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Standard Guide for Air Monitoring at Waste Management Facilities for Worker Protection[1]

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1. Scope

1.1 This guide is intended to provide a standardized approach for establishing and carrying out an air monitoring program to protect workers at waste management facilities. This guide may apply to routine operations at an active treatment, storage, or disposal site or the extraordinary conditions that can be encountered in opening and cleaning up a remedial action site.

1.2 The user shall understand that it is impossible to predict all the issues that could arise at a waste management facility due to hazardous airborne emissions. Although air contaminant measurements obtained in accordance with this guide may indicate acceptable or tolerable levels of toxic agents are present, care and judgment must still be exercised before concluding that all atmospheric contaminants at the site are under control and that a reasonable safe work environment exists.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres
D1605 Practices for Sampling Atmospheres for Analysis of Gases and Vapors (Withdrawn 1992)[3]
D2820 Test Method for C Through C Hydrocarbons in the Atmosphere by Gas Chromatography (Withdrawn 1993)[3]
D2913 Test Method for Mercaptan Content of the Atmosphere
D3162 Test Method for Carbon Monoxide in the Atmosphere (Continuous Measurement by Nondispersive Infrared Spectrometry)
D3249 Practice for General Ambient Air Analyzer Procedures
D3269 Test Methods for Analysis for Fluoride Content of the Atmosphere and Plant Tissues (Manual Procedures) (Withdrawn 2010)[3]
D3413 Test Method for Lead (Inorganic) in Workplace Atmospheres by Atomic Absorption Spectrometry (Withdrawn 1989)[3]
D3449 Test Method for Sulfur Dioxide in Workplace Atmospheres (Barium Perchlorate Method) (Withdrawn 1989)[3]
D3476 Test Method for bis (Chloromethyl) Ether (bis CME) in Workplace Atmospheres (Gas Chromatography-Mass Spectrometry (Withdrawn 1989)[3]
D3614 Guide for Laboratories Engaged in Sampling and Analysis of Atmospheres and Emissions
D3686 Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method)
D3687 Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method
D3824 Test Methods for Continuous Measurement of Oxides of Nitrogen in the Ambient or Workplace Atmosphere by the Chemiluminescent Method
D4185 Practice for Measurement of Metals in Workplace Atmospheres by Flame Atomic Absorption Spectrophotometry
D4240 Test Method for Airborne Asbestos Concentration in Workplace Atmosphere (Withdrawn 1995)[3]
D4323 Test Method for Hydrogen Sulfide in the Atmosphere by Rate of Change of Reflectance
D4490 Practice for Measuring the Concentration of Toxic Gases or Vapors Using Detector Tubes
D4532 Test Method for Respirable Dust in Workplace Atmospheres Using Cyclone Samplers
D4599 Practice for Measuring the Concentration of Toxic Gases or Vapors Using Length-of-Stain Dosimeters
D4600 Test Method for Determination of Benzene-Soluble Particulate Matter in Workplace Atmospheres
D4687 Guide for General Planning of Waste Sampling
D5681 Terminology for Waste and Waste Management

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[1] This guide is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.04 on Workplace Air Quality.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

D6561 Test Method for Determination of Aerosol Monomeric and Oligomeric Hexamethylene Diisocyanate (HDI) in Air with (Methoxy-2–phenyl-1) Piperazine (MOPIP) in the Workplace

D6562 Test Method for Determination of Gaseous Hexamethylene Diisocyanate (HDI) in Air with 9-(N-methylaminomethyl) Anthracene Method (MAMA) in the Workplace

D6785 Test Method for Determination of Lead in Workplace Air Using Flame or Graphite Furnace Atomic Absorption Spectrometry

D6832 Test Method for the Determination of Hexavalent Chromium in Workplace Air by Ion Chromatography and Spectrophotometric Measurement Using 1,5-diphenylcarbazide

D7035 Test Method for Determination of Metals and Metalloids in Airborne Particulate Matter by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

D7036 Practice for Competence of Air Emission Testing Bodies

D7539 Practice for Using a Test Chamber for Humidity Conditioning of Test Panels of Pavement Marking Paints

D7773 Test Method for Determination of Volatile Inorganic Acids (HCl, HBr, and HNO_3) Using Filter Sampling and Suppressed Ion Chromatography

D7948 Test Method for Measurement of Respirable Crystalline Silica in Workplace Air by Infrared Spectrometry

E1370 Guide for Air Sampling Strategies for Worker and Workplace Protection

2.2 *ISO Standard:*

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories[4]

2.3 *Federal Standards:*

OSHA Analytical Methods Manual[5]

NIOSH Manual for Analytical Methods[6]

OSHA, 29 CFR Part 1910 Hazardous Waste Operations and Emergency Response; Interim Final Rule, December 1986[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Terminology commonly used in air monitoring can be found in Terminology D1356. Terminology commonly used in waste and waste management can be found in Terminology D5681.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *operating site*—an operating site is a location or facility where waste is treated, stored, or disposed as part of an on-going operation.

3.2.2 *remedial action site*—a remedial action site is a location or facility that may pose a threat to human health and the environment.

4. Summary of Guide

4.1 The procedures described in this guide address safety considerations, acute health hazards, and chronic health hazards due to airborne hazardous materials.

4.2 Monitoring concepts are described for cleanup operations at remedial action sites as well as routine activities at operational waste management sites.

5. Significance and Use

5.1 The techniques of air monitoring are many and varied. This guide is intended to describe standard approaches that are used in designing an air monitoring program to protect waste management site workers.

5.2 When entering a remedial action site to initiate an investigation or a cleanup operation, operating personnel may be faced with fire, explosion, and acute or chronic health hazards. A robust safety and health program, including site-specific injury and illness prevention program (IIPP) and a safety and health plan, must be in place to direct worker activity. Details for such plans can be found in the OSHA Interim Final Rule for Hazardous Waste Operations and Emergency Response and Refs (**1, 2**).[8] Air monitoring is an integral part of such a program. This guide describes equipment and sampling procedures which can be used to evaluate the airborne hazard potential so as to gain and maintain a safe work environment at the site.

5.3 Upon obtaining air quality measurements at the site, a decision must be made as to whether conditions are under control and safe or not. That decision will depend on the nature and concentrations of the contaminants (toxicity, reactivity, volatility, etc.), the spatial extent (area affected, number of workers, etc.) of the contaminants, and the level of worker protection available and needed. Since all such parameters are typically site specific, this guide does not include air quality measurement based guidance on decision making.

5.4 This guide does not include monitoring sites containing radioactive materials, nor does it cover general safety aspects, such as access to emergency equipment or medical support for emergency needs. These items should be covered in a work place safety and health plan.

5.5 Ideally, this guide is used in combination with Guide D4687.

6. General Considerations

6.1 The scientific field addressing the assessment of airborne hazards to workers is industrial hygiene. Professional industrial hygienists, besides performing such tasks as measuring the concentration of contaminants in air, recommend the means for controlling such airborne hazards, protecting

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[4] Adopted by ASTM as an American National Standard.

[5] 1985 manual available from Occupational Safety and Health Administration, OSHA Analytical Laboratory, Salt Lake City, UT.

[6] Fifth edition manual, January 2015, available from the National Institute of Occupational Safety and Health, (NIOSH), Cincinnati, OH.

[7] Available from the Superintendent of Documents, Government Printing Office, Washington, DC, 20401.

[8] The boldface numbers in parentheses refer to the list of references at the end of this guide.

workers, and demonstrating compliance with applicable laws and regulations. A certified industrial hygienist generally offers the optimum combination of background and credentials for recognizing, evaluating, and controlling workplace health hazards. If industrial hygiene staff support is not available on site, coverage can be obtained through the use of consultants and possibly through loss prevention insurance carriers. The remainder of this guide reflects the general thought process that an industrial hygiene professional would likely go through in establishing an air monitoring program to protect workers at a waste management site.

6.2 *Establishing a Test Protocol:*

6.2.1 Various combinations of equipment and sampling techniques are used in work place air monitoring. The best monitoring program is one that combines accuracy with timely response in a cost effective manner.

6.2.2 The particular test protocol that is selected for an industrial hygiene study depends on the nature of the contaminants and the end purpose of the monitoring effort (that is, routine monitoring, searching for worst case exposure, looking for contaminant leaks in a process, etc.) (See Guide E1370.)

6.3 *Selecting Specific Methods:*

6.3.1 The choice of sampling method is generally dependent on analytical methodology to be employed. There may be no difference in the analytical work whether it is for a 15-min ceiling sample or a 7-h integrated sample. If an analytical method has poor sensitivity, however, it may be necessary to increase the pump flow rate for the short duration sampling to make certain that sufficient sample is collected for a meaningful analysis. Adjustments such as this are determined by sampling personnel and laboratory personnel based upon the measurement needs of the study and workplace limitations. Guidance on air sampling strategies for worker and workplace protection can be found in Test Method E1370. Extensive guidance on the latest developments in air sampling technology is available in Refs (**3**, **4**).

6.3.2 Information describing general methodology is available from a number of sources. Practice D1605 lists some of the classic methods that have been used when sampling for gases or vapors. The American Conference of Governmental Industrial Hygienists offers a publication, Ref (**5**), that provides a review of some equipment and methodologies. The combination of equipment and procedures selected is based on the precision, accuracy, and sensitivity needed to support the test protocol.

6.3.3 Once the goals and protocol for the sampling program have been defined, specific sampling/analytical methods are selected. Within the *Annual Book of ASTM Standards*, Volume 11.03 is dedicated to atmospheric analysis and to occupational health and safety issues. Some applicable methods from that reference are listed in Annex A1. Other sources of health and safety support include the NIOSH Manual of Analytical Methods and the OSHA Analytical Methods Manual. Specific equipment and sampling media for a particular set of airborne contaminants and sampling conditions are selected from these types of sources.

7. Procedures

7.1 *Operating Site:*

7.1.1 The procedures described in this section apply to air monitoring activities at an operational waste treatment, storage, or disposal site. At an operating site, controls (work practices, engineering controls, and personal protective equipment) are used to minimize the exposure of workers to hazardous conditions. These are defined in the site health and safety plan.

7.1.2 *Knowledge of Materials*—Knowledge of the materials arriving at or present at an operating site is critical to the design of a sampling plan. If hazardous wastes are received by a site, it is critical that they be listed on a manifest. The results of incoming shipment waste sample analyses is also helpful for identifying substances of greatest threat to healthy and safety. Information on wastes and their hazards may also be available from knowledge that specific disposal site users will tend to deliver the same types of wastes to the site due to a consistent generating process and shipment history. For example, paint manufacturers will tend to send mixtures of solvents, resins, and pigments, whereas plating firms will generally send alkaline heavy metal waste sludge, and so on. Deviation from established patterns, however, is possible and should not be discounted in sampling plan design.

7.1.3 *Worker Sampling:*

7.1.3.1 Personal sampling of the worker's breathing zone is typically the most critical of workplace sampling that is needed. While some workers may be stationed in an operations trailer at a control panel and sedentary, others may be moving about the work site and very physically active. Addressing these different situations requires an assessment capable of following and appropriate to the activity of the worker.

7.1.3.2 The first type of personal monitoring to consider is long duration time-weighted-average (TWA) sampling. For an 8-h work shift, ensure that TWA samples are at a minimum of 7-h duration either as a single sample or a series of two or more samples. For any other work hour situation, the procedure is to sample for the duration of the shift less 1 h. For workers handling organic wastes (for example, vapor degreaser solvent waste) the sampling program could include charcoal tube sampling followed by analysis for one or two of the solvents most likely to be present in the waste. Such TWA monitoring would be repeated periodically to asses worker exposure and ensure that exposure is not increasing.

7.1.3.3 Another type of personal monitoring that can be carried out is for peak exposures. For example, a 15-min ceiling sample might be taken while a set of containers is being opened for inspection or removal of its contents. The same type of sampling might be done while contents of a truck are pumped into a holding tank. In cases such as these, personal protective equipment (for example, respiratory protection) is often used to minimize worker exposure to vapors. Ceiling samples help ensure that workers are using respirators having a sufficient filtration and capture efficiency for worker safety.

7.1.3.4 In some cases, ceiling samples might be the only type of monitoring necessary for certain toxic agents. For example, steel mill waste acid pickling solution received for neutralization may only require sampling for and determination of hydrogen chloride. In that instance, only 15-min samples would be of interest, since exposure to HCl is controlled on a 15 min exposure basis by health/regulatory agencies.

7.1.3.5 Personal dosimeters, worn by the employees, have come into general use. These devices give an overall average exposure assessment and also record the instantaneous exposures of the worker during the day. These units, which are read out on a smartphone, laptop, or notebook computer, are generally good for only one specific contaminant, although the same electronic system can be used for other specific contaminants. These might be very useful in monitoring a heavy equipment operator for exposure to carbon monoxide or a waste treatment plant attendant for exposure to sulfur dioxide.

7.1.3.6 Another consideration in monitoring, safety, and health plans is the additive effect of certain substances. Paragraph 7.1.3.2 presented the concept of screening for only one or two solvents. When this is done, the eventual comparison with permissible exposure limits must be done using a safety factor. This safety factor is intended to account for the possible effects of other similar compounds that may be present, but are not measured routinely.

7.1.4 *Area Monitoring:*

7.1.4.1 A good complement to personal monitoring is fixed location area monitoring. This can be done with either sample collecting-type equipment, direct measurement instruments, or specialized fixed-parameter monitors such as those described in 7.1.3.5. Area monitoring offers the advantage of potentially providing an early warning for area worker exposure.

7.1.4.2 A combustible vapor meter in a solvent storage area can give a warning before an employee enters the area.

7.1.4.3 A carbon monoxide monitoring system around a pyrolyzer or incinerator can warn both the operator in the control room and workers in the loading area of a hazard due to a system upset or other unexpected event.

7.1.4.4 An oxygen meter permanently mounted in a below ground pit can warn an employee of an oxygen-deficient atmosphere before they enter the confined space.

7.1.4.5 Direct reading colorimetric tubes Ref (**6**), offer a convenient means for obtaining a quick reading. Besides their suitability for qualitative checks (see Annex A2), they also provide reasonable quantitative estimates.

7.1.5 *Complex Exposure Potential:*

7.1.5.1 Although much of the sampling effort may involve monitoring for one or two particular contaminants, there will be other times when the exposure potential is more complex. Examples of more complex monitoring might include:

(1) where a sludge is handled on site, and there is a chance of spillage and eventual spreading of the debris around the site by vehicular traffic and wind—monitoring will include periodic collection of dust samples requiring analysis for heavy metals;

(2) where waste from a polymer plant (such as one processing nitrile rubber, acrylonitrile butadiene styrene, or (ABS) plastic, or a combinations thereof) is handled on site. This may require a sampling protocol that looks for trace quantities of acrylonitrile in an atmosphere dominated by one or two less harmful organic vapors;

(3) where polychlorinated biphenyl, (PCB) vapor can be carried into the atmosphere by methane gas evolving from a closed site. Fugitive emission (see Ref **7**) monitoring shall include these and perhaps other compounds; and

(4) where a range of similar compounds are present, such as in some organic wastes and landfill gas. In this case, the cumulative effect shall be estimated rather than the potential effect of individual contaminants.

7.1.6 *Data Storage and Analysis:*

7.1.6.1 The various forms of air monitoring described in 7.1.3, 7.1.4, and 7.1.5 will result in the accumulation of a large amount of data by the site operator. The data need to be recorded and catalogued in a manner that provides for ready retrieval and comparison.

7.1.6.2 Store and retrieve data so that the level of airborne contamination can be reviewed over time. In this way annual, seasonal, or diurnal trends as well as source specific contamination may be identified.

7.1.6.3 The site operator may want to determine if certain shipments or customers are sending waste material that is particularly hazardous and difficult to handle.

7.1.7 *Quantitative Considerations*—Even the best run waste site may have to analyze for unknowns in the work atmosphere. Following are situations that can arise and will require appropriate monitoring and mitigative action to ensure worker safety.

7.1.7.1 The premise of most of the discussion of Section 7 is that the site operator has at least some working knowledge of the materials being handled. This may not always be the case.

7.1.7.2 An unexpected odor or phase separation may indicate an unknown or unexpected substance is present in the waste material.

7.1.7.3 An abnormal reaction in a neutralization process may be a sign that an unexpected volatile is being emitted.

7.2 *Remedial Action Site:*

7.2.1 The level of hazard that is found by air monitoring at a remedial action waste site can vary from relatively innocuous to very dangerous. The uncertainty associated with the types and composition of wastes present at these sites complicates virtually every aspect of site cleanup and monitoring. For these reasons a thorough site characterization must be made before work is started to provide data for development of a site-specific health and safety plan, including subsequent air monitoring needs.

7.2.2 *Qualitative Assessment:*

7.2.2.1 From an operational viewpoint, a prime difference between a remedial action site and an operating site is the need for qualitative assessment. The unknowns at an abandoned site require a qualitative analysis of the work environment prior to any quantitative measurements.

7.2.2.2 Before starting cleanup activity, check available records to gain knowledge of the materials that were or might have been treated, stored, or buried on the site. Be sure that labels on drums also are checked to see if there is some information on the hazardous nature of the material contained inside the drums.

7.2.2.3 Qualitative assessment must be conducted in a systematic fashion. Be sure that the operating areas are mapped and perhaps gridded so that the assessment can be done with minimal chance of overlooking zones.

7.2.3 *Safety Monitoring:*

7.2.3.1 Identify life threatening situations due to fire, explosion, and toxic exposure hazards as the first air monitoring concerns for personnel starting a cleanup action.

7.2.3.2 Enclosed spaces bring the danger of suffocation by excessive chemical vapors causing an oxygen deficiency.

7.2.3.3 For these reasons make sure that the first pieces of equipment on site, Ref (**8**) are organic and combustible vapor meters and oxygen meters. These would be used to scan the area and map out any potentially high hazard areas.

7.2.3.4 Personal monitoring devices are also available to warn workers of unsafe conditions immediately. This type of unit, which has a preset alarm, is worn by workers on their belts as they go about the site performing their work.

7.2.3.5 When a new area of the site is entered or another level is unearthed, the mapping routine for potential imminent danger situation is repeated. The routine monitoring of the site-specific health and safety plan is then followed.

7.2.4 *Direct Reading Meters and Dosimeters:*

7.2.4.1 Once the initial safety survey has been completed, a more comprehensive screening is needed to determine the presence of acute and chronic health hazards. It may be necessary to use the air data to define potentially contaminated zones where specific personal protective equipment and decontamination procedures are required.

7.2.4.2 A wide array of direct reading instruments and personal dosimeters can be used to search for classes of, or specific, chemical agents.

7.2.4.3 Most direct reading instruments either lack specificity or are susceptible to interferences. The technology used for the basic design, the relative price of the instrument within a given design, and the skill of the operator will determine the suitability of an instrument in terms of freedom from such bias.

7.2.4.4 The complexity of the chemical matrix at the site will determine the level of sophistication of instrument array that will be needed to obtain a reliable identification of the hazardous agents that are present.

7.2.4.5 A listing of such equipment along with a discussion of capabilities and limitations is presented in Annex A1. Additional information on the useful application of such equipment is available in Refs (**4, 5, and 9**).

7.2.5 *Qualitative Sample Collection:*

7.2.5.1 Just as with quantitative determination, the most reliable technique in qualitative sampling is concentration of airborne contaminants using a collection device followed by appropriate laboratory analysis.

7.2.5.2 For metal dusts (or dust containing heavy metal contaminants) a series of 37-mm diameter membrane samples or high volume filter samples are taken at various locations around the site.

7.2.5.3 These would then be submitted for analysis via some general analytical technique such as inductively-coupled plasma spectrometry, which can determine a large number of metals per sample. Certain volatile materials, such as arsenic compounds or mercury, require separate sampling.

7.2.5.4 Organic vapors can be sampled by drawing site air through an array of absorbent packed tubes or can be collected in passivated canisters. By using different tube packing materials in a manifold system or collecting a canister sample, it is possible to sample and determine a wide range of organics concurrently.

7.2.5.5 A popular combination of packings is charcoal, magnesium silicate,[9] phenylene oxide porous polymer,[10] and silica gel. These sample tubes would be desorbed either thermally or using an appropriate mix of solvents for eventual analysis via a combination gas chromatograph/mass spectrometer or other appropriate analytical method. Alternatively, canister samples can be interfaced to a gas chromatograph with a mass spectrometer, flame ionization detector, or other detection system. Note that decomposition can be a problem using thermal desorption. Where this may be an issue, canister samples may be the better option

7.2.5.6 Additional techniques, more specific in nature, can be used for other agents. If acid gases are suspected, air can be bubbled through a buffer solution which is then checked by pH meter, specific ion electrode, or analyzed by ion chromatography. For pesticides and PCBs even more specific sampling/analysis combinations are available.

7.2.5.7 A direct reading meter is unavailable for asbestos, so care is required if suspicious deposits are encountered or anticipated. Bulk samples require qualitative identification using a technique such as polarizing light microscopy. Any attempt to use an air sample for qualitative identification of asbestos fibers will likely result in use of an extremely demanding analytical procedure, such as a scanning electron microscope with X-ray diffraction analysis. Once asbestos has been positively identified, conventional fiber counting techniques are used for quantitation in air samples.

7.2.6 *Select Toxic Agents for Monitoring:*

7.2.6.1 Previous procedures described in 7.2.1 through 7.2.5 should provide site operating or survey personnel with an appreciable amount of qualitative information from instrumental and laboratory analysis of collected air samples. In addition, data should be available from site documentation and from laboratory results on the analysis of bulk samples taken from waste drums, lagoons, tanks, other equipment, and perhaps contaminated soil.

7.2.6.2 Select key parameters to be monitored quantitatively based on:

(a) Those which must be monitored due to applicable air regulatory controls (for example, lead, benzene).

(b) Those offering the most severe risk to health and safety, even in trace quantities (for example, methyl isocyanate).

(c) Those that are dominant in the site environment due to quantity and volatility or dispersion (for example, chlorinated solvents).

7.2.7 *Quantitative Assessment:*

7.2.7.1 Once the hazardous agents have been identified, air sampling routines are established to determine the concentration of those substances in the site atmosphere. This information is needed to ensure that site workers are adequately protected and for regulatory requirements.

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[9] Magnesium silicate available from various sources under the tradename Florisil, has been found suitable for this purpose.

[10] Phenylene oxide porous polymer available from various sources under the tradename Tenax, has been found suitable for this purpose.

7.2.7.2 *Operating Site Similarity*—Once potentially significant unknown contaminants are identified, establishment of a testing program similar to that for an operating disposal site is accomplished. Refer then to 7.1 for guidance except for the following modifications:

7.2.7.3 *Increased Sampling Frequency*—Conditions at a cleanup site are much more unstable than at an operating disposal site. The control of airborne emissions can be greatly reduced and difficult in a cleanup operation as compared to an operating disposal site. As a result, much wider inter-day and intra-day fluctuations in the concentrations of airborne contaminants can be expected. To account for such variations, increase frequency of sampling and analysis for air contamination. In a cleanup operation, daily quantitative monitoring may be required.

7.2.7.4 *Timely Analytical Support*—Considering the wide range of environmental and working conditions that are possible at remedial action sites, it is most important that timely analytical support be available. If an intense sampling program has been designed in attempting to correct an out-of-control condition, a 2 to 4 week wait for analytical results is unreasonable. Since some samples in the sampling program may be of less significance than others, waiting for analytic results may be unnecessary. For this reason, it is prudent to establish a priority system to identify those samples that are critical to worker safety and samples that can provide useful information but are not critical to worker safety.

7.2.7.5 *Periodic Qualitative*—To detect residual unknown emissions at a site, it is prudent to conduct qualitative determinations periodically. Note that the results of these tests may require additional quantitative monitoring. As a minimum, the results for the analysis of bulk samples should be reviewed periodically to identify any new compounds which may become airborne hazards.

8. Quality Assurance

8.1 The sampling and analysis of workplace air shall be conducted with a firm awareness of and adherence to quality control procedures that will provide scientifically sound results of a known quality. Procedures must be in place to control the calibration of direct reading meters and sampling equipment, sample handling, analytical precision and bias, and data handling.

8.2 A comprehensive quality assurance program can be developed using Practice D3614.

8.3 If a certain segment of the surveillance effort, such as analytical support, is to be handled by an outside organization, then the quality program must be extended to cover the outside organization. One approach is to restrict analytical support to a professionally accredited industrial hygiene laboratory. Such an organization will generally have a quality control program satisfying the requirements to maintain certification, but it is still incumbent on users of the service to review the organization's quality control program. Practice D7036 provides guidelines for performing this assessment.

ANNEXES

(Mandatory Information)

A1. INDUSTRIAL HYGIENE TEST METHODS AND PRACTICES

TABLE A1.1 ASTM Standards[A]

Test Requirements	
Asbestos	D4240 Test Method for Airborne Asbestos Concentration in Workplace Atmosphere (Withdrawn 1995)
bis (Chloromethyl) Ether	D3476 Test Method for *bis* (Chloromethyl) Ether (*bis* CME) in Workplace Atmospheres (Gas Chromatography—Mass Spectrometry) (Withdrawn 1989)
Carbon Monoxide	D3162 Test Method for Carbon Monoxide in the Atmosphere (Continuous Measurement by Nondispersive Infrared Spectrometry)
Detector Tubes	D4490 Practice for Measuring the Concentration of Toxic Gases or Vapors Using Detector Tubes
Fluoride	D3269 Test Methods for Analysis for Fluoride Content of the Atmosphere and Plant Tissues (Manual Procedures) (Withdrawn 2010)
General Air Analyzer	D3249 Practice for General Ambient Air Analyzer Procedures
Hexamethylene Diisocyanate	D6561 Test Method for Determination of Aerosol Monomeric and Oligomeric Hexamethylene Diisocyanate (HDI) in Air with (Methoxy-2-phenyl-1) Piperazine (MOPIP) in the Workplace
Hexamethylene Diisocyanate	D6562 Test Method for Determination of Gaseous Hexamethylene Diisocyanate (HDI) in Air with 9-(N-methylaminomethyl) Anthracene Method (MAMA) in the Workplace
Hexavalent Chromium	D6832 Test Method for the Determination of Hexavalent Chromium in Workplace Air by Ion Chromatography and Spectrophotometric Measurement Using 1,5-diphenylcarbazide
Hydrocarbon Gases	D2820 Test Method for C_1 through C_5 Hydrocarbons in the Atmosphere by Gas Chromatography (Withdrawn 1993)
Hydrogen Sulfide	D4323 Test Method for Hydrogen Sulfide in the Atmosphere by Rate of Change of Reflectance
Inorganic Acids	D7773 Test Method for Determination of Volatile Inorganic Acids (HCl, HBr, and HNO3) Using Filter Sampling and Suppressed Ion Chromatography
Inorganic Lead	D3413 Test Method for Lead (Inorganic) in Workplace Atmospheres by Atomic Absorption Spectrometry (Withdrawn 1989)
Lead	D6785 Test Method for Determination of Lead in Workplace Air Using Flame or Graphite Furnace Atomic Absorption Spectrometry
Length-of-Stain Dosimeters	D4599 Practice for Measuring the Concentration of Toxic Gases or Vapors Using Length-of-Stain Dosimeters
Mercaptans	D2913 Test Method for Mercaptan Content of the Atmosphere
Metals	D4185 Practice for Measurement of Metals in Workplace Atmosphere by Flame Atomic Absorption Spectrophotometry
Organic Vapors	D3687 Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method
Organic Vapors	D3686 Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method)
Oxides of Nitrogen	D3824 Test Methods for Continuous Measurement of Oxides of Nitrogen in the Ambient or Workplace Atmosphere by the Chemiluminescent Method
Particulate (Coke Ovens)	D4600 Test Method for Benzene-Soluble Particulate Matter in Workplace Atmospheres, Determination of
Particulates	D7035 Test Method for Determination of Metals and Metalloids in Airborne Particulate Matter by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
Particulates	D7539 Test Method for Determination of Elements in Airborne Particulate Matter by Inductively Coupled Plasma-Mass Spectrometry
Respirable Dust	D4532 Test Method for Respirable Dust in Workplace Atmospheres Using Cyclone Samplers
Sampling	E1370 Guide for Air Sampling Strategies for Worker and Workplace Protection
Silica	D7948 Test Method For Determination of Moisture Content of Bituminous Mixtures
Sulfur Dioxide	D3449 Test Method for Sulfur Dioxide in Workplace Atmospheres (Barium Perchorate Method) (Withdrawn 1989)
Asbestos	D4240 Test Method for Airborne Asbestos Concentration in Workplace Atmosphere (Withdrawn 1995)

[A] This table may not be all inclusive. The user is encouraged to review test methods under ASTM Subcommittees D22.03, D22.04, and D22.05.

A2. DIRECT READING AIR MONITORING EQUIPMENT AND DOSIMETERS

A2.1 *Photo-Ionization Meter-Battery Operated Device*:

A2.1.1 *Basic Design*—Draws in air and ionizes organic compounds using ultra-violet radiation; charged plates measure proportional current flow due to ionized field Ref (**2**).

A2.1.2 *Limits*—Sensitivity down to the ppm range, but non-specific except for very broad categories (for example, aromatic versus non-aromatic) by selection of lamp with appropriate UV output.

A2.2 *Colorimetric Indicator Tubes*:

A2.2.1 *Basic Design*—Single use glass tubes containing chemical reactants which change color in presence of the pertinent analyte; length of stain is proportional to concentration Ref (**3**).

A2.2.2 *Limits*—Convenient apparatus with poor precision but good sensitivity. Response is generally for an entire class of compounds (for example, chlorinated hydrocarbon) and sometimes susceptible to interferences (oxidizer may bleach out color).

A2.3 *Electrolytic Cell Detectors*:

A2.3.1 *Basic Design*—Battery operated monitors using solid state electrolytic cell in which conductivity of cell material changes in proportion to concentration of H_2S, CO, CH_4, SO_2, or O_2.

A2.3.2 *Limits*—Good sensitivity and freedom from interferences, but each cell is for a specific gas resulting in five different instruments to cover all five gases.

A2.4 *Portable Gas Chromatograph*:

A2.4.1 *Basic Design*—Truly portable GC equipment with choice of Flame Ionization Detector (FID), Electron Capture Detector, (ECD), or Photo Ionization Detector, (PID) and with choices of standard packed columns; though not a direct reading instrument, it is used in the field.

A2.4.2 *Limits*—Relatively good sensitivity and can separate mixtures in a gas sample, but as with GC, requires calibration with analytes of interest at time of use.

A2.5 *Portable Combustible Gas Meter*:

A2.5.1 *Basic Design*—Battery operated catalytic combustion changes electrical conductivity of detector; for H_2, CO, and any combustible organic.

A2.5.2 *Limits*—Used for higher concentrations, particularly in low percent range to check for explosive atmospheres. Non-specific and can be a source of ignition.

A2.6 *Portable Infrared Analyzer*:

A2.6.1 *Basic Design*—Sometimes battery operated, senses organic or inorganic gases capable of IR absorption.

A2.6.2 *Limits*—If a non-dispersive instrument, it is not specific. Dispersive instruments not battery powered, but are selective. Requires experienced analyst when dealing with a mixture of compounds.

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