United States Environmental Protection Agency | Office of Emergency and Remedial Response Washington, DC 20460 | Office of Research and Development Cincinnati, OH 45268

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EPA

Engineering Bulletin

Design Considerations for Ambient Air Monitoring at Superfund Sites

Purpose

Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates the Environmental Protection Agency (EPA) to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants and contaminants as a principal element." The Engineering Bulletins are a series of documents that summarize the latest information available on selected treatment and site remediation technologies and related issues. They provide summaries of and references for the latest information to help remedial project managers (RPMs), on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to evaluate a technology for potential applicability to their Superfund or other hazardous waste site. Those documents that describe individual treatment technologies focus on remedial investigation scoping needs. Addenda will be issued periodically to update the original bulletins.

Abstract

Ambient air monitoring (AAM) may be useful or necessary for determining the air migration of toxic contaminants from Superfund sites. Emissions may be from point or area sources and may be gaseous or particulate in nature.

There are three basic approaches to air monitoring at hazardous waste sites: 1) integrated sample collection using a network of point monitors; 2) monitoring using continuous, realtime instruments or monitors using a network of point monitors; and 3) comprehensive fenceline monitoring using continuous, line source instruments (open-path, optical remote sensing). Selection of an appropriate air monitoring approach will require consideration of relevant project factors in the course of designing the air monitoring program. These basic approaches and the applicable monitoring technologies will be discussed.

This Engineering Bulletin is intended to help the RPM design the site-specific air monitoring program needed before, and during site remediation. The types of AAM activities of interest at Superfund sites are selecting the most appropriate approach, establishing the data quality objectives, and selecting the proper sampling and analytical techniques. Key design considerations, limitations, a procedure for designing the air monitoring program, and other relevant technical information regarding AAM at Superfund sites are presented. This bulletin also provides a point of contact for further information.

Air Monitoring System Design

Toxic air emissions may originate from the site: in the undisturbed state; waste handling; or onsite waste treatment and preparation processes (point source) such as solidification, separation activities, waste mixing/shredding, pyrolysis, incineration, stripping, etc. Some of these processes may be in situ treatment processes such as soil flushing, vitrification, etc., which may further be uncontrolled, generating point and fugitive emissions. Due to potential emissions of air toxics, an appropriate air monitoring system must be considered in order to assess harm to the public and environment.

It is essential to conduct a proper Air Pathway Analysis (APA) in order to design a proper air monitoring program [1]*. The APA method is outlined in a four volume series [2, 3, 4, 5]. State and local regulations may require AAM at the fenceline. The air monitoring program used need not be elaborate, technically sophisticated, or require a significant share of the project resources. In fact, if the air monitoring program is properly designed and implemented, the data generated may be used to maintain contractor schedules and even reduce costs of several aspects of the program, such as onsite personnel level of protection (by avoiding shutdown, reducing cost of health/safety supplies and worker break time). The application of air emission control technologies such as area, point, or operational controls can also result in significant net cost savings by avoiding project shutdowns. The primary benefit to the program is the execution of a successful site restoration program that avoids an adverse impact on the local community and air surrounding the site.

The proper design of air monitoring programs at hazardous waste sites is also dependent on the site characteristics, properties of the waste, and other project factors (Figure 1).

* [reference number, page number]

FIGURE 1. KEY SITE FACTORS THAT INFLUENCE OR CONTROL THE DESIGN AND IMPLEMENTATION OF AIR MONITORING PROGRAMS

SITE CHARACTERISTICS

Available Utilities
Access to Monitoring Locations
Site Terrain
Local Meteorological Conditions

PROJECT FACTORS

Program Objectives
Availability of
Applicable Sampling Methods
Project Resources

WASTE PROPERTIES

Range of Waste Types
Volatility of Contaminants
Toxicity of Contaminants
Homogeneity of the Waste

Site Characteristics

Available utilities may influence the choice of monitors used. Some programs can utilize battery-powered instruments or integrated sample collection techniques; others require line or generator power if many stations are needed or if the program will operate for several months. A water supply is generally needed only for decontamination and worker convenience. Caution needs to be taken in order that emissions from the power generator are not monitored inadvertently.

Access to monitoring locations is also a consideration. Ideally, the perimeter of the property (where most monitoring takes place) will have a road that allows for vehicle access to all fixed and mobile monitoring locations. Access roads save time and effort required to hand-carry equipment and supplies over rough terrain for large sites.

Site terrain directly influences the extent and the design of the air monitoring program. If the site terrain is complex, the migration of contaminants via the air contaminant pathway will be complex and highly variable. In addition, air dispersion modeling for such terrain is difficult and modeled results are often less precise and nonrepresentative. This means that there is an increased likelihood that point source monitors will not measure true site emissions. This situation can be addressed by: 1) increasing the number of point monitor stations and selecting locations to transect the downwind plume, and in some cases 2) using line monitoring techniques such as optical remote sensing (Fourier transform infrared (FTIR) or ultraviolet differential optical adsorption spectroscopy (UV-DOAS)) [3] [6].

Local meteorological conditions also influence the design of the monitoring system. Dominant meteorological conditions should be considered so that monitors are properly located and can provide representative site samples.

Waste Properties

The range of waste types will dictate the number of compounds to be monitored. Although monitoring may be considered for each type of waste, it may be acceptable to select target compounds based on effective risk. This approach is common and can reduce complexity. If individual compounds are of interest, the number of analyses can increase the complexity and cost of the program.

Physical state or volatility of contaminants will affect the air sampling and analysis technique selection. Volatility of contaminants ranges from volatile (found mostly in the gaseous state), semivolatile (found as a gas and solid), to nonvolatile (particulate matter found mostly in the solid state).

The relative toxicity of contaminants will affect the decision as to which compounds will be monitored in the program. It is important to monitor those compounds that dominate the health risk assessment given equivalent receptor exposure.

Homogeneity of the waste will generally reduce the complexity and cost of the air monitoring program. The air monitoring program can be simplified to monitor for one or more indicator compounds.

Project Factors

Program objectives serve to direct and focus the air monitoring program. Available and applicable methods determine if program objectives can be achieved.

The availability of applicable sampling and analytical methods may limit the monitoring effort. There are several sources that provide current reference methods [3] [7] [8] [9] [10]. However, the method available may not be compatible with the project needs: for example, if the need arises to continuously monitor a contaminant and have realtime data available onsite, but the proposed method is integrated sample collection and analysis with a 36-hour turnaround. This situation is encountered frequently when there is a need to monitor a semivolatile or nonvolatile compound found as particulate matter. The standard approach is to use high- volume collection on filters or foam with offsite laboratory analysis. The appropriate project strategy would be to correlate onsite realtime analysis, such as monitoring with a dust analyzer (screening level monitoring), with high volume sampling and assume a percentage of screening level monitoring response as the contaminant concentration. By combining screening and in-depth approaches and assuming loading, data can be obtained for situations where there are no sampling techniques available to meet the program needs.

Project resources affect what type and level of air monitoring can be conducted at any given site. The amount of resources allotted to the air monitoring program should provide for the selection of methods and how they are to be applied. Resource restrictions may influence the application of methods by limiting frequency (representativeness) or repeatability of the monitoring effort, or it may influence which methods are selected and used.

Limitations

Selection of an air monitoring method involves consideration of both the application of the method and its limitations. Limitations that may affect most air monitoring approaches include:

1) Frequency of monitoring affects data representativeness, regardless of air monitoring approach or method. A well-defined program must monitor at sufficient frequency for the data to be representative.

2) Monitoring of large numbers of specific compounds is costly and time intensive. The requirement for this level of surveillance must be supported at the onset of the program.

3) General class or broad-band monitoring of contaminant species also has advantages and limitations. The advantage of broad-band monitoring is that most of the emissions from the site are monitored. These data can be used with composition data to estimate individual species or types of compounds (i.e., total hydrocarbons as aromatics, or total aromatics as benzene). However, broad-band monitoring is often a conservative estimate and therefore the site may be considered more toxic or to carry a greater risk than is the case.

4) A limited number of monitoring stations affects the coverage at the fenceline. Line source monitoring versus point monitoring should be considered if fenceline coverage is an issue.

5) Meteorological conditions greatly influence the air monitoring program and may affect the design of the program or result in limited data capture. Climate characteristics like a marine environment (i.e., moist, salty air), diurnal wind patterns, and seasonal conditions should be factored into the design to avoid poor data capture.

Design Procedures

The important tasks in designing an air monitoring program for a hazardous waste site restoration activity are: selecting the most appropriate approach, establishing the data quality objectives, and selecting the proper sampling and analytical techniques. Since no two hazardous waste sites are alike, the best way to assist the RPM to design an air monitoring program specific to a site is to develop a protocol that can be applied to any site and to provide useful information that will result in effective air monitoring programs. Figure 2 lists the twelve steps for designing an AAM program. They are described in the following subsections.

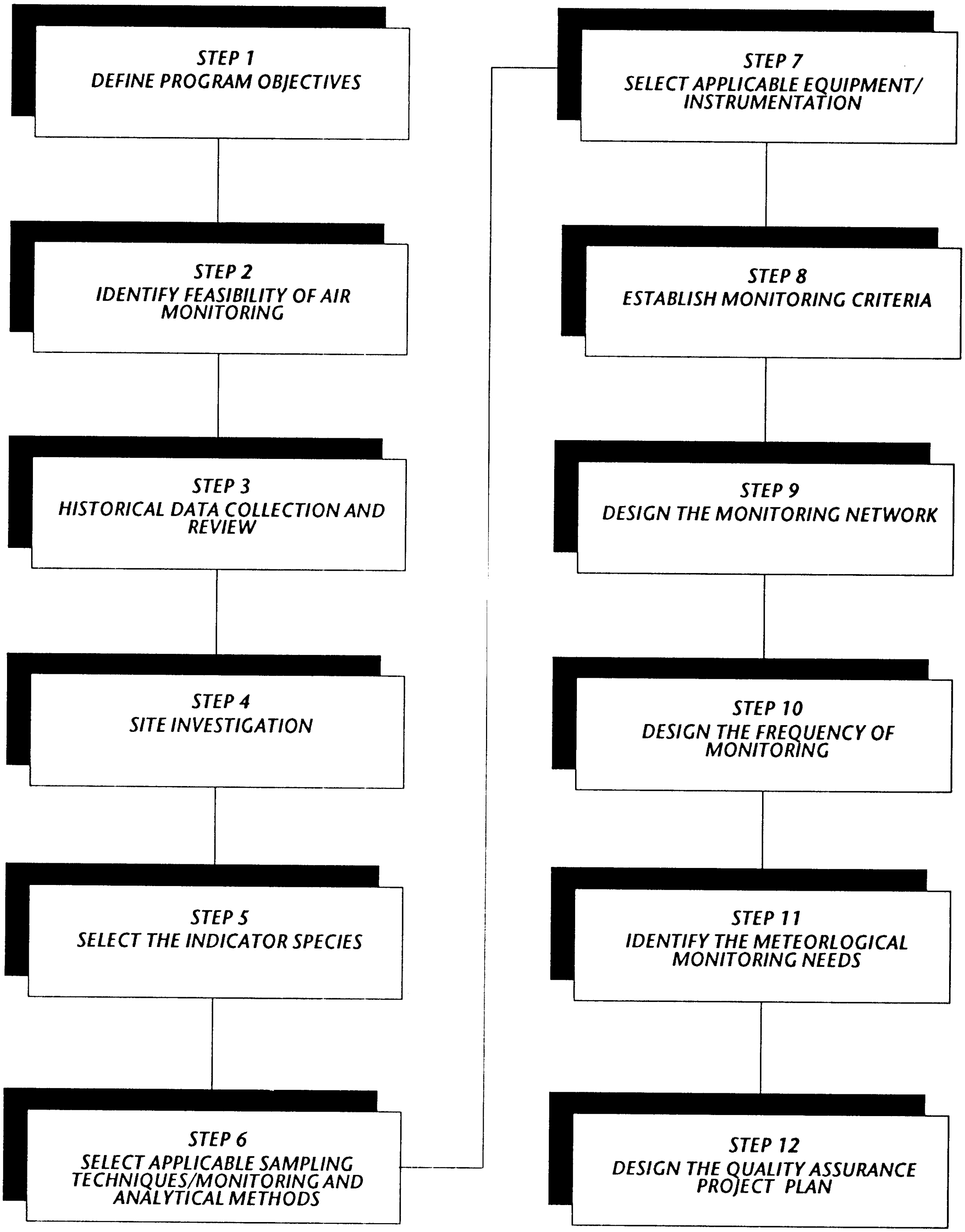
Program objectives must be defined so that they are specific and detailed. A reviewer of these objectives must have a clear understanding of all major aspects of the program. It will be necessary to review these objectives at various times in designing and implementing the program to ensure the program objective will be met. If there is a need to modify the program objective, all parties involved should concur and approve of the program redirection.

Identifying the feasibility of air monitoring is critical at this early stage before significant time and effort is expended pursuing a conceptual program that is not feasible. This should include an analysis of the site characteristics, the properties of the waste, and key project factors. Although this initial analysis does require some prior knowledge of later stages, it is important to take some time to consider what is known and whether or not the project objectives are feasible.

Historical data collection and review will provide some of the information needed for evaluating applicability of air monitoring. Site scoping may include researching the site record, site manifest files, and operating permits; locating regulatory involvement documentation; collecting odor/nuisance complaints; conducting interviews with involved parties; evaluating historical site characterization data; and reviewing historical aerial photography of the site (if available). The objective is to identify the type, physical state, and likely emissions from the site in the undisturbed and disturbed states. Waste composition data and predictive modeling may be used to estimate emission rates of contaminants [3]. These estimates can be used with empirical factors and simple models [4] to estimate emissions from disturbed waste. These data are then used with a dispersion model like the Industrial Source Complex Short Term model (ISCST) to predict contaminant concentration at the fenceline for different meteorological conditions. These estimates of contaminants and their concentrations provide excellent data for planning the air monitoring program.

Site investigation is an opportunity to collect specific and useful data from the site for designing the air monitoring program.

FIGURE 2. FLOWCHART OF ACTIVITIES FOR DESIGNING THE AIR MONITORING PROGRAM



Screening technologies include head space analysis of a sample in a bottle, upwind/downwind air sampling, realtime instrument survey, and the use of predictive models. These technologies are recommended for determining if the waste has the potential for air emissions [3]. In-depth technologies include the surface flux chamber, soil vapor probes, downhole flux chamber, and fenceline monitoring and modeling. The advantages and limitations of these preferred screening and in-depth level technologies are discussed in the APA Engineering Bulletin [1]. These technologies are recommended for determining undisturbed and disturbed waste emission rate estimates from the site and may be useful to emphasize air monitoring techniques if a pretest site screening is needed to support the air monitoring program design. One approach is to preview one or more of the candidate techniques for air monitoring at a "first alert" station so that their performance can be evaluated. Information for identifying candidate sample collection and analytical/monitoring techniques is found in references 1, 3, 9 and 10. Emission rates from the disturbed waste are likely to increase significantly during waste disturbance, and applicable monitoring techniques must be able to detect maximum and minimum concentrations.

The site investigation data are critical in selecting sampling and analytical techniques, establishing contaminants and the likely contaminant concentration range, and evaluating candidate monitoring approaches and/or sampling and analytical technologies.

Selecting the indicator species is important to the selection of air monitoring techniques and will determine the representativeness of the air monitoring data. Indicator species are used to represent the type, range, and concentration of all air contaminant release from the site. The emissions from the waste must be relatively homogeneous for the indicator species concept to be useful. Usually, there are many types of air contaminants released from the site, and it is often not possible to monitor all species. It is often necessary to rely on indicator species monitoring. Further, even if there were resources available to monitor all of the species released, it would probably not be technically feasible, since there are only a handful of valid sampling/analytical methods.

The overall objective of selecting candidate indicator species is to find species that are common to the waste and can be sampled and analyzed using conventional techniques. The ideal indicator species should be found uniformly in the waste and at a relatively constant ratio to other contaminants in the downwind plume; a relatively nonreactive or a stable air contaminant, found in the downwind plume well above the detection limit of the sample collection/analytical technique or air monitoring approach selected; unique to the site and not found in the upwind air at significant levels. Representativeness of the indicator(s) should be demonstrated at the onset and perhaps throughout the program. This is accomplished by collecting samples using techniques that identify and quantify the indicator as well as other dominant and significant compounds. This verification of indicator species is critical for the air monitoring program to properly function.

Selecting applicable sampling and analytical techniques or monitoring methods is the central issue in designing the air monitoring program. The project objective will provide guidance as to the type of contaminant (volatile organic compound (VOC), volatile inorganic compound (VIC), semivolatile organic compound (SVOC), particulate matter (PM)) and which approach is most appropriate (i.e., continuous monitoring, line versus point monitoring, integrated point monitoring, emission measurement and modeling). The project objective should be developed with knowledge of the project needs, site characteristics, waste properties, and project factors. Without this direction, it is not possible to select applicable sampling and analytical techniques or monitoring methods. Table 1 lists general guidance on monitoring, collection, and analysis.

References 8 and 9 contain information that is applicable to many sites and is specific for toxic organic compounds. They provide data on sampling technique, sample collection, and analytical technique for general classifications of compounds commonly found at hazardous waste sites. These approaches are relevant for point monitoring using integrated sample collection and are common for sites that need low level detection, where realtime data is not part of the project objective. Table 2 lists the toxic organic compendium methods.

Selecting applicable equipment/instrumentation follows after the sampling and monitoring method has been selected. Several tables have been assembled to assist in selecting appropriate sampling and analytical methods as well as selecting applicable equipment and instrumentation. These tables provide vendor information, product nomenclature, analyte detection data, and 1991 cost estimate information for field survey and air monitoring techniques and instruments. This information was too extensive to be included in this document, but can be obtained from the EPA contact. This listing is not comprehensive or meant to serve as an endorsement of these products. It is intended as supportive information for the air monitoring design steps that involve identifying, evaluating, and selecting air monitoring approaches and specific technologies.

There are several considerations, however, that will be a part of the selection process: 1) range of detection for the technology in comparison to the project objectives; 2) duration of the sampling period and the capability of the technology; 3) portability of the technology and required support functions; 4) data turnaround time and the project needs; 5) technical expertise needed to operate the technology properly; 6) cost and availability of the technology from the vendor.

Establishing monitoring criteria may happen early in the design process or be part of the program objectives; however, these criteria should be established when air monitoring methods are being evaluated. Project-specific criteria must be established using available health data, site factors such as distance to receptors, exposure criteria such as threshold limit value (TLV) and permissible exposure limit (PEL) data, and a health risk assessment. This process should be used to develop a time-weighted set of criteria that will protect the health of the public and allow for restoration of the site [11] [12].

Designing the air monitoring network and siting monitoring stations involves considering needs for representativeness of these air monitoring data and project resources. In addition to the standard fenceline surveillance, it may be ad-

TABLE 1. GENERAL GUIDANCE FOR INTEGRATED, POINT MONITORING, SAMPLE COLLECTION AND ANALYSIS

CLASSIFICATION	*SAMPLING TECHNIQUE*	*SAMPLE CONDITIONING*	*ANALYSIS TECHNIQUE*
VOLATILES	TENAX ADSORBENT	THERMAL DESORPTION, CYROGENIC TRAPPING AND FOCUSING	GC/MS
	SUMMA CANISTER	NAFION DRYER	GC/MS
		CRYOGENIC TRAPPING (OPTION)	GC/MS
		MODIFIED WATER PURGE TO ADSORBENT TRAP, THEN THERMAL DESORPTION	GC/MS
SEMI-VOLATILES, INCLUDING PESTICIDES AND PCBs	FILTER FOLLOWED BY COMBINATION PUF/XAD-2 ADSORBENT TRAP USING HIGH-VOLUME SAMPLER	10% ETHER/HEXANE SOXHLET EXTRACTION, SILICA GEL CLEAN-UP	GC/MS
METALS	FILTER	MICROWAVE EXTRACTION USING HNO3/HCI ACID SOLUTION	ICAP

GC/MS - GAS CHROMATOGRAPHY/MASS SPECTROMETRY
PUF-XAD-2 - POLYURETHANE FOAM - XAD-2 RESIN
ICAP - INDUCTIVELY COUPLED ARGON PLASMA SPECTROSCOPY

TABLE 2. SUMMARY OF TOXIC ORGANIC (TO) COMPENDIUM METHODS

COMPENDIUM METHOD	*TYPE OF COMPOUND*	*SAMPLE COLLECTION*	*ANALYTICAL METHOD*
TO-1	VOLATILE ORGANIC COMPOUNDS	TENAX SOLID SORBENT	GC/MS
TO-2	VOLATILE ORGANIC COMPOUNDS	MOLECULAR SIEVE SORBENT	GC/MS
TO-3	VOLATILE ORGANIC COMPOUNDS	CRYOTRAP	GC/FID
TO-4	PESTICIDES	POLYURETHANE FOAM	GC/ECD
TO-5	ALDEHYDES/KETONES	IMPINGER	HPLC
TO-6	PHOSGENE	IMPINGER	HPLC
TO-7	AMINES	ADSORBENT	GC/MS
TO-8	PHENOLS	IMPINGER	HPLC
TO-9	DIOXINS	POLYURETHANE FOAM	GC/MS
TO-10	PESTICIDES	POLYURETHANE FOAM	GC/ECD
TO-11	ALDEHYDES/KETONES	SEPELCO-PAK	HPLC
TO-12	NON-METHANE ORGANIC COMPOUNDS	CANISTER	PDFID
TO-13	POLYAROMATIC HYDROCARBONS	POLYURETHANE FOAM	GC/MS,HPLC
TO-14	VOLATILE ORGANIC COMPOUNDS	CANISTER	GC/MS

GC/MS - GAS CHROMATOGRAPHY/MASS SPECTROMETRY
GC/FID - GAS CHROMATOGRAPHY/FLAME IONIZATION DETECTION
GC/ECD - GAS CHROMATOGRAPHY/ELECTROLYTIC CONDUCTIVITY DETECTOR
HPLC - HIGH PRESSURE LIQUID CHROMATGRAPHY
PDFID - PRECONCENTRATION AND DIRECT FLAME IONIZATION DETECTION

vantageous to add a downwind work-zone monitoring station that could serve two purposes: worker protection and adherence to the health and safety plan and a "first-alert" station that could provide rapid response data and valuable information to the site manager regarding site restoration activities. This information could assist in controlling site activities or the source of fugitive emissions and could potentially reduce the threat of impact at the fenceline.

Most air monitoring programs that use point monitoring have at a minimum one station located at the daytime upwind (dominant) position and two or more at downwind positions. The sector approach uses 8 to 12 stations located in each major compass direction for coverage in all dominant wind directions. The selection of number and position of stations will depend on the program objectives and resources. The choice of line monitoring versus point monitoring addresses this issue of representativeness in the data. Line monitoring using optical remote sensing (FTIR, UV-DOAS) can provide complete fenceline monitoring which would be equivalent to placing point monitors (integrated sample collection or instrumental monitors) side-by-side along the fenceline of concern. The other advantage of line monitoring is that data may be processed onsite and essentially realtime [13]; these two features distinguish line monitoring from all other methods. Project needs, detection limits, and detectability will determine if optical remote sensing is appropriate for the air monitoring approach.

Designing the frequency of AAM can range from limited monitoring on selected days to monitoring at all locations every day. Frequency of sampling may be comprehensive, but analysis of samples of data collected may reflect wind direction or site activities. For instance, sector monitoring with 8 to 12 monitoring locations could involve 24-hour monitoring. However, the dominant upwind and 2 or 3 downwind monitoring station samples may be selected for analysis thus preventing the analysis of useless sample media. Frequency of monitoring will reflect the program AAM objectives.

Identifying the project meteorological monitoring needs usually involves designing a micro-meteorological network for onsite monitoring and/or arranging for data collection from a local airport and/or meteorological monitoring network. Onsite data are recommended so that fenceline concentrations can be evaluated considering site factors such as terrain. Typically, site meteorological monitoring consists of at least one station with a 10-meter tower and sensors for wind speed, wind direction, and temperature. Data are typically collected and stored on a data logger and processed as 5-minute and hourly averages.

Designing the Quality Assurance Project Plan involves defining the type and level of program quality assurance, quality control, and independent auditing. The Quality Assurance Project Plan (QAPP) elements include project description and objectives, all field sampling/monitoring direction, all analytical procedures, data quality objectives, data evaluation procedures, system and performance auditing, and corrective action protocols. This document serves two purposes: 1) provides a complete guidance document for project implementation and execution, and 2) specifies the level of data quality and provides a program for attaining the specified level of data quality. Every air monitoring program needs a site-specific QAPP.

Site Requirements

Site requirements for air monitoring will vary according to the objectives of the air monitoring program and the specific monitoring techniques used. A screening type program may only require minimum support facilities. A more detailed air monitoring program may require weatherproof shelters powered by 110-volt service for each fixed monitoring station and may include data transfer by line or radio to a data processing/computer center. Support needs including utilities and access to monitoring locations should be considered when designing the air monitoring program.

EPA Contact

Technology-specific questions regarding air monitoring during Superfund remediation may be directed to:

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Or to one of the Regional Air/Superfund Coordinators:

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Alison Devine, Region II New York, NY (212) 264-9868	Wayne Kaiser, Region VII Kansas City, KS (913) 551-7603
Patricia Flores, Region III Philadelphia, PA (215) 597-9134	Norm Huey, Region VIII Denver, CO (303) 293-0969
Lee Page, Region IV Atlanta, GA (404) 347-2864	Kathy Diehl, Region IX San Francisco, CA (415) 744-1133
Charles Hall, Region V Chicago, IL (312) 886-9401	Chris Hall, Region X Seattle, WA (206) 553-1949

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REFERENCES

1. Engineering Bulletin: Air Pathways Analysis. EPA/540/S-92/013, U.S. Environmental Protection Agency, Cincinnati, Ohio, November 1992.

2. Air Superfund National Technical Guidance Study Series, Volume 1: Application of Air Pathway Analysis for Superfund Activities, Interim Final. EPA/450/1-89/001, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

3. Air Superfund National Technical Guidance Study Series, Volume 2: Application of Air Pathway Analysis for Superfund Activities, Appendix, Interim Final. EPA/450/1-89/002, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

4. Air Superfund National Technical Guidance Study Series, Volume 3: Estimation of Air Emissions from Cleanup Activities at Superfund Sites, Interim Final. EPA/450/1-89/003, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

5. Air Superfund National Technical Guidance Study Series, Volume 4: Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis, Interim Final. EPA/450/1-89/004, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1989.

6. Spellicy, R. L., Spectroscopic Remote Sensing: Addressing Requirements of the Clean Air Act. 24, Spectroscopy, 6(9) Nov/December 1991.

7. Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air. EPA/ 600/ 4-83/027, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1983.

8. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air (Supplement to EPA/ 600/4-84/041). EPA/600/4-87/006, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1986.

9. Second Supplement to Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA/600/4-89/018, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1988.

10. Lodge, J. P., Editor, Methods of Air Sampling and Analysis, 3rd Edition, Lewis Publisher, Inc., Chelsea MI, 1989.

11. Gravitz, N., Derivation and Implementation of Air Criteria During Hazardous Waste Site Cleanups, Journal of the Air Pollution Control Association, 35(7), July 1985.

12. Estimation of Air Impacts for Soil Vapor Extraction (SVE) Systems. EPA 450/1-92/001, U.S. Environmental Protection Agency, January 1992.

13. Hudson, J., et al. Remote Sensing of Toxic Air Pollutants at a High Risk Point Source Using Long Path FTIR, 91-57.1, Presented at the 1991 Air and Waste Management Association Annual Meeting, Vancouver, BC, June 1991.

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