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16. ABSTRACT

This report presents available methods for estimating air emissions at Superfund hazardous waste sites prior to any remedial action. Methods described include direct emission measurement techniques, indirect measurements and predictive emissions modeling. Information is provided on selecting from among the range of methods available given the associated range of costs and uncertainties. This report revises and expands an earlier report, Procedures For Conducting Air Pathway Analyses For Superfund Activities, Volume II, Estimation Of Baseline Air Emissions At Superfund Sites, EPA-450/1-89-002. It is one in a series of reports that provide guidance on conducting air pathway analysis at Superfund hazardous waste sites.

The purpose of this report is to assist EPA Air and Superfund staff, State Air Superfund program staff, Federal and State remedial and removal contractors, potentially responsible parties and others in designing, conducting, and reviewing air pathway analyses at undisturbed hazardous waste sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

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AIR/SUPERFUND NATIONAL TECHNICAL GUIDANCE STUDY SERIES. VOLUME II - ESTIMATION OF BASELINE AIR EMISSIONS AT SUPERFUND SITES

* This document revises earlier edition, EPA-450/1-89-002.

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Contract Number 68-02-4392

U. S. ENVIRONMENTAL PROTECTION AGENCY

Office Of Air and Radiation

Office Of Air Quality Planning And Standards

Research Triangle Park, North Carolina 27711

PREFACE

This report revises and expands an earlier report, Procedures For Conducting Air Pathway Analyses For Superfund Activities, Volume II, Estimation Of Baseline Air Emissions At Superfund Sites, EPA 450/1-89-002. It is one in a series of reports that provide guidance on conducting air pathway analysis at Superfund hazardous waste sites. It was developed for the Office of Air Quality Planning and Standards in cooperation with the Office of Emergency and Remedial Response (Superfund).

This report have been reviewed by the National Technical Guidance Study Technical Advisory Committee, State agencies, various groups within the U.S. Environmental Protection Agency, and the private sector. It provides technical guidance for use by a diverse audience including EPA Air and Superfund Regional and Headquarters staff, State Air Superfund program staff, Federal and State remedial and removal contractors, and potentially responsible parties in analyzing air pathways at hazardous waste sites. This report is written to serve the needs of individuals having different levels of scientific training and experience in designing, conducting and reviewing air pathway analyses. Remedial Project Managers, On Scene Coordinators, and the Regional Air program staff, supported by the technical expertise of their contractors, will use this volume when developing baseline emission estimates for undisturbed hazardous waste sites.

Because assumptions and judgments are required in many parts of an air pathway analysis, an analysis requires a strong technical background in air emission estimation methods, measurements, modeling and monitoring. Air pathway analyses cannot be reduced to simple "cookbook" procedures. Therefore, this volume is designed to be flexible, allowing the use of professional judgment. The procedures presented in this report are intended solely for technical guidance. They are not intended, nor can they be relied upon, to create rights substantive or procedural, enforceable by any party in litigation with the United States.

This edition of Volume II will be periodically updated to incorporate new data and information on air pathway analysis procedures. The Agency reserves the right to act at variance with these procedures and to change them as new information and technical tools become available on air pathway analyses without formal public notice. The Agency will, however, attempt to make any revised or updated manual available to those who currently have a copy through the registration form included with the report.

Copies of this report are available as supplies permit, through the Library Services Office (MD-35), U.S. EPA, MD-35, Research Triangle Park, NC 27711 or from the National Technical Information Services, 5285 Port Royal Road, Springfield, VA 22161.

This report has been reviewed by the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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GLOSSARY OF FREQUENTLY USED TERMS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Building D-5, Cincinnati, OH 45211.
Adsorption	A physical process in which molecules of gas, dissolved substances, or liquids adhere in an extremely thin layer to the surfaces of solid bodies with which they are in contact.
Air Monitoring	A gas phase sampling technique where ambient air is sampled. It can be used to develop emission rate estimates and is similar to indirect emission measurement except measurements usually are taken at greater distances from the waste site.
APA	Air Pathway Analyses. APA are designed to assess the potential for air emissions from a hazardous waste site.
BEEs	Baseline Emission Estimates. These are estimates of baseline emission rates from a hazardous waste site in its undisturbed conditions.
Calibration	Establishment of a relationship between the response of a measurement system obtained by introducing various calibration standards into the system. The calibration levels should bracket the range of levels for which actual measurements are to be made.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980. Modified by SARA in 1986. The Acts created a special tax that goes into a trust fund, commonly known as Superfund, to investigate and clean up abandoned or uncontrolled hazardous waste sites.
Co-disposal Site	A waste site that has received and mixed municipal and hazardous wastes.
Detection Limit	The minimum quantity of a compound which yields a "measureable response." Measurable response has many statistical definitions. Be careful to differentiate "instrumental detection limit," which refers to the minimum quantity of material introducible into a measurement system that can be detected, from "method detection limit," which means the minimum concentration of a compound in a sample which, when put through the entire sampling and analysis process, can be detected.
Direct Emissions Measurement	A measurement made directly on or above the waste to determine the emission rate of volatile species from a liquid or solid surface.

Disturbed Condition	Changes in a hazardous waste site as remediation takes place that usually involve increasing the emission rate of volatile species and particulate matter.
Emissions	The total of substances discharged into the air from a discrete source.
EPA	U.S. Environmental Protection Agency.
FS	Feasibility Study. Analysis and selection of alternative remedial actions for hazardous waste sites.
Fugitive Dust	Atmospheric dust arising from disturbance of granular matter exposed to the air; called "fugitive" because it is not released to the atmosphere in a confined flow stream.
Hazardous	Those wastes that are regulated or "listed" under RCRA (40 CFR Part 261) or wastes that are ignitable, corrosive, reactive, or toxic.
In-depth Technologies	Very detailed methods for measuring emissions. These technologies produce detailed, reliable data.
Indicator Species	Species found in hazardous waste that can be used to represent a group of species in determining emissions from a site.
Indirect Emissions Measurement	A gas phase sampling technology that measures ambient air concentrations at short distances down-wind of a hazardous waste site. Data are collected to satisfy specific needs of specialized models used to estimate air emissions.
Lagoon	In this manual, lagoon encompasses surface impoundments or impoundments designed to hold liquid wastes or wastes containing free liquids.
Landfill	For purposes of this manual, a landfill is a facility, usually an excavated pit, into which wastes are placed for permanent disposal.
mg/m3	Milligrams per cubic meter. This is a measure of mass per unit volume. The units mg/m3 are commonly used to describe concentrations of particulates, dusts, fumes, and mists.
NIOSH	National Institute for Occupation Safety and Health, Centers for Disease Control, Public Health Service, U.S Department of Health and Human Services.
NPL	National Priorities List. A list of waste sites for which EPA has assessed the relative threat of site contamination on soil, air, surface water, ground water, and the population at risk. Site listing is found under CERCLA (Section 105) and is updated three times a year.

OSHA	Occupational Safety and Health Administration, U.S. Department of Labor.
OVA	Organic vapor analyzer.
Particulate Matter	Airborne solid or liquid matter.
PEL	OSHA permissible exposure limit, expressed as ppm or mg/m^3 of substance in air.
ppb	Parts per billion.
ppm	Parts per million.
Probe	A tube used for gas phase concentration sampling or for measuring pressures at a distance from the actual collection or measuring apparatus.
Quality Assurance	A system of activities designed to assure that the quality control system is performing adequately.
Quality Control	A system of specific efforts designed to test and control the quality of data obtained.
RI	Remedial Investigation. Field investigations of hazardous waste sites to determine pathways and nature and extent of contamination.
RPM	Remedial Project Manager, equivalent to a site manager at non-NPL sites.
Sampling	The process of withdrawing or isolating a fractional part of the whole. In air or gas analysis, it is the separation or a portion of an ambient atmosphere with or without the simultaneous isolation of selected components.
SARA	Superfund Amendments and Reauthorization Act. Modifications of CERCLA enacted on October 17, 1986.
Screening Technologies	Quick and simple methods for estimating baseline emissions.
Undisturbed Condition	The condition in which a hazardous waste site is discovered or may be left if a no-action remedial alternative is selected.
VOCs	Volatile organic compounds. An organic compound (containing carbon) that evaporates (volatilizes) readily at room temperature.

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

The United States Environmental Protection Agency (EPA) is responsible for the assessment and cleanup of the National Priority List (NPL) sites under CERCLA and SARA. EPA's Remedial Program Managers (RPMs) are required to assess the potential for air emissions and air quality impacts caused by NPL sites prior to and during cleanup. To date, no standard approach for assessing the air pathway at NPL or other hazardous waste sites has been available. As a result, performing air pathway analyses (APA) has been less straightforward than evaluating other pathways such as the impacts on ground water or surface water quality. This manual assists RPMs in determining if an uncontrolled site has the potential for significant air emissions and, if so, how to characterize the baseline air emissions potential from the site.

This volume is one in a series of manuals prepared for EPA to assist its RPMs in the assessment of the air contaminant pathway and developing input data for risk assessment. Volume I (1) of the series provides generalized guidance for addressing air issues throughout the overall Superfund process. This manual (Volume II) provides guidance on developing baseline emission estimates for hazardous waste sites. Baseline emission estimates (BEEs) are defined as emission rates estimated for a site in its undisturbed state. Volume III (2) provides guidance on estimating emissions from cleanup activities, and Volume IV (3) provides guidance on ambient air monitoring and on dispersion modeling. Together these four manuals provide a complete treatment of air issues for superfund applications.

CERCLA and SARA mandate the characterization of all contaminant migration pathways from the waste or hazardous material to the environment and evaluation of the resulting environmental impacts. However, air pathway analyses are often overlooked because many sites have little or no perceptible air emissions in their baseline or undisturbed state. Even low level emissions, however, may be significant if toxic or carcinogenic compounds are present. Also, emissions during clean-up may be much higher than baseline emissions. Emissions of potential concern include volatile and semi-volatile organics, acid gases, particulate matter, and toxics associated with windblown particulate matter such as metals, PCBs and dioxins.

A remedial investigation is typically necessary to provide data on air emissions from the site. These emission can be measured directly, or estimated indirectly from chemical and physical data collected during the RI and used as inputs to predictive models. Remedial investigations (RIs) often include ambient air monitoring to assess baseline air quality impacts from the site, but measurements of emission rates or soil-gas concentrations are less widely employed. An introduction to these techniques is a major emphasis of this manual. Emission rate or soil-gas data can be useful for: 1) identifying "hot spots" e.g. areas of higher than average waste content or pockets of subsurface gases, 2) serving as model inputs (source terms) to estimate ambient air concentrations under meteorological conditions other than those encountered during the RI, and 3) estimating emissions during remediation. For this last use, the air emissions investigation during the RI stage would include emission measurements of both the undisturbed wastes and the exposed or disturbed wastes.

While not strictly part of baseline emission estimates, measurements of emissions from exposed or disturbed wastes can generally be performed during the RI using the same techniques presented in this manual for performing baseline emission measurements. These data along with the BEEs can be used in the procedures outlined in Volume III of this series to help evaluate remediation options, design an engineering approach to the site mitigation, and determine whether air emission control technologies or an air monitoring program may be necessary as part of the remedial alternatives.

1.2 OBJECTIVES

The overall objective of this manual is to assist RPMs or site managers in assessing the impacts on air quality from undisturbed sites. Specifically the manual is intended to:

- Present a protocol for selecting the appropriate level of effort to characterize baseline air emissions.
- Assist site managers in designing an approach for estimating baseline emissions.
- Identify available methods for developing site-specific baseline emission estimates (BEEs).

1.3 APPROACH

To meet the objectives of this program, three steps were undertaken to compile and assess existing information: 1) Conduct a literature search, 2) Perform a survey of key researchers, and 3) Review and evaluate the collected information. This work served as the basis for developing the protocol for estimating air emission factors for remediation presented herein. Each step of the approach is discussed below.

A computer-assisted search of 15 databases was performed to identify published literature of potential interest. Keywords were formulated into a search strategy to identify abstracts related to both baseline and remedial emissions. Approximately 1400 abstracts were reviewed, and over one hundred publications were identified as pertinent and obtained by staff librarians.

The literature search was augmented by a telephone survey to locate and access unpublished data or research in progress. A list of contacts was developed that included regional EPA personnel, employees of EPA research offices, EPA contractors, university researchers, and referrals from those initially contacted. A set of questionnaires was used to put the responses obtained during the phone survey in a standard format.

The collected information was reviewed and evaluated with respect to its applicability to estimating baseline air emissions from NPL and other hazardous waste sites.

1.4 RECOMMENDED USES OF THIS MANUAL

This manual is, to the extent possible, a complete, stand-alone document. It is, however, intended to complement existing guidance manuals for the Superfund program.

This manual has certain limitations:

- The manual is a decision making tool but it is not intended to relieve the site managers of their decision making responsibility.
- The protocol is not a "cookbook" for designing air pathway investigations or for determining BEEs.
- The determination of BEEs for a site will not by itself, yield an assessment of actual or potential air impacts, but it is a useful part of that evaluation process.

The steps in the overall NPL site clean-up process are shown in Figure 1. The primary intended use for this manual (Volume II) is for estimating air impacts as part of the evaluation of the undisturbed site. Therefore the manual's guidance is input to the record of decision (ROD) step, as well as, the RI/FS step.

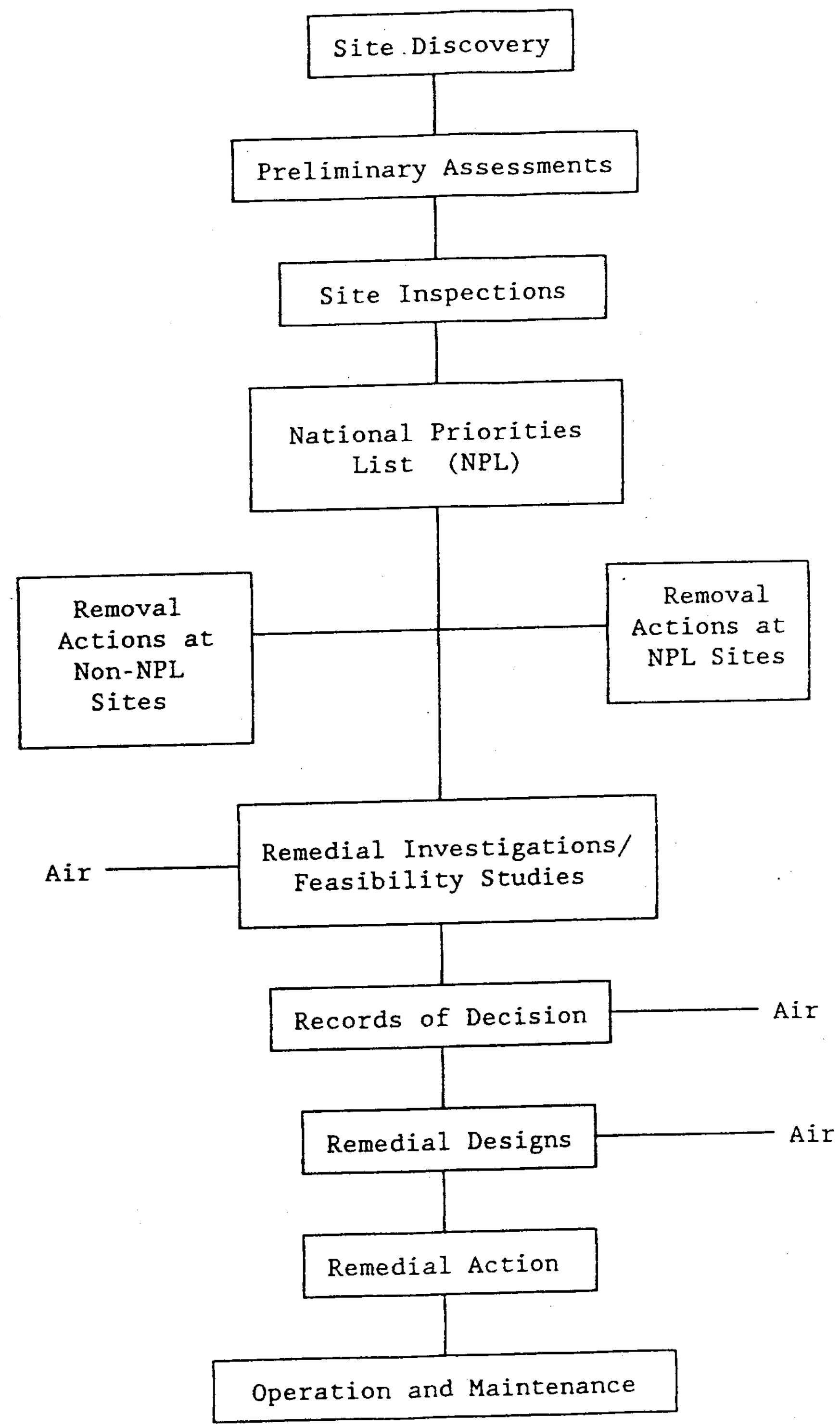

Figure 1. Superfund Flow Chart, Noting Elements Where This Manual May Apply.

Furthermore, this manual provides the important function of standardizing the air pathway analysis (APA) for baseline NPL sites, thereby ensuring that a uniform and systematic approach is followed for the diverse universe of NPL sites. The manual provides a protocol for estimating air quality impacts resulting from undisturbed sites. For each step, a three-tiered approach is presented. The approaches in order of preference are:

1. Use of site-specific field data;

2. Use of predictive models using site-specific inputs;

3. Use of tabulated default values when site-specific information is unavailable.

Therefore, emissions can be estimated regardless of the state of knowledge regarding a given site. Of course, the confidence of the emissions estimates depends on the associated confidence of the inputs to the estimation procedure.

Limitations of the emissions estimation procedures should be borne in mind. The primary limitation is that the data quality of any emissions estimate is dependent on the data quality of the inputs and on the quality of the assumptions that are made. The use of site-specific data as input to the estimation procedure is preferable to the use of predictive models, which in turn are preferable to the use of tabulated generic emission factors. Data of known quality (confidence) should be used whenever available. In many cases, the conceptual site model will be developed from a limited database. The resulting estimates of volume of contaminated material, the type of contaminants present, the concentration of the contaminants, etc. will have large associated uncertainties. Therefore any emissions derived from such data will have an even larger overall uncertainty.

1.5 DOCUMENT ORGANIZATION

There are five remaining sections to Volume II. General information on the potential for air contaminant emissions from hazardous waste sites is presented in Section 2. Section 3 offers a protocol for determining if BEEs are required and how to develop site-specific BEEs. Information on sampling methods that can be used to obtain BEEs is provided in Section 4. Section 5 describes case studies in which BEEs were needed and/or determined for hazardous waste sites. References are given in Section 6.

An annotated bibliography of the information reviewed for this project is included as Appendix A. Appendix B identifies chemical and physical properties of waste material that may affect is emissions potential. A guide to developing an overall emission rate from individual emission rate measurements is included as Appendix C. Information on databases containing potential input values for predictive models is given in Appendix D. Descriptions of remote sensing systems are contained in Appendix E.

SECTION 2

AIR EMISSIONS FROM HAZARDOUS WASTE SITES

This section presents information on landfills and lagoons, the two general types of sites used in this manual to demonstrate methods for estimating the potential for air emissions. For this manual, all types of uncontrolled solid waste sites, land disposal sites in particular, will be referred to as "landfills" and all types of uncontrolled liquid waste sites will be referred to as "lagoons." The estimation methods described for application to landfills and lagoons may generally be applied to solid and liquid hazardous waste, respectively.

This section addresses potential emission sources and potential air quality impacts. Discussion of potential air quality impacts covers the general types of air quality impacts by waste site category, and the basic transport mechanisms involved with the movement of contamination from lagoons and landfills. Where not otherwise specified, the general term hazardous waste site is used to refer to both landfills and lagoons that contain hazardous wastes and/or substances. Figures 2 and 3 depict these two types of sites in generalized schematic drawings.

The site and contaminant characteristics discussed below are general background information for working with the protocol presented in Section 3. The information provided will assist the site manager in developing conceptual models of landfills and lagoons. Based on this conceptual understanding, the site manager can then develop strategies for assessing the potential impacts and for estimating potential air emissions from these sites. The references cited in this section and those listed in the annotated bibliography contain further background material.

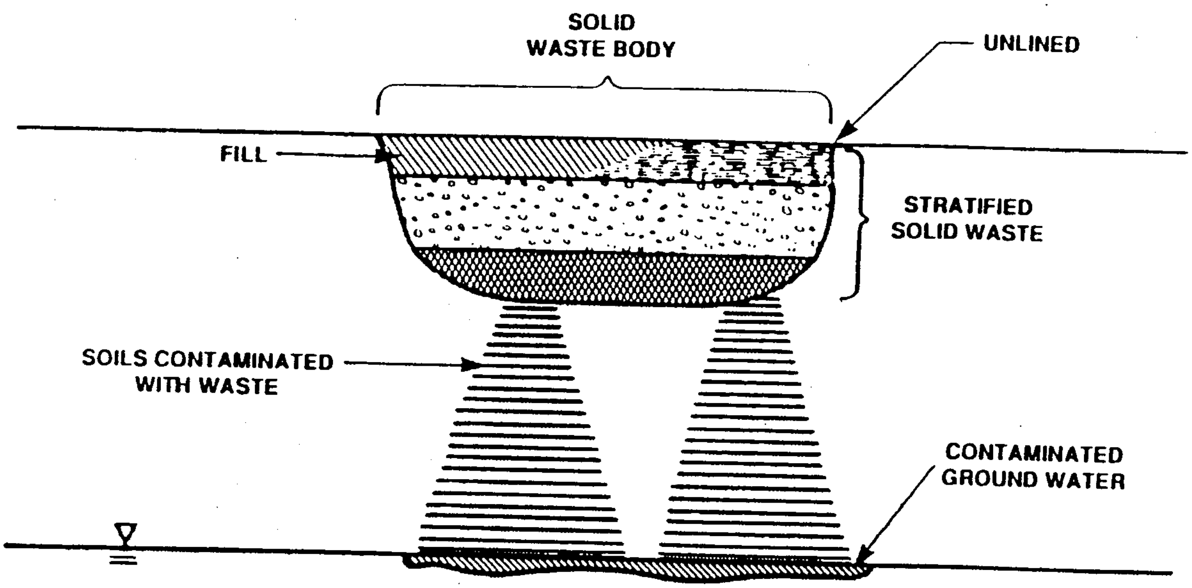

Figure 2. Conceptual schematic of a landfill.

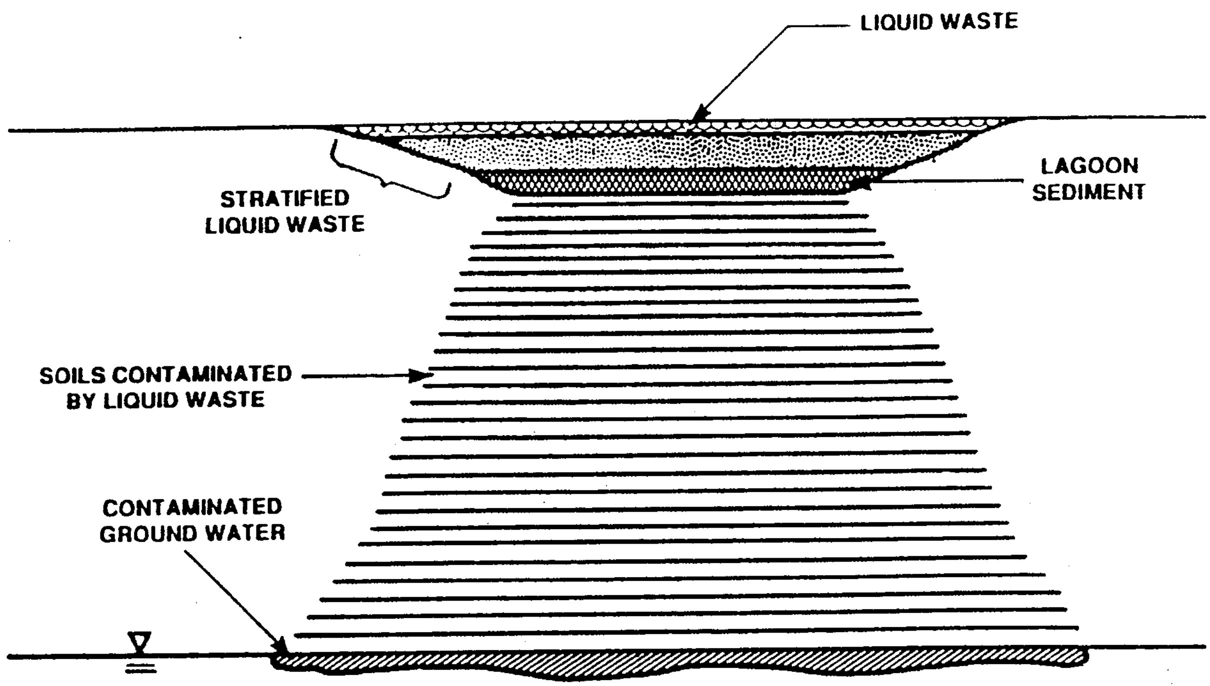

Figure 3. Conceptual schematic of a lagoon.

2.1 GENERAL DESCRIPTION

2.1.1 Landfills

Landfills are facilities into which wastes are placed for permanent disposal, and often are simply excavated pits. Landfills may vary in size from a few tenths of an acre to several hundred acres, and other landfill characteristics can also vary greatly from one site to the next. Most variations are attributable to the types of stored wastes, the operating practices and the age of the facility, and hence, its design.

Commercial landfills can be categorized by design criteria such as liners and gas-venting systems. Older landfills are usually unlined. Newer landfill designs may specify liner systems to retard transport of leachate and wastes into soils and ground water. Some landfills have built-in gas venting systems to prevent build up of landfill gases.

Landfills can be further differentiated by the types of waste they store. Commercial landfills are commonly classified as municipal or hazardous, depending on the types of waste accepted. Municipal landfills accept solid, semi-solid, and liquid nonhazardous wastes, including garbage, glass, plastics, paper, plant matter, ashes, some industrial wastes, and demolition and construction wastes.

Hazardous waste landfills accept hazardous sludge, liquids, semi-solids, residues, concentrates, or leachate or ash originating from a waste. Much of the hazardous waste originates from manufacturing, petrochemical, and chemical industries. Federal, state, and local regulations establishing minimum design standards and restricting types of acceptable landfill wastes have evolved over the last 25 years. In the past, mixtures of liquid and solid waste were common practice. Today, landfills can no longer accept liquid wastes or solids that contain free liquids unless they've been treated with fixatives and stabilizers to eliminate the free liquids prior to disposal.

Co-disposal landfills are sites that have received and mixed municipal and hazardous wastes. Any available disposal records may relate types of wastes and location/mixing within the landfill.

Most landfills that are selected as Superfund sites have undergone some form of closure. In some cases, currently operating facilities may have abandoned hazardous landfills at the same site. The appearance of a closed landfill will depend on when it was closed. Closure may mean that the site is covered with vegetation or that no waste is exposed. Telltale signals of covered waste are seeping leachate and odors. In the past, landfills were often sited in unpopulated areas close to the industry or industries generating the wastes, but population growth and development may result in people living or working in close proximity to the site.

Superfund sites may differ in significant ways from the types of commercial landfills discussed above. In some cases, the site history will be one of relatively indiscriminate disposal of hazardous substances. The sites may contain buried drums or pockets of dumped/spilled wastes that are not uniformly distributed across the disposal area. Information on waste types, disposal practices, date of disposal, etc. may be limited or non-existent. However, the protocol and measurement techniques presented in this manual are sufficiently generalized that they can be applied to such uncontrolled sites. Conversely, the emission models presented here may be of only limited use for sites where the chemical and physical parameters that serve as model inputs are poorly defined.

Potential Site Conditions--

The conditions encountered when investigating landfill sites will vary from site to site because of the differences in location, design, use, and operation. Figure 2 presents a conceptual schematic of a landfill site. The condition of the site cover material will vary greatly and is dependent, to a large extent, on the landfill's operational history. In the best situation, the landfill cover will extend over the entire land disposal area; the cover will have been constructed to minimize rainfall percolation into the waste body and regulated to minimize erosion of the cover. The degree to which the air, the surrounding native soils, and the ground water are protected from contamination from the wastes stored in the landfill will depend both on the landfill design and on the construction and operation of the waste storage facility. If the wastes have been disposed of in an unlined storage area, the likelihood of contamination of surrounding soils and eventual contamination of the ground-water beneath the landfill increases. If the landfill has been constructed at or below the ground-water table, the rate of transport of pollutants into the ground water further increases. Waste material in the landfill may be stratified by age of disposal and/or settling of the more dense waste.

Emission of air pollutants from landfills is dependent on the chemical and physical properties of the stored wastes and on the landfill design components which may have been implemented to reduce air emissions. Municipal landfills are sources of significant amounts of methane and carbon dioxide, and variable amounts of other non-methane hydrocarbons. Hazardous waste landfills often are sources of non-methane hydrocarbons, including volatile organic compounds (VOCs) and semi-volatiles, including pesticides. Co-disposal sites combine the emission potentials of both municipal and hazardous waste sites. The methane gases generated often can increase the migration potential of the high concentrations of non-methane hydrocarbons by acting as a carrier medium during bulk flow transport of these contaminants.

2.1.2 Lagoons

For purposes of this discussion, the term "lagoon" refers to the class of facility also known as surface impoundment or impoundment. This type of facility generally includes a natural topographic depression, a man-made excavation, or a diked area formed primarily of earthen materials. Lagoons are designed to hold liquid wastes or wastes containing free liquids. Lagoons include holding, storage, settling, and aeration ponds.

These waste sites may range in surface area from a few tenths of an acre to hundreds of acres. Man-made lagoons typically range in depth anywhere from 2 to 30 or more feet below land surface.

In some cases, for certain wastes, lagoons may be lined to minimize any fluid seepage. Clay, asphalt, soil sealant, and synthetic membranes are typical lining materials.

To prevent migration of pollutants into the native soils and ground water beneath the lagoon, lagoons are usually built above the naturally occurring water table and take advantage of any impermeable surface or subsurface soils. In areas with high ground-water tables, lagoons may be constructed on the land surface to minimize ground-water contact. Of course, use of liners and building above the water table will not prevent the release of contaminated air emissions from the surface of the lagoon, but these practices limit the possible routes of air emissions (see Section 2.2). Equally important are operating practices and the characteristics of wastes in the lagoon. The importance of these factors tends to parallel the landfill discussion above, as does the importance of lagoon siting practices.

Potential Site Conditions--

Actual site conditions that will be encountered when investigating lagoon sites will vary because of siting, lagoon design, lagoon usage, and differences in lagoon operations. Figure 3 presents a conceptual schematic of a lagoon site. The condition of the lagoon will depend, in large part, on the wastes stored there and the lagoon's operational history. Mixed wastes typically separate into stratified layers with the lighter materials near the surface and the denser liquids, sludges, and sediments having settled to the lagoon bottom. Contaminated soils around and beneath the lagoon are likely, as well as possible contamination of the underlying ground water.

2.1.3 Equivalent Units

Sites containing mixed wastes or having other types of inherent variability may require separate remedial options to be considered for each equivalent area. During the remedial investigation, the site should be theoretically divided into equivalent units for estimating baseline emissions and evaluating potential emissions during remediation. For example, a site containing an abandoned landfill, sludge pits, and buried drums would have at least three distinct units and maybe more. If the type, concentration, or distribution of a given form of contamination varies, then further subdivision of the units should be considered. Similarly, if the soil media or proximity of receptors varies significantly across the site, then further subdivision of the units may be warranted.

2.2 ROUTES OF EXPOSURE

Waste site characterizations performed during a remedial investigation are intended to determine potential or existing contaminant migration by the direct contact, surface water, ground water, and air pathways. Each pathway represents a potential route of exposure to the public and the general environment. Figures 4 and 5 show the potential routes for contaminant migration from landfills and lagoons, respectively. The focus of this manual is the air pathway, and several routes exist for contaminant emissions within this one pathway.

Organic and inorganic emissions from surface wastes may occur as gases, aerosols, and contaminated particulate matter. Where gas migration controls, (e.g., gas venting systems) have been installed, volatile emissions from the controls are likely to be higher than emissions from the site surface. The lateral migration of solid and liquid wastes into the surrounding soils and beneath the containment area can create large areas of contaminated subsurface soils. The contaminated soils also represent a source of potential air emissions via the transfer of contaminants into the air-filled spaces in the soil matrix. The contaminated soil gas can then transfer contaminants into the atmosphere at the surface soil/atmosphere interface.

The generation of leachate from landfills and lagoons can accelerate the pollutant migration into the ground water below and provide an additional source of air emissions resulting from the volatilization of dissolved contaminants in the ground water. The contaminated groundwater also can transfer contaminants into the soil gas and hence the atmosphere.

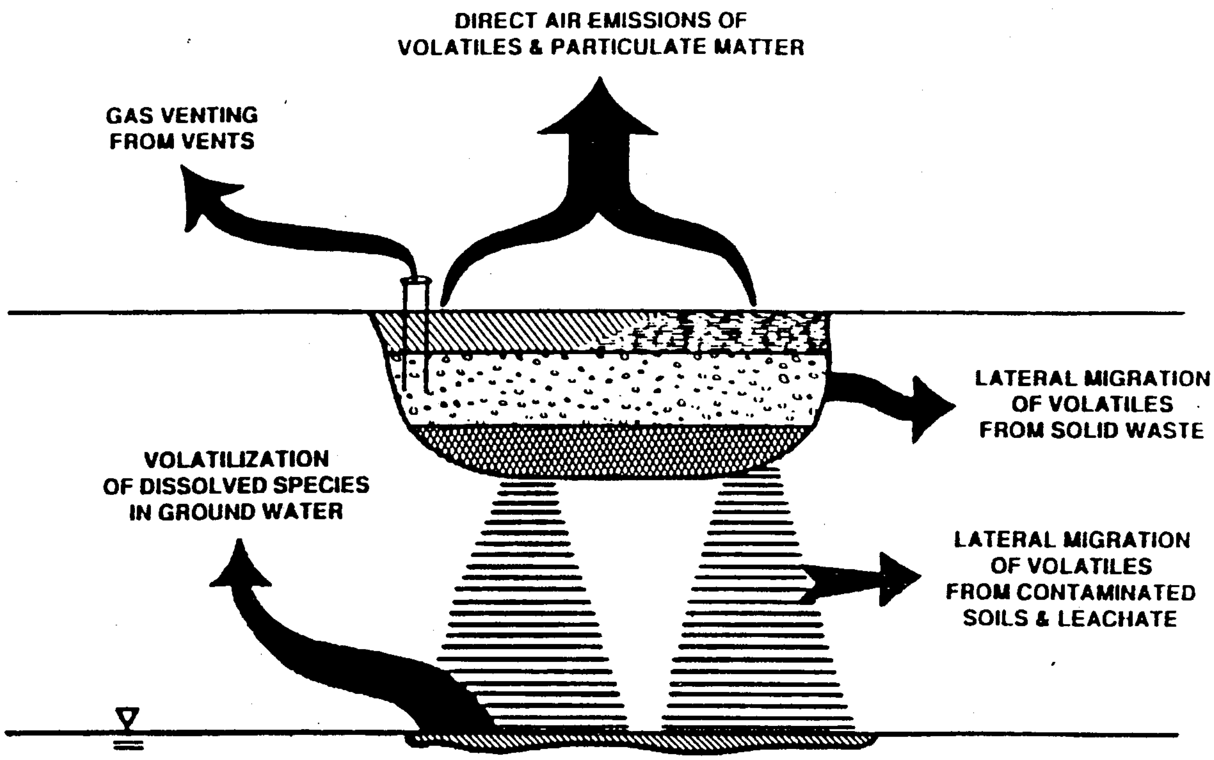

Figure 4. Conceptual Schematic Showing Air Contaminant Pathways From an Unlined Landfill.

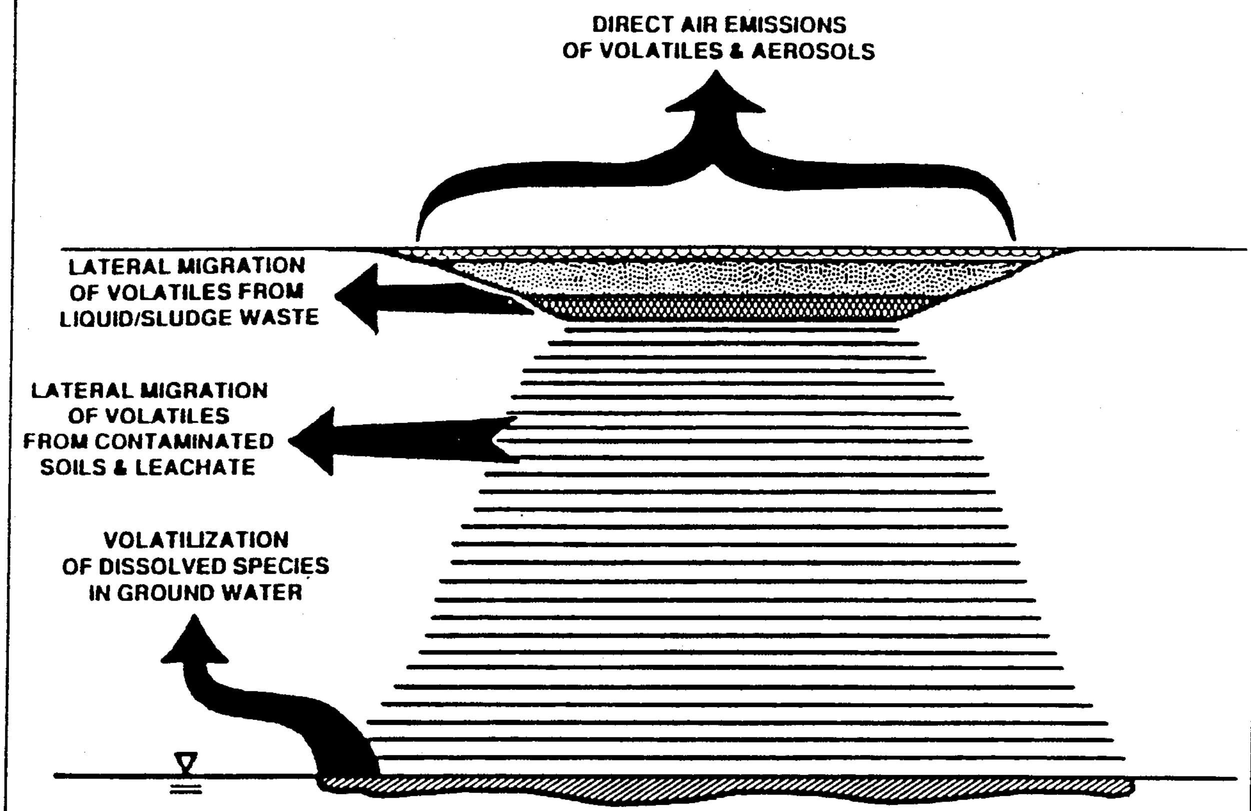

Figure 5. Conceptual Schematic Showing Air Contaminant Migration From an Unlined Lagoon with No Cover.

2.2.1 Key Parameters and Critical Factors Affecting Emissions from Landfills

The generation of landfill emissions depends on several key chemical and physical properties of the waste materials stored at these sites along with site and meteorological factors. Table 1 presents these key factors along with the qualitative effects these factors may have on baseline emissions. These qualitative effects can be used to help estimate the potential air emissions from the site, given critical factors imposed by the site. A discussion of each parameter is outside the scope of this document, but in general, for volatile compounds the rate limiting step is the movement of vapors through the soil. Volatilization into the soil pore spaces is usually quite rapid as is the transfer from the soil-gas into the atmosphere once the soil/air interface has been reached.

Additional information about the key physical and chemical properties of the waste material are presented in Appendix B. Users should consult the references cited below and those listed in the annotated bibliography (Appendix A) for additional background material. General reading materials that may prove helpful include: Guidance Document for Cleanup of Surface Impoundment Sites,(4) Model Prediction of Volatile Emissions,(5) Air Pollution Assessment of Toxic Emissions from Hazardous Waste Lagoons and Landfills,(6) Air Quality Assessment for Land Disposal of Industrial Wastes,(7) Estimating Air Emissions from Disposal Sites,(8) and Air Pollution Problems of Uncontrolled Hazardous Waste Sites.(9)

2.2.2 Key Parameters Affecting Emissions from Lagoons

Figure 5 presents a generalized schematic of the volatilization process from lagoons. In general, the process consists of two steps: vaporization from the surface liquid layer into the boundary air layer and then mass transfer from the boundary layer to the bulk atmosphere. The rate of vaporization is dependent on factors such as the compound's concentration, Henry's Law constant, water solubility and the system temperature. Mass transfer into the bulk atmosphere is dependent on compound properties such as molecular weight and diffusion coefficient, and site-related factors such as

TABLE 1. IMPORTANT PARAMETERS IN DETERMINING AIR EMISSIONS AND THEIR QUALITATIVE EFFECTS ON BASELINE EMISSION ESTIMATES (BEEs)

Parameter	Qualitative Effect on BEEs[a]	
	Volatiles	Particulate Matter
Site Conditions		
Size of Landfill or Lagoon	Effects overall magnitude of emissions but not rate per area.	Effects overall magnitude of emissions, but not rate per area.
Amount of Exposed Waste	High	High
Depth of Cover on Landfills	Medium	High
Presence of Oil Layer	High	High
Compaction of Cover on Landfills	Medium	Low
Aeration of Lagoons	High	High
Ground Cover	Medium	High
Weather Conditions		
Wind Speed	Medium	High
Temperature	Medium	Low
Relative Humidity	Low	Low
Barometric Pressure	Medium	Low
Precipitation	High	High
Solar Radiation	Low	Low
Soil/Waste Characteristics		
Physical Properties of Waste	High	High
Adsorption/Absorption Properties of Soil	Medium	Low
Soil Moisture Content	High	High
Volatile Fraction of Waste	High	Low
Semi-Volatile/Non-Volatile Fraction of Waste	Low	High
Organic Content of Soil and Microbial Activity	High	Low

[a] High, medium, and low in this table refer to the qualitative effect that the listed parameter typically has on baseline emissions.

temperature, pressure, and wind speed. Berms, wind breaks, and lagoon geometry affect the wind speed at the liquid surface and can thereby control the rate of mass transfer. In general, volatility increases as the molecular weight of the compounds present decreases.

2.3 MAGNITUDE OF AIR EMISSIONS

The magnitude of baseline air emissions from landfills and lagoons is dependent on waste-specific chemical and physical factors and site-specific environmental factors. Limited data are available on measured air emission fluxes (rate per area) from previously studied waste sites (Table 2). These data can be used to give the site manager some idea of typical baseline emission estimation (BEEs) and a limited comparison of BEEs for different types of waste sites. Emission flux data for disturbed or exposed wastes are included to demonstrate the potential for increased emissions of volatiles during waste remediation.

2.4 EMISSIONS OF POTENTIAL INTEREST AT NPL SITES

The types of emissions at a hazardous waste site are dependent on the types of waste present, and these in turn are dependent on the types of industries and manufacturers that produced the waste. A listing of the typical wastes generated by 30 various industries and manufacturers can be found in the Handbook of Industrial Waste in California (11). The 25 most frequently detected compounds at 546 hazardous waste sites are summarized in

TABLE 2. SUMMARY OF AVERAGE BASELINE EMISSIONS FOR VARIOUS EMISSION SOURCES

Waste Type	Source Type	Baseline Emission Estimate For TNMHC[a] (ug/m^2-min)	Disturbed or Exposed Waste Emissions For TNMHC (ug/m^2-min)
NPL/Hazardous Waste Sites	Landfills		
	Site A	360	190,000
	Site B	740	26,000
	Site C	29	170,000
	Lagoons		
	Site D	43	640,000
Industrial Waste	TSDF[c] Facilities		
	Active Landfills		
	Site E	---	44-150
	Site F	---	47
	Site G	---	9
	Inactive Landfills		
	Site H (covered)	<1.2	---
	Site I (covered)	<1.2	---
	Land Treatments		
	Site J	---	610-9600
	Lagoons		
	Site K	120	---
	Site L	570	---
	Site M	9-31[b]	---
	Site N	630	---

[a] TNMHC = Total Non-Methane Hydrocarbons.
[b] Different assessment techniques were used.
[c] Transfer, storage, and disposal facilities (RCRA)

Source: Reference 10.

Table 3 according to the type of media, i.e., groundwater, surface water, or air. The table shows the number of sites where each contaminant was detected and the contaminant's relative rank for each type of media. Another useful listing for selecting contaminants with the potential for emissions of concern, is the list of toxic compounds most commonly addressed by state and local regulatory agencies given as Table 4.

2.5 SUMMARY OF POTENTIAL RECEPTORS

Receptors can be divided into three broad categories:

- On-site workers;
- Off-site populace; and
- Non-human receptors.

The on-site workers are in the closest proximity to the hazardous waste site and are potentially subject to the most acute exposure to hazardous substances. The use of personal protective equipment, real-time field instruments, personnel monitoring, site controls, and designated work zones are designed to ensure that field personnel are properly protected against the hazards present at the work site.

The off-site (and any on-site) population in close proximity to the hazardous waste site is another receptor of primary concern. These people are often acutely aware of the hazardous waste site and the potential for contaminant exposure. Section 3 provides an approach for estimating emissions which can subsequently be used to predict the airborne contaminant concentration for downwind receptors to assist in the establishment of appropriate action levels. Use of this protocol, coupled with an effective monitoring and modeling program, will provide useful information for the site's community relations program.

TABLE 3. MOST FREQUENTLY REPORTED SUBSTANCES AT 546 NATIONAL PRIORITY LIST SITES

Substance Identified at Hazardous Waste Disposal Sites	Sites[a]	Air Number of Sites (Rank)[bc]	Ground Water Number of Sites (Rank)[b]	Surface Water Number of Sites (Rank)[b]
Most Frequently Occurring				
1. Trichloroethylene	179	8 (5)	127 (1)	49 (3)
2. Lead	162	7 (6)	77 (4)	84 (1)
3. Toluene	153	1 (3)	81 (3)	40 (4)
4. Benzene	143	1 (2)	84 (2)	36 (5)
5. Polychlorinated Biphenlys (PCBs)	121	6 (4)	29 (21)	54 (2)
6. Chloroform	111	1	70 (6)	24 (11)
7. Tetrachloroethylene	90	3 (16)	57 (7)	17 (14)
8. Phenol	84	3 (16)	43 (9)	28 (8)
9. Arsenic	84	2 (17)	45 (8)	35 (6)
10. Cadmium	82	31 (17)	28 (16)	28 (9)
11. Chromium	80	1	34 (14)	33 (7)
12. 1,1,1-Trichloroethane	79	3 (18)	58 (6)	20 (12)
13. Zinc and Compounds	74	2	28 (17)	27 (10)
14. Ethylebenzene	73	7 (7)	36 (12)	14 (20)
15. Xylene	71	9 (4)	32 (15)	8 (25)
16. Methylene Chloride	63	2	36 (13)	17 (15)
17. Trans-1,2-Dichloroethylene	59	1	42 (10)	17 (16)
18. Mercury	54	4 (10)	27 (20)	20 (13)
19. Copper and Compounds	47	6	17 (24)	16 (18)
20. Cyanides (Soluble Salts)	46	2	16 (25)	16 (19)
21. Vinyl Chloride	44	4 (11)	28 (18)	10 (23)
22. 1,2-Dichloroethane	44	2	25 (21)	17 (17)
23. Chlorobenzene	42	0	23 (23)	9 (23)
24. 1,1-Dichloroethane	42	0	28 (19)	8 (24)
25. Carbon Tetrachloride	40	2	25 (22)	12 (21)

a

Number of sites at which substance is present. Substances may be present in one, two, or all three environmental media at all sites at which it is known to be rpesent. Therefore, the number of sites at which each substance is detected in environmental media may not equal the number in this column.

b

Not all ranks will be represented in all media because not all chemicals found in media are among those found most frequently at site.

c

Volatile organics not otherwise specified were reported as being detected most often (rank 1) in the air medium.

Source: Reference 12

TABLE 4. TOXIC POLLUTANTS MOST COMMONLY ADDRESSED BY STATE AND LOCAL AGENCIES

Acetaldehyde	Hexachlorocylopentadiene
Acrolein	Hydrazine
Acrylonitrile	Hydrogen Sulfide
Allyl Chloride	Lead
Arsenic	Lindane
Asbestos	Maleic Anhydride
Benzene	Manganese
Benzidine	Mercury
Benzo(a)pyrene	Methyl Bromide
Benzyl Chloride	Methyl Chloride
Beryllium	Methyl Chloroform
Bis(chloromethyl)ether	Methylene Chloride
1,3-Butadiene	beta-Naphthylamine
Cadmium	Nickel
Carbon Tetrachloride	Nitrobenzene
Chlordane	n-Nitrosodimethylamine
Chlorobenzene	Nitrosomorpholine
Chloroform	Parathion
Chloroprene	Perchloroethylene
Chromium	Phenol and Chlorinated Phenols
Cresol	Phosgene
1,4-Dichlorobenzene	Polychorinated Biphenyls (PCBs)
3,3-Dichlorobenzidine	Polycyclic Aromatic Hydrocarbons (PAH)
Dimethyl Sulfate	Propylene Oxide
1,3-Dioxane	Radionuclides
Dioxins	Styrene
Epichlorohydrin	1,1,2,2-Tetrachlorethane
Ethylene Dibromide	Tetrahydrofuran
Ethylene Dichloride	1,1,2-Trichloroethane (vinyl trichloride)
Ethylene Oxide	Toluene
Ethylenimine (azridine)	Trichoroethylene
Formaldehyde	Vinyl Chloride
Heptachlor	Vinylidene Chloride
	Xylene

Source: Reference 12.

Non-human receptors also may be a concern at some hazardous waste sites. Disturbance of the site may lead to exposure through inhalation of contaminated air or exposure through ingestion of or direct contact with contaminants deposited on plant and inert surface. The possibility of inhalation exposure may affect feral or domesticated animals downwind of the site. This also impacts humans in that animal exposure to pollutants can lead to contamination accumulation in the food chain.

Certain gaseous pollutants (e.g., ozone, oxides of sulfur and nitrogen), if present in high concentrations, also can affect plant and animal growth. Deposition of airborne contaminants may cause stressed vegetation, release pesticides and herbicides, or impact the value/usability of agricultural crops. Also, deposition of metals or other pollutants in surface waters may impact marine life. Copper and some other metals can cause fish kills at very low concentrations.

SECTION 3
PROTOCOL FOR BASELINE EMISSION ESTIMATES

This section presents a protocol for developing baseline emission estimates (BEEs). This protocol is a component of an air pathway analyses (APA) program to assess potential air quality impacts from hazardous waste sites. While not all sites will require BEEs, the first three steps in the protocol should be implemented to see if BEEs are necessary for a given site. The protocol is a recommended guideline; the level of effort that is required or the need to develop BEEs for individual sites must be determined on a case-by-case basis.

3.1 PROTOCOL STEPS FOR DEVELOPING BEEs

Figure 6 diagrams a protocol for developing BEEs. The protocol was developed to help the site manager to determine baseline emission rates and absolute levels of emissions. These values can be used as inputs to dispersion models to assess the air impacts for receptor locations of interest. The activities identified in this flow chart are consistent with the steps of the CERCLA remedial investigation process that involve the assessment of the air contaminant migration pathway. Although the protocol was developed for NPL sites, it also applies to assessing air emissions from other hazardous waste sites. The flow chart is applicable to all sites, regardless of the type of site (landfill, lagoon, waste pile, etc.), type of waste, or the potential for the site to generate air emissions. Each step of the protocol is described below.

3.1.1 Define the APA Objective

CERCLA and SARA legislation highlight the basic objectives for all remedial investigations. Simply stated, these objectives are to provide data that are "necessary and sufficient" to characterize the "nature and extent" of contamination on site. In addition, they mandate that "all potential

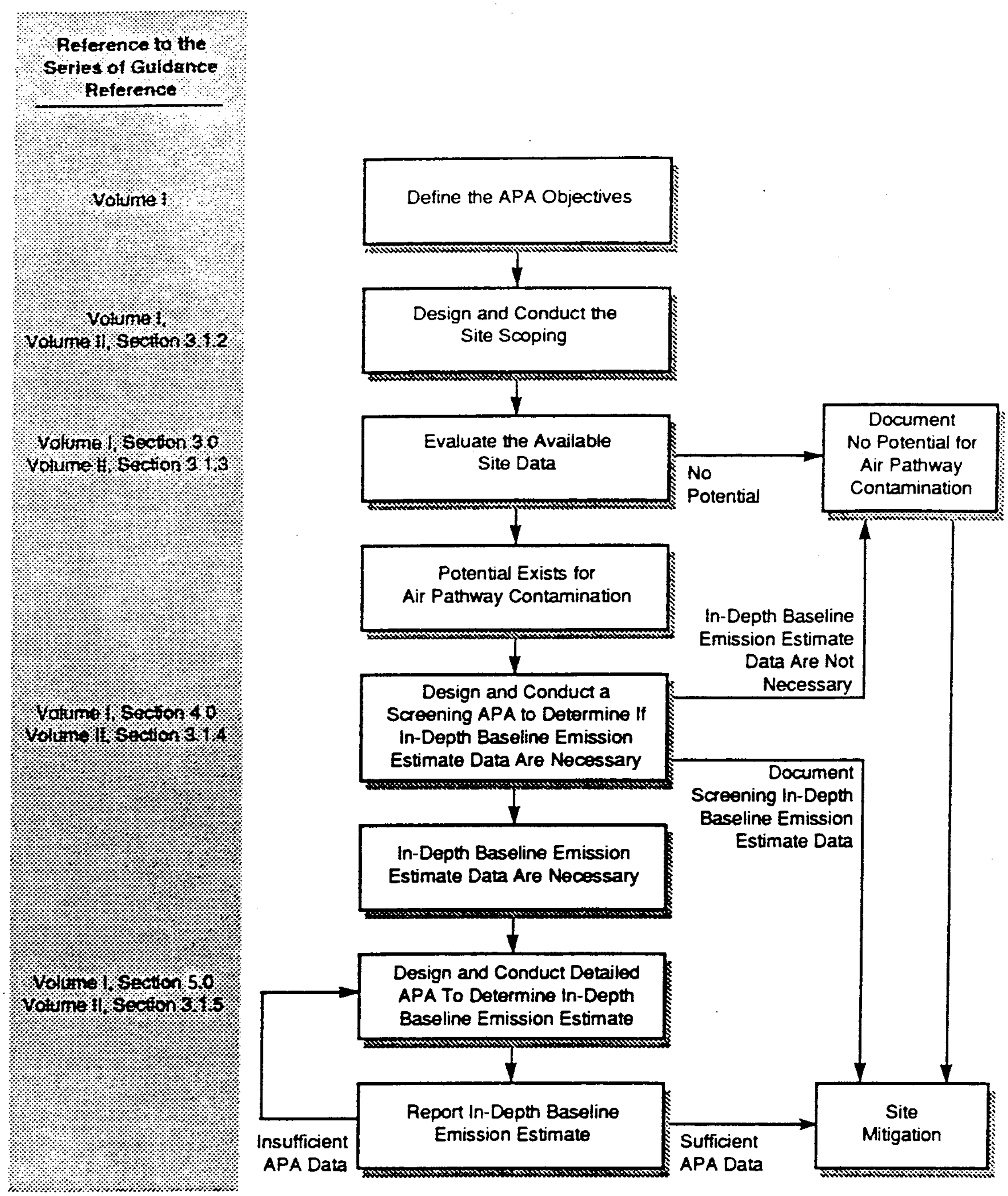

Figure 6. Flowchart of activities for developing screening and in-depth baseline emission estimates.

migration pathways for contaminations" require characterization. As the first step of the protocol to assess baseline emissions, site-specific objectives should be developed; this will generally occur simultaneously with the performance of Steps 2 and 3 (data collection and review) of the protocol. The site manager should consider the following issues when formulating site-specific objectives:

- What information is already available? As described in Section 3.1.2, available information should first be reviewed before developing final site-specific objectives. This preliminary review of information will provide necessary background information and aid in identifying data gaps.

- What pathways must be considered? Except in rare cases, all pathways, namely air, soil, and water, must be considered.

- What is technically possible? Site and situational factors that may adversely affect the air pathway investigation should be identified to avoid establishing unrealistic objectives. These factors can range from complexity in site geology/hydrogeology and complex terrain to the feasibility of detecting the contaminants of interest.

- What time deadlines exist? Schedule constraints can affect the nature of the investigation and must be balanced with technical concerns.

- What data quality objectives are required? Data must be of a known accuracy and precision for use in evaluating the air pathway.

- What program is most cost effective? The type, level, and extent of contamination per migration pathway will primarily determine how the available resources are apportioned. It is also necessary to collect, integrate, and consider a variety of types of data, including technical information, institutional issues, political issues, public protection, community relations issues, and community concerns.

- <u>What contaminants must be considered?</u> The investigation will typically involve identifying and characterizing the extent of the contamination. Concentrations of individual or summed indicator compounds are often selected to represent the extent of total contamination. Site-specific objectives should neither identify specific indicator compounds nor require characterization of all compounds.

Table 5 provides examples of objectives related to baseline emissions estimates. The first step in developing site-specific APA objectives is to collect and review readily available site historical records. The potential for air emissions can be inferred from the review of preliminary site information. While baseline emissions may be low, during remediation sites have the potential for air emissions of particulate matter (semi-volatile organics, metals, and other inorganic contaminants) and enhanced volatile organic emissions.

Among the types of information that can be reviewed and used to develop site-specific APA objectives are: waste characteristics; distribution of the waste; orientation of the general public to the emission source concerns; technical feasibility; and program resources. The first three items are discussed below.

- <u>Waste Characteristics</u>. Knowledge of the industrial process or the waste source involved can suggest the types of chemicals or agents that may be in the waste. For example, volatile emissions are likely from waste sites with organic solvents or petroleum waste. Wastes in liquid form tend to have higher baseline emissions than wastes in solid form. In addition, identifying common decomposition products of the chemicals identified in the waste may be useful. It is helpful to categorize potential air contaminants by their generic volatility: volatiles, semi-volatiles, and non-volatiles.

TABLE 5. EXAMPLES OF APA OBJECTIVES FOR BEEs

- Characterize the air emissions potential for volatile species and particulate matter from the undisturbed site.
- Characterize the air emissions potential for volatile species and particulate matter from the disturbed site.
- Identify contaminants of concern.
- Provide baseline emission estimates that can be used to assess the health risk and the need to mitigate.
- Provide baseline emission estimates that can be used to assess the need for on-site or fenceline ambient monitoring.

Examples of the types of compounds in each category are listed in Table 6. The categories group together compounds with similar physical behavior in the atmosphere and thus are useful for predicting emissions potential.

- Distribution of the Waste. The relative position of the waste can influence the potential for air emissions and, thus, the APA objectives. The amount and nature of overburden strongly influences the baseline emissions at a site. Semi-volatiles and non-volatiles present near the surface can be emitted as windblown particulate matter. Waste piles may have relatively high emissions of both volatile organics and particulate matter due to their geometry and surface area to volume ratio.

- Location of the Affected Population and Community Concerns. The population potentially at risk from exposure to toxic air emissions from the site must be identified and the exposure characterized. The close proximity of residential areas may require the addition of measurement and monitoring activities for health and safety purposes that are beyond what is necessary to develop BEEs for the site. Thus, the site-specific objectives may include a component related to determining the potential impact on the nearest population (e.g., air monitoring at the site boundary).

The APA objectives should be documented and circulated for peer review by staff members that have knowledge of the site, APA, and the site mitigation process. The review process may also help identify site characterization data needs. Developing site-specific objectives is an iterative process; more than one round of data gathering, review, and discussion may be needed to develop satisfactory objectives.

TABLE 6. POTENTIAL AIR CONTAMINANTS BY GENERIC TYPE OF CONTAMINANT

Volatiles (>1 mm mercury vapor pressure at 25°C)

- All monochlorinated solvents; also trichloroethylene, trichloroethane, tetrachloroethane
- Most simple aromatic solvents: e.g. benzene, xylene, toluene, and ethylbenzene
- Most alkanes up to decane (C_{10})
- Inorganic gases: e.g. hydrogen sulfide, chlorine, and sulfur dioxide

Semivolatiles ($1\text{-}10^{-7}$ mm mercury vapor pressure at 25°C)

- Most polychlorinated biphenyls, dichlorobenzenes, aniline, nitroaniline, and phthalates
- Most pesticides: e.g. dieldrin, toxaphene, and parathion
- Most complex alkanes: dodecane and octadecane
- Most polynuclear aromatic's: e.g. napthalene, phenanthrene, and benz(a)anthrencene
- Mercury

Non Volatiles or Particulate Matter ($<10^{-7}$ mm mercury vapor pressure at 25°C)

- Larger polynuclear aromatics: e.g. chrysene
- Metals: e.g. lead and chromium
- Other inorganics: e.g. asbestos, arsenic, and cyanides

3.1.2 Site Scoping

The second step in the development of BEEs is collection of available information about the site. This should be a quick, straightforward information search, involving the collection of records, reports, shipping manifests, newspaper clippings, and information from interviews with people living close to or affiliated with the site. For NPL sites, data should be available from the preliminary assessment and site inspection conducted prior to inclusion on the NPL. The type of information to be collected parallels, for the most part, the factors considered in creating the objective. These include:

- Source of the waste (type of industry);
- Composition of the waste (organic-volatile/semi-organic; inorganic-metals, others; biological; radioactive);
- Distribution of the waste and cover material limiting volatilization and uptake of particulate matter from the waste;
- Distance from the waste to the property fenceline; and
- Representative meteorological data.

3.1.3 Evaluate Available Site Data

The existing site information (including the site inspection report) should be evaluated to determine the potential for release of air emissions. Examples of types of contaminants and situations to be evaluated are provided in Table 7. If it is determined through this assessment that the site poses no significant potential for air pathway contaminant emissions, then no further evaluation of the baseline emissions is required. The site manager must record the basis for this decision and include these data in the site investigation documentation. In most cases, insufficient information will be available at this stage, and further work

TABLE 7. EXAMPLES OF TYPES OF CONTAMINANTS AND SITUATIONS THAT MAY INDICATE A POTENTIAL FOR AIR PATHWAY CONTAMINATION

Situation/Condition	Volatiles	Particulate Matter	Comment
• Site Odors, Neighborhood Complaints	√		Indicates moderate to high levels of BEEs.
• Observation of Dust Clouds During Wind		√	Check soil cover and look for waste piles.
• Evidence of Metal Corrosion	√	√	Look for corrosive agents.
• Vent pipes	√		Check records to determine if the site is a codisposal facility.
• Seeps of Waste	√		Probable buried wastes.
• Weathered Waste Surface	√		Emissions of disturbed waste may be very high.
• Aged and Layered Waste	√		Likely that volatiles are higher in underlying lay chemicals possible.
• Aerated Lagoons	√	√	Increased emissions.
• Exposed Waste	√	√	Increased emissions.
• Industrial Wastes	√		Waste mixtures likely, check for particular solvent types, aromatic and halogenated organic solvents.
• Petroleum Wastes	√		Tar/wastes with volatile emissions likely.
• Industrial Wastes/ Paint Wastes	√		Organic volatiles likely.

(Continued)

TABLE 7. (Continued)

Situation/Condition	Volatiles	Particulate Matter	Comment
• Recycling or Plating Wastes		√	Metal-containing particulate matter likely.
• Municipal Wastes	√		Methane/carbon dioxide volatiles likely; look for industrial waste.
• Hospital Wastes	√	√	Solvent used likely; biological hazards and radioactive waste possible.
• Chemical Production or Storage	√	√	High concentrations of specific chemicals likely.
• Site Inspection	√		Gas detection results indicate the presence of gas species and the potential for emissions.
		√	Visual inspection and particle counting/detection results indicate the potential for particulate matter emissions.

will be warranted. If air emissions are a potential concern, the next step of the protocol (site screening study) should be implemented to provide additional information to make a judgement regarding the potential for air emissions from the site. At this point the site-specific APA objectives should be reviewed by the site RPM to ensure they are still realistic, attainable, and applicable.

3.1.4 Design and Conduct the Site Screening Study

Designing a site screening study to assess the air emissions potential involves the selection of an air emissions measurement/assessment method. The four broad categories of measurement/assessment approaches include:

- Direct emissions measurement;
- Indirect emissions measurement;
- Air monitoring/modeling; and
- Emissions (predictive) modeling.

Each approach includes a range of possible methods that can be categorized according to their level of complexity as screening (quick and simple) methods or in-depth (very detailed) methods.

The activities necessary to design and conduct the site screening study are:

- Determine the feasibility of obtaining the screening data. (Identify any site factors that may limit this activity.)

- Select appropriate tracer species, screening methods, and applicable equipment/instrumentation.

- Design the site inspection technical approach and test plan, including the Quality Assurance/Quality Control Program. Make sure that all units of a combined site are studied.

- Circulate the site screening approach for review and ensure the screening addresses the site-specific objective(s).

- Modify the site screening program, as necessary.

- Conduct the site screening study and document the findings.

- Determine if the site screening study was adequate to characterize the air contamination migration pathway and if detailed BEE data are necessary. If detailed BEEs are necessary, initiate the in-depth site characterization study. If not, document the site inspection survey results and the basis for discontinuing the APA.

One preliminary step is to evaluate those key factors that affect the air emissions of volatiles and particulate matter. The factors were presented in Section 2 and are summarized in the check-list presented in Figure 7. This figure can be used to summarize site information and facilitate the decisions regarding selecting and implementing screening methods. If the site contains a waste type that has the potential to create air emissions, the most important factors which determine the baseline emissions are typically site conditions and weather conditions. Once the checklist (Figure 7) has been completed and some knowledge of the factors affecting air emission processes is gained, the site manager must select appropriate indicator species and select air emission screening methods, equipment, and instrumentation.

Indicator species are species found in the waste that can be used to represent a group of species in determining emissions. If little is known about which specific species are present at the site, select an indicator that represents a family or class of species so that gross data on emissions can be obtained and then later refined. Table 8 provides information that will aid in this selection process. All highly toxic compounds likely to be present at the site should be on the target compound list, along with the indicator species. The ideal indicator species or class of species is:

Parameter	General Effect Volatile	General Effect PM	Site Information	Effect on Emissions: Volatiles Increase	Effect on Emissions: Volatiles Decrease	Effect on Emissions: Particulate Matter Increase	Effect on Emissions: Particulate Matter Decrease
SITE CONDITIONS							
Amount of Exposed Waste	High	High					
Depth of Soil	Medium	High					
Presence of Oil Layer	High	High					
Compaction of Cover	Medium	Low					
Aeration of Lagoons	High	High					
Ground Cover	Medium	High					
WEATHER CONDITIONS							
Wind Speed	Medium	High					
Temperature	Medium	Low					
Relative Humidity	Low	Low					
Barometric Pressure	Medium	Low					
Precipitation	High	High					
Solar Radiation	Low	Low					
SOIL/WASTE CHARACTERISTICS							
Physical Properties	High	High					
Sorption of Soil	Med	Low					
Soil Moisture	High	High					
Volatile Fraction	High	Low					
Semi/Non-Volatile Fraction	Low	High					
Organic Content of Soil	High	Low					

Figure 7. Checklist of factors affecting air emissions per unit. The site manager should use this to summarize site data on critical factors to determine how these factors may affect the air emissions potential.

TABLE 8. FACTORS TO CONSIDER IN SELECTING AN INDICATOR SPECIES FOR STUDY

1) Homogeneity of waste and representativeness of proposed indicator species;

2) Variety of types of air contaminants (organic, inorganic, biohazard, radioactive);

3) Physical state of air contaminants (gas, liquid, solid);

4) Level of air contaminant emission;

5) APA objectives;

6) Feasibility of air monitoring for proposed indicator species;

7) Availability of standard sampling/analytical/monitoring techniques;

8) Potential interferences for the proposed indicator species; and

9) Health effects.

- Present in the air emissions in a fixed ratio;
- A non-reactive or stable species;
- Present at levels above analytical detection limits;
- Unique to the site (not in background air samples);
- Representative of the "worst case" toxicity for compounds at the site; and
- Applicable for existing measurement and monitoring technologies; and
- Of known toxicity and exposure criteria.

A list of candidate indicator species can be developed from those species previously identified in analysis of the waste or by identifying broad-band type indicators that represent the type of waste identified in the scoping. Candidate species should match as closely as possible the characteristics of an ideal indicator species. The two main required characteristics are presence in the air emissions from the site and the ability to measure/monitor the species using commercially available methods and instruments. Examples of broad-band, class and indicator species are given in Table 9.

In addition to selecting indicator species, the site manager must select the most suitable air emissions sampling methods for screening. Screening methods are summarized in Table 10. Air emissions measurement/assessment methods are described in detail in Section 4. The four general approaches for screening emissions are described below.

TABLE 9. EXAMPLES OF BROAD-BAND, CLASS, AND INDICATOR SPECIES

BROAD BAND	CLASSES OF COMPOUNDS	INDICATOR SPECIES
Volatile Organics	Aliphatics	Alkanes, Total Hydrocarbons as Pentane
	Aromatics	Benzene, Xylene, Toluene
	Halogenated Species	Trichloroethene, Trichloroethane, Vinyl Chloride
	Oxygenated Species	Ethanol, Formaldehyde
	Sulfur Containing Species	Mercaptans, Thiophenes
	Nitrogen Containing Species	Benzonitrile
Volatile Inorganics	Acid Gases	Sulfur Dioxide, Hydrogen Chloride
	Sulfur Containing	Hydrogen Sulfide
Semi-Volatile Organics	Polynuclear Aromatics (PAH)	Napathalene, Benzo-(a)Pyrene
	Polychlorinated Biphenols (PCBs)	PCBs As Aroclor 1254
Non-Volatiles	Metals	Lead, Chromium, Zinc

TABLE 10. TYPES OF SCREENING METHODS FOR ESTIMATING EMISSIONS*

- Direct Emissions Measurement
  - Head Space Sampler
  - Head Space Analysis of Bottled Sample

- Indirect Emissions Measurement
  - Upwind/Downwind
  - Mass Balance
  - Real-time Instrument Survey

- Air Monitoring/Modeling
  - Upwind/Downwind

- Emissions (Predictive) Modeling
  - Superfind Exposure Assessment Manual (SEAM) models
  - Any model using literature values and assumed concentrations

*See Section 4 for more detail.

- Direct Emissions Measurement. Concentration measurements can be made of the air directly above the waste, either the "head space" or air space of a sampler placed on the waste, or the head space of a sample bottle half-filled with waste material. The screening provides a relative measure of the emission potential of various wastes/locations. High concentrations of volatile species in the head space can indicate high potential for air emissions from the site. Likewise, low concentrations can indicate low potential for air emissions. The advantage of these screening methods is that they are relatively quick, easy and inexpensive to perform. They also can have the highest sensitivity (i.e., detect the contaminants even at low concentrations), since they measure concentrations at the source. The techniques are only applicable to volatile gas species. These data can be used to estimate emission factors to indicate the potential for air emissions.

- Indirect Emissions Measurement. These types of sampling methods can be used for any type of contaminant such as volatiles and/or particulate matter. It is probably the most common screening approach used, though it is usually not used to develop emission estimates. Screening measurements can be made upwind and downwind and directly above waste material using real-time instruments to estimate potential for air emissions. Air concentration measurements made at short distances (<40 meters) downwind of the waste can be used to indicate the potential for air emissions from the site. Downwind measurements should be corrected for any instrument bias and upwind interferences. Meteorological factors can influence the air concentration of volatiles and particulate matter so field notes must include on-site observations and meteorological conditions during testing.