Cal}\sqrt{\frac{P_{cal}}{P_{Field}} \times \frac{T_{Field}}{T_{cal}}} \qquad (15)$$

Where:

Q_{Field} = Flow Rate at field sample conditions (L/min)
Q_{Cal} = Flow Rate Indicated during Calibration (L/min)
P_{cal} = Pressure during Calibration (torr)
T_{cal} = Temperature during calibration (__°C+273)
P_{Field} = Pressure at Field Sampling Location (torr)
T_{Field} = Temperature at Field Sampling Location (_°C+273)

Example*:*
Your air sampling pump was calibrated to 2.0 lpm in Cincinnati, OH at an elevation of 575 feet (744 torr) and a temperature of 24°C. The pump was then used to obtain a sample at an elevation of 6000 feet (605 torr) with a temperature of 10°C. You sampled for 2 hours. What sample volume should you report to the laboratory?

Determine the actual flow rate through the pump at the time of sampling using equation (15):

$$Q_{Field} = 2.0 \text{ lpm}\sqrt{\frac{744 \text{ torr}}{605 \text{ torr}} \times \frac{10°C+273}{24°C+273}} = 2.17 \text{ lpm}$$

$$\text{Reported Volume} = \frac{2.17 \text{ L}}{\text{min}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times 2 \text{ hr} = 259.8 \text{ Liters}$$

C8. Unit Conversions

Unit Conversions

$$mg/m^3 = (ppm) \times \frac{Molecular\ Weight\ of\ Contaminant\ of\ Concern}{24.45} \quad (16)$$

***Example**:*
Personal air sampling was performed on workers exposed to benzene in Salt Lake City, UT (ambient air temperature = 33°C, measured barometric pressure = 670 torr). The sample flow rate is 0.050 L/min for a duration of 126 minutes. The analytical laboratory reports a collected sample mass of 6.33 µg (0.00633 mg). You wish to compare the results to the TLV-TWA of 100 ppm. The molecular weight of benzene is 88.15 AMU.

Example Sample Results:

Client Sam [illegible]C2 — Date Sampled: [illegible]
Lab Samp 02A — Date Received:
Sample Type: [illegible]B
Air Vol.(L): 6.3 — Analyst: RAB
Site Identifier: 0710 FAFS 336A — Approver:
Sample Loc [illegible]IR
Prep: — Prep Date:

Analyte	Concentration (ug)	Concentration (mg/m³)	Concentration (ppm)	Reporting Limit (ug)	Qual	DF	Date / Time Analyzed
Method Reference: NIOSH 1501							
Benzene	6.33	1.01	--	5.49		1	12/21/2011 10:56:05 AM
Toluene	63.9	10.1	--	5.42		1	12/21/2011 10:56:05 AM
Xylenes, Total	262	41.6	--	10.8		1	12/21/2011 10:56:05 AM
Method Reference: NIOSH 1550							
JP-8 Jet Fuel	5540	879	--	122		3	

Step 1. Calculate the sample volume collected at the sampling site (note that the sample volume is not adjusted to NTP conditions). Then calculate the TWA exposure concentration measured at the sampling site:

a.) Sample Volume = $\frac{0.050\ \text{L}}{\text{min}} \times 126\ \text{min} = 6.3\ \text{L}$ *or*

$$= \frac{0.050\ \text{L}}{\text{min}} \times 126\ \text{min} \times \frac{\text{m}^3}{10^3\text{L}} = 0.00625\ \text{m}^3$$

b.) Sample Concentration = $\frac{0.00633\ \text{mg}}{0.00625\ \text{m}^3} = 1.01\ \text{mg/m}^3$

c.) 8-h TWA = $\frac{(1.01\ \text{mg/m}^3)\times(126\ \text{min})}{480\ \text{min}} = 350\ \text{mg/m}^3$

Step 2. Convert the TLV ppm concentration to a mg/m^3 concentration using equation (16):

$$\text{mg/m}^3 = (100\ \text{ppm}) \times \frac{88.15}{24.45} = 360\ \text{mg/m}^3$$

Step 3. Directly compare the TWA exposure concentration to the TLV®-TWA:

Sampling Site TWA Exposure Concentration	ACGIH TLV®-TWA Concentration
350 mg/m^3	**360 mg/m^3**

C9. Chemical Mixtures

Chemical mixtures can have three different effects: additive, independent, or synergistic.

- *Additive Effects.* Additive effects may be combined by summing the exposure severity when chemicals in a mixture have the same target organ. If the exposure severity of the mixture ($Y_{mixture}$) is greater than one, the exposure is considered to exceed the OEEL for the mixture.
- *Independent Effects.* If the chemical substances in the mixture have different biological actions, the data must not be combined into a single exposure value. Instead, the concentration of each chemical substance must be separately compared to its OEEL.
- *Synergistic Effects.* If the chemical substances in the mixture have synergistic effects, interpretation of the data should be done on a case-by-case basis and with great caution.
-

Equivalent Exposure Severity for a Mixture

$$Y_{mixture} = \frac{C_1}{OEEL_1} + \frac{C_2}{OEEL_2} + \cdots + \frac{C_n}{OEEL_n} \quad (17)$$

Example:
You would like to calculate the exposure to three different but additive substances:

Material	*8-h Exposure*	*8-h TWA OEEL*
Substance 1	500	1000
Substance 2	80	200
Substance 3	70	200

$$Y_{mixture} = \frac{500}{1000} + \frac{80}{200} + \frac{70}{200} = 1.25$$

Since $Y_{mixture} > 1$, the OEEL for the mixture has been exceeded.

C10. Non-Traditional Work Schedules

Standards based on 8-hour exposures may not provide appropriate protection when non-traditional work schedules are used, i.e., four 10-hour days per week. Comparison of the full-shift exposure measured during a non-traditional work schedule requires that the 8-hour OEEL be adjusted to account for differences in the number of exposure (i.e., work) hours and recovery (i.e., non-work) hours. Reduced down time means less time for the body to eliminate chemicals, resulting in increased body burden. The goal is to ensure that workers with unusual shifts do not exceed the same threshold body burden, resulting in health effects.

The two most 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 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. Adjusted OEELs may be selected in DOEHRS when determining employee TWAs.

C10.1 OSHA Compliance and Extended Work Shifts

The lead standards for construction and general industry standards 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.

Historical versions of the OSHA Field Inspection Reference Manual included the *OSHA model* for adjusting PELs for extended work shifts. This 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.

C10.2 Brief and Scala Model

The Brief and Scala model is the preferred model for calculating adjustments of 8-hour TWA exposure standards. This model is a conservative approach to adjusting OEELs for unusual work shifts, incorporating increased work shift exposures and decreased recovery time. 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. As a general rule, OEEL 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 (i.e., 6-200 hours) are likely to have day-to-day accumulation during the week, even at exposures at or near the OEEL.
- The model assumes average body burden for the chemical rather than peak burden.
- The model can be used if the OEEL is based on systemic 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 (i.e., the OEEL should NEVER be adjusted upward for shortened workdays or weeks). In addition, neither adjustment equation is appropriate for 24-hour (i.e., continuous) exposure.
- Do not make OEEL adjustments when the chemical is a primary irritant (i.e., PEL based on sensory irritation effects). In such cases, the chemical's action is based on "compartmental" vice whole body effects. Further, the irritation threshold is probably independent of the number of hours worked.

The adjusted OEEL is then used for comparison with the employee's TWA exposure and its upper or lower confidence limits as appropriate.

Brief and Scala Model

Work Week Less Than 7 Days (18,19)

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

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

7-Day Work Weeks

$$\textbf{Adjusted OEEL} = \textbf{OEEL} \times \left(\frac{40}{h} \times \frac{168-h}{128}\right)$$

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

***Example**:*
The Allied Trades employees at your installation work four consecutive 12-hour shifts with 3 days off. Workers perform sanding operations on hexavalent chromium. The applicable OEEL was determined to be the ACGIH TLV of 0.005 mg/m^3. Using the Brief and Scala method, determine the adjusted OEEL.

$$\text{Adjusted OEEL} = 0.005\ \text{mg/m}^3 \times \left(\frac{8}{12} \times \frac{24-12}{16}\right) = 0.0025\ \text{mg/m}^3$$

C11. Conversion of Sample Results from an Element to a Compound

In a metal scan, iron (Fe), zinc (Zn), and vanadium (V) concentrations (in mg/m^3) are reported instead of the metal oxide concentrations (i.e., Fe_2O_3, ZnO, and V_2O_5) for which one is actually sampling. To convert a sample result from an element to a compound containing that element, the below equation can be used. The equation assumes the only source of the elemental metals is from the metal oxide.

Conversion of Sample Results from Element to a Compound

$$\textbf{RC} = \textbf{RR} \times \frac{\textbf{MWC}}{\textbf{MWE}} \quad (20)$$

Where:
RC = Result for Compound (mg/m^3)
RR = Reported Result for Element (mg/m^3)
MWC = Molecular Weight of Desired Compound
MWE = Molecular Weight of Reported Element

***Example**:*
Your results from the lab reported sodium (Na) as 100 mg/m^3. The only source of sodium during your sampling event was sodium hydroxide (NaOH). You wish to determine the NaOH concentration. [Note: MW of Na is 23; MW of NaOH is Na(23) + O(16) + H(1)]

$$\text{RC} = 100\ \text{mg/m}^3\ \text{Na} \times \frac{40\ (\text{MW of NaOH})}{23\ (\text{MW of Na})} = 173.0\ \text{mg/m}^3$$

Other $\frac{\text{MWC}}{\text{MWE}}$ examples include:

Zinc Oxide: $\frac{\text{MW of ZnO}}{\text{MW of Zn}} = \frac{81.4}{65.4} = 1.245$

Vanadium Pentoxide: $\frac{\text{MW of } V_2O_5}{\text{MW of } V_2} = \frac{181.9}{101.9} = 1.785$

Iron Oxide: $\frac{\text{MW of } Fe_2O_3}{\text{MW of } Fe_2} = \frac{159.7}{111.7} = 1.43$

C12. Radiological Sampling Times

Minimum Required Sampling Time

$$t_{min} = \frac{L_c \times 10}{Q \times DAC} \quad (21)$$

Where:

L_c = Critical Level for Analysis Method (Bq) (determined by the lab)
DAQ = Derived Air Concentration (Bq/m^3) from 10 CFR 20, Appendix B
Q = Sampling Flow Rate (m^3/min)

C13. List of Equations

1. Pump Flow Rate Difference	$\frac{(\textbf{pre} - \textbf{calibration flow rate}) - (\textbf{post} - \textbf{calibration flow rate})}{\textbf{pre} - \textbf{calibration flow rate}} \times \mathbf{100}$
2. Sample Collection Time	$\text{Air Sampling Time (min)} = \frac{\text{Volume (L)}}{\text{Flow Rate (L/min)}}$
3. Minimum Air Volume	$\text{Minium Air Volume (L)} = \frac{\text{RL}}{(\text{OEEL}) \times (\text{Desired Fraction})}$
4. Blank Corrections	$\text{Blank Corrected Result } \left(\frac{\text{mg}}{\text{m}^3}\right) = \frac{[\text{Field Result } (\mu\text{g})] - \text{ avg}[\text{Blank Results } (\mu\text{g})]}{\text{Sample Volume (L)}}$
5. 8-h TWA, Unsampled Portion Equals Zero	$\text{TWA}_{8\text{ h}} = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{480\text{ min}}$
6. TWA-STEL	$\text{TWA}_{15\text{ min}} = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{15\text{ min}}$
7. 8-h TWA or 15-min STEL, Unsampled Portion Equals Avg Concentration	$\text{TWA} = \frac{C_1T_1 + C_2T_2 + \ldots + C_nT_n}{T_1 + T_2 + \ldots + T_n}$
8. OSHA Sampling and Analytical Error	$\text{SAE} = \text{CV}_\text{T} \text{ X } 1.645$
9. NIOSH Sampling and Analytical Error	$\text{SAE} = S_{rT} \text{ X } 1.645$
10. SAE Using Laboratory Method Uncertainty	$\text{SAE} = \sqrt{(\text{CV}_\text{A})^2 + (\text{CV}_\text{P})^2} \text{ X } 1.645$
11. Analytical Coefficient of Variation	$\text{CV}_\text{A} = \frac{\frac{U}{2}}{100+B}$
12. Exposure Severity	$Y = \frac{X}{\text{OEEL}}$
13. Full-Period, Continuous Single Sample $LCL_{95\%}$ and $UCL_{96\%}$	$LCL_{95\%} = Y - \text{SAE}$ $UCL_{95\%} = Y + \text{SAE}$
14. Full-Period, Consecutive Sampling $LCL_{95\%}$ and $UCL_{96\%}$	$LCL_{95\%} = Y - \frac{\text{SAE}\sqrt{(T_1X_1)^2 + (T_2X_2)^2 + \cdots + (T_nX_n)^2}}{\text{PEL}\,(T_1 + T_2 + \cdots + T_n)}$ $UCL_{95\%} = Y + \frac{\text{SAE}\sqrt{(T_1X_1)^2 + (T_2X_2)^2 + \cdots + (T_nX_n)^2}}{\text{PEL}\,(T_1 + T_2 + \cdots + T_n)}$
15. Flow Corrections for Temperature and Pressure	$Q_{\text{Field}} = Q_{\text{Cal}} \sqrt{\frac{P_{\text{cal}}}{P_{\text{Field}}} \times \frac{T_{\text{Field}}}{T_{\text{cal}}}}$
16. Unit Conversions	$\text{mg/m}^3 = (\text{ppm}) \times \frac{\text{Molecular Weight of Contaminant of Concern}}{24.45}$
17. Equivalent Exposure Severity for a Mixture	$Y_{\text{mixture}} = \frac{C_1}{\text{OEEL}_1} + \frac{C_2}{\text{OEEL}_2} + \cdots + \frac{C_n}{\text{OEEL}_n}$
18. Brief and Scala Method, Work Week Less than 7 Days	$\text{Adjusted OEEL} = \text{OEEL} \times \left(\frac{8}{\text{h}} \times \frac{24-\text{h}}{16}\right)$
19. Brief and Scala Method, 7-Day Work Weeks	$\text{Adjusted OEEL} = \text{OEEL} \times \left(\frac{40}{\text{h}} \times \frac{168-\text{h}}{128}\right)$
20. Conversion of Sample Results from an Element to a Compound	$RC = RR \times \frac{\text{MWC}}{\text{MWE}}$
21. Minimum Required Radiological Sampling Time	$t_{\text{min}} = \frac{L_c \times 10}{Q \times \text{DAC}}$

APPENDIX D: SAMPLE COLLECTION AND CALIBRATION

D1. Sample Collection and Calibration Trains

The accuracy of final laboratory sampling results is directly dependent on the accuracy of the volume reported by field personnel. Therefore, correct sample train assembly and calibration of the pump/airflow through the sample collection devise are an absolute necessity.

Dead Volume. Dead volume is the gas volume between a flow generator and the instrument taking the measurement. Since gas is compressible, this gas can act as a spring between the flow source and the measurement instrument. For best accuracy, this volume should be kept to a minimum. The recommended tubing length on either side of the media to the pump and the calibrator should be no more than 20 inches.

Luer Adapters. The small plastic adapter used to connect the filter cassette to the sample collection tubing, known as the luer adapter, should not be used on the inlet side of the filter cassette during calibration. Since the adapter is only used on the outlet side during sample collection, it should be assembled in the same manner during calibration to obtain a representative flow pattern.

Refer to Figures D-1 and D-2 for general filter and sorbent tube sample train assembly as well as proper placement in the employee's breathing zone. For detailed sample pump operation and calibration instructions, refer to your pump's operating manual.

D2. Sample Pump Calibration

The accuracy of determining the concentration of a toxic substance in air is no greater than the accuracy with which the air volume is measured. Therefore, accurate calibration of the airflow rate through the sampling train is necessary before field use (pre-calibration, same day) and after field use (post-use flow-rate check, same day).

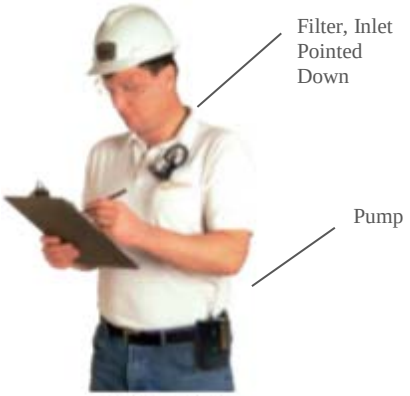
Both pre-use and post-use flow rate checks must be made using an unused sample media (tube or filter) from the same lot number used for the actual air sampling event. Only one tube or filter needs to be checked, since all media in a given lot number are packed to provide a uniform pressure drop.

If using a nickel-cadmium (NI-CAD) battery-operated pump, run a fully charged air sampling pump for at least 10 minutes to achieve a normal, stable flow rate prior to calibration. This is necessary because fully charged NI-CAD batteries have an initial high voltage peak and the 10-minute operating time allows the battery voltage to stabilize. It is also a good idea to allow the pump to equilibrate after moving from one temperature extreme to another before calibrating or sampling.

FILTER AND CYCLONE SAMPLE TRAIN ASSEMBLY

Filter and Cyclone Sample Train Assembly

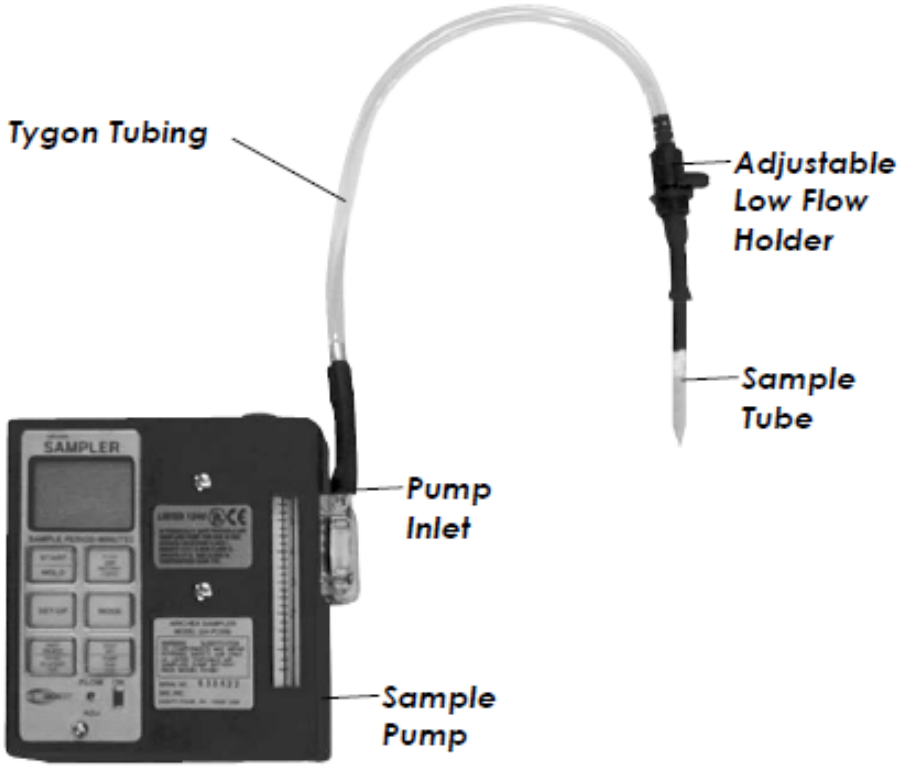
Calibration train with filter cassette

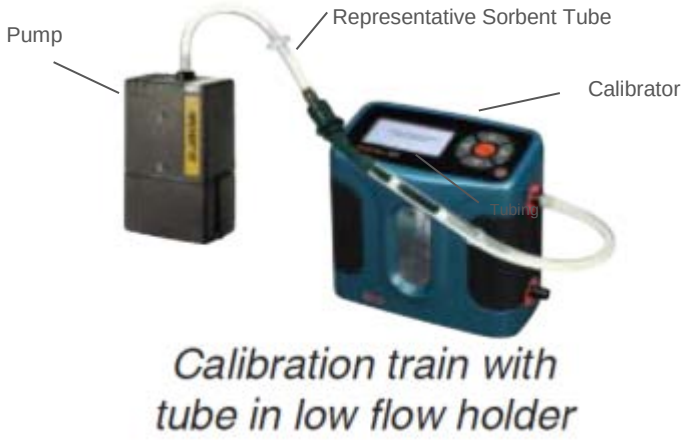


Clip sample medium to worker and pump to belt.

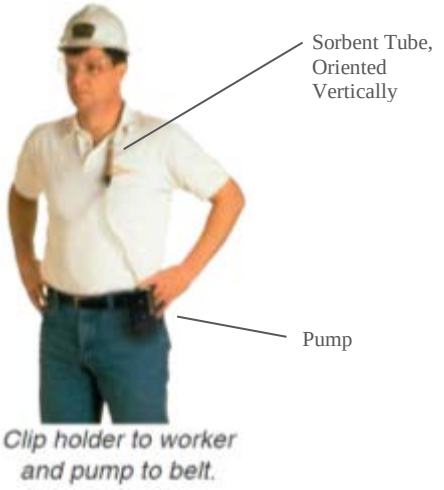
Figure D-1: Sample Collection and Calibration Trains for Filters (Courtesy of SKC Inc.)

SORBENT TUBE SAMPLE TRAIN ASSEMBLY





Calibration train with tube in low flow holder



Sorbent Tube Sample Train Assembly

Figure D-2: Sample Collection and Calibration Trains for Sorbent Tubes (Courtesy of SKC Inc.)

APPENDIX E: WEB SITES

AIHA Exposure Assessment Strategies Committee, IHSTAT Excel Spreadsheet:	https://www.aiha.org/get-involved/VolunteerGroups/Documents/EXASSVG-IHSTAT-V233.xls
AIHA Laboratory Accreditation Program, LLC:	www.aihaaccreditedlabs.org
ASTDR Minimal Risk Levels:	http://www.atsdr.cdc.gov/mrls/index.asp
Chemistry Lab and the Automated Sampling Guide (ASAGE) [restricted access]:	https://hpws.afrl.af.mil/dhp/oealims/customeraccess/
Clean Water Act Analytical Methods:	http://water.epa.gov/scitech/methods/cwa/
E-publishing:	http://www.e-publishing.af.mil/
SurveyMonkey Comment Website	http://www.surveymonkey.com/s/OECUSTOMERSURVEY
International Air Transport Association:	http://www.iata.org/
Laboratory Response Network:	http://www.bt.cdc.gov/lrn/
National Environmental Methods Index:	https://www.nemi.gov/methods/browse_methods/
NIOSH Manual of Analytical Methods:	http://www.cdc.gov/niosh/docs/2003-154/
Omega Specialty Instrument Co. (Iso-Chek Protocol):	http://www.skcinc.com/prod/225-9022.asp
NIOSH Pocket Guide to Chemical Hazards:	http://www.cdc.gov/niosh/npg/npgsyn-a.html
OSHA Index of Sampling and Analytical Methods:	http://www.osha.gov/dts/sltc/methods/toc.html
USAFSAM ESOH Service Center [restricted access]:	https://hpws.afrl.af.mil/dhp/OE/ESOHSC/
USAFSAM IH Stats Web Seminar (Dec 2008) [restricted access]:	https://kx.afms.mil/kxweb/dotmil/kjPage.do?functionalArea=ESOH&cid=CTB_103609

USAFSAM Laboratory Website [restricted access]	https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=742
U.S. EPA Drinking Water Analytical Methods:	http://water.epa.gov/scitech/drinkingwater/labcert/analyticalmethods.cfm#approved
U.S. EPA Integrated Risk Information System:	http://www.epa.gov/iris/
U.S. EPA Maximum Contaminant Levels:	http://water.epa.gov/drink/contaminants/index.cfm
U.S. EPA Monitoring Methods - Air Toxics (TO) Methods:	http://www.epa.gov/ttn/amtic/airtox.html#compendium
U.S. EPA Monitoring Methods - Inorganic (IO) Compendium Methods:	http://www.epa.gov/ttnamti1/inorg.html
U.S. EPA National Ambient Air Quality Standards:	http://www.epa.gov/air/criteria.html
U.S. EPA SW-846 Online:	http://www.epa.gov/wastes/hazard/testmethods/sw846/online/index.htm
Visual Sample Plan Software:	http://vsp.pnnl.gov/

APPENDIX F: DOEHRS TUTORIAL

F1. Introduction

Appendix F of the USAFSAM Sampling and Analysis Guide is not intended to be a used as a standalone guide for DOEHRS data entry guidance. It should be used in conjunction with the guidance in the USAFSAM Laboratory and Analysis Guide, ASAGE, the Air Sampling DERG and the USAFSAM Sampling forms within that DERG, and all applicable DOEHRS Student guides to help you complete a successful sampling event. This appendix assumes that general workplace surveillance data entry has already been completed IAW Air Force Instruction (AFI) 48-145, *Occupational and Environmental Health Program*, and Air Force Manual (AFMAN) 48-146, *Occupational and Environmental Health Program Management*, (e.g. the creation of IH Shops, Processes and Controls), therefore does not address these areas except where required for successful completion of entering an air sample in DOEHRS.

Further Guidance can be obtained from the Analytical Services Website https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=742, the DOEHRS Support Office Website https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=751, or the ESOH Service Center Website https://hpws.afrl.af.mil/dhp/OE/ESOHSC/

For questions or concerns with this appendix please refer to AF DOEHRS Support Office website or contact the DSO by email at ESOH.Service.Center@us.af.mil.

F2. How to Export DOEHRS XML File

IH samples must be loaded as DOEHRS Process or SEG samples before the sample data and lab results can be exported or imported and matched to DOEHRS IH samples. Once that has been accomplished, follow the steps outlined below and you will be ready to send your samples to the Laboratory.

Step 1. Select the Export Samples hyperlink in the Industrial Hygiene menu.

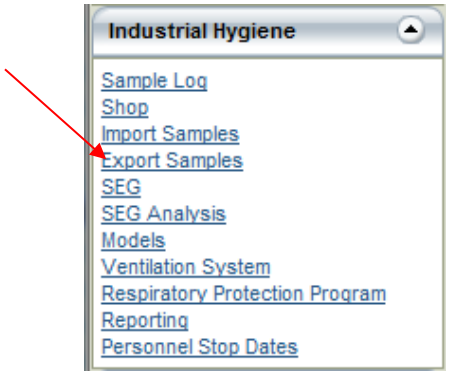


Figure 1. Industrial Hygiene Menu (Export Samples link)

You will be taken to the Export Samples – Search page.

Step 2. Search for the Shop where the samples are located.

Step 3. Select 'USAFSAM –OEAL' as your IH Global Lab.

Note: When selecting the IH Global Lab in this Search box, you are specifying that all samples in this batch (XML file) are going to that Lab.

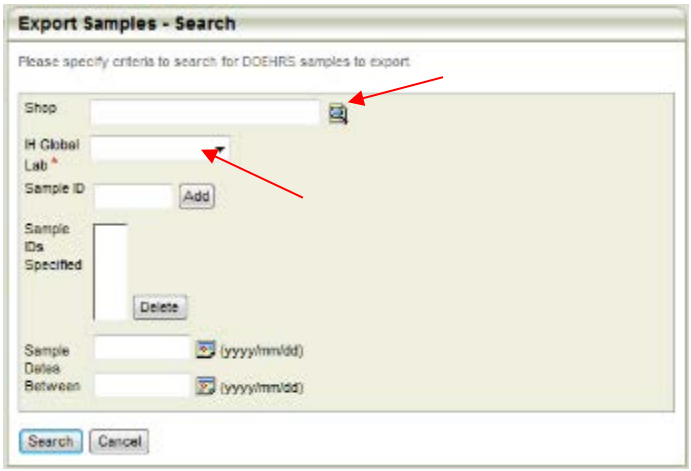


Figure 2. Export Samples – Search page

Step 4. Enter the sample ID of the sample you are sending to the lab and click the Add button for it to move down to the Sample IDs Specified field. Repeat this step for all applicable sample IDs.

Note: You can highlight a Sample ID and press the Delete button if you need to remove a sample from the list.

Step 5. Click the Search button

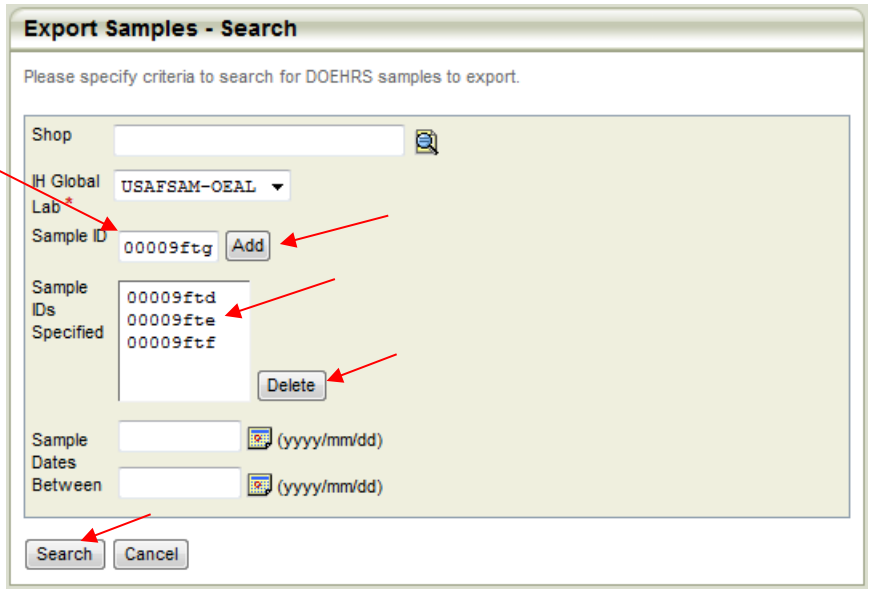


Figure 3. Export Samples – Search page

This takes you to the Select Samples for Export page.

Step 6. Select the samples for export by checking the checkbox in the Select column of the desired samples individually or by pressing the “Select All” button.

Step 7. Press the “Export Sample Data” button.

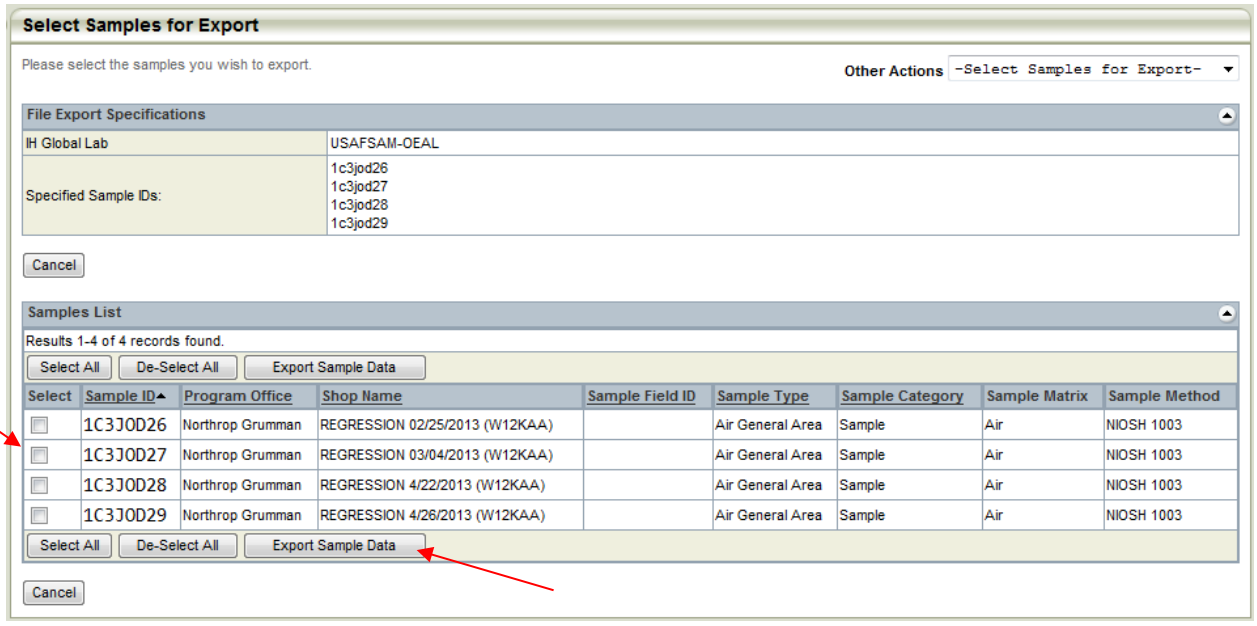


Figure 4. Select Samples for Export page

You will get a File Download pop-up window to open or save the file.

Step 8. Save the file to an accessible location on your computer network. Ensure you remember the location and filename of the file you saved.

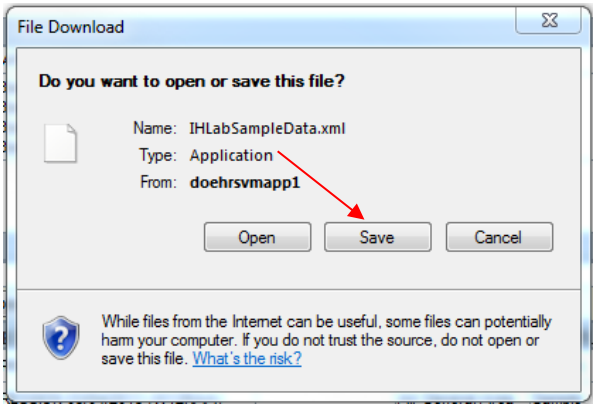


Figure 5. File Download pop-up window

Note: Save file names with the following naming convention: ‘Base Name_DOEHRS Export_Date’ (i.e. Wright-Patterson_DOEHRS Export_17Nov2014)

Step 9. Before you send your physical samples to the Lab, send the DOEHRS generated XML file by email to USAFSAM/OEHTA WPAFB Analytical at USAFSAM.OEHTACal@us.af.mil

F.3 DOEHRS Sample Submission Procedures

The standard sample submission form is the Business Objects- Transactional *USAFSAM Sample Submission* Form (Located: Transactional Reports; TR-Shared IH; TR- Air Force; 02B- IH~OH PRGM- Special Surveillance: USAFSAM Sample Submission Forms (IH) (Updated). This form replaces the outdated Discoverer version, the hard copy AF Form 2750 series forms and any locally generated versions bases may be using.

USAF
SCHOOL OF AEROSPACE MEDICINE

USAFSAM/OEA
2510 Fifth Street, Bldg 840, Rm W327N
Wright Patterson AFB, OH 45433
DSN: 798-2523
Commercial: (937) 938-2523

For SAMPLER only
I acknowledge that QA review was performed on sample planning, collection, handling, and shipping IAW the USAFSAM Laboratory Sampling Guide, Quality Control Checklist

USAFSAM Analytical Services Website
Shaded area for USAFSAM use only

USAFSAM ANALYTICAL REQUEST FORM (ARF)

REPORT TO: (Unit Address)	SAMPLER NAME, RANK, DSN, E-MAIL	INSTALLATION	BASE CODE	SEG
		Davis-Monthan AFB	0047Z	030B PAINT SHOP
	WORKPLACE			ACTIVITY NAME
	030B AMARG PAINT SHOP			Depainting/Desealing Manual

ADDITIONAL REPORTING: (Up to 3 additional. Add POC e-mail)	COMMENTS/ADDITIONAL INFORMATION:	SAMPLES REFRIGERATED? (Place check mark)	REQUESTING METHOD OF UNCERTAINTY? (Mark Yes/No)

	USAFSAM LAB ID	COLLECTION DATE	SAMPLE ID	ANALYTICAL METHOD	COLLECTION MEDIA	ANALYTE OR HAZARD	CAS #	For Swipe Only Area Size/Unit	For Air & Swipe Only Error Check	Active Sampler Vol. (L)	Passive Monitor Sample Time (Min)
1	Air Breathing Zone - Field Blank	03 Mar 2015	0000D9T0	NIOSH 7300 - ELEMENTS by ICP (Nitric/Perchloric Acid Ashing)	FILTER (0.8-um MCEF membrane, 37mm diameter)	CADMIUM	7440-43-9	N/A	OK - Blank	0	N/A
2	Air Breathing Zone - Field Blank	03 Mar 2015	0000D9T0	NIOSH 7300 - ELEMENTS by ICP (Nitric/Perchloric Acid Ashing)	FILTER (0.8-um MCEF membrane, 37mm diameter)	CHROMIUM METAL	7440-47-3	N/A	OK - Blank	0	N/A
3	Air Breathing Zone - Field Blank	03 Mar 2015	0000D9T0	NIOSH 7300 - ELEMENTS by ICP (Nitric/Perchloric Acid Ashing)	FILTER (0.8-um MCEF membrane, 37mm diameter)	CHROMIUM(VI)	18540-29-9	N/A	OK - Blank	0	N/A
				NIOSH 7300 -	FILTER (0.8-um						

Figure 6: Business Objects- Transactional- 'USAFSAM Lab Sample Submission Form (IH)'

This page intentionally left blank.

Table 40: USAFSAM Lab Sampling Submission Form (IH)

Form Field	Auto/Manual Input	DOEHRS page	DOEHRS tile	DOEHRS field
		DOEHRS Explanations		
Report To:	Manual Input			
Sampler Name, Rank, DSN, E-mail	Manual Input			
Installation	Auto populates			
Base Code	Auto populates			
SEG	Auto populates	SEG- Details page (user selects at master schedule task step #)	SEG information tile	SEG Name field
Workplace	Auto populates	Shop Details page (user selects at master schedule task step #)	Shop Information tile	Shop Name field
Activity Name	Auto populates	Process – Detail page (user selects at master schedule task step #)	Process Information tile	Process Name field
Additional Reporting: Up to 3 additional. Add POC e-mail	Manual Input			
Comments/ Additional Information	Manual Input			
Samples Refrigerated? (Mark Yes/No)	Manual Input			
Requesting Method of Uncertainty? (Mark Yes/No)	Manual Input			
USAFSAM Lab ID	Manual Input (lab use only)			
Collection Date	Auto populates	Sample Form page	General Sample Information tile	Sample Date field
Sample ID	Auto populates	Sample Form page- Individual Sample ID Information page	Sample Collection Information tile	Sample ID field
Analytical Method	Auto populates	Sample Form page- Individual Sample ID Information page	Sample Collection Information tile	Sampling Method field
Collection Media	Auto populates	Sample Form page	General Sample Information tile	Sampling Media field
Analyte or hazard	Auto populates	Sample Form page	Hazard Information tile User selects at individual sample tile	N/A
CAS #	Auto populates	Hazard-More Information page	More Information tile	CAS # field

For Swipe Only Area Size/Unit	**Auto populates**	**General Wipe Swipe Form page**	**Sample Collection Information tile**	**Size of Area Wiped field (with unit) area must be greater than zero**
For Air & Swipe Only Error Check	**Auto populates**			
Active Sampler Vol. (L)	**Auto populates**	**Sample Form page**	**Sample Collection Information**	**Total Volume Sampled field**
Passive Monitor Sample Time (Min)	**Auto populates**	**Sample Form page**	**Sample Collection Information**	**Total Sampling Time field**

How to Navigate to the USAFSAM Sample Submission Form

From the Business Objects Homepage, you click on the following:

-Document List

-Public Folders

-Transactional Reports (Formerly Discoverer Reports)

-TR- Shared IH

-TR- Air Force

-02B- IH-OH PRGM – Special Surveillance: USAFSAM Sample Submission Form (IH) (Updated)

-USAFSAM Sample Submission Form (IH) (Updated)

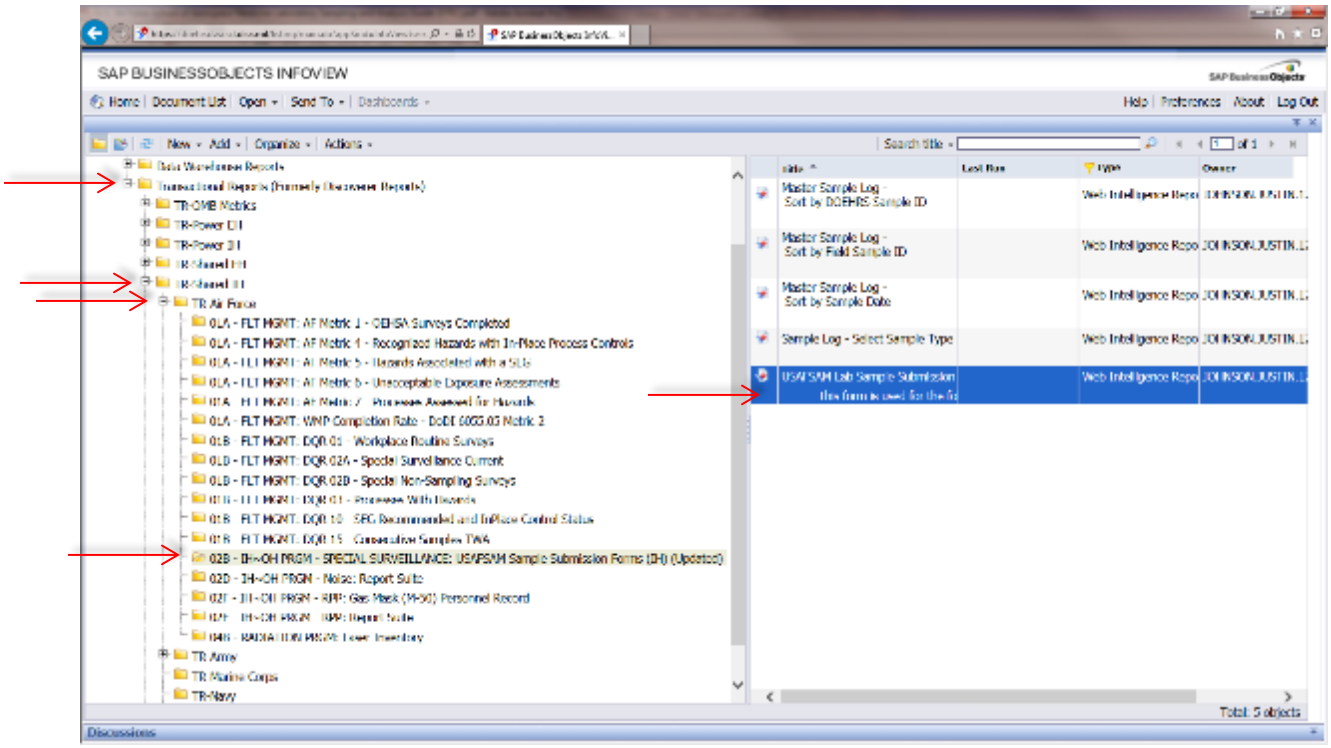


Figure 7: Business Objects- Transactional – 'USAFSAM Lab Submission Form (IH)' Location

How to Generate the USAFSAM Sample Submission Form

Use calendars and your Hierarchy were applicable.

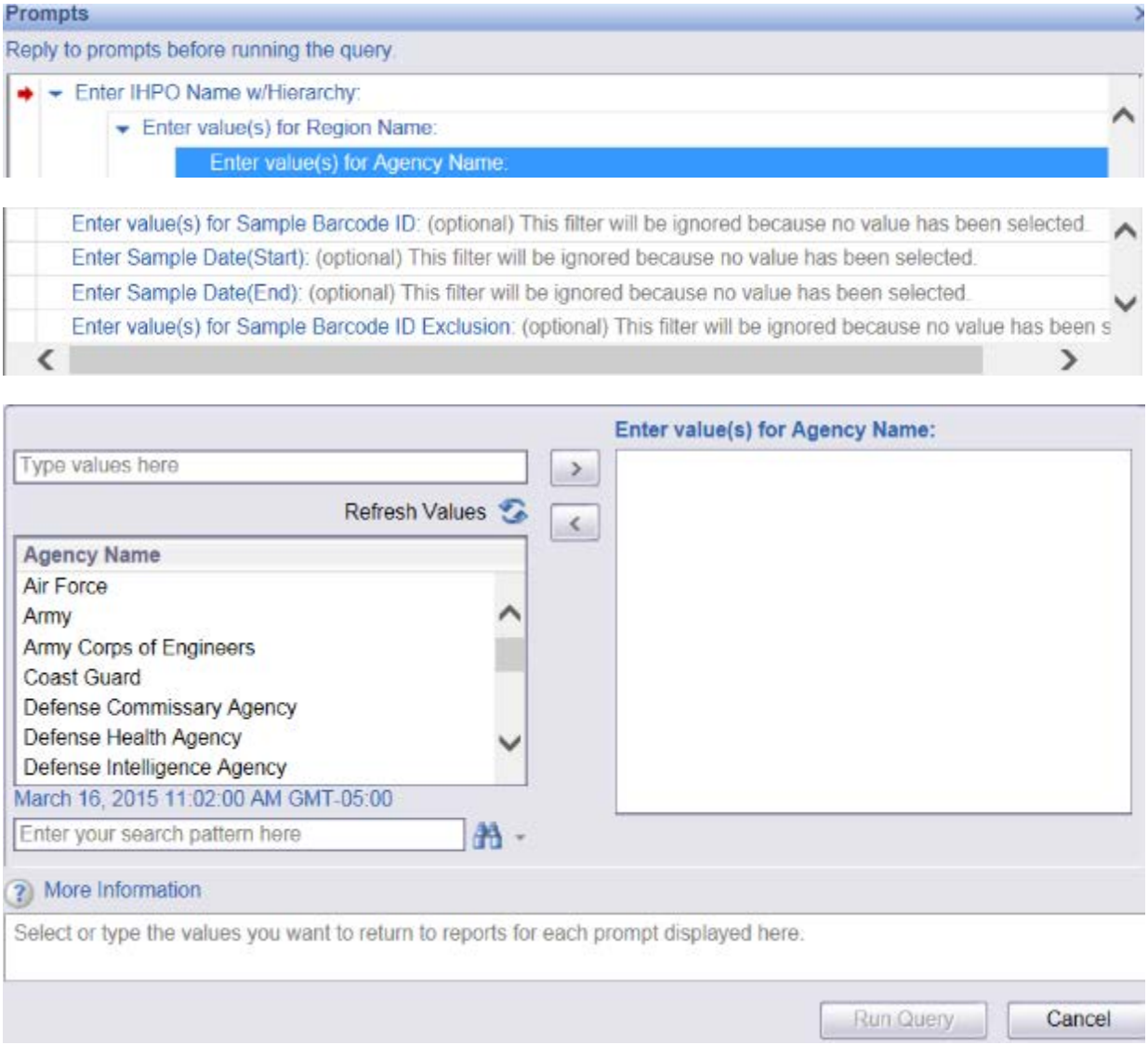


Figure 8: Business Objects- Transactional- 'USAFSAM Lab Sample Submission Form (IH)' Prompts Menu

USAFSAM Sample Submission Form Prompts

Enter value(s) for Agency Name (e.g. Air Force)

Enter value(s) for Region Name: (e.g. Air Combat Command)

Enter IHPO Name w/Hierarchy: (e.g. Davis-Monthan AFB)

Enter value(s) for Sample Barcode ID: (optional)

Note: An alternative method to selecting a date range is to enter the exact Sample Barcode ID's desired in the report. This method maybe desired if there are few samples being submitted to the lab and other samples were taken on the same day which isn't being turned into the lab.

Enter Sample Start date: (e.g. 3/2/2015 12:00:00 AM) use calendar selection

Enter Sample End Date: (e.g. 3/4/2015 12:00:00AM) use calendar selection

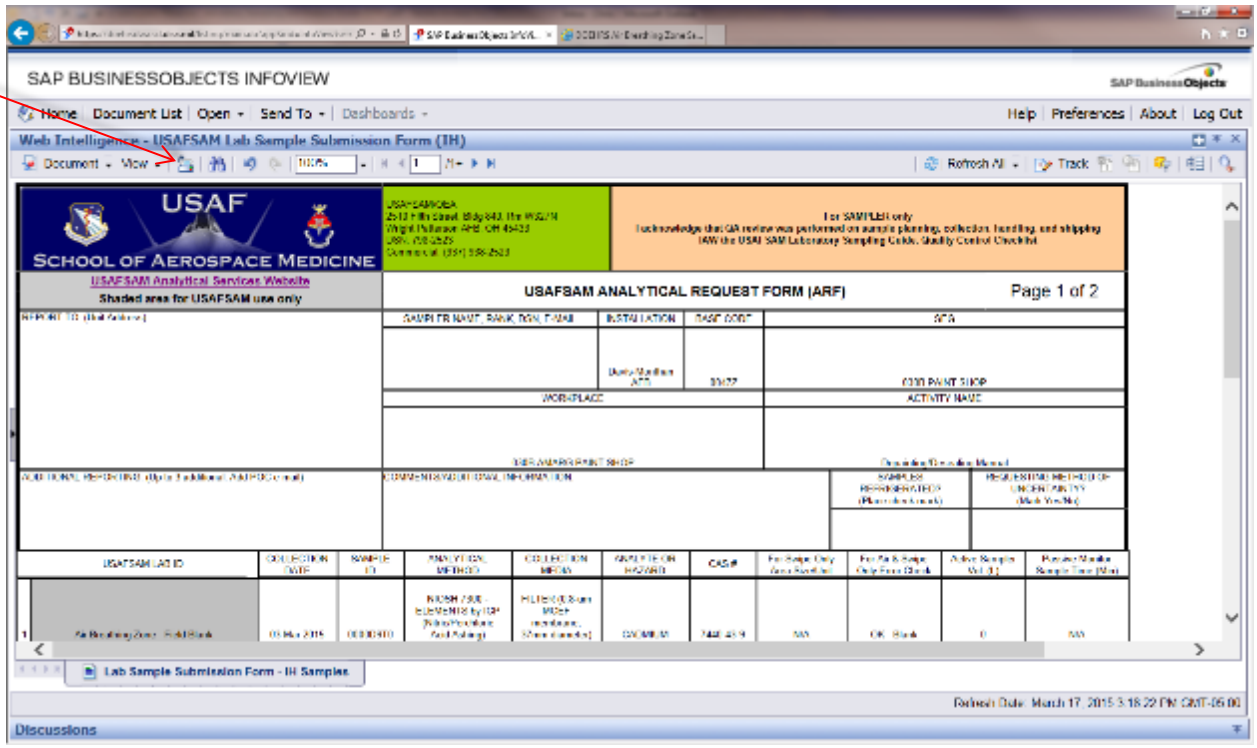
Note: must enter day of actual sampling for start date and day after sampling for End date because the report automatically pulls the time of 12 am for each date picked. If same date is selected for start and end it is essentially picking the same date and time for start and stop date and time and report will be blank.

Enter value(s) for Sample Barcode ID Exclusion: (optional)

Note: This method maybe desired if there are many samples being submitted to the lab and other samples were taken on the same day which isn't being turned into the lab. This option allows the user to enter the Barcode ID that should be excluded from the form.

How to Print the USAFSAM Sample Submission Form

Click the 'Export to PDF for Printing' button



Click the Print button

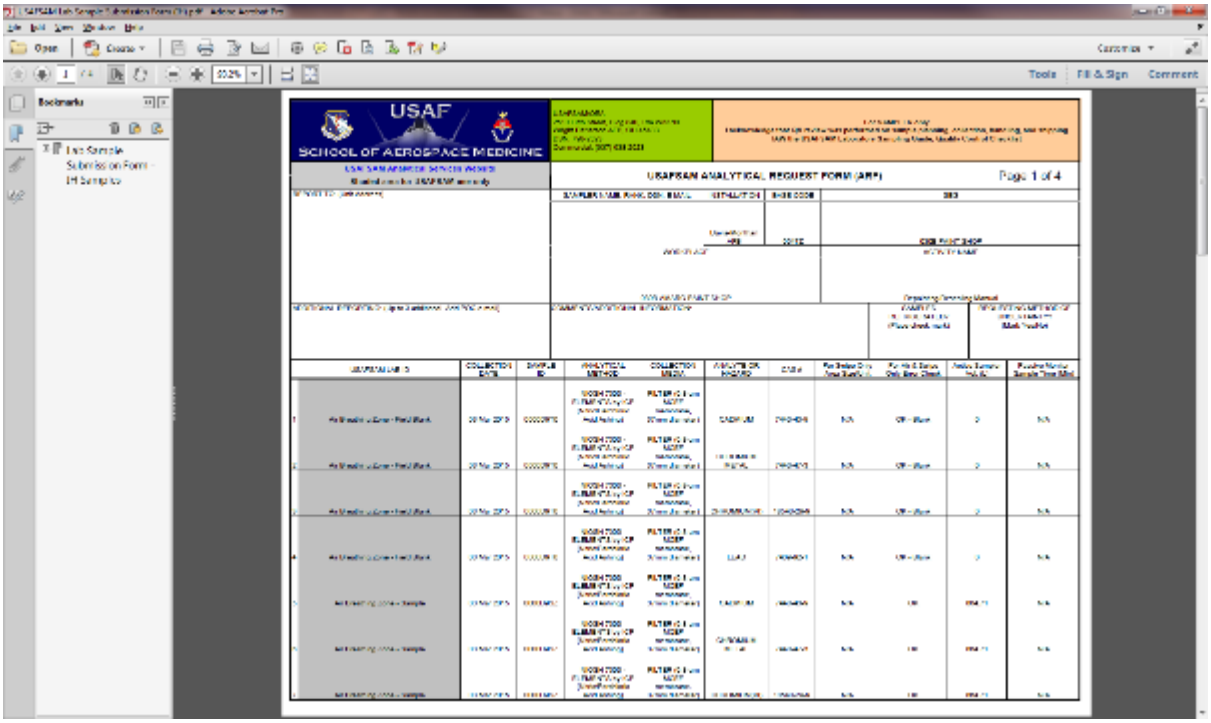


Figure 9: Screenshots showing how to print USAFSAM Sample Submission Form

F.4 Air Sampling Media in DOEHRS

It is important to indicate the type of media actually used during your sampling event. This is accomplished in DOEHRS during the sampling method selection. In the example below, lead has been selected as the analyte of concern and the following list of methods is provided by DOEHRS. Notice multiple NIOSH 7300 methods are listed, each with a different media.

Select	Sampling Methods
○	NIOSH 7082 Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	NIOSH 7105 Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	NIOSH 7700 Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	NIOSH 7701 Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	NIOSH 7702 Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	NIOSH 8003
○	NIOSH 9100 Bulk/Disposable towellettes moistened with wetting agent
○	OSHA 125 Navy Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	OSHA 206 Navy Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
◉ ←	NIOSH 7300 Air/FILTER (0.8-um MCEF membrane, 37mm diameter)
○	NIOSH 7300 Air/FILTER (5-um PVC membrane)
○	NIOSH 7300 Air/IOM 0.8 um MCEF
○	NIOSH 7300 Air/IOM (5-um PVC membrane)
○	EPA 7000B Bulk/Paint Chip
○	No Sampling Method

Air Sampling Methods and Associated Media

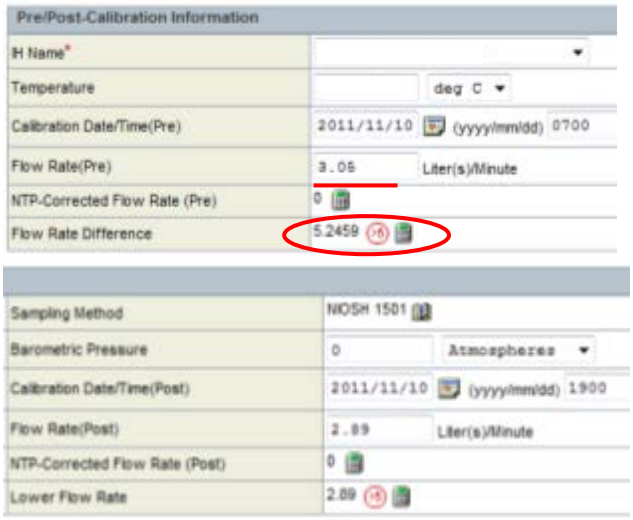
Once a method is selected, the associated media is pulled into the sampling event:

General Sample Information	
Shop	TRH Welding (FFCH4)
SEG	TRH Welding
Sample Date	2011/11/10 (yyyy/mm/dd)
Mission ID	
Sampling Method	NIOSH 7300
Sampling Media	FILTER (0.8-um MCEF membr
Sampling Media Expiration Date	2012/05/25 (yyyy/mm/dd)

Annotating Media in General Sample Information Screen

F.5 Air Sampling Pump Pre- and Post-Calibration in DOEHRS

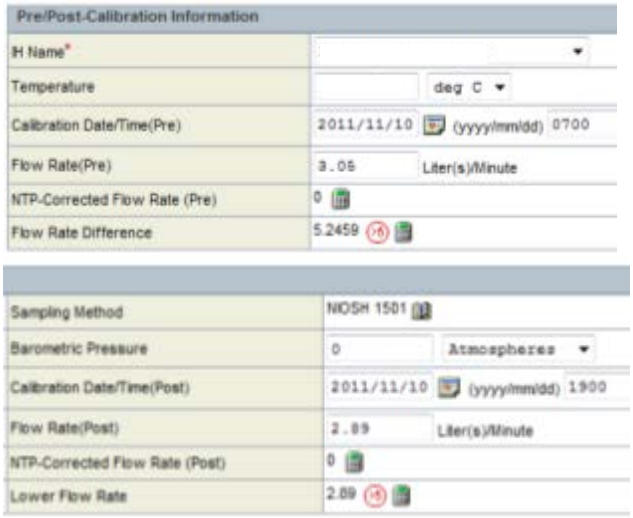
The flow rate difference of the pre- and post-calibration flow rates is automatically calculated by DOEHRS. Values greater than 5% are flagged with the >5 red icon.



Flow Rate Difference

F.6 Normal Temperature and Pressure Corrections in DOEHRS

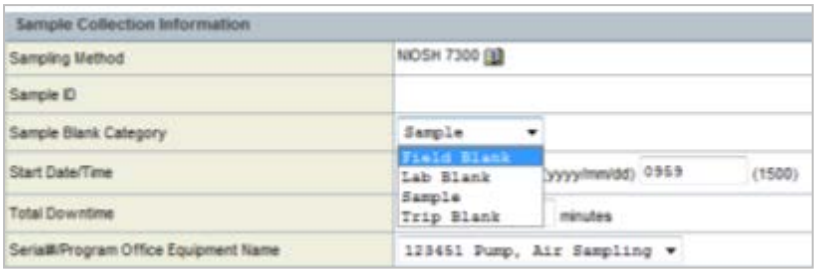
NTP corrections are automatically calculated by DOEHRS when the temperature and pressure are provided in the pre- and post-calibration screen. Do not change the default values; by doing so you may inadvertently alter the sample volume reported to the lab. Volumes reported to the lab should be sample volumes at site temperature and pressure conditions (not corrected to NTP).



NTP Corrections

F.7 Selecting Blanks and Documenting Blank Corrections in DOEHRS

Blank samples should be indicated in DOEHRS using the appropriate dropdown menu.



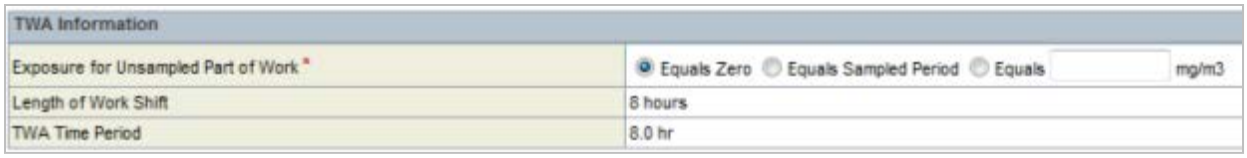
Blank Selections

Blank corrections should be documented when recording sample results in DOEHRS. See below for how the example should be recorded in DOEHRS. Pay attention to units when recording results. The method detection limit /limit of detection will be listed as the *Reporting Limit* on USAFSAM in-house sample reports and will usually be reported as mass/sample (i.e., µg/filter).

Blank Corrections

F.8 Time-Weighted Average Calculations

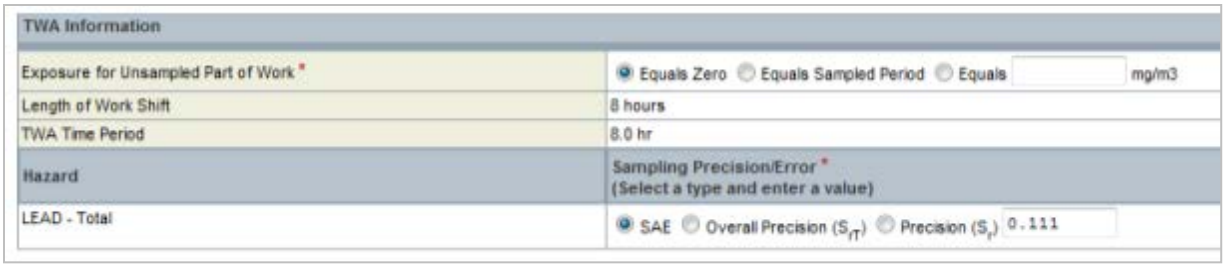
When calculating TWAs in DOEHRS, the user must make an assumption regarding the unsampled period of the work shift. By selecting *Equals Zero*, the user assumes the employee is only exposed to the contaminant during the sampled portion and Equation (7) is used to calculate the TWA. Selecting *Equals Sampled Period*, the user assumes the employee exposure during the unsampled part of the work is equal to the average of the sampled period and Equation (9) is used to calculate the TWA. The third option, *Equals [ ] mg/m*^{3}, may be used if the unsampled exposure is estimated using another method.



Time-Weighted Average Calculations

F.9 Sampling and Analytical Error

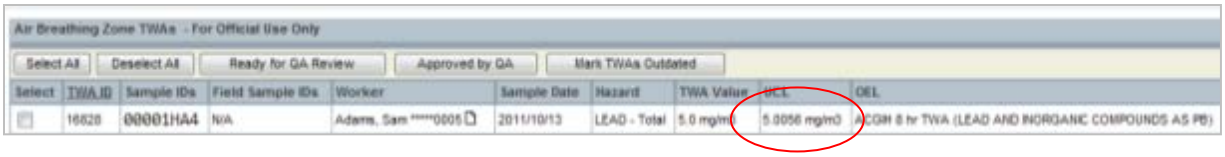
For most analytical methods listed in DOEHRS, the published sampling and analytical error (CV_T or S_{rT}) has been included in the DOEHRS tables. When known, these published error values are used for subsequent calculations including UCL and LCL. For the methods without a published CV_T or S_{rT}, the actual sampling precision/error should be entered in DOEHRS. The example below is a screen shot captured during a TWA calculation for sampling by NIOSH 7300 for lead, which does not have a published S_{rT}. The user has the opportunity to provide S_{rT}, S_r, or SAE values.



Sampling and Analytical Error (SAE)

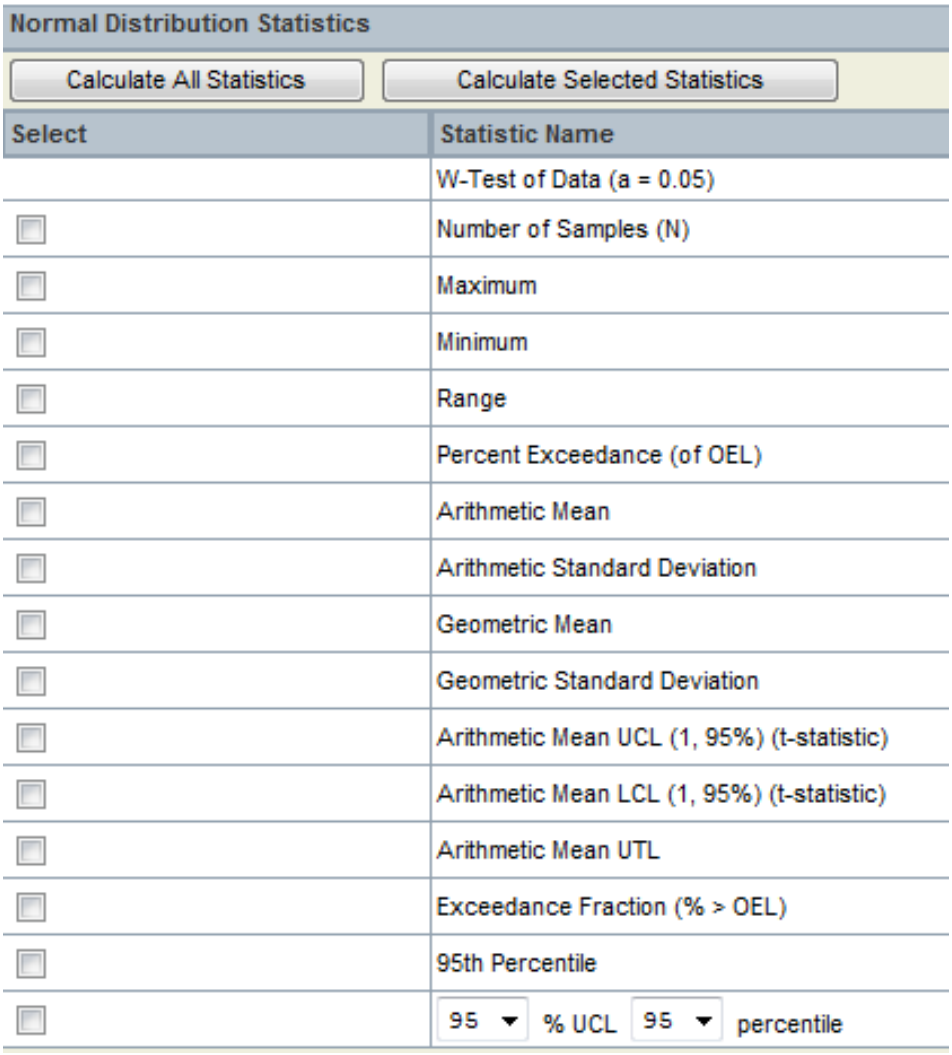
F.10 Upper and Lower Confidence Limits

UCLs are calculated by DOEHRS using the published or user-provided sampling precision/error values. The UCL is always listed in the *Air Breathing Zone TWAs* table.



UCL Calculations Shown on TWA Tables

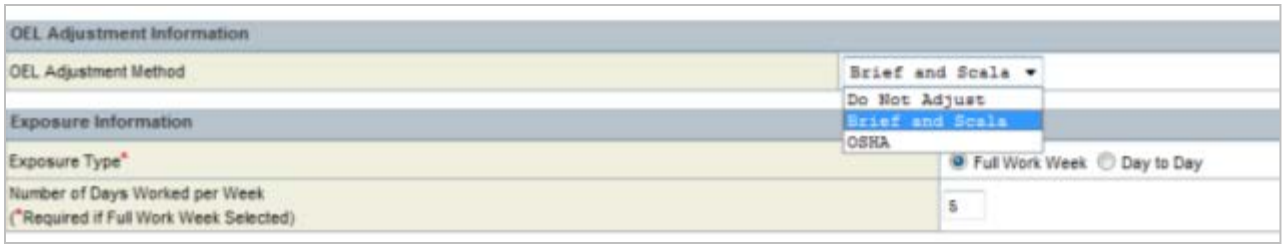
Additionally, once six samples have been collected, an Industrial Hygiene SEG Assessment may be completed using normal distribution statistics. These statistics allow you to adjust the confidence interval and percentile for the UCL as well several additional statists. The default settings are set at 95% UCL 95th percentile IAW with the OSHA Technical Manual.



Available Statistical Analyses in IH Assessments

F.11 Extended Work Shifts

DOEHRS can calculate OEEL adjustments automatically using either the Brief and Scala or OSHA model. For extended work shifts greater than 8 hours, the following screen shot will appear when calculating TWAs. The user must choose *Do Not Adjust, Brief and Scala,* or *OSHA* prior to proceeding with the TWA calculation. As stated in SectionC10, the Brief and Scala method is the preferred method for adjusting OEELs. The user is also required to define the exposure as a day-to-day exposure or if the exposure is present through the full work week. If the latter is true, the number of days in the work week must also be defined by the user.



OEEL Adjustments for Extended Work Shifts

TWA Adjustments for Extended Work Shifts

F12. Example Analyte/Hazard DOEHRS Data Entry Steps

Steps	Entering Chromium (VI)/Hexavalent Chromium Air Sampling (Air Breathing Zone)	
1	Click on the SEG link found under the Industrial Hygiene menu	The SEG - Search page is displayed
2	Enter SEG Name in the search text field and click Search to find SEG	The SEG Search Results page is displayed
3	Click on the desired SEG Name link	The SEG - Detail page is displayed
4	Click on the + node located in front of the SEG Name found under the Industrial Hygiene menu	The SEG Name link on the left will expand with the Samples link visible

5	Under the SEG, click on the Samples link	The Samples page is displayed with a list of samples associated with the SEG based on that particular menu tab *NOTE*: The ⊞ icon is available at this point but will create a new sampling event only for the sample type displayed in that particular menu tab
6	*NOTE*: Make sure to be in the Air Breathing Zone Samples tab	
	Select Add Sampling from the Other Actions pick list or click on the ⊞ icon	The Add Sampling - Step 1 of 4/5 - Select Sampling Type page is displayed *NOTE*: If the ⊞ icon was selected, Step 4 is skipped
7	Select the Sample Type from the pick list • i.e. Air Breathing Zone	
8	Click Continue	The Add Sampling - Step 2 of 4/5 - Select Shop and Processes page is displayed
9	Select the Shop for sampling from the pick list • i.e. Patty (Battelle) Workplace	The processes associated with the shop will display
10	Select (highlight) process for sampling • i.e. Patty (Battelle) Workplace *NOTE:* Hold Control to select multiple selections	The Create Sampling Task - Step 5 of 7 - Select Hazards page is displayed
11	Click Continue	The Add Sampling - Step 3 of 5 - Select Hazards page is displayed
12	*NOTE*: Make sure to be in the Chemical Hazards tab	
	Select the Chromium (VI) for consideration or inclusion in the sampling and click Continue	The Add Sampling - Step 4 of 5 - Select Sampling Method page is displayed
13	If applicable select (highlight) Inspirability and click Add Selected to shuttle selection to the right side	

	NOTE: Hold Control to select multiple selections	
14	Select the Sampling Methods for sampling task	
DOEHRS Sampling Method Choices		
Sampling Media	Sampling Method	DOEHRS Method Description
Filter, (0.8-um, cellulose ester membrane	NIOSH 7605	Chromium, Hexavalent by Ion Chromatography
Filter (5-um PVC membrane)	NIOSH 7605	Chromium, Hexavalent by Ion Chromatography
14	Click Continue	The Air Breathing Zone Sample Form page is displayed
Air Breathing Zone Sample Form		
General Sample Information		
15	Enter data or select data from the pick list in the following fields: • Sample Date: i.e. 2014/06/21 (date samples were taken) • Status: i.e. In Progress • Sampling Media Expiration Date: i.e. 2014/12/12	
Personnel Information		
16	Click on the icon to search for Personnel Name (individual used for the sampling)	The Find Personnel page is displayed
17	Select radio button next to Name and click Add to Form *NOTE*: Only one person per form is permitted	Returned to the Air Breathing Zone Sample Form *NOTE*: Majority of fields for individual will be automatically populated
18	Enter or select data for the following fields: • Length of Work Shift: i.e. 8 hrs	Ensure that the work shift entered will not be exceeded by any sampling period. The system will display an error of "Sample Period Cannot Exceed Work Shift" when

	• Exposure Origin: i.e. Operator Position • Sample Position: i.e. Right shoulder	attempting to run a TWA calculation. If this were to occur the work shift can be changed on the sample event form to compensate for the discrepancy of incompatible times
Control Information		
19	Click on the ⊞ icon to add control	The Find Control page appears giving the option to conduct a Quick Search or an Advanced Search to find Control
20	Select PPE from the Control Type pick list found under Advanced Search and click Search	The Find Control Result page is displayed
21	Select the radio button for the PPE control and click Add to Form • i.e. 3M 6000 Series Full Face Air Purifying Respirator	Returned to the Air Breathing Zone Sample Form *NOTE*: The control is now listed under the Control Information tile
Program Office Equipment Information		
NOTE: Calibrator and air sampling pump must be added already as program office equipment under the Administration menu by users with the equipment administrator role		
22	Click on the ⊞ icon to add the Air Sampling Pump and Calibrator	The Air Breathing Zone Sample Form - Program Office Equipment page is displayed
Air Breathing Zone Sample Form - Program Office Equipment		
Program Office Equipment Information		
23	Select the desired Air Sampling Pump from the Serial #/Program Office Equipment Name pick list • i.e. PATTY Pump, Air Sampling	The fields will automatically populate for Manufacturer, Model # and Last Calibration Date

Calibration Equipment Information		
24	Select desired Calibrator from the Serial #/Program Office Equipment Name pick list • i.e. PATTY Calibrator, Air Sampling Pump	The fields will automatically populate for Manufacturer, Model # and Last Calibration Date
Pre/Post-Calibration Information		
25	Open tile and enter data or select data from the pick lists in the following fields: • IH Name: i.e. Johnson, Justin • Temperature: • Barometric Pressure: • Calibration Date/Time(Pre): i.e. 2014/06/21/0700 • Calibration Date/Time(Post): i.e. 2014/06/22/1200 • Flow Rate(Pre): i.e. 2 Liter(s)/Minute • Flow Rate(Post): i.e. 2 Liter(s)/Minute	
	NOTE: Do not adjust for temperature/pressure if you are using the Dry Cal for calibration. DOEHRS will perform auto correction for you if ambient conditions data is entered into the system.	
26	Click Save	Returned to Air Breathing Zone Sample Form
Note: Once you save the DOEHRS Sample Form you can no longer go back to change the method! You will have to re-enter the above information with the proper corrections.		
Air Breathing Zone Sample Form		
Hazard Information		
27	Open the Hazard Information tile and ensure the correct Hazard is shown • Chromium (VI)	
Individual Samples		

28	Click on the icon to add a sample	The Air Breathing Zone Sample Form - Individual Sample ID Information page is displayed
Air Breathing Zone Sample Form - Individual Sample ID Information		
Sample Collection Information		
29	Enter data or select data from the pick lists in the following fields if applicable: • Field Sample ID: i.e. XXX-Field Blank • Sample Blank Category: Field Blank • Lab Sample ID: • Start Date/Time: i.e. 2014/06/21 / 0800 • Stop Date/Time: i.e. 2014/06/21 / 0800 • Total Downtime: i.e. 0 minutes • Total Sampling Time: i.e. 0 minutes (to ensure accuracy click on to calculate) • Serial#/Program Office Equipment Name(Pre Cal Date Time): i.e. PATTY Pump, Air Sampling (2014/06/21 0700) (air sampling pump used during sampling) • Total Volume Sampled: i.e. 0 (click on to calculate) • Sample Description/Source of Contaminant:	
Gravimetric Analysis		
30	Enter data in the following fields if applicable: • Sampled Weight (Pre): • Sampled Weight (Post): • Sampled Weight (Net): will auto-populated according to figures entered above. This is the weight added to the sample filter.	
Measurement Information (If sending samples to USAFSAM, just verification is needed)		

31	Open tile and enter data or select data from the pick lists in the following fields: • Invalid: Select the check box if applicable • Analytical Method: i.e. NIOSH 7605 • MDL/LOD: • Not Detected: Select the check box if applicable • Mass Result: • Concentration Result: i.e. Measured >2.2, Corrected=4.9 UOM mg/m3 • Comments:	
Location Information		
32	Open the Location Information tile and ensure the correct Parent Location is shown	
	If the correct location is not shown click on the on the icon to search for Parent Location	The Locations - Search page is displayed
33	Enter Location Name or leave blank and click Search	The Locations - Search Results page is displayed
34	Select radio button next to Location Name and click Add To Form	Returned to Air Breathing Zone Sample Form - Individual Sample ID Information and the location now appears in the Parent Location field
Program Office Information		
35	Open the Program Office Information tile and select the Responsible Program Office Personnel from the pick list and click Save	Returned to Air Breathing Zone Sample Form
Air Breathing Zone Sample Form		
Lab Information		

36	Open tile and enter data or select data from the pick lists in the following fields if applicable: • Lab Name: i.e. USAFSAM-AD (GLOBAL) • Date Sent: i.e. 2014/06/23 • Requested Turn-around: i.e. 15 days • Date Analyzed: • Date Reported: • Expected Date of Return: i.e. 2014/07/21 • Date Returned: • Comments:	
Chain of Custody		
37	Open the tile and click on the Chain of Custody Form link	The Air Breathing Zone Sample Form Chain of Custody page is displayed
Air Breathing Zone Sample Form - Chain of Custody		
Chain of Custody		
38	Enter data or select data from the pick lists in the following fields if applicable: • Installation: i.e. Wright-Patterson • Project #: • Project Officer: i.e. Lenos, Eddie • Packed By: i.e. Johnson, Justin • Carrier Used: i.e. FEDEX • Airbill #: • Date Shipped: i.e. 2014/06/23 • Seal Intact: Select the check box if applicable • Comments:	

Sample Records		
39	Click on the ⊞ icon to add Sample Records	
Air Breathing Zone Sample Form-Chain of Custody - Sample Record		
40	Enter data or select data from the pick lists in the following fields if applicable: • Sample ID: select from picklist • Relinquished By: • Relinquished Date/Time: • Received By: • Received Date/Time: • Comments	
41	Click Save	Returned to Air Breathing Zone Sample Form-Chain of Custody page
Air Breathing Zone Sample Form - Chain of Custody		
42	Click Save	Returned to Air Breathing Zone Sample Form
Air Breathing Zone Sample Form		
Associated Samples		
43	Open tile and if applicable select (highlight) Samples and click Add Selected to shuttle selection to the right side *NOTE:* Hold Control to select multiple selections	
Ambient Conditions		
44	Open tile and enter data or select data from the pick lists in the following fields if applicable: • Ambient Barometric Pressure (Start/Pre: • Ambient Barometric Pressure (End/Post): • Ambient Temperature (Start/Pre):	

	• Ambient Temperature (End/Post): • Relative Humidity (End/Post): • Wind Speed: • Wind Direction:	
Location Information		
45	Open the Location Information tile and ensure the correct Parent Location is shown	
	If the correct location is not shown click on the on the icon to search for Parent Location	The Locations - Search page is displayed
46	Enter Location Name or leave blank and click Search	The Locations - Search Results page is displayed
47	Select radio button next to Location Name and click Add To Form	Returned to Air Breathing Zone Sample Form - Individual Sample ID Information page and the location now appears in the Parent Location field
Attachments		
48	Click on the icon to upload any document pertaining to survey	The Upload Attachment File page is displayed
49	Enter the Name for document in the Description field *NOTE*: This step may be accomplished after browsing for document. Click Browse to locate and select document to upload	
50	Click Upload	Returned to Air Breathing Zone Sample Form
Program Office Information		
51	Open the Program Office Information tile and select the Responsible Program Office Personnel from the pick list	
52	Click Save	The Samples page is displayed

APPENDIX G: TEMPLATE QC CHECKLIST

Shop Name:		**BLDG:**		
SEG Name:				
Item No.	**PRE-SAMPLING**		**Yes**	**No**
1	Complete an assessment using breathing zone calculations or using a direct reading instrument to determine the need for personal air sampling.		☐	☐
2	Complete *USAFSAM Air Sampling Strategy Form.		☐	☐
3	Use the Automatic Sampling Guide (ASAGE) to ensure proper strategy & method are chosen and contact "the USAFSAM Laboratory" (DSN-798-2523) to affirm availability of method analysis.		☐	☐
4	Call Shop Supervisor/POC to schedule sampling time and date (See Step 14 Note:)		☐	☐
	-Name of Person spoke with:			
	-Evaluation Date Scheduled:			
5	Ensure equipment is charged and available for use.		☐	☐
6	Populate applicable information of the **USAFSAM Air Sampling Narrative Form. (General Information and General Sample Information sections)		☐	☐
Item No.	**SAMPLING**		**Yes**	**No**
7	Pre-Calibrate air sampling pump(s) (**USAFSAM Air Sampling Narrative Form)		☐	☐
8	Complete your sampling in the field. (**USAFSAM Air Sampling Narrative Form)		☐	☐
	Annotate sampling pump on and off times, and when, where and how personnel perform the task (**USAFSAM Air Sampling Narrative Form)		☐	☐
9	Ensure USAFSAM Air Sampling Narrative Form is complete (all except post sample information)		☐	☐
Item No.	**POST-SAMPLING**	**N/A**	**Yes**	**No**
10	Post-Calibrate air sampling pump(s) (**USAFSAM Air Sampling Narrative Form)		☐	☐
11	Enter all data from the **USAFSAM Air Sampling Narrative Form in DOEHRS		☐	☐
12	Generate DOEHRS data (XML file) and email lab (USAFSAM.OEHTA_analytical@WPAFB.af.mil.)	☐	☐	☐
13	Generate USAFSAM Lab Sample Submission Form (Business Objects)		☐	☐
14	Ensure sample is shipped according to the method requirement. Ship samples within the analytical method parameters.(Note: consider not sampling on a Friday for hazards with short holding times)		☐	☐
15	Lab Samples sent to:		☐	
16	DOEHRS entries completed (To include making Observations and Notes comments)		☐	☐

*USAFSAM Air Sampling Strategy Form is used in the collection of information to produce an air sampling strategy

**USAFSAM Air Sampling Narrative Form is used to collect air sampling information needed to annotate/describe how the tasks are being accomplished by the worker as well as to properly populate DOEHRS
Forms can be found on the DOEHRS Support Office Website
(https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=751)

USAFSAM AIR SAMPLING EVALUATION CHECKLIST (V3)

APPENDIX H: DEFINITIONS

1. *Occupational and Environmental Exposure Limit (OEEL).* OEELs are limits of exposure established to protect personnel from occupational and environmental health threats. The OEEL is the most appropriate exposure limit adopted from established recognized standards including, but not limited to, those in AFIs and AFOSH standards; the latest edition of the *TLV® Booklet* published annually by ACGIH; 29 CFR 1910.1000 Tables Z-1, Z-2, and Z-3; and 40 CFR 141.

2. *Action Level (AL).* The AL is the exposure level that dictates active air monitoring, medical monitoring, and/or employee training. The AL for airborne exposures is typically one-half the OEEL for TWA exposures except where 29 CFR 1910 designates a different concentration or where the statistical variability of sample results indicates a lower fraction of the OEEL should be used as the AL.

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

4. *Threshold Limit Value (TLV).*The TLV is a level of airborne concentrations of chemical substances to which it is believed nearly all workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects. TLVs are established by the ACGIH. While the OSHA PEL is legally enforceable, the TLV is a recommendation from ACGIH and is only a guideline. Most TLVs are 8-hour TWA concentrations; however, a TLV may also be a short-term exposure limit or ceiling.

5. *Averaging Time.* An OEEL averaging time refers to the time span for which an average exposure is estimated. The appropriate averaging time is set by the sponsor of the OEEL (OSHA, ACGIH®, etc.) and can extend from seconds and minutes to a single shift, to multiple shifts, to months and years. Four typical averaging periods are listed below:

6. *8-hour Time-Weighted Average (TWA).* The time weighted average concentration for a normal 8-hour workday and a 40-hour work week that cannot be exceeded. The most common industrial hygiene TWA duration is 8 hours, which is the length of the common work day. A TWA may be determined by a single sample or by mathematical combination of one or more consecutive samples.

7. *Short-Term Exposure Limit (STEL).* A 15-minute TWA exposure that should not be exceeded at any time during the workday. The STEL is not an independent exposure limit but rather supplements the 8-hour TWA in cases where there are recognized acute effects from a substance whose toxic effects are primarily chronic. Exposures above the 8-hour TWA OEEL up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. Also, there should be at least 60 minutes between successive exposures in this range.

8. *Excursion Limit (EL).* Only one contaminant, asbestos, currently has a substance-specific standard with an OSHA EL. The OSHA EL for asbestos was set as a TWA over a 30-minute period, which distinguishes it from a STEL, which has a shorter averaging period. Additional

substances can be found in 1910.1000 Table Z-2 (i.e., benzene, beryllium, toluene, etc.). These substances list maximum acceptable peaks above the acceptable ceiling concentration and the allowed maximum duration. Additionally, ACGIH states that for the vast majority of substances with a TLV-TWA, there is not enough toxicological data available to warrant a STEL. For these substances, excursions may exceed three times the TLV-TWA for no more than a total of 30 minutes during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded.

9. *Ceiling (C).* A ceiling is the contaminant concentration that should not be exceeded during any part of the working exposure. If instantaneous monitoring is not feasible, samples are collected and assessed as a 15-minuteTWA exposure. Ideally, ceiling measurements are taken using a DRI.

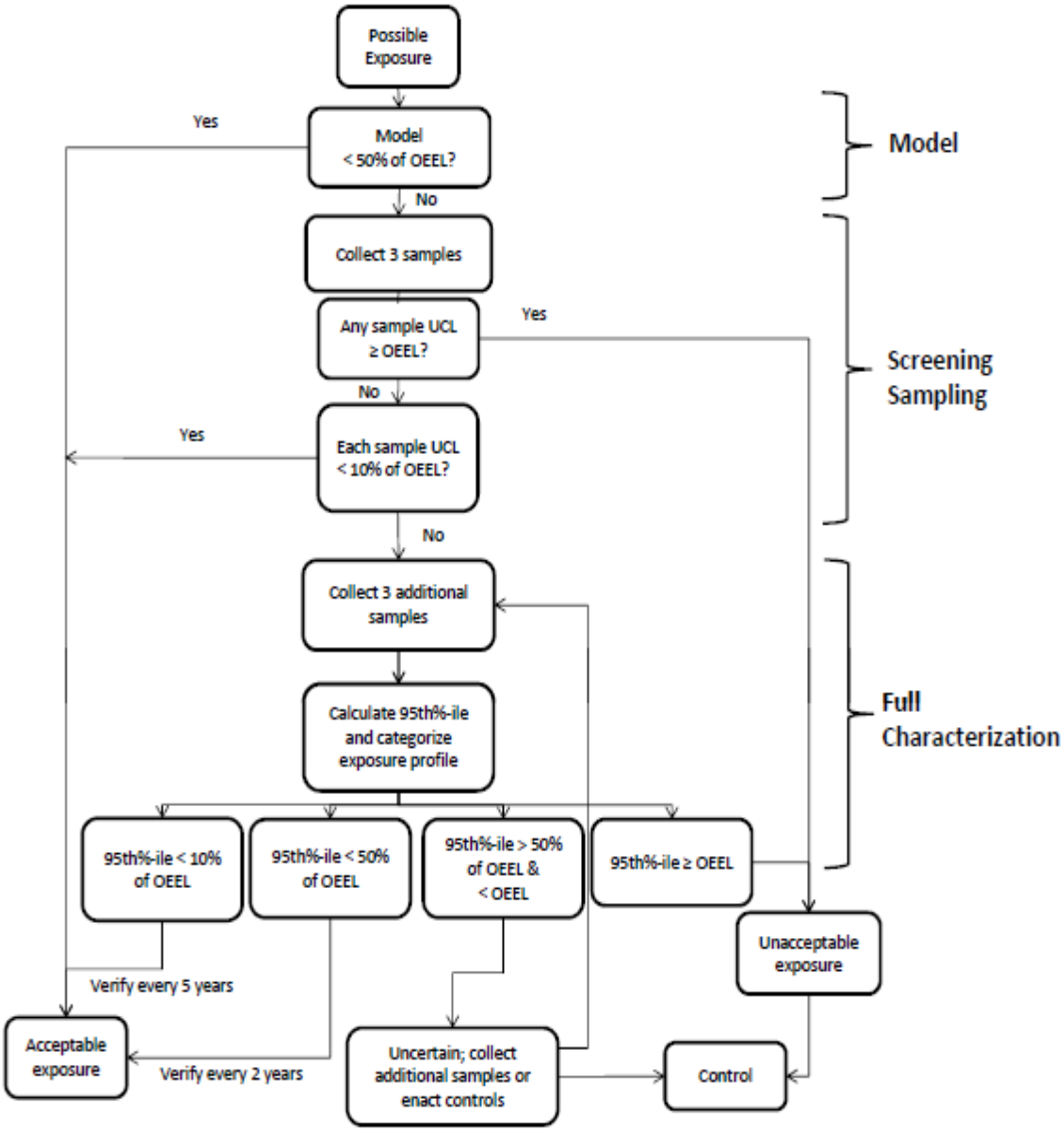
10. *Gases*. Substances that completely occupy a space and can be converted to a liquid or solid by increasing pressure or decreasing temperature. A gas is a chemical substance whose molecules are moving freely within a space in which they are confined at normal temperature and pressure. Gases assume no shape or volume. OEELs for gases are typically established in terms of parts of gas per million parts of contaminated air by volume (ppm).

11. *Vapors*. A gaseous form of a substance that is normally a solid or liquid at room temperature. The amount of vapor given off by a chemical substance is expressed as the vapor pressure and is a function of temperature and pressure. OEELs for vapors are typically established in terms of parts of vapor per million parts of contaminated air by volume (ppm).

12. *Aerosol*. Liquid droplets or solid particles dispersed in air. Aerosols may be characterized by their aerodynamic behavior and the site of deposition in the human respiratory tract. OEELs for aerosols are usually established in terms of mass of the chemical substance in air by volume (mg/m^3). Other terms used to describe aerosols include:

    - *Dust*. Solid particles generated by mechanical action (crushing, grinding, impact, etc.). Size ranges are usually between 0.1 µm and 30.0 µm.
    - *Fume*. Airborne solid particles formed by condensation of vapor (i.e., welding fumes). Size ranges are usually between 0.001 µm and 1.0 µm.
    - *Mist*. Suspended liquid droplets generated by atomization of bulk liquids through mechanical processes such as splashing, bubbling, or spraying. Size ranges are between 0.01 µm and 100.0 µm.
    - *Fogs*. Suspended liquid droplets generated by the physical condensation of the vapor phase. These droplets are typically smaller than mechanically generated mists and range between 0.01 µm and 10.0 µm.
    - *Fibers*. Elongated particulates with an aspect ratio (length to width) of 3:1.
    - *Smoke*. An aerosol of fine particulate matter originating from combustion. Smoke usually contains droplets and dry particles. Size ranges are usually between 0.01 µm and 1.0 µm.

APPENDIX I: EXPOSURE ASSESSMENT STRATEGY FLOWCHART



APPENDIX J: CENSORED DATA ANALYSIS

A data set is considered censored when one or more measurements are less than the limit of detection (LOD) for a particular combination of sampling method (using the laboratory-reporting limit), flow rate, and sampling time.

A censored data set can be simple or complex, with a simple data set containing measurements with a single LOD or two or more LODs all at the low end of the data set. A complex data set is one that contains measurements at two or more LODs with uncensored (detects) measurements scattered in between.

Tables J-1 and J-2 are examples for both a simple and complex data set, respectively. Censored data should not be ignored or omitted, since by doing so the estimated mean will be biased high, and by setting to zero, the estimated mean will be biased too low [J-1]. In the worst-case approach, assigning the value of the LOD will bias the estimated mean high and cannot be used to prove that an unacceptable risk exists [J-2].

Table J-1: Simple Censored Data Set

Rank	"<"	TWA (mg/m^3)
1	<	1.01
2	<	2.02
3	<	2.20
4		3.06
5		4.41
6		7.23
7		8.29
8		9.52
9		19.94
10		20.25

Table J-2: Complex Censored Data Set

Rank	"<"	TWA (mg/m^3)
1	<	1.01
2		2.02
3		2.20
4		3.06
5	<	4.41
6		7.23
7	<	8.29
8		9.52
9		19.94
10		20.25

The data analysis methods for estimating the parameters (i.e., geometric mean, geometric standard deviation, and 95th percentile) of the exposure profile that contain censored data tend to fall into one of four categories: 1) substitution methods, 2) log-probit regression methods, 3) maximum likelihood estimation methods, and 4) non-parametric methods.

The maximum likelihood estimation (MLE) is a method for estimating the parameters (i.e., mean and standard deviation) of a statistical distribution from observed data and is considered the "gold standard" for analysis when dealing with censored data [J-3]. The MLE method utilizes the mean and standard deviation of the log-transforms to maximize the probability of observing the data if they were randomly drawn from the assumed statistical distribution.

It is assumed that random occupational and environmental samples are lognormally and independently distributed both within any particular workshift and over many daily exposure averages [J-4].

The log-probit regression utilizes the log-probability plot to estimate the geometry mean and geometric standard deviation from the regression coefficients [J-5]. The data set is sorted, log-transformed, and plotted against z-value calculated from the ranked plotting position. A linear regression is fit to the non-censored data to estimate the geometric mean (GM) and geometric standard deviation (GSD).

Substitution methods are the most often utilized method because they are easy to implement and have the advantage of automatically accommodating for multiple LODs. In the substitution methods, each LOD result is replaced with an appropriately chosen value of LOD/2 or LOD/$\sqrt{2}$. The conventional statistical analysis is performed to generate estimations of the GM and GSD, which then can be used to estimate the compliance statistics such as the 95th percentile. Depending on the true GSD and the percent censored data, substituting LOD/2 or LOD/$\sqrt{2}$ will bias the GM and GSD of the exposure profile either high or low. The LOD/2 method assumes a uniform distribution of samples below the LOD, meaning that every value between zero and LOD has an equal probability of occurring. The LOD/$\sqrt{2}$ method assumes that the distribution of samples below the LOD is not uniform and the probability of occurrence is better approximated by the right triangle.

When the data set is highly censored (nondetectables = 30%) and highly skewed (GSD of approximately 3.0 or greater), then the LOD/2 method is more appropriate; otherwise, the LOD/$\sqrt{2}$ would be more appropriate [J-1].

Figures J-1 and J-2 graphically depict the comparison of the LOD/2 and LOD/$\sqrt{2}$ substitution methods' ability to represent the area under the probability distribution curve of the true lognormal distribution for samples below the LOD.

The DOEHRS statistical package utilizes the LOD/$\sqrt{2}$ substitution method to analyze all censored data sets when calculating a TWA. DOEHRS applies the LOD/$\sqrt{2}$ substitution to the individual sample level to calculate the statistics.

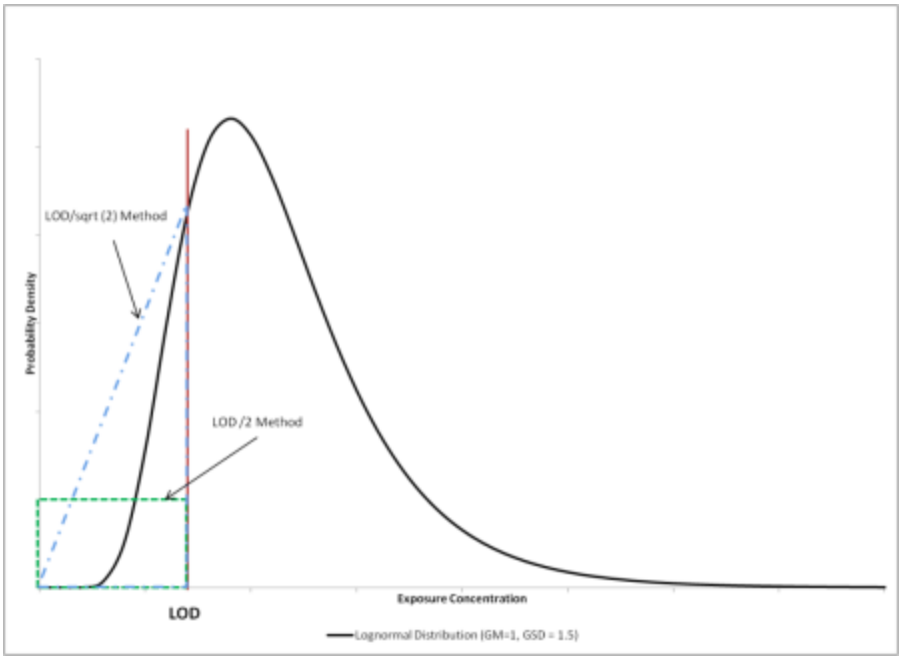


Figure J-1: Substitution Approximation

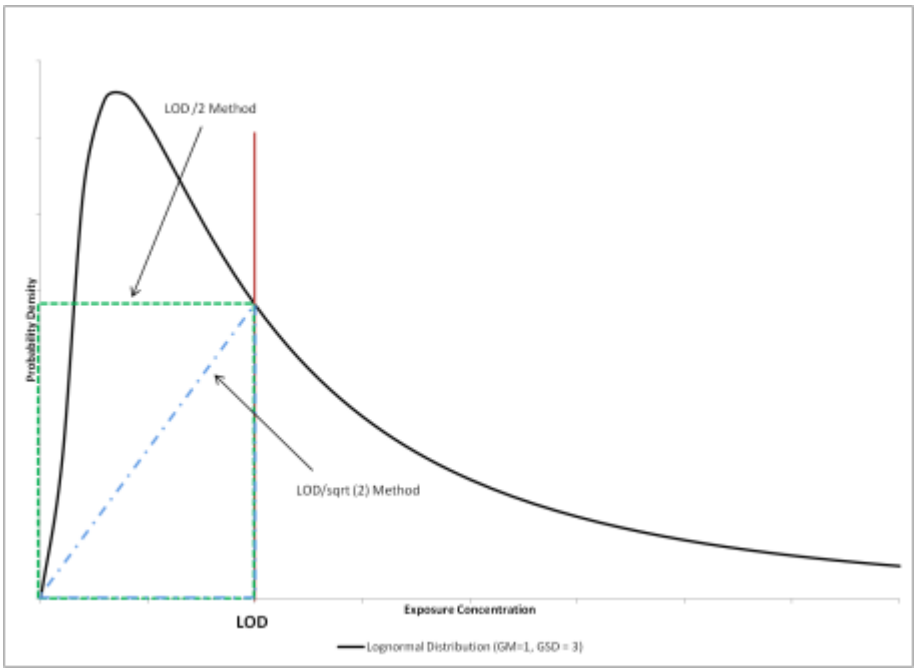


Figure J-2: Substitution Approximation (Large Censored Data Set/Large GSD)

Bases should plot a histogram of the detectable data only, and if the frequency in the first or second interval is less than one or more of the subsequent intervals, the LOD/√2 substitution method should be adequate. Otherwise, if the frequency of the data steadily declines in every interval, then LOD/2 would be appropriate [J-1]. A histogram is a visual representation of the data collected into groups or bins and frequency of occurrence Figure J-3 is an example of a data set where the LOD/√2 would be appropriate, and Figure J-4 is an example of a data set where the LOD/2 would be appropriate.

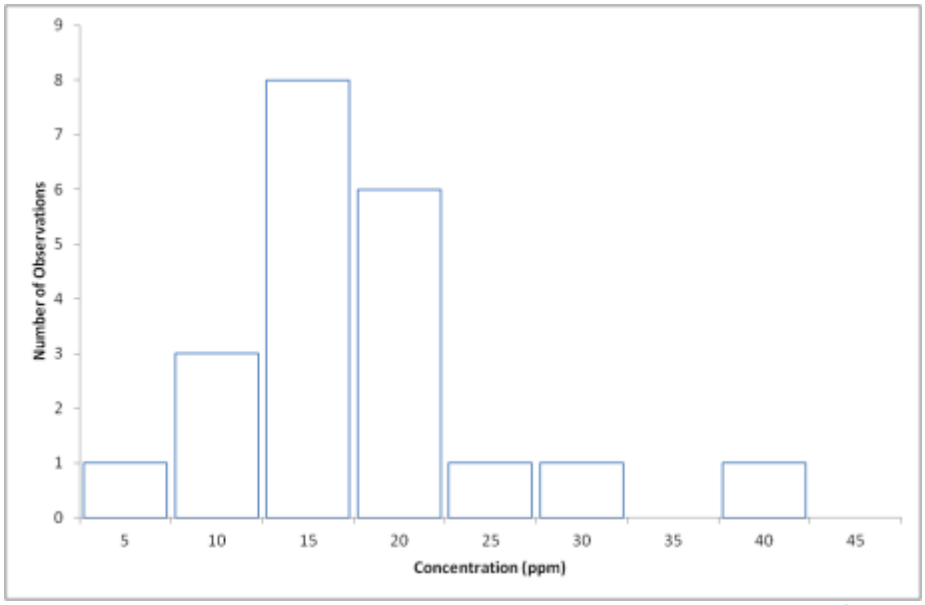


Figure J-3: A Histogram of Concentration Frequencies (LOD/√2)

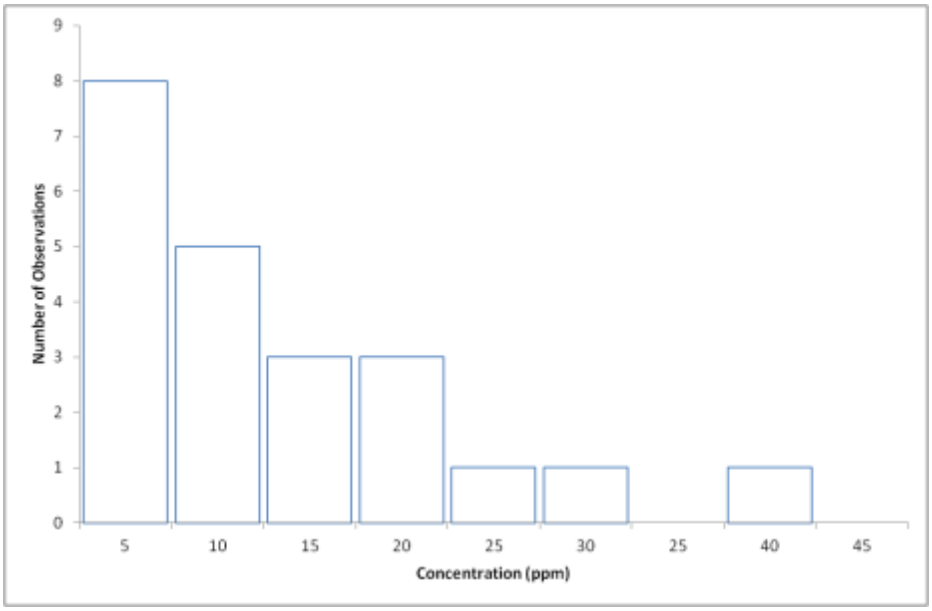


Figure J-4: A Histogram of Concentration Frequencies (LOD/2)

A third substitution method, called β-substitution, involves a number of calculations from the uncensored data to derive a β factor for adjusting each LOD value [J-3]. The β-substitution algorithm can be performed using a spreadsheet; the intent is to be used in place of LOD/2 or LOD/√2 and that the β factor will result in near zero bias.

The data analysis methods for estimating the parameters described above can be performed using a spreadsheet or statistical software package. An example spreadsheet is posted on the USAFSAM Analytical Services website (https://hpws.afrl.af.mil/dhp/OE/ESOHSC/pages/index.cfm?id=748) [restricted access] for use by base-level personnel. There are no general procedures that are applicable in all cases, so an individual needs to select the appropriate method with consideration of the degree of censoring (% nondetects), the number of samples, the required accuracy, and the goal of the exposure assessment. When the nondetect portion of the data set is small (<15%), the MLE, β-substitution, log-probit, and appropriate LOD/2 or LOD/√2 should be adequate to perform statistical analysis. For larger (>15%) censored data sets, the MLE, β-substitution methods, or other statistical methods should be utilized.

Even though in principle the MLE method can be applied to virtually any sample size and where percent censored data exceeds 50%, the β-substitution method may be the more appropriate choice when dealing with sample sizes less than 20 [J-3]. For highly (>70%) censored data sets, it is very difficult to produce good estimates of decision statistics. Individuals should contact the USAFSAM ESOH Service Center for consultation before proceeding with analysis. Regardless of which analysis method is chosen, the individual assessor should explain his/her choice and how it may affect the data supporting the assessment to avoid misrepresenting the data or biasing the results.

REFERENCES

J-1. Hornung RW, Reed LD. Estimation of average concentration in the presence of nondetectable values. Appl Occup Environ Hyg 1990; 5(1):46-51.

J-2. U.S. Environmental Protection Agency. Guidelines for exposure assessment. Washington, DC: U.S. EPA; 1992:66-8. Report No. EPA/600/Z-92/001.

J-3. Ganser GH, Hewett P. An accurate substitution method for analyzing censored data. J Occup Environ Hyg 2010; 7(4):233-44.

J-4. Leidel NA, Busch KA, Lynch JR. Occupational exposure sampling strategy manual. Cincinnati: National Institute for Occupational Safety and Health; 1977 Jan. DHEW (NIOSH) Publication No. 77-173.

J-5. Hewett P. Analysis of censored data. In: Ignacio JS, Bullock WH, eds. A strategy for assessing and managing occupational exposures, 3 ed. Fairfax, VA: AIHA Press; 2006:415-21.

BIBLIOGRAPHY

American Conference of Governmental Industrial Hygienists. Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: ACGIH; 2001.

Decamp D, Schneider D, Batten T. Industrial chemical air sampling strategies. Presented at the 2011 Air Force Environment, Safety and Occupational Health Training Symposium; 2011 Mar 21-25; Nashville, TN.

Department of Laboratory Sciences. DLS customer guide, ver. 3, rev. 5. Landstuhl, Germany: U.S. Army Public Health Command-Europe; 2010 Apr 23. Retrieved 1 February 2014 from http://www.chppmeur.healthcare.hqusareur.army.mil/sites/dls/downloads/DLS_Customer_Guide.pdf.

Finkelstein MM, Verma DK. Exposure estimation in the presence of nondetectable values: another look. AIHAJ 2001; 62(2):195-8.

Gabos KG. Defense Occupational and Environmental Health Readiness System (DOEHRS) guidance. Brooks City-Base, TX: U.S. Air Force School of Aerospace Medicine; 2009 Jul. Retrieved 1 February 2014 from www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA510897.

National Institute for Occupational Safety and Health. Particulates not otherwise regulated, respirable: method 0600. In: NIOSH manual of analytical methods (NMAM), 4th ed. 1998. Retrieved 10 April 2013 from http://www.cdc.gov/niosh/docs/2003-154/pdfs/0600.pdf.

National Institute for Occupational Safety and Health. Silica, crystalline, by XRD (filter redeposition): method 7500. In: NIOSH manual of analytical methods (NMAM), 4th ed. 1998. Retrieved 10 April 2013 from http://www.cdc.gov/niosh/docs/2003-154/pdfs/7500.pdf.

National Institute of Standards and Technology., National Voluntary Laboratory Accreditation Program. 2013 Jun 4. Retrieved 1 February 2014 from http://www.nist.gov/nvlap/.

Navy Environmental Health Center. Industrial hygiene field operations manual. Norfolk, VA: NEHC; 1999 Mar. Retrieved 7 November 2011 from http://www.med.navy.mil/sites/nmcphc/industrial-hygiene/industrial-hygiene-field-operations-manual/Pages/default.aspx.

Occupational Safety & Health Administration. Section 1.2, Principle. In: Quartz and cristobalite in workplace atmospheres. OSHA Method Number ID-142. Retrieved 10 April 2013 from https://www.osha.gov/dts/sltc/methods/inorganic/id142/id142.pdf.

Occupational Safety & Health Administration. Sampling and analytical methods. (n.d.). Retrieved 1 February 2014 from http://www.osha.gov/dts/sltc/methods/index.html.

Perkins JL, Cutter GN, Cleveland MS. Estimating the mean, variance, and confidence limits from censored (< limit of detection), lognormally distributed exposure data. AIHAJ 1990; 51(8):416-9.

Stephenson DJ, Lillquist DR. The effects of temperature and pressure on airborne exposure concentrations when performing compliance evaluations using ACGIH TLVs and OSHA PELs. Appl Occup Environ Hyg 2001; 16(4):482-6.

Succop PA, Clark S, Chen M, Galke W. Imputation of data values that are less than a detection limit. J Occup Environ Hyg 2004; 1(7):436-41.

U.S. Air Force. Drinking water surveillance program. Washington, DC: Department of the Air Force; 2010 Sep 28. Air Force Instruction 48-144.

U.S. Air Force. Ionizing radiation protection. Washington, DC: Department of the Air Force; 2011 Sep 21. Air Force Instruction 48-148.

U.S. Air Force. Occupational and environmental health exposure controls. Washington, DC: Department of the Air Force; 2008 Oct 1. Air Force Manual 48-155.

U.S. Air Force. Occupational & environmental health program management. Washington, DC: Department of the Air Force; 2012 Oct 9. Air Force Manual 48-146.

U.S. Air Force. Occupational and environmental health site assessment. Washington, DC: Department of the Air Force; 2007 Mar 28. Air Force Manual 48-154.

U.S. Air Force. Swimming pools, spas and hot tubs, and natural bathing areas. Washington, DC: Department of the Air Force; 2012 Mar 7. Air Force Instruction 48-114.

U.S. Army Center for Health Promotion and Preventive Medicine. Technical guide for collection of environmental sampling data related to environmental health site assessments for military deployments. Aberdeen Proving Ground, MD: USACHPPM; 2009 Feb. Report TG 317. Retrieved 1 February 2014 from http://phc.amedd.army.mil/PHC%20Resource%20Library/TG%20317%20(Technical%20Guide%20for%20Collection%20of%20Enviro%20Sampling%20Data%20Related%20to%20Enviro%20Health%20Site%20Assessments).pdf.

U.S. Army, U.S. Navy, U.S. Air Force. Sanitary control and surveillance of field water supplies. Washington, DC: Departments of the Army, Navy, and Air Force; 2010 May 1. TB MED 577/NAVMED P-5010-10/AFMAN 48-138_IP.

U.S. Environmental Protection Agency. Soil sampling quality assurance user's guide, 2nd ed. Las Vegas: Environmental Monitoring Systems Laboratory; 1989 Mar. Report No. EPA/600/8-89/046. Retrieved 1 February 2014 from http://www.epa.gov/tio/download/char/soilsamp.pdf.

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

AA	**atomic absorption spectrometry**
ACGIH	American Conference of Governmental Industrial Hygienists
ACM	asbestos-containing material
AFCENT	Air Forces Central Command
AFI	Air Force Instruction
AFMAN	Air Force Manual
AFRRAD	Air Force Radioactive Recycling and Disposal
AHERA	Asbestos Hazard Emergency Response Act
AIHA	American Industrial Hygiene Association
AL	action level
ALARA	as low as reasonably achievable
ALI	annual limits of intake
AOC	area of concern
ASAGE	Automated Sampling Guide
ASTDR	Agency for Toxic Substance and Disease Registry
ASTM	American Society for Testing and Materials
B	bias
BCE	base Civil Engineering
BE	Bioenvironmental Engineering
BPA	Blanket Purchase Agreement
C	ceiling
CAA	Clean Air Act
CAS	chemical abstract number
CBRN	chemical, biological, radiological, and nuclear
COC	chain-of-custody
Cr(VI)	hexavalent chromium
CSD	Customer Service Division
CV_P	pump coefficient of variation
CV_T	total coefficient of variation
CWA	Clean Water Act
DAQ	derived air concentration
TPML	USAFSAM Detachment 3
DHP	Defense Health Programs
DOEHRS	Defense Occupational and Environmental Health Readiness System
DOT	Department of Transportation
DPS	Deployable Sampler System
DQA	data quality assessment

DQO	data quality objectives
DRI	direct reading instrument
EDS	energy dispersive spectroscopy
EL	excursion limit
ELLAP	Environmental Lead Laboratory Accreditation Program
EPA	Environmental Protection Agency
ESOH	environmental, safety, and occupational health
FedEx	Federal Express
GC/FID	gas chromatography/flame ionization detector
GC/MS	gas chromatography/mass spectrometry
GFF	glass fiber filters
GLD	generally licensed device
GM	geometric mean
GSD	geometric standard deviation
HCl	hydrochloric acid
HPLC/UV	high performance liquid chromatography/ultraviolet detector
HRA	health risk assessment
IAW	in accordance with
IC	ion chromatography
ICP/MS	inductive coupled argon plasma/mass spectrometry
ICP/OES	inductive coupled argon plasma/optical emission spectrometry
ID	identification
IHLAP	Industrial Hygiene Laboratory Accreditation Program
IHSTAT	AIHA free spreadsheet on industrial hygiene statistics
IOM	Institute of Occupational Medicine
IRIS	Integrated Risk Information System
L/min	liters per minute
LCL	lower confidence limit
LIMS	Laboratory Information Management System
LOD	limit of detection
LRN	Laboratory Response Network
LSC	liquid scintillation counting
µCi	microcurie
MAMA	9-(N-methylaminomethyl) anthracene
MARSSIM	Multi-Agency Radiation Survey & Site Investigation Manual
MCE	mixed cellulose ester
MCL	maximum contaminant level
MLE	maximum likelihood estimation
MRL	minimum risk level
NAAQS	National Ambient Air Quality Standards

NCRP	National Council on Radiation Protection
NI-CAD	nickel cadmium (batteries)
NIOSH	National Institute for Occupational Safety and Health
NMAM	NIOSH Manual of Analytical Methods
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Committee
NTP	Normal Temperature and Pressure
NVLAP	National Volunteer Laboratory Accreditation Program
OEA	Occupational and Environmental Analytical Services Division
OEAS	OEA Analysis Support Branch
OEEL	occupational and environmental exposure limit
OEH	occupational and environmental health
OEHSA	Occupational and Environmental Health Site Assessment
OSHA	Occupational Safety and Health Administration
PACAF	Pacific Air Forces
PCB	polychlorinated biphenyls
PCM	phased contrast microscopy
PEL	permissible exposure limit
PLM	polarized light microscopy
PLM/MC	polarized light microscopy/materials characterization
PM	particulate matter
ppb	parts per billion
ppm	parts per million
PTFE	polytetrafluoroethylene (trade name Teflon®) filter
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RL	reporting limit
RSO	Radiation Safety Officer
S_{rT}	overall precision
SAE	sampling and analytical error
SAED	selected area electron diffraction
SAM	sampling, analysis, and monitoring
SDS	safety data sheet
SDWA	Safe Drinking Water Act
SEG	similar exposure group
SEM	scanning electron microscopy
SG	Surgeon General
SiO_2	silica

SSDR	Sealed Source Device Registry
SSN	Social Security number
STEL	short-term exposure limit
SVOC	semi-volatile organic compound
TAT	turnaround time
TEM	transmission electron microscopy
TLV	threshold limit value
TMO	Traffic Management Office
TO	Technical Order
TSCA	Toxic Substance Control Act
TSP	total suspended particulates
TWA	time-weighted average
U	uncertainty
UCL	upper confidence limit
USAFSAM	United States Air Force School of Aerospace Medicine
USAPHC	United States Army Public Health Command (formerly CHPPM)
VOA	volatile organic analysis
VOC	volatile organic compound
VSP	Visual Sample Plan
WPAFB	Wright-Patterson Air Force Base
Y	exposure severity