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Engineering Bulletin
Air Pathway Analysis

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, 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

This bulletin presents information on estimating toxic air emissions from Superfund and hazardous waste sites. The focus is on the collection of air emissions data during the site investigation (SI) and remedial investigation/feasibility study (RI/FS). Emissions of volatile compounds and particulate matter during site disturbances, such as excavation, may be several orders of magnitude greater than the emissions levels of an undisturbed site [1]*. The potential air emissions from the undisturbed and disturbed site must be understood before developing a site mitigation strategy.

The USEPA has developed a systematic approach, called an Air Pathway Analysis (APA), for determining what air contaminants are present and at what level these compounds may be released into the atmosphere. The APA method is outlined in a four volume series [2,3,4,5]. The intent of this bulletin is to help Remedial Project Managers (RPMs) and On Site Coordinators (OSCs) conduct adequate APAs to characterize sites and prevent problems during site investigation and remedial action.

This bulletin presents information on how to conduct an APA, equipment and methods for assessing the extent of an air emission problem, and the requirements and limitations of an APA. The emission assessment techniques address all types of air contamination: volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), volatile inorganic compounds (VICs), and particulate matter (PM) including metals, dioxins, etc. Points of contact are provided for further information.

APA Applicability

The protocol for an APA (Figure 1) consists of four major steps: (1) defining the APA objectives; (2) site scoping; (3) site screening; and (4) in depth APA [3, p. 24].

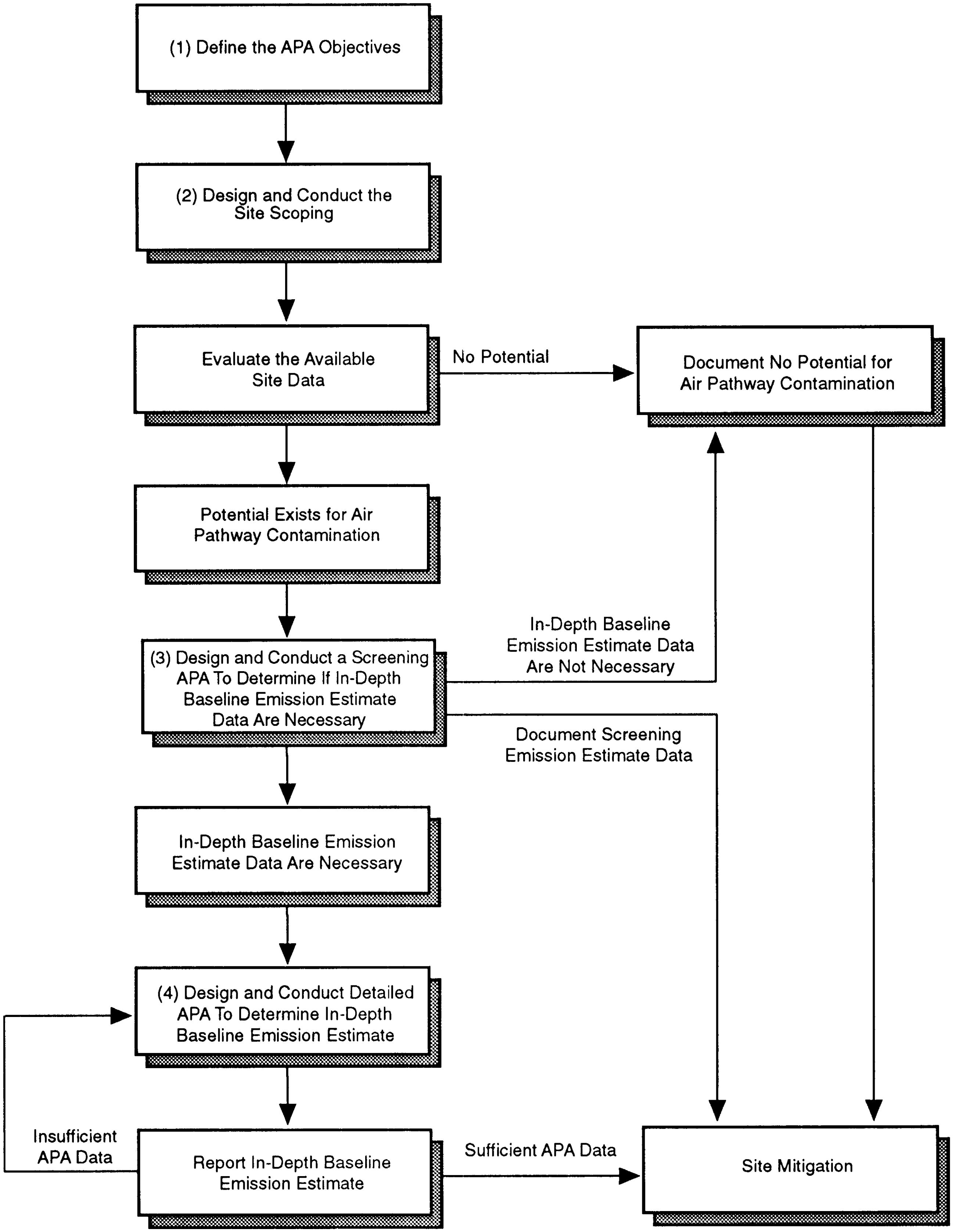
The process is initiated by defining the APA objectives, the most critical step. The objectives should address specific questions or needs (e.g. determine the maximum, short-term exposure levels at the site fenceline) rather than being overly general. The next step is to investigate available file information to determine the level of screening activity appropriate for the site. Site screening is used to determine if the site has the potential to emit air contaminants in its undisturbed or disturbed state. If the site screening indicates that the site does not have the potential to emit significant levels of air contaminants, the RPM can document "no potential" for adverse emissions and the APA is complete. If the potential exists, an in-depth APA should be designed and conducted. In-depth sampling techniques generally are used to collect emission rate data from small areas to estimate what the emissions would be from the entire site.

An initial APA should be conducted as part of the site investigation with a more complete APA performed once the RI/FS data are available. Unfortunately, it is common for air pathway concerns not to be raised until the RI/FS stage of a site. In cases where the RI is complete and insufficient data are available, it may be necessary to return to the site for a limited field study.

Conducting a proper APA also requires that air monitoring be conducted during site remediation to ensure that site activi-

* [reference number, page number]

FIGURE 1. FLOWCHART OF ACTIVITIES FOR DEVELOPING SCREENING AND IN-DEPTH EMISSION ESTIMATES (3, p. 24)



ties, such as excavation or treatment technologies, do not create a short term health risk. Most sites have a significant increase in air emissions when the waste is disturbed.

One important aspect of designing and conducting a successful APA is understanding the pathways by which air contaminants leave the site and factors that influence site emissions. Figures 2 and 3 provide conceptual schematics of likely emission sources for landfills (i.e. any subsurface waste) and lagoons. There are both surface and subsurface pathways. Some pathways are important in the undisturbed state; while others are important in the disturbed state. Most sites have weathered, aged surfaces that inhibit air emissions so the subsurface sources are more dominant for undisturbed sites. Subsurface migration pathways form through the soil and along subsurface conduits. Emissions generally will be dominated by materials handling operations and exposure of freshly disturbed waste (e.g. open pits, stockpiles).

APA Techniques

In general, all screening and in-depth emission assessment techniques fall into one of four basic approaches for obtaining APA data. The techniques include: direct measurement, indirect measurement, fenceline monitoring/modeling and predictive modeling. The variety of available methods allows for cost-effective data collection. Some methods for conducting screening and in-depth air pathway analyses and their applications are shown in Table 1. Selection of the type of the screening or in-depth technology will depend on project resources, schedule, personnel capabilities, emission contaminant type(s) present, site emission potential, and the intended use of the APA data [3].

The direct measurement approach consists of techniques that provide an empirical measurement of emissions. This approach allows for accurate estimates of emissions with known uncertainty but these techniques may be more expensive and time consuming than other techniques. If emission data are needed for health risk assessment, the direct emission measurements may be the most appropriate approach.

Indirect emission measurement techniques involve the collection of ambient concentration data and meteorological information under specific conditions. These data typically are used to develop inputs for a numerical model to estimate the emission rate. These methods are usually less precise than direct methods, but an emission estimate can be calculated without having the specific field data.

The fenceline monitoring/modeling approach requires operation of a monitoring network to tabulate ambient upwind and downwind concentration data with simultaneously collected meteorological data. A dispersion model, based on field study data or published emission factors, can give estimates of downwind concentrations. The model output can be refined by adjusting the hypothetical input until the output matches the actual ambient air monitoring data. The fenceline monitoring/modeling approach is often preferred to other assessment methods when valid, comprehensive ambient air monitoring data are available.

Predictive modeling may be useful in estimating emissions from a site. An appropriate theoretical model is selected to represent the site (i.e., landfill, non-aerated lagoon with oil layer, etc.) and site information is used to estimate gross emissions from the site. Since many variables affect emission rates from a site, this approach is limited by the representativeness of the model and by the input used. This approach is usually used as a screening-level evaluation to support or refute the need for additional APA, but should not be used without site-specific data to support planning or decision-making activities (e.g. health risk assessments).

Screening Level Assessment Techniques

Head space analysis of bottled waste is a simple but effective direct screening measurement technique that involves collecting waste material in a bottle with "significant" head space and allowing the waste/head space to reach equilibrium. The head space gas is then analyzed for volatile compounds with simple real time analyzers. This activity can be conducted in conjunction with a soils investigation. These data are often used to make field decisions regarding which soil/sludge samples should undergo compound specific analyses. If the screening consistently shows little or no volatile emissions from samples across the site, then an in-depth study may not be necessary. Subsurface soils may need to be assessed in addition to surface soils. Little or no volatile emissions are defined as less than three times the analytical detection limit. It is recommended that a few gas samples be collected for a gas chromatograph/mass spectrometry speciation analyses to confirm the emission levels. If these screening level data suggest a strong potential for emissions, then they can be used to help design the in-depth APA.

Particulate matter emissions can also be tested in a screening manner. Collected samples can be analyzed for particle size and soil moisture or tested for "dustiness" [6] or can be estimated via modeling techniques [3]. Experimental waste handling and visual observation can also indicate the emissions potential of PM. These data are used to make the decision as to whether or not further APA activities are needed.

Upwind/downwind survey monitoring is an indirect screening method used to study emissions by monitoring upwind/downwind concentrations of ambient target compounds. A conventional monitoring strategy and air sampling/monitoring approach is used. Often, real time analyzers with flame ionization and photoionization detection are used for organic emission detection. Integrated air samples (e.g., grab samples) are collected using techniques such as evacuated, stainless steel canisters for VOCs and high-volume filter samples for particulate matter. Advanced techniques such as optical remote sensing can also be used to quantify emission potential for the detection of compounds.

A realtime instrument survey is similar to upwind/downwind screening except that the screening usually takes place directly over the waste to obviate modeling by testing the air above the surface. This approach can identify "hot spots" of emissions and zones of similar emissions.

FIGURE 2. CONCEPTUAL SCHEMATIC SHOWING AIR CONTAMINANT PATHWAYS FROM AN UNLINED LANDFILL (3, p. 13)

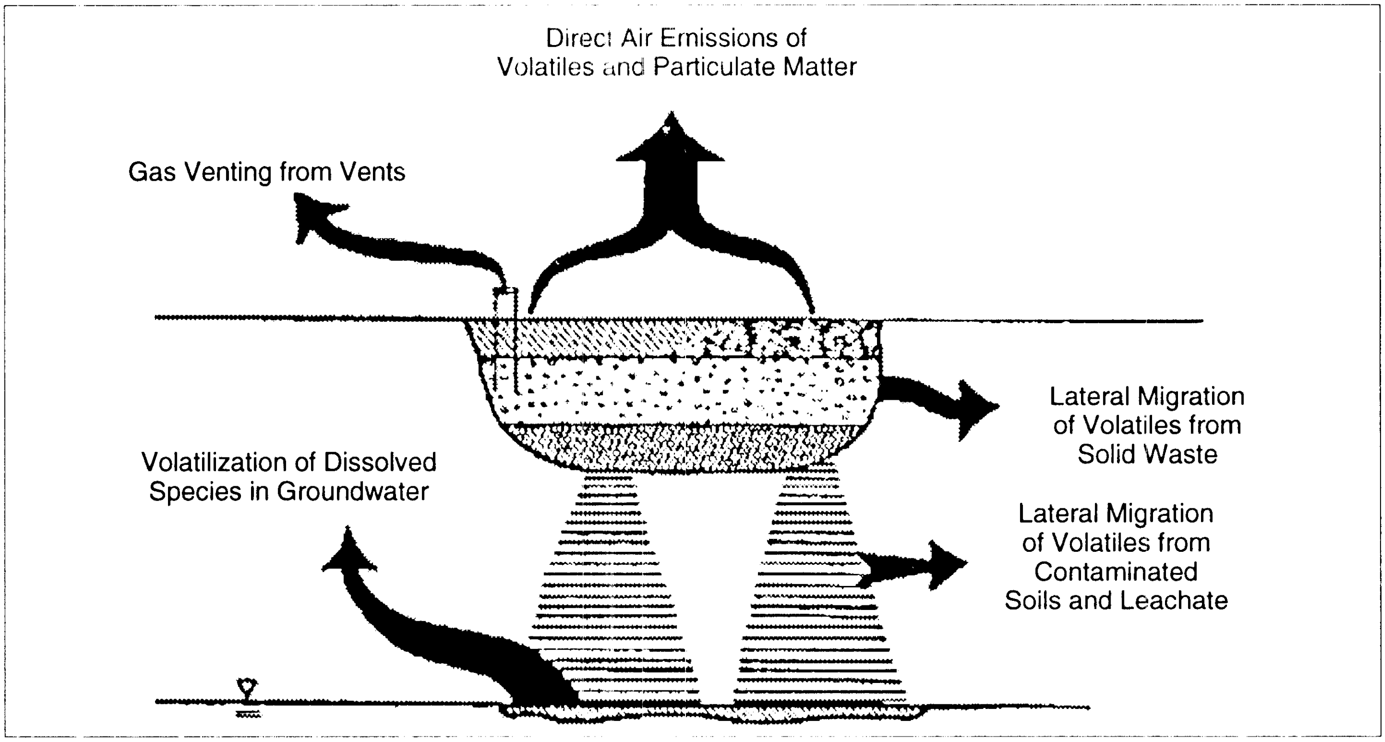


FIGURE 3. CONCEPTUAL SCHEMATIC SHOWING AIR CONTAMINANT PATHWAYS FROM AN UNLINED LAGOON WITH NO COVER (3, p. 14)

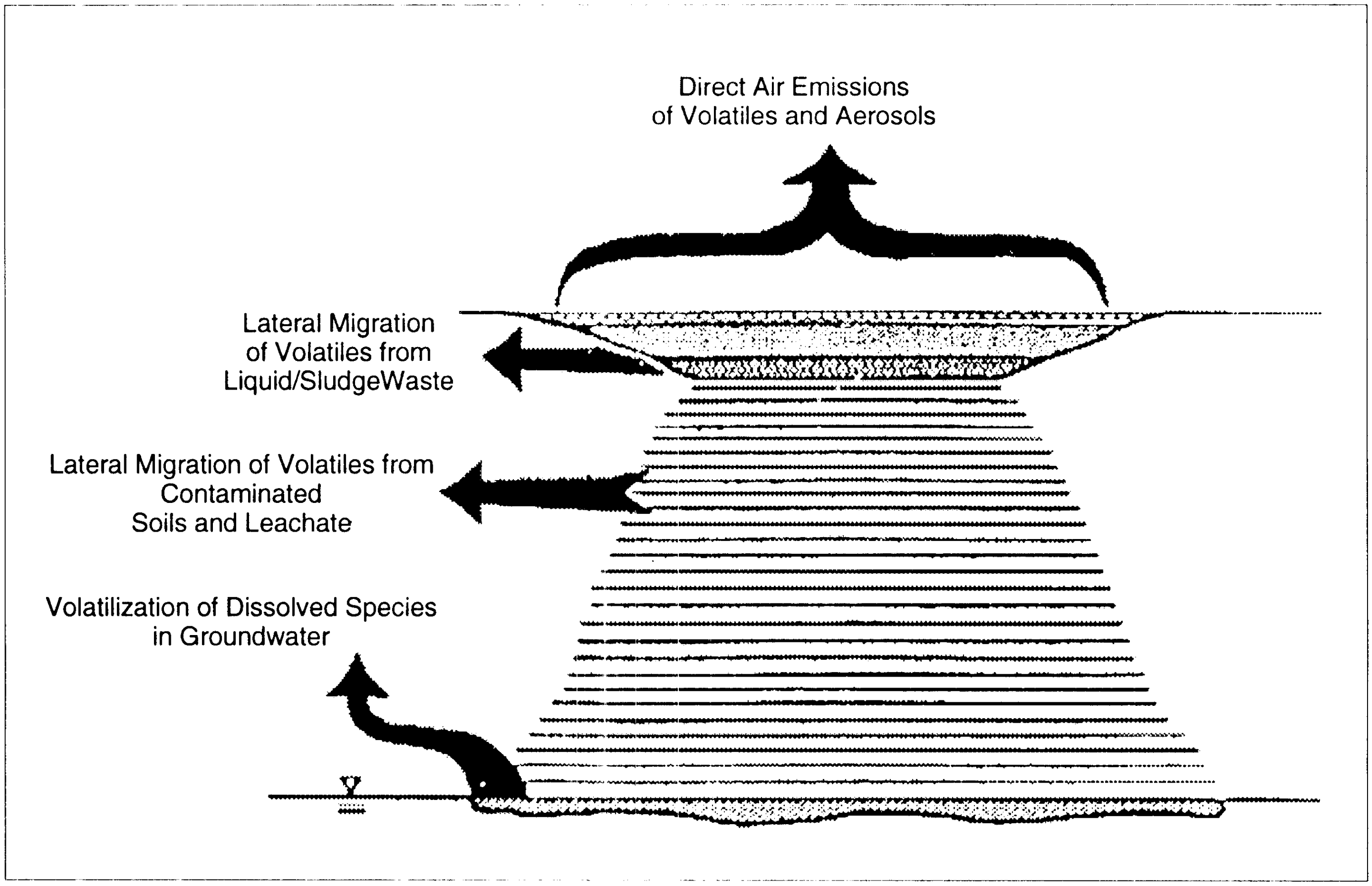


TABLE 1. DATA COLLECTION OPTIONS AND APPLICATIONS

TECHNIQUES	COLLECTION METHOD	LEVEL OF EFFORT	APPLICATION	COMPOUNDS [1]	DETECTORS [2]
Head Space Analysis	Bottle	Screening	Field Measurement	VOC, SVOC; VIC	OVA, PID for VOCs and SVOCs; SD for VICs
Static Chamber	Canisters; Tedlar Bags	Screening/ In-Depth	Field Measurement	VOC, SVOC; VIC	OVA, PID for VOCs and SVOCs; SD for VICs
Realtime Instrument Survey	Instrument on/near Waste Surface	Screening	Field Measurement	VOC, SVOC; VIC; PM	OVA , PID for VOCs and SVOCs;SD, H/S for VICs; DM for PM
Upwind/Downwind Survey	Polyurethane Foam; Solid Sorbent; Filter	Screening	Field Measurement	VOC, SVOC; VIC; PM	OVA , PID for VOCs and SVOCs;SD, H/S for VICs; DM for PM; GC/MS
Modeling	Data Required: Soil Contaminants/Concentrations; Porosity; Moisture	Screening/In-Depth	Field Measurements for Soil Characteristic Data or can use Model Defaults	VOC, SVOC; VIC; PM	N/A
Surface Flux Chamber	Enclosure	In-Depth	Field Measurement;(can use directly on freshly disturbed soil)	VOC, SVOC; VIC; PM	OVA, PID for VOCs and SVOCs; SD, GS/MS
Soil Vapor Probes	Probes	In-Depth	Field Measurement; Conduct Limited Transect (One Upwind, Two or Three Downwind)	VOC, SVOC; VIC; PM	OVA, PID for VOCs and SVOCs; SD, GS/MS
Downhole Flux Chamber	Enclosure	In-Depth	Field Measurement	VOC, SVOC; VIC	OVA, PID for VOCs and SVOCs; SD, GC/MS
Transect	Optical Remote Sensing or Array of Point Samples	In-Depth	Field Measurement	VOC, SVOC; VIC	FTIR, UV-DOAS, GFC, FBPA, Laser, PAS, LIDAR, etc.[3]
Fenceline Monitoring/ Interactive Modeling	Any of Above Methods	In-Depth	Field Measurement	VOC, SVOC; VIC	OVA PID for VOCs and SVOCs; SD

[1] VOC = Volatile Organic Compounds
SVOC = Semivolatile Organic Compounds
VIC = Volatile Inorganic Compounds
PM = Particulate Matter

[2] OVA = Organic Vapor Analyzer
PID = Photoionization Detector
SD = Specific Compound Detector
H/S = Health/Safety Director
DM = Dust Monitor

[3] Optical Remote Sensing Detectors
FTIR = Fourier Transform Infrared
UV-DOAS = Ultraviolet-Differential Optical Absorbance
GFC = Gas Filter Correlation
FBPA = Filtered Band Pass Absorption
Laser = Laser Absorption
PAS = Photoacoustic Spectroscopy
LIDAR = Light Detection And Ranging
ETC = Diode-Laser Spectroscopy

Predictive models can be used to determine if the site has an emissions potential. This is a good screening approach provided that waste composition and concentration data are available. (Since most models are conservative, predictive modeling is generally used to determine if a site does not have a significant emissions potential and that no further APA is required.) This approach can also be used for an in-depth APA, provided that measured and representative model input, including waste composition and physical data, are used with an appropriate model.

In-Depth Level Technologies

Surface flux chamber is a preferred direct measurement approach applicable to many types of waste sites [3] and capable of generating both undisturbed and disturbed emission rate data for volatile and semivolatile compounds. The technology uses a chamber to isolate a surface emitting gas species (organic or inorganic); emission rates are calculated by measuring the gas concentration in the chamber and using the chamber sweep air flowrate and surface area.

Soil vapor probe is a direct measurement method that uses a chamber and sweep air to measure emission rates [3]. The chamber is a small exposed area at the end of a ground probe where sweep air is added at a fixed, known rate and gas samples are collected and analyzed for volatile and semivolatile compounds. While this technology is typically used for plume mapping it is capable of generating emission rate data that represent waste emissions as if the land surface were disturbed and exposed.

Downhole flux chamber, a third direct measurement technology, is similar to the soil vapor probe method in that it obtains subsurface gas emission rates that represent disturbed waste. However, this technology is used with a hollow-stem drilling rig, and emission rates are obtained from subsurface waste up to 100 feet below the surface (or more if necessary). A cylindrical chamber is lowered down the annulus of the hollow-stem auger and the air at the freshly exposed waste at the depth of the borehole is sampled. Both the soil vapor probe and the downhole flux chamber technologies provide useful disturbed waste emission rate data without the need to excavate the waste.

Transect technology is an indirect method that involves the collection of ambient concentration data for gaseous compounds and/or particulate matter using a two-dimensional array of point samplers. These data, along with micro-meteorological data, can be used to estimate the emission rate of the source by using a specific dispersion model. Data can be obtained that represent emissions from a complex or heterogeneous site or an activity that generates fugitive air emissions.

Ambient concentration data can also be collected using path averaged techniques or line integration such as optical remote sensing techniques.

Fenceline monitoring/modeling can be used to develop screening or in-depth emission rate data. Data quality depends on the type of air monitoring conducted, the extent of the data set, the quality of the meteorological data, and the dispersion model used to simulate the emission event. This approach is often used to support emission rate data obtained from other approaches or when fenceline monitoring is conducted for other purposes. It is typically not performed for the sole purpose of providing emission rate data.

Limitations

Screening Level Technologies

Head space analysis of a sample in a bottle is limited by the procedure and instrument used to perform the screen. Typically, a broad-band realtime gas analyzer is used (e.g., an Organic Vapor Analyzer). This type of analyzer provides useful information but is often subject to interferences.

Upwind/downwind survey monitoring is generally limited in its ability to identify properly the emission potential of the site for the following reasons: testing out of the plume; not accounting for upwind interferences; or using survey instruments that are incapable of detecting the compounds emitted.

Realtime instrument survey has the same limitations as upwind/downwind screening except that measurements are generally made over the waste; therefore meteorological conditions have less of an influence on the results.

Predictive models are inherently limited by the assumptions of the model itself. It is important that an appropriate model be selected and site-specific input data are used where possible.

In-Depth Level Technologies

Surface flux chamber is limited by the number of data points that are needed or required to describe the source. If the site is heterogeneous, each area of similar emissions potential requires an assessment. The number of data points needed to describe each unit may be significant. The technology is not applicable to particulate matter and is of limited use for assessing emissions from active processes with fugitive emissions.

Soil vapor probe technology has the same limitations as the surface flux chamber regarding the number of data points required to assess the source and is also limited to gaseous emissions. Further, the depth of the investigation is limited to assessing emissions typically up to 10 feet below the land surface. While the waste source may be deeper, the exposed surface is small, resulting in emission rate estimates of higher uncertainty than other direct technologies.

Downhole flux chamber limitations are similar to those of the soil vapor probe technology, but the maximum depth is generally up to 100 feet below land surface. A drilling rig is required, increasing the costs of the operation. Combining downhole flux chamber measurements with other site assessment activities using hollow-stem augers can substantially reduce costs.

Transect technology is limited by upwind interferences, analytical limits of detection, meteorological influences, and the need to use a model to estimate emission rate. It can be time consuming and expensive to collect the required field data since the meteorological conditions of the model must be met prior to data collection in order for the model to be effective.

Fenceline monitoring/modeling is generally limited by the extent of the monitoring network, the quality of these data, upwind interferences, analytical sensitivity, and the need to use modeling to estimate emission rates. This method has the same limitations as the transect technology and, in addition, is usually considered less accurate because the model used is not specific to the conditions by which the ambient data were collected.

Site Requirements

There are no specific site requirements for an APA assessment other than a secure site, site access, and standard support facilities. As with all site investigation work, a site trailer equipped with 110 volt, 50 or 100 amp electric service, lighting, and a telephone provides a functional work area. Portable field instruments usually are battery powered and require charging overnight. A trailer with 110 volt power permits recharging of the analyzers on the trailer overnight, thereby keeping the equipment onsite. Since many field analyzers require calibration, an area, perhaps along the side of the trailer, can be equipped with a gas bottle rack for safe storage and use of compressed gases (e.g., calibration and support gases). An ambient monitoring network may require weatherproof, AC-powered shelters. Worker support facilities are also recommended but are not required. A facilities trailer equipped with storage and decontamination areas is often useful.

Status of the APA Process

EPA has provided technical guidance for conducting an analysis of the air pathways for air toxic species at waste sites and for conducting air monitoring. This technical guidance is contained in a four-volume series:

VOLUME I Application of Air Pathway Analysis for Superfund Activities

VOLUME II Estimation of Baseline Air Emissions at Superfund Sites

VOLUME III Estimation of Air Emissions from Cleanup Activities at Superfund Sites

VOLUME IV Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis

These volumes are currently being revised. Any of the EPA contacts will be aware of the current status of the APA documents.

The amended National Contingency Plan expands upon the requirement to conduct and fully document an air pathway analysis. The process is defined as a "systematic approach involving a combination of modeling and monitoring methods to assess actual or potential receptor exposure to air contaminants" [2, p. 2-1]. Volume I explains this approach and how the APA integrates into the site remediation process. Volume II provides the "how to" information needed to conduct an APA including all recommended screening and in-depth technologies for assessing air emissions [3]. Estimating emissions from remedial processes is covered in Volume III [4], and air modeling and air monitoring approaches are presented in Volume IV [5]. This series was written with the EPA RPM as the target audience.

Research efforts are underway to improve these assessment methods and explore further applications. Current research is focused on using these methods to design and then test the effectiveness of various air emission control technologies. Other studies have been proposed to provide correlations for data obtained from screening and in-depth methods so that better estimates of emission rates can be obtained from cost-effective field studies.

EPA Contact

Technology-specific questions regarding air emissions assessment and air monitoring at hazardous waste sites may be directed to:

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Or to one of the Regional Air/Superfund Coordinators:

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Mr. Ed Bates	U.S. EPA, RREL
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