

7. Air Monitoring

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Introduction

Airborne contaminants can present a significant threat to worker health and safety. Thus, identification and quantification of these contaminants through air monitoring is an essential component of a health and safety program at a hazardous waste site. Reliable measurements of airborne contaminants are useful for:

- Selecting personal protective equipment.
- Delineating areas where protection is needed.
- Assessing the potential health effects of exposure.
- Determining the need for specific medical monitoring.

This chapter delineates the factors to consider when conducting air monitoring at a hazardous waste site. It presents strategies for assessing airborne contamination at hazardous waste sites and describes instruments and methods for measuring exposures.

Measuring Instruments

The purpose of air monitoring is to identify and quantify airborne contaminants in order to determine the level of worker protection needed. Initial screening for identification is often qualitative, i.e., the contaminant, or the class to which it belongs, is demonstrated to be present but the determination of its concentration (quantification) must await subsequent testing. Two principal approaches are available for identifying and/or quantifying airborne contaminants:

- The onsite use of direct-reading instruments.
- Laboratory analysis of air samples obtained by gas sampling bag, filter, sorbent, or wet-contaminant collection methods.

Direct-Reading Instruments

Direct-reading instruments were developed as early warning devices for use in industrial settings, where a leak or an accident could release a high concentration of a known chemical into the ambient atmosphere. Today,

some direct-reading instruments can detect contaminants in concentrations down to one part contaminant per million parts of air (ppm), although quantitative data are difficult to obtain when multiple contaminants are present. Unlike air sampling devices, which are used to collect samples for subsequent analysis in a laboratory, direct-reading instruments provide information at the time of sampling, enabling rapid decision-making.

Direct-reading instruments may be used to rapidly detect flammable or explosive atmospheres, oxygen deficiency, certain gases and vapors, and ionizing radiation. They are the primary tools of initial site characterization. The information provided by direct-reading instruments can be used to institute appropriate protective measures (e.g., personal protective equipment, evacuation), to determine the most appropriate equipment for further monitoring, and to develop optimum sampling and analytical protocols.

All direct-reading instruments have inherent constraints in their ability to detect hazards:

- They usually detect and/or measure only specific classes of chemicals.
- Generally, they are not designed to measure and/or detect airborne concentrations below 1 ppm.
- Many of the direct-reading instruments that have been designed to detect one particular substance also detect other substances (interference) and, consequently, may give false readings.

It is imperative that direct-reading instruments be operated, and their data interpreted, by qualified individuals who are thoroughly familiar with the particular device's operating principles and limitations and who have obtained the device's latest operating instructions and calibration curves. At hazardous waste sites, where unknown and multiple contaminants are the rule rather than the exception, instrument readings should be interpreted conservatively. The following guidelines may facilitate accurate recording and interpretation:

- Calibrate instruments according to the manufacturer's instructions before and after every use.
- Develop chemical response curves if these are not provided by the instrument manufacturer.
- Remember that the instrument's readings have limited value where contaminants are unknown. When recording readings of unknown contaminants, report them as "needle deflection" or "positive instrument response" rather than specific concentrations (i.e., ppm). Conduct additional monitoring at any location where a positive response occurs.
- A reading of zero should be reported as "no instrument response" rather than "clean" because quantities of chemicals may be present that are not detectable by the instrument.
- The survey should be repeated with several detection systems to maximize the number of chemicals detected.

Tables 7-1 and 7-2 list several direct-reading instruments and the conditions and/or substances they measure. The flame ionization detector (FID) and the photoionization

Table 7-1. Some Direct-Reading Instruments for General Survey

INSTRUMENT	HAZARD MONITORED	APPLICATION	DETECTION METHOD	LIMITATIONS	EASE OF OPERATION	GENERAL CARE AND MAINTENANCE	TYPICAL OPERATING TIMES
Combustible Gas Indicator (CGI)	Combustible gases and vapors.	Measures the concentration of a combustible gas or vapor.	A filament, usually made of platinum, is heated by burning the combustible gas or vapor. The increase in heat is measured.	Accuracy depends, in part, on the difference between the calibration and sampling temperatures. Sensitivity is a function of the differences in the chemical and physical properties between the calibration gas and the gas being sampled. The filament can be damaged by certain compounds such as silicones, halides, tetraethyl lead, and oxygen-enriched atmospheres. Does not provide a valid reading under oxygen-deficient conditions.	Effective use requires that operator understand the operating principles and procedures.	Recharge or replace battery. Calibrate immediately before use.	Can be used for as long as the battery lasts, or for the recommended interval between calibrations, whichever is less.
Flame Ionization Detector (FID) with Gas Chromatography Option	Many organic gases and vapors.	In survey mode, detects the total concentrations of many organic gases and vapors. In gas chromatography (GC) mode, identifies and measures specific compounds. In survey mode, all the organic compounds are ionized and detected at the same time. In GC mode, volatile species are separated.	Gases and vapors are ionized in a flame. A current is produced in proportion to the number of carbon atoms present.	Does not detect inorganic gases and vapors, or some synthetics. Sensitivity depends on the compound. Should not be used at temperatures less than 40 °F (4 °C). Difficult to absolutely identify compounds. High concentrations of contaminants or oxygen-deficient atmospheres require system modification. In survey mode, readings can be only reported relative to the calibration standard used.	Requires experience to interpret data correctly, especially in the GC mode. Specific identification requires calibration with the specific analyte of interest.	Recharge or replace battery. Monitor fuel and/or combustion air supply gauges. Perform routine maintenance as described in the manual. Check for leaks.	8 hours; 3 hours with strip chart recorder.
Gamma Radiation Survey Instrument	Gamma radiation.	Environmental radiation monitor	Scintillation detector	Does not measure alpha or beta radiation	Extremely easy to operate, but requires experience to interpret data. Rugged, good in field use.	Must be calibrated annually at a specialized facility.	Can be used for as long as the battery lasts, or for the recommended interval between calibrations, whichever is less.

Table 7-1. (cont.)

INSTRUMENT	HAZARD MONITORED	APPLICATION	DETECTION METHOD	LIMITATIONS	EASE OF OPERATION	GENERAL CARE AND MAINTENANCE	TYPICAL OPERATING TIMES
Portable Infrared (IR) Spectrophotometer	Many gases and vapors.	Measures concentration of many gases and vapors in air. Designed to quantify one- or two-component mixtures.	Passes different frequencies of IR through the sample. The frequencies adsorbed are specific for each compound.	In the field, must make repeated passes to achieve reliable results. Requires 115-volt AC power. Not approved for use in a potentially flammable or explosive atmosphere. Interference by water vapor and carbon dioxide. Certain vapors and high moisture may attack the instrument's optics, which must then be replaced.	Requires personnel with extensive experience in IR spectrophotometry.	As specified by manufacturer.	
Ultraviolet (UV) Photoionization Detector (PID)	Many organic and some inorganic gases and vapors.	Detects total concentrations of many organic and some inorganic gases and vapors. Some identification of compounds is possible if more than one probe is used.	Ionizes molecules using UV radiation; produces a current that is proportional to the number of ions.	Does not detect methane. Does not detect a compound if the probe used has a lower energy level than the compound's ionization potential. Response may change when gases are mixed. Other voltage sources may interfere with measurements. Readings can only be reported relative to the calibration standard used. Response is affected by high humidity.	Effective use requires that the operator understand the operating principles and procedures, and be competent in calibrating, reading, and interpreting the instrument.	Recharge or replace battery Regularly clean lamp window. Regularly clean and maintain the instrument and accessories.	10 hours; 5 hours with strip chart recorder.

detector (PID) (see Table 7-1) are commonly used at hazardous waste sites. However, some of these devices may not detect some particularly toxic agents, including hydrogen cyanide and hydrogen sulfide. Thus, these devices must be supplemented with other methods of detection.

Laboratory Analysis

Direct-reading personal monitors are available for only a few specific substances and are rarely sensitive enough to measure the minute (i.e., parts of contaminant per billion parts of air) quantities of contaminants which may, nevertheless, induce health changes. Thus to detect rela-

tively low-level concentrations of contaminants, long-term or "full-shift" personal air samples must be analyzed in a laboratory. Full-shift air samples for some chemicals may be collected with passive dosimeters, or by means of a pump which draws air through a filter or sorbent. Table 7-3 lists some sampling and analytical techniques used at hazardous waste sites.

Selection of the appropriate sampling media largely depends on the physical state of the contaminants. For example, chemicals such as PCBs (polychlorinated biphenyls) and PNAs (polynuclear aromatic hydrocarbons) occur as both vapors and particulate-bound contaminants. A dual-media system is needed to measure both

Table 7-2. Some Direct-Reading Instruments for Specific Survey

INSTRUMENT	HAZARD MONITORED	APPLICATION	DETECTION METHOD	LIMITATIONS	EASE OF OPERATION	GENERAL CARE AND MAINTENANCE	TYPICAL OPERATING TIMES
Direct-Reading Colorimetric Indicator Tube	Specific gases and vapors.	Measures concentrations of specific gases and vapors.	The compound reacts with the indicator chemical in the tube, producing a stain whose length or color change is proportional to the compound's concentration.	The measured concentration of the same compound may vary among different manufacturers' tubes. Many similar chemicals interfere. Greatest sources of error are (1) how the operator judges stain's end-point, and (2) the tube's limited accuracy. Affected by high humidity.	Minimal operator training and expertise required.	Do <i>not</i> use a previously opened tube even if the indicator chemical is not stained. Check pump for leaks before and after use. Refrigerate prior to use to maintain shelf life of about 2 years. Check expiration date of tubes. Calibrate pump volume at least quarterly. Avoid rough handling which may cause channeling.	
Oxygen Meter	Oxygen (O ₂).	Measures the percentage of O ₂ in air.	Uses an electrochemical sensor to measure the partial pressure of O ₂ in the air and converts that reading to O ₂ concentration.	Must be calibrated prior to use to compensate for altitude and barometric pressure. Certain gases, especially oxidants such as ozone, can affect readings. Carbon dioxide (CO ₂) poisons the detector cell.	Effective use requires that the operator understand the operating principles and procedures.	Replace detector cell according to manufacturer's recommendations. Recharge or replace batteries prior to expiration of the specified interval. If the ambient air is more than 0.5% CO ₂ , replace or rejuvenate the O ₂ detector cell frequently.	8 to 12 hours.

forms of these substances. The volatile component is collected on a solid adsorbent and the nonvolatile component is collected on a filter. More than two dozen dual-media sampling techniques have been evaluated by NIOSH [1,2].

A major disadvantage of long-term air monitoring is the time required to obtain data. The time lag between sampling and obtaining the analysis results may be a matter of hours, if an onsite laboratory is available, or days, weeks, even months, if a remote laboratory is involved. This can be a significant problem if the situation requires immediate decisions concerning worker safety. Also, by the time samples are returned from a remote laboratory, the hazardous waste site cleanup may have progressed to a different stage or to a location at which different contaminants or different concentrations may exist. Careful planning and/or the use of a mobile laboratory on site may alleviate these problems.

Mobile laboratories may be brought on site to classify hazardous wastes for disposal. A mobile laboratory is generally a trailer truck that houses analytical instruments capable of rapidly classifying contaminants by a variety of

techniques. Typical instruments include gas chromatographs, spectrofluorometers, and infrared spectrophotometers. When not in use in the mobile laboratory, these devices can be relocated to fixed-base facilities. Onsite laboratory facilities and practices should meet standards of good laboratory safety.

Usually, a few of the field samples collected are analyzed on site to provide rapid estimates of the concentration of airborne contaminants. These data can be used to determine the initial level of worker personal protection necessary to modify field sampling procedures and to guide the fixed-base laboratory analysis. If necessary, samples screened in the mobile laboratory can be subsequently reanalyzed in sophisticated fixed-base laboratories. The mobile laboratory also provides storage space, countertop staging areas for industrial hygiene equipment, and facilities for recharging self-contained breathing apparatus.

Site Monitoring

Priorities for air monitoring should be based on the information gathered during initial site characterization (see

Table 7-3. Some Sample Collection and Analytical Methods

SUBSTANCE	COLLECTION DEVICE ^a	ANALYTICAL METHOD ^b	TYPICAL DETECTION LIMIT OF ANALYTIC INSTRUMENT (μg)
Anions:	Prewashed silica gel tube	Ion chromatography	
Bromide			10
Chloride			5
Fluoride			5
Nitrate			10
Phosphate			20
Sulfate			10
Aliphatic Amines	Silica gel	GC/NPD	10
Asbestos	MCEF	PCM	100 ^c
Metals	MCEF	ICP-AES	0.5
Organics	Charcoal tube	GC/MS	10
Nitrosamines	Thermosorb/N	GC/TEA	0.01
Particulates	MCEF	Gravimetric	
PCBs	GF filter and florasil tube	GC-ECD	0.001
Pesticides	13-mm GF filter and chromosorb 102 Tube	GC/MS	0.05

^a MCEF = mixed cellulose ester filter.
GF = glass fiber filter.

^b GC/NPD = gas chromatography and nitrogen/phosphorus detector; PCM = phase contrast microscopy; ICP-AES = inductively coupled plasma atomic emission spectrometry; GM/MS = gas chromatography and mass spectrometry; GC/TEA = gas chromatography using a thermal energy analyzer; GC-ECD = gas chromatography using an electrical conductivity detector.

^c Units in fibers per mm² of filter (Method No. 7400 from the NIOSH Manual of Analytical Methods, 3rd edition).

Chapter 6). This information serves as the basis for selecting the appropriate monitoring equipment and personal protective equipment (PPE) to use when conducting site monitoring. Depending on site conditions and project goals, four categories of site monitoring may be necessary: monitoring for IDLH and other dangerous conditions, general onsite monitoring, perimeter monitoring, and periodic monitoring.

Monitoring for IDLH and Other Dangerous Conditions

As a first step, air monitoring should be conducted to identify any IDLH and other dangerous conditions, such as flammable or explosive atmospheres, oxygen-deficient environments, and highly toxic levels of airborne contaminants. Direct-reading monitoring instruments will normally include combustible gas indicators, oxygen meters, colorimetric indicator tubes, and organic vapor monitors. Other monitoring instruments may be necessary based on the initial site characterization. When time permits, air samples should be collected for laboratory analysis. Extreme caution should be exercised in continuing a site survey when atmospheric hazards are indicated. Monitoring personnel should be aware that conditions can suddenly change from nonhazardous to hazardous.

Acutely hazardous concentrations of chemicals may persist in confined and low-lying spaces for long periods of time. Look for any natural or artificial barriers, such as hills, tall buildings, or tanks, behind which air might be still, allowing concentrations to build up. Examine any confined spaces such as cargo holds, mine shafts, silos, storage tanks, box cars, buildings, bulk tanks, and sumps where chemical exposures capable of causing acute

health effects are likely to accumulate. Low-lying areas, such as hollows and trenches, are also suspect. Monitor these spaces for IDLH and other dangerous conditions. Also consider whether the suspected contaminants are lighter or heavier than air. Then, based on the type of contaminants present, consider sampling on hilltops, under any cover or canopy where workers might work or congregate, and in trenches and low-lying areas.

In open spaces, toxic materials tend to be emitted into the atmosphere, transported away from the source, and dispersed. Thus acutely hazardous conditions are not likely to persist in open spaces for extended periods of time unless there is a very large (and hence, readily identifiable) source, such as an overturned tankcar. Open spaces are therefore generally given a lower monitoring priority.

General Onsite Monitoring

Air sampling should be conducted using a variety of media to identify the major classes of airborne contaminants and their concentrations. The following sampling pattern can be used as a guideline. First, after visually identifying the sources of possible generation, collect air samples downwind from the designated source along the axis of the wind direction. Work upwind, until reaching or getting as close as possible to the source. Level B protection (see Table 8-6 in Chapter 8) should be worn during this initial sampling. Levels of protection for subsequent sampling should be based upon the results obtained and the potential for an unexpected release of chemicals.

After reaching the source, or finding the highest concentration, sample cross-axis of the wind direction to determine the degree of dispersion. Smoke plumes, or plumes of instrument-detectable airborne substances, may be released as an aid in this assessment. To ensure that there is no background interference and that the detected substance(s) are originating at the identified source, also collect air samples upwind of the source.

Perimeter Monitoring

Fixed-location monitoring at the "fenceline" or perimeter, where personal protective equipment is no longer required, measures contaminant migration away from the site and enables the Site Safety Officer to evaluate the integrity of the site's clean areas. Since the fixed-location samples may reflect exposures either upwind or downwind from the site, wind speed and direction data are needed to interpret the sample results.

Periodic Monitoring

Site conditions and thus atmospheric chemical conditions may change following the initial characterization. For this reason, monitoring should be repeated periodically, especially when:

- Work begins on a different portion of the site
- Different contaminants are being handled.
- A markedly different type of operation is initiated (e.g., barrel opening as opposed to exploratory well drilling).
- Workers are handling leaking drums or working in areas with obvious liquid contamination (e.g., a spill or lagoon).

Personal Monitoring

The selective monitoring of high-risk workers, i.e., those who are closest to the source of contaminant generation, is highly recommended. This approach is based on the rationale that the probability of significant exposure varies directly with distance from the source. If workers closest to the source are not significantly exposed, then all other workers are, presumably, also not significantly exposed and probably do not need to be monitored.

Since occupational exposures are linked closely with active material handling, personal air sampling should not be necessary until site mitigation has begun. Personal monitoring samples should be collected in the breathing zone and, if workers are wearing respiratory protective equipment, outside the facepiece. These samples represent the actual inhalation exposure of workers who are not wearing respiratory protection and the potential exposure of workers who are wearing respirators. It is best to use pumps that automatically maintain a constant flow rate to collect samples, since it is difficult to observe and adjust pumps while wearing gloves, respirators, and other personal protective equipment. Pumps should be protected with disposable coverings, such as small plastic bags, to make decontamination procedures easier.

Personal monitoring may require the use of a variety of sampling media. Unfortunately, single workers cannot

carry multiple sampling media because of the added strain and because it is not usually possible to draw air through different sampling media using a single portable, battery-operated pump. Consequently, several days may be required to measure the exposure of a specific individual using each of the media [3,4]. Alternatively, if workers are in teams, a different monitoring device can be assigned to each team member. Another method is to place multiple sampling devices on pieces of heavy equipment. While these are not personal samples, they can be collected very close to the breathing zone of the heavy equipment operator and thus would be reasonably representative of personal exposure. These multimedia samples can yield as much information as several personal samples [5].

When considering employee monitoring, procedures and protocols found in OSHA's *Industrial Hygiene Technical Manual* may be useful [6].

Variables of Hazardous Waste Site Exposure

Complex, multisubstance environments such as those associated with hazardous waste sites pose significant challenges to accurately and safely assessing airborne contaminants. Several independent and uncontrollable variables, most notably temperature and weather conditions, can affect airborne concentrations. These factors must be considered when developing an air monitoring program and when analyzing data. Some demonstrated variables include:

- Temperature. An increase in temperature increases the vapor pressure of most chemicals.
- Windspeed. An increase in wind speed can affect vapor concentrations near a free-standing liquid surface. Dusts and particulate-bound contaminants are also affected.
- Rainfall. Water from rainfall can essentially cap or plug vapor emission routes from open or closed containers, saturated soil, or lagoons, thereby reducing airborne emissions of certain substances.
- Moisture. Dusts, including finely divided hazardous solids, are highly sensitive to moisture content. This moisture content can vary significantly with respect to location and time and can also affect the accuracy of many sampling results.
- Vapor emissions. The physical displacement of saturated vapors can produce short-term, relatively high vapor concentrations. Continuing evaporation and/or diffusion may produce long-term low vapor concentrations and may involve large areas.
- Work activities. Work activities often require the mechanical disturbance of contaminated materials, which may change the concentration and composition of airborne contaminants.

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