



# **Exposure Monitoring Participant Guide**

### Acknowledgments

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The Midwest Consortium developed this course for Hazardous Waste Workers and Emergency Responders under cooperative agreement number U45 ES 06184 from the National Institute of Environmental Health Sciences (NIEHS).

We encourage you to comment on these materials. Please give your suggestions to the individual leading the course or click on ‘contact us’ at <https://mwc.umn.edu/contact/>.

### Warning

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The Midwest Consortium has copyrighted this material for workers who monitor the air to detect and/or measure contaminants or who collects air, water, soil or surface samples for analysis at a laboratory. A recipient of the material, other than the Federal Government, may not reproduce it without permission of the copyright owner.

The material was prepared for use by facilitators experienced in the training of persons who are or who anticipate being employed assessing exposure. Authors of this material have prepared it for the training of this category of workers as of the date specified on the title page. Users are cautioned that the subject is constantly evolving. Therefore, the material may require additions, deletions, or modifications to incorporate the effects of that evolution occurring after the date of this material preparation.

### Disclaimer

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The Occupational Safety and Health Administration (OSHA) rule to help ensure worker health and safety at hazardous waste sites and during a range of emergency response activities may require monitoring for hazard evaluation. This program is intended to increase skills of those using a range of devices to characterize the environment during these types of activities.

Additional training is necessary to perform many activities. These activities include troubleshooting monitoring equipment, interacting with laboratory personnel and safety practices when collecting water or soil samples. For information about these matters, consult the facilitator, your company health and safety representative and relevant SOPs.

These materials were updated January 31, 2024; all web links are active as of that date. If you find an error, please inform the facilitator so that it can be updated.

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## **Introduction**

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Detecting and measuring hazardous substances at a work site is very important for the safety and health of workers and the community. Potentially toxic compounds can be detected and measured using a variety of different monitoring instruments.

Exposure levels and explosive limits have been determined by government agencies as well as non-governmental organizations. These levels and limits are used to determine proper protective equipment and ensure a safer work environment.

### **Objectives**

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When you have completed this program, you will be better able to:

- Illustrate hazards that can be detected and measured through monitoring, including those that may result in adverse health or environmental effects
- Identify several types of monitoring that may be performed
- Describe the procedures to be followed when using selected monitoring devices
- Conduct monitoring for a specific purpose (optional)

## **Monitoring for Workplace Hazards**

Monitoring provides important information about the presence of hazardous substances at a work site. Proper use of sampling equipment can provide information needed to protect life and property.

OSHA has a number of standards that require monitoring, including:

### **29 CFR 1910.120 requires air monitoring:**

- Upon initial site entry
- When work begins on a different part of the site
- When you start handling chemicals that weren't found before
- At the start of a different operation, such as opening drums instead of well drilling
- When you are handling leaking drums or working with liquid contamination, such as a spill or a lagoon
- During various stages of emergency response

### **29CFR1910.146 requires air monitoring:**

- Permit-required confined spaces

### **29CFR1910.1000 and chemical specific standards require air monitoring:**

- To evaluate workplace exposure

EPA and other agencies also have guidelines for sampling air, water, soil and surfaces.

Monitoring is performed when there is a question as to whether employees may be exposed to hazardous substances; the results are used as one factor in selecting PPE.

The reasons for monitoring are:

- To **detect** whether potential hazardous condition(s) exist or a hazardous substance is present.
- To **measure** the concentration of hazardous substances.

pH paper – used to DETECT

pH = 11 (caustic vapor or mist)



solid sorbent tube, personal pump, lab analysis (MEASURE ammonia concentration)



Monitoring is also done in order to:

- Determine the effectiveness of hazard controls, such as ventilation.
- Determine whether hazardous materials are present during normal operations.
- Determine possible immediate effects of hazards, especially conditions which are immediately dangerous to life and health (IDLH).
- Determine when sudden releases of toxic materials occur that would require a change in work practice or donning of a specific type of protective equipment.
- Determine the levels of hazardous substance(s) remaining after a sudden release.

Whenever a contaminant is detected, it is desirable to measure the concentration if possible and the result can be compared to occupational exposure limits.

Measurement of concentrations is necessary in order to:

- Determine worker exposure level.
- Determine the extent of hazardous conditions.
- Determine community exposure.
- Assist in planning work activity, including PPE needed.
- Provide records of exposure.
- Provide a historical record to submit to regulatory agencies.
- Determine whether there is a need for medical monitoring.

Initial entry monitoring is designed to detect IDLH situations at representative areas of the site. Other situations to be identified as part of initial entry monitoring include possible overexposure to chemicals, dusts or radioactive materials, or other dangerous situations such as the presence of flammable or oxygen-deficient atmospheres.

Real-time monitoring will alert workers to hazardous conditions and should be conducted when an IDLH condition is suspected, flammable atmospheres, or indications that exposures may have increased above permissible or published exposure limits since the last monitoring. It is possible that exposures may have changed when:

- Work begins in a different area of the site or tasks change
- Contaminants other than those previously identified are being handled
- Chemical contamination is identified in the work area

The results of monitoring of employees with high exposures will be used to determine future sample collection and:

- If some workers exceed exposure limits, then the program is expanded to identify all overexposed workers
- The monitoring must be repeated if work activities or types of materials handled change
- A medical surveillance program could be considered

### Exposure Records

Results of any exposure monitoring conducted by your employer are considered part of your medical record and must be available to you upon request.

See the OSHA Standard “Access to Employee Exposure and Medical Records” (1910.1020). Records which workers can request include either environmental information or personal medical records. When requested, the employer must provide access within fifteen working days after the request is made. The employer can comply by either making a copy of the requested record at no cost to the employee, allowing the employee to use the employer copy machine to copy the requested record, or by allowing the employee an opportunity to inspect the record.

### Basic principles for using monitoring equipment

- No one monitor can be used to detect all hazardous situations. Select the monitor with the correct sensors for the potential chemicals present in the work area you are entering.
- Know how they work and how to use them.
- Know the limitations (consult manufacturer data) of the monitor to be used.
- Try to use more than one type of monitor technology to verify identification.

## **OCCUPATIONAL EXPOSURE LIMITS**

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Legally-enforceable airborne exposure limits are set by OSHA. NIOSH and non-governmental agencies (such as the American Conference of Governmental Industrial Hygienists [ACGIH]) have also established limits which are used to determine exposures. These guidelines and recommendations are not legally enforceable. A review is provided here.

### **Objectives**

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When you have completed this section, you will be better able to:

- Describe measurement of air quality
- Contrast the enforceable and recommended exposure limits
- Demonstrate use of the NIOSH Pocket Guide to find Occupational Exposure Limits

Legally-enforceable airborne exposure limits are set by OSHA.

NIOSH and non-governmental agencies (such as the American Conference of Governmental Industrial Hygienists [ACGIH]) have also established limits which are used to determine exposures. These guidelines and recommendations are not legally enforceable. However, they may be updated more often than OSHA's. Some exposure limits have a "skin" description, which means that the material is readily absorbed through the skin. Several exposure terms are described below.



## **Measures of Concentration**

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Exposure limits are expressed as an airborne concentration. Concentration is the amount of a substance contained in a certain volume of something else, in this case - air. Concentrations of gases or vapors in air are usually measured in parts per million (ppm) or percent by volume of air:

Emphasize that 1 ppm, 1 mg/m<sup>3</sup>, or 1 f/cc are very dilute concentrations. Some chemicals are hazardous even at these low concentrations.

Percents are used for higher concentrations; a concentration of 1% is 10,000 ppm

Concentrations of particulates, dust, and mists are usually measured in milligrams per cubic meter of air (mg/m<sup>3</sup>).

- There are about 455,000 milligrams in one pound.
- There are about 35 cubic feet in one cubic meter. (A meter is about 40 inches.)

Fiber concentrations are measured in fibers per cubic centimeter (f/cc).

- A cc is about the size of a sugar cube.

## **Immediately Dangerous to Life and Health (IDLH)**

IDLH is a concentration or condition that poses an immediate threat to life or health or might prevent someone from escaping such an environment. An IDLH condition may exist where a chemical is present above the IDLH concentration, where oxygen concentrations are too low in the air, or in other dangerous circumstances such as in a structure fire.

## **Permissible Exposure Limits (PELs)**

Permissible exposure limits (PELs) are legal exposure levels set by OSHA. Employers are required by law to keep exposures below the PELs. In most cases, the PELs have not been updated for many years.

## **Threshold Limit Values (TLVs)**

Threshold limit values are recommendations for exposure limits which are prepared by the ACGIH, a private, non-governmental agency. TLVs, which are not legally enforceable, do include updates of some levels each year. They are usually more protective (lower) than PELs. TLVs are not listed in the NPG, and the full listing and basis for the concentration are not available for free. The TLV is listed in safety information from chemical suppliers.

### Recommended Exposure Limits (RELs)

Recommended exposure limits (RELs) are set by NIOSH. RELs are not legally enforceable. Like TLVs, RELs are generally more protective than the legally-enforceable PELs.

### Short-Term Exposure Limits (STELs)

These exposure limits are set by ACGIH, OSHA, and NIOSH. The STEL is a maximum average concentration a person may be exposed to over a short period of time, usually 15 minutes. It is legally enforceable if set by OSHA. STEL is sometimes abbreviated further to ST.

### Ceiling Limits (C)

The ceiling limit is an exposure level set by ACGIH, OSHA, and NIOSH which should not be exceeded at any time. It is legally enforceable if set by OSHA.

### Time-Weighted Averages (TWAs)

Most PELs, TLVs, and RELs are 8-hour time-weighted average concentrations. The purpose of this type of average exposure is to characterize an 8-hour work shift. An example of how the TWA is calculated follows:

An employee is exposed to acetone at 60 ppm for 6 hours and 12 ppm for 2 hours. What is the TWA?

$$\text{TWA} = \frac{(\text{Exposure}_1 \times \text{Time}_1) + (\text{Exposure}_2 \times \text{Time}_2) + \dots}{(\text{Time}_1 + \text{Time}_2 + \dots)}$$

$$\text{TWA} = \frac{(60 \text{ ppm} \times 6 \text{ hrs}) + (12 \text{ ppm} \times 2 \text{ hrs})}{(6 \text{ hrs} + 2 \text{ hrs})}$$

$$\text{TWA} = \frac{(360 + 24) \text{ ppm hrs}}{8 \text{ hrs}}$$

$$\text{TWA} = 48 \text{ ppm}$$

Compare this result with the current OSHA PEL for acetone of 1000 ppm.

- Has the PEL been exceeded?
- Was it exceeded for any portion of the time sampled?
- Is there a REL, ST or C designation in the *NIOSH Pocket Guide to Chemical Hazards*?

For more information on biological exposure guidelines, see individual OSHA standards for enforceable limits and the section on Biological Exposure Indices in the ACGIH annual publication, TLVs® and BEIs®.

### **Exercise – Using the NIOSH Pocket Guide to find Occupational Exposure Limits**

Utilize the NIOSH Pocket Guide to determine the occupational exposure limits for a chemical suggested by the facilitator or of interest to the group. Complete the Worksheet provided.

# EXPOSURE MONITORING

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Examples of what can be monitored in air, water, soil and on surfaces are provided. Overall guidance for monitoring chemicals in any of these media is described and need for a sampling plan or protocol is shown in order to ensure that the results are accurate and useful.

## Objectives

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When you have completed this section, you will be better able to:

- Describe relevant chemicals that can be monitored in your workplace
- Demonstrate use of instruments and tools for sampling
- Explain reasons for a sampling plan
- Describe use of monitoring during emergencies

## What Can Be Monitored in the Air?

Air monitoring can be used to detect and measure many hazards, including:

1. Oxygen Deficiency/Enrichment
2. Fire and Explosion Hazards
3. Toxic Chemicals
4. Corrosivity
5. Radioactivity
6. Biological Hazards

### Oxygen-Deficiency/Enrichment

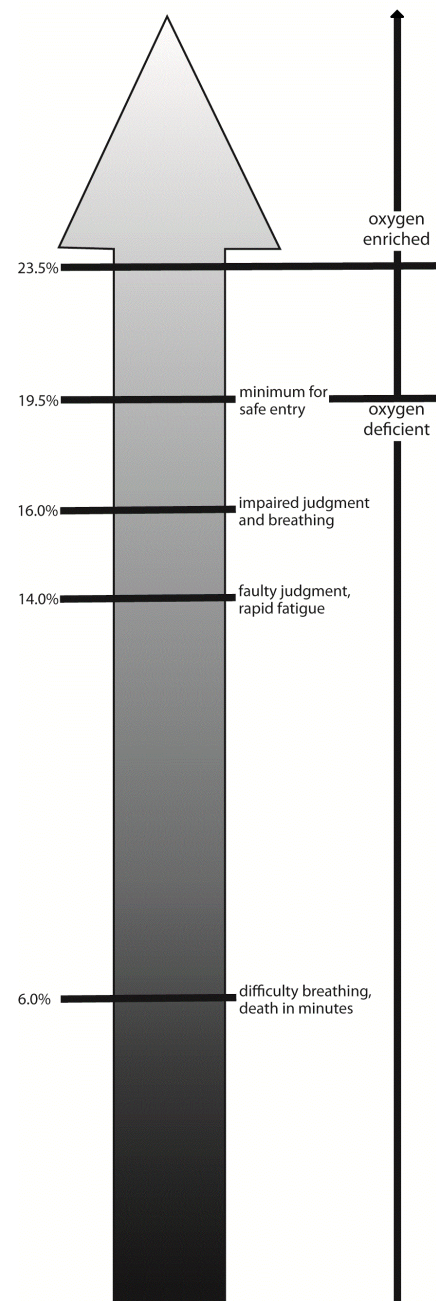
#### Oxygen Deficiency

Without an adequate concentration of oxygen in the air, the worker is in an immediately dangerous to life and health (IDLH) atmosphere. Normal breathing air contains 20.9% oxygen. OSHA requires a minimum of 19.5% oxygen to be present at the site; otherwise the atmosphere is considered oxygen-deficient. Confined spaces such as tanks, pits, silos, pipelines, boilers, vaults, and sewers are examples of possible oxygen-deficient work areas. Oxygen levels can be reduced during certain chemical reactions, rusting, or some bacterial action (fermentation). Oxygen-deficient atmospheres may cause a person to feel lethargic and potentially lose consciousness. OSHA requires supplied-air respiratory protection in atmospheres below 19.5% oxygen.

#### Oxygen Enrichment

The atmosphere is defined as **oxygen-enriched** if it contains more than 23.5% oxygen. This situation poses a threat of explosion, especially if flammable materials are present. As a result, special procedures are necessary in the area.

Note: At 19.5% most people should be able to make good decisions and safely escape the environment.



**Discussion Question:**

O<sub>2</sub> levels were measured prior to entry into a trench. Please review the measurement reported and comment on whether entry is permitted and any notes or considerations that you might have regarding the reading.

a) O<sub>2</sub> = 19.5%

b) O<sub>2</sub> = 20.5%

c) O<sub>2</sub> = 23.5%

Oxygen can be displaced by other chemicals. This is particularly a concern in confined spaces. For compounds with a relative gas density (R<sub>GasD</sub>, vapor density of the substance compared with air) greater than 1, the vapor will tend to go to the lowest level; those with values less than 1 will tend to rise.

**Fire and Explosion Hazards**

Determining whether there is a possibility of fire or explosion is critical. Flammable and explosive atmospheres develop when reactions occur with oxygen in the air, evaporation of flammables, gas leaks, and dust accumulation. Potentially flammable atmospheres must be monitored frequently in accordance with the Emergency Response Plan (ERP). Protective clothing and respirators which protect the worker from toxic hazards provide little, if any, protection against fire or explosions.

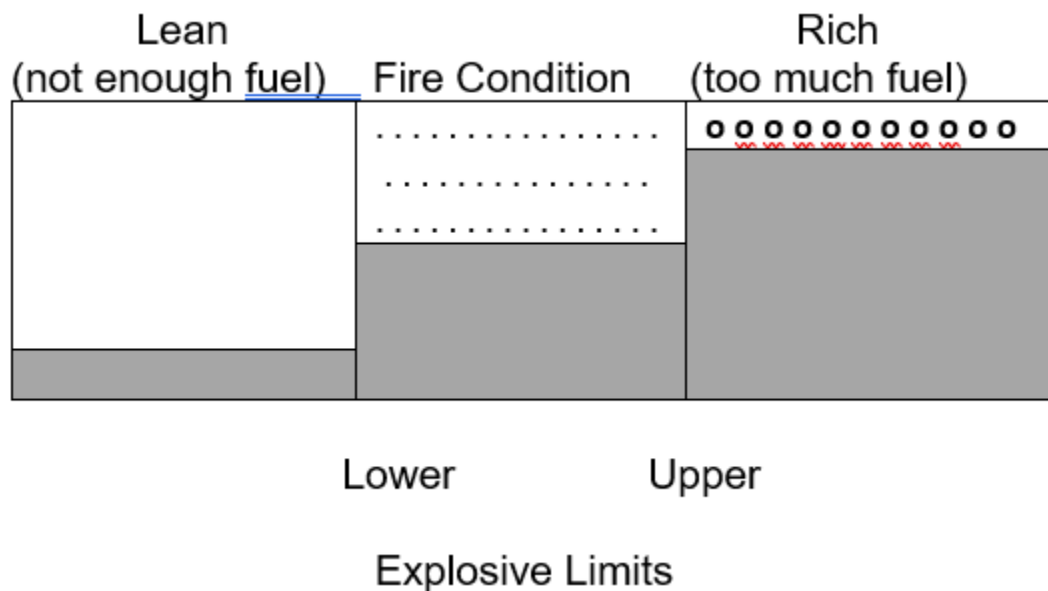
Explosive Limits

Monitoring results reported as percentage can provide information about substances in the air which may potentially cause an explosion. For flammable vapors and dusts, explosive limits have been determined. Two determined limits are listed below:

**Lower Explosive Limit (LEL)** is the minimum concentration of a flammable gas in the air which can result in ignition. Concentrations below the LEL will not ignite. Below the LEL, the mixture is called “lean.”

**Upper Explosive Limit (UEL)** is the maximum concentration of a flammable gas in the air which can result in ignition. Concentrations above the UEL will not ignite. Above the UEL, the mixture is called “rich.”

**Explosive Range** is the concentration of a flammable gas in the air between the LEL and UEL. In this range, the substance will readily ignite.



**Toxic Chemicals**

The ability to determine the specific hazard by monitoring the air, soil, water, or surfaces will be limited to the capabilities of the monitoring instrument used.

For immediate results direct reading instruments are used; these provide information about the presence (detect) and sometimes the concentration (measure) of the gas, vapor or dust hazard. These are generally used near active work or the breathing zone of workers; this is referred to as area monitoring. Conducting personal monitoring of gas, vapor, or dust exposure requires wearing a sampling device. Generally the sample is sent to a laboratory to measure of the concentration of specific materials in the air. Soil, water and surface contamination samples generally are analyzed in a laboratory.

**Corrosivity**

Corrosives (acids or bases, having significantly low or high pH) can have adverse health effects, including damage to skin, eyes and the respiratory system. In addition, they can damage monitoring equipment and PPE. Corrosive compounds in the air can be detected using pH paper. If strong acids or bases are present, the pH paper will change color.

**Radiation from radioactive substances**

If the presence of radioactive materials is detected, adequate precautions can be implemented to prevent exposure. The presence of radiation usually requires special technicians (Radiation Safety Officers) to conduct monitoring. No single instrument can measure all forms of radiation accurately.

**Biological Hazards**

Workers may also be exposed to biological hazards such as bacteria, viruses, certain parasites, mold and animal droppings. Specialized training and equipment are needed to detect and measure biological hazards. The presence of these agents will help determine the selection of PPE, as well as decontamination and disposal procedures. When it is suspected that biological hazards are present, specialists must be brought in to investigate.



## **What Can Be Monitored in Soil, Water or on Surfaces?**

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Evaluation of contaminants in media other than air may be performed. Assessment of water, soil, and surface contamination may be conducted. In addition, corrosivity and compatibility tests may be conducted.

See manufacturer literature for the range environmental monitoring equipment. For specific protocols, search the EPA website.

### Soil Sampling

Soil samples may be collected at a site, or on neighboring property to determine if a material has migrated and been released to the soil. Laboratory analysis of soil samples will indicate if there is contamination and the depth and area of the contamination. Contamination by solids, liquids and vapor may be evaluated.

### Water Sampling

Sampling and laboratory analysis of effluent groundwater and water from wells, ponds, and streams may be performed at a site to determine whether hazardous substances (examples: metals, biologic, organic compounds) are present or have migrated off-site.

### Wipe (Swipe) Testing for Surface Contamination

Surface contamination is evaluated by collecting a sample by passing a filter or wipe across a surface according to a specified procedure and then submitting the sample to a laboratory for analysis. Swipes are often used to evaluate metals and radiation hazards. Contamination of PPE or human skin can also be evaluated by wipe testing.

## **Overall Guidance**

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Work site management is responsible for selecting equipment appropriate for routine sampling and anticipated emergencies. Manufacturers provide information about equipment used and its limitations. NIOSH and the EPA also provide information about equipment.

Real-time monitoring with direct-reading instruments provides an immediate result and can be done with a range of devices depending on the information required. If the exposure of a worker is to be evaluated, personal monitoring is conducted; the sample is sent to a laboratory and is therefore not available immediately.

Some general considerations when selecting/using monitoring equipment follow:

- The unit should be intrinsically safe. (It will not produce sparks that could trigger an explosion.) Check the label and the manufacturer guide.
- Most direct-reading instruments are designed to detect or measure only one contaminant or group of contaminants. And most don't identify the contaminant.
- There are no instruments which can sample all toxic substances.
- Equipment should be easy to transport and operate in the field under changing conditions, and be decontaminated after use, as needed.
- Instruments should operate properly at temperatures which are anticipated during site activities.
- Instrument training should be provided through routine "hands-on" practice.
- Many sampling instruments have rechargeable batteries that typically last longer than 8 hours when new and fully charged. Operation may reduce the battery life. Cold temperatures also reduce battery duration of use; never store fully charged equipment in a cold location prior to use.
- Some equipment can be operated with non-rechargeable batteries that can be an option when working in the field.
- For rechargeable batteries, periodically discharge the battery fully and recharge to prevent 'battery memory'.
- Many instruments do not reach the highest readout instantaneously. For chemical sensors, the time to reach 90% of the actual concentration is referred to as T90 and is typically in the range of 15 seconds to 2 minutes.



## Sampling Plan or Protocol

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A sampling plan is designed to provide representative and accurate information on exposure.

A sampling plan includes:

- Areas where sampling is required
  - By regulation
  - By Site Safety and Health Plan
- Equipment needed

- Frequency, duration and procedures
- Sampling methods
- Analytical method (if needed)
- Benchmarks for comparison of result with accepted values
- Name (and signature)/date of plan developer and any amendments

Documentation for sampling generally includes:

- Pre- and post-calibration (if specified in protocol; initials of person doing it)
- Name/number of sampling analytical method (if used)
- Person conducting the monitoring
- Person monitored (if personal monitoring)
- Equipment ID number
- Drawings showing location of sample collection
- Notes regarding activities conducted during sampling
- Notes regarding work practices and other exposure controls
- Use of any PPE
- Any observed problems with the equipment
- Any deviation from the sampling method
- Result (recorded by sampling personnel or laboratory report)
- Record of transmitting result to person sampled (if personal monitoring)

A Calibration and Maintenance Log Book will include the following for each device:

- Description of required calibration and maintenance
- Date of each calibration/maintenance
- Results (often as a letter from an external source)
- Location of Manufacturer Literature for review, as needed

Note: electronic calibrators must be calibrated according to manufacturer's recommendations

Sampling personnel must be trained in the collection method(s) and use of all needed equipment and how to recognize problems during sample collection.

## **Before you sample...**

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For any sample collection, first make sure you have been trained in the methods and the use of the equipment. It is also important to be trained to recognize problems during sample collection, and who to alert if you need assistance. Below are several considerations for use of instruments during exposure monitoring:

### Direct-reading instruments

#### 1. Calibrate

Check with the safety officer to be sure that it has been properly calibrated. Calibration involves exposing the instrument to a known concentration of a compound and testing for the proper response. It is important that all instruments be calibrated on a regular basis. Some direct-reading instruments are compatible with a docking station interface (consult manufacturer's data for more information).

#### 2. Be conservative

If the instrument gives an unexpectedly high response, assume that it is correct. If the reading is suspiciously low, assume that there may be an instrument problem.

#### 3. A zero reading does not mean clean air

Always remember that a reading of zero does not mean that the air is clean. Some highly toxic materials are not detected by common direct-reading instruments. A reading of "zero" may mean contaminants are present but at levels below the detection capability of the instrument.

#### 4. Read even a small response as positive

Any response, even a small one, on a direct-reading instrument should be interpreted as indicating a potentially dangerous situation. It is far safer to assume that if the instrument can detect a chemical, the concentration may be high enough to pose a health threat.

#### 5. Use multiple instrument types.

Whenever possible, use more than one type of direct-reading instrument. Remember that each type of instrument has different capabilities, so a reading of zero on one instrument could turn out to be a high reading on another instrument.

#### 6. Have maintenance guidelines been followed?

All equipment is supplied with a recommended maintenance schedule. Follow it. Should any indication of malfunction be noted during routine checks or usage report them to the safety officer.

## **After you Sample...**

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After sampling actions are also part of the plan. These activities are specific to the type of sampling conducted and may include:

1. Is there reason to decontaminate the equipment before leaving the field?
  - Follow protocol, as appropriate
  - Dispose of contaminated materials appropriately
2. Post calibrate, if included in the protocol.
  - Record results and determine if the sample is valid as described in the protocol
3. Complete paperwork.
  - Record results, chain of custody etc.
  - Log any problems with the instrument and notify appropriate personnel
  - Report results as required
4. Prepare samples for shipment, as needed.
  - Follow instructions from the receiving laboratory
5. Ensure proper disposal of waste.
  - For example, the glass shards from colorimetric tubes and the tubes must be disposed of in a manner to ensure no one is cut when handling waste
6. Follow post-use, back-to-service protocol.
  - Store equipment, recharge, restock depleted supplies, etc.

## **Sampling Instruments and Tools**

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Uses of some types of instruments and tools for taking samples of air, soil, water and surface contamination are described in this section, specifically:

- pH paper
- Oxygen/Combustible Gas/Combination Instruments
- Colorimetric tubes

- Personal Alarms
- Hydrocarbon Detectors
  - Flame Ionization Detectors
  - Photo Ionization Detectors
- More specialized Instruments
  - Infrared Spectroscopy
  - Ion Mobility Spectrometry
  - Surface Acoustic Wave
  - Raman Spectroscopy
  - Gas Chromatography
  - Metal Oxide Sensors
- Radiation Exposure Monitoring
- Noise Monitoring
- Personal Monitoring for Organic Vapors and Particles
- Water Sampling
- Soil Sampling
- Surface Contamination Sampling

Use, readout, notes and tips are shown for a variety of units below. These overviews do not replace detailed manufacturer instructions.

**ALWAYS: read and follow the manufacturer instructions carefully**

### pH paper

When exposed to a chemical, pH paper changes color.

Use:

- Measure presence of corrosive substance

Read-out:

- Observed color matched to chart

Notes:

- When pH paper changes color in the presence of corrosive liquids, the color change is easy to interpret. The color change may be harder to interpret when testing vapors.
- Hydrocarbons, which generally have neutral pH may appear to change the color of the paper. In this case, the border between the wet and dry sides of the paper will be straight. If the border is jagged, multicolored, and the liquid seems to be wicking through the pH paper, the liquid is actually corrosive.
- Readings can sometimes not give a clear understanding of chemicals present. In the presence of hydrocarbons, the pH paper may give a misleading reading.
- When using the wetted pH paper for corrosive vapor detection, a neutral reading should not give you a sense of security. Other hazards may be present.
- pH paper can be attached to a stick or an extension tool when entering an unknown situation, such as during site characterization.
- Utilize two pieces of pH paper (one wetted and one dry). The wetted paper reacts more quickly than the dry paper especially for low levels of a chemical in the air. The wetted pH paper is used for detecting corrosive vapor and dry is used to dip into liquids.
- Wetting pH paper with tap water will cause it to turn light blue.

Tip: meters are subject to interferences, so pH paper is preferred.

### Oxygen and Combustible Gas Meters, and Combination Meters

#### Oxygen Meter



Use:

- To sample oxygen concentration, particularly near and in confined spaces

Read-out:

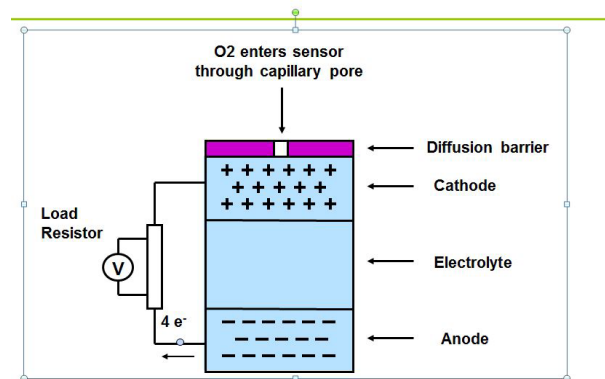
- Usually 0%–25% oxygen concentration.
- At greater than 23.5% oxygen, the explosion hazard increases.
- The normal oxygen concentration is 20.9% at sea level - any deviation from this is abnormal and should be investigated as to why there is a change. (Theoretically, a 0.1% decrease in oxygen due to displacement of the air by another chemical is indicative of a concentration of approximately 5,000 ppm of other chemicals –replacing 1/5 of O<sub>2</sub> and 4/5 of N<sub>2</sub>).
- At less than 19.5%, do not enter without an SCBA or SAR.

### Oxygen Sensor (Simplified)

Notes:

#### O<sub>2</sub> sensors

- Need about 2-3 minutes to warm up
- Continuously react with the air
- Contain electrolyte solution
- Usual operating range: -5° to 120°F
- Affected by temperature and pressure.
- High carbon dioxide levels may affect reading.
- Typically the meter calibrates for oxygen during each startup.
- Follow manufacturer recommendations regarding purging after use.
- Requires maintenance. (Life of sensor is approximately 2 years under normal use.)
- Acid vapors shorten the life of the electrochemical sensor
- Condensation and/or absorption may occur in long probes
- User must be trained

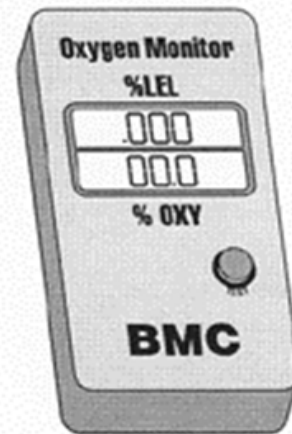


Tip: At -5°F to 32°F sensor reaction time slows and eventually will freeze at extreme temperature.



**Combustible-Gas Indicator (CGI)/ LEL Meter/Explosion Meter****Use:**

- To measure flammable vapor concentration in percent, particularly near and in confined spaces
- General purpose for most combustible hydrocarbons
- Responds to all combustibles present

**Read-out:**

- % LEL (sometimes referred to as Lower Flammability Limit, or LFL).
- A reading above 10% should be considered a potentially explosive atmosphere. For added safety, many companies use lower values such as any positive reading, or 5%. The primary reason for this is for a flammable chemical that is also toxic. A low meter reading, or no reading at all, could still be a dangerous environment.
- Accurate over most of its range

**Notes:**

- Requires periodic calibrations. Normal practice is at least every 30 days.
- Relatively unaffected by temperature and humidity
- Does not respond the same to all vapors
- Oxygen must be measured first. Many combustible-gas instruments require sufficient oxygen (consult manufacturer's manual) in order to determine LEL.
- User must be trained.
- Calibration should be checked or done before each use, as per the manufacturer's requirements. Recommendations vary by manufacturer, but before each use is best practice. It is a good idea to check calibration after using an instrument to verify good data and confirm the sensor was not compromised or injured.
- Should be bump tested to ensure that all sensors are operating before each use
- Nonspecific. Reflects total flammables present. The specific flammable(s) is not identified. The %LEL is read as if the flammables were the calibration gas. (If a single flammable is present, the manufacturer may provide correction factors.)
- Not recommended for chlorinated hydrocarbons or tetraethyl lead-containing compounds

- Avoid exposing sensors to these poisons (lead compounds, compounds with sulfur, silicones, phosphates and phosphorous) and inhibitors (hydrogen sulfide, halogenated hydrocarbons).

Example:

LEL of methane is 5% by volume

100% LEL = 5% VOL = 50,000 PPM (ignite)

10% LEL = 5,000 PPM Alarm

1% LEL = 500 ppm (LEL 1)

449 PPM  $\Rightarrow$  meter displays 0

Example:

calibrated with methane, used in an atmosphere known to only contain pentane  
reading of 5%

pentane correction factor is 2.0

$\rightarrow$  actual value is 10% of the pentane LEL

Example:

At an abandoned paint factory, a leaking drum of toluene results in an LEL reading of 8% 30 feet from the drum. The calibration gas was methane. Using the toluene correction factor of 1.3,

What is the LEL % for toluene?

What is the ppm?

What type of respiratory protection should be used?

Tip: The common LEL meter is calibrated to read 100% at the LEL of the calibration gas. A small % reading on the meter, while indicating a low risk of fire/explosion at the meter may indicate a potentially toxic concentration. For methane a reading of 5% on the meter indicates a methane concentration of 0.25% or 2,500 ppm.

Important background: LEL sensor technology is typically either catalytic bead on a wire or infrared (IR). The flammable is burned at the bead, increasing the resistance in the wire; the resistance is adjusted for air temperature using a Wheatstone bridge and converted to a reading of LEL. Therefore, oxygen is needed for the meter to function; typically 14% is the minimum required (see manufacturer specs). The IR sensor does not require oxygen for operation.

**Combination Instruments**

A meter to measure combustible gases can also measure oxygen. This is a common combination. Combination real-time monitors for oxygen and flammability (LEL, explosivity, combustibility) are approved for use in flammable environments where the oxygen does not exceed 20.9%, unless tested and approved for use in high-oxygen environments. An alternative is to have sample tubing (probe) to draw the air into the meter that is positioned at a location with acceptable oxygen concentration. The length of the sample tubing will vary for each meter, but typically ranges from 30 to 100 feet. Common problems with drawing samples through tubing include condensation of vapors, and absorption onto the tubing.

Three or more hazards can be measured with other combination meters. These multi-gas instruments, which may be called 3-gas or 4-gas meters or something similar, are used to measure oxygen and combustibles and other gases such as carbon monoxide and/or hydrogen sulfide. They are often used to test the atmosphere before entry into a confined space.

**Notes:**

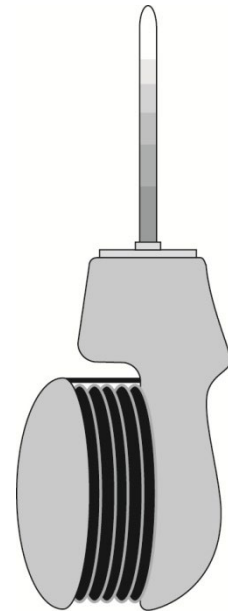
- The chemical sensors respond to a specific chemical or class of chemicals. Interferences are usually limited (refer to manufacturer literature).
- In addition to temperature, a limitation of these electrochemical sensors is that use in high concentration atmospheres may use up all the reactivity of a cell in a single measurement, rendering the cell useless until there has been time (hours) for the cell to re-stabilize.

Tip: do not sample at heated sources.

While investigating the source of CO in a warehouse demolition, putting the CO monitor near the exhaust of the pay loader may oversaturate it and require replacement or recalibration of the sensor.

**Colorimetric Detector Tubes (sources include: Draeger, MSA, Sensidyne, RAE)**

A colorimetric detector tube is a glass tube filled with a solid material or gel that has been impregnated with an indicator chemical. When the detector tube is used, the ends are broken off and the tube is inserted into a bellows or piston pump. An arrow on the tube indicates which end of the tube to insert into the pump orifice. A predetermined volume of air is pulled through the pump. The contaminant of interest reacts with the chemical in the tube. This reaction produces a stain in the tube with a length proportional to the concentration of the contaminant. Reagent changes include color intensity, length of change and change of color. Compare color to unused tube as changes can be very subtle.

**Use:**

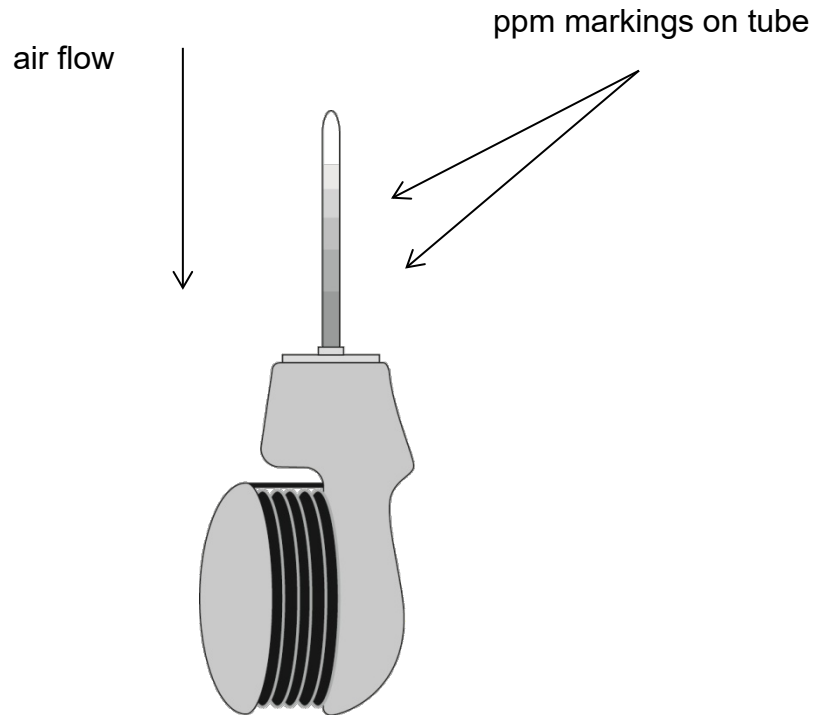
- Measure gas or vapor concentration
- Identify chemical family of contaminant using manufacturer decision charts and tables.

**Read-out:**

- Concentration in ppm, mg/m<sup>3</sup> or percent is indicated by color change or length of color stain.

**Notes:**

- Not very accurate—within 25% of the real value at best
- Pump must be checked for leaks and calibrated.
- Tubes have a limited lifetime, so the expiration date on the container should be checked before use.
- User must be trained in reading the scales on the tubes used.
- User must follow specific pump-stroke requirements and all other directions.
- Interferences are possible; not very specific.
- May be misread if the sample-taker is color blind
- Specific temperature and humidity ranges shown in directions
- Tube heaters are available from some manufacturers
- Tubes may be marked with number of required pump strokes



Tip: The Draeger Chip Measurement System (CMS) is supplied with a chip that will perform 10 measurements of the concentration of a single chemical, instead of utilizing individual detector tubes. It provides an electronic readout of concentration. Note that there are not as many chemicals available in the CMS as there are when using single colorimetric tubes.

### Personal Alarms

Monitors worn on the belt or in a pocket are used to detect a specific level of a contaminant and sound an alarm to exit the area. Worker in areas where there may be an oxygen deficiency or exposure to carbon monoxide or hydrogen sulfide are among those who may use personal alarms.

Oxygen meter with two alarms, audible and visible, shown here



Use:

To detect gas or vapor compared with a pre-set concentration in any workspace. Alert workers to levels of contaminants to which they should not be exposed.

Read-out:

Audible alarm and sometimes visible alarm and/or display of concentration (examples: ppm or %).

Notes:

- Inaccurate readings may be given if there are interferences.
- Battery-operated.
- Wearers must be trained in actions to take if the alarm sounds.

Hydrocarbon Detectors

The total amount of all detectable flammable organic compounds can be measured using a device with either a Flame Ionization Detector (FID) or a Photoionization Detector (PID). These devices are used to measure exposure to solvents, fuels and volatile organic compounds (VOCs) in the work area; results are compared with exposure guidelines.

Photo Ionization Detectors (PID)

In PID instruments, ultraviolet radiation is used to ionize (break apart the molecules) gases and vapors. The current produced is proportional to the number of ions and is a measure of concentration.

The energy needed to ionize a compound is its characteristic “ionization potential” (IP) or “ionization energy” (IE), expressed in electron volts (eV). Ionization potentials for selected materials are shown below.

Chemical	IP(eV)	Chemical	IP(eV)
Hydrogen cyanide	13.9	Hydrogen sulfide	10.5
Methane	13.0	Hexane	10.2
Chlorine	11.5	Acetone	9.7
Benzene	9.2	Phenol	8.5



Use:

- To sample toxic and some flammable vapor concentration, particularly near and in confined spaces
- Detects organic and some inorganic gases such as Ammonia, Arsine, Phosphine, Hydrogen Sulfide, Bromine, and Iodine (0.1 – 10,000ppm) (most 1-2000 ppm.)
- Can alert to areas of concern or contamination and be used to find leaks.

Readout:

- Concentration in ppm

Notes:

- Ability to detect wide variety of chemicals in small amounts
- Does not destroy sample
- Quick response
- Can operate in low-oxygen environment
- Detects only those compounds with ionization potentials less than the energy of the lamp.
- Response affected by composition of mixed gases.
- Only quantifiable if measuring a known substance
- Lamps affected by high humidity, high levels of methane and dust
- Does not detect methane, CO, CO<sub>2</sub>, or SO<sub>2</sub>
- Cannot separate mixtures
- Other voltage sources may interfere.
- Requires calibration (usually with isobutylene).
- User must be trained.
- Must know lamp voltage and correction factor (CF).
- Requires regular maintenance

## Correction Factors (10.6 eV Lamp)

	<i>RAE</i>	<i>BW</i>	<i>Ion</i>		<i>IP (eV)</i>
<i>Acetaldehyde</i>	5.5	4.6	4.9		10.21
<i>Acetone</i>	1.1	0.9	0.7		9.69
<i>Ammonia</i>	9.7	10.6	8.5		10.2
<i>Benzene</i>	0.5	0.55	0.5		9.25
<i>Butadiene</i>	1	0.9	0.85		9.07
<i>Diesel fuel</i>	0.8	0.93	0.75		n/a
<i>Ethanol</i>	12	13.2	8.7		10.48
<i>Ethylene</i>	10	11	8		10.52
<i>Gasoline</i>	0.9	0.73	1.1		n/a
<i>n-Hexane</i>	4.3	4	3.3		10.18
<i>Jet fuel (J.P.8)</i>	0.6	0.51	0.7		n/a
<i>Kerosine</i>	n/a	1.11	0.8		n/a
<i>Methylethylketone</i>	0.9	0.78	0.77		9.53
<i>Naptha (iso-octane)</i>	1.2	1.2	1.1		9.82
<i>Styrene</i>	0.4	0.45	0.45		8.47
<i>Toluene</i>	0.5	0.53	0.51		8.82
<i>Turpentine</i>	0.4	0.45	0.45		n/a
<i>Vinyl chloride</i>	2	2.19	2.2		10.0
<i>Xylene</i>	0.4	0.5	0.43		8.5



PIDs are often calibrated with isobutylene, which has a correction factor of 1.0. If you know that a single gas is present in the atmosphere, you multiply the correction factor for that gas by the instrument reading to obtain the true concentration of the chemical.

Example:

A RAE instrument is being used to measure toluene, with a CF of 0.5.

The instrument calibrated with isobutylene reads 100 ppm.

The actual concentration is:

$$C = 0.5_{CF} \times 100 \text{ ppm}_{iso} = 50 \text{ ppm of toluene}$$

### Flame Ionization Detectors (FID)

In FID instruments, the gases and vapors are ionized (molecules broken apart) in a flame. A current is produced which is proportional to the number of carbon atoms. The current is converted to a measure of concentration.



Use:

To detect many organic gases and vapors.

Can see chemicals with higher IP than PID (more accurate) (1.0-100,000ppm)

Only organics

Readout:

ppm.

Notes:

- Requires gas chromatography option to identify and measure specific compounds.
- Does not detect inorganics

- Affected by low temperatures, high contaminant concentrations, and oxygen-deficient atmospheres.
- Must be calibrated.
- User must be trained.
- Requires maintenance and leak checks.
- Must be intrinsically safe if used where explosive atmospheres may exist. Some models are not intrinsically safe.
- Flame out in high wind
- Only carries limited amount of hydrogen
- Destroys sample
- Needs O<sub>2</sub> to operate



PID/FID combination

### **More-specialized monitoring instruments**

In addition to the widely-used instruments listed previously, newer types of instruments are increasingly being employed at work sites. The following instruments may have specialized capabilities or lower measurement ranges than the instruments described before. In many cases, they are more expensive.

#### Infrared Spectroscopy

Infrared (IR) Spectroscopy may be used to detect and measure chemicals in air, liquids and solids. It functions by comparing the infrared absorption spectra of contaminants to the known spectra of pure chemicals. It can be used for contaminants such as volatile and semi-volatile organics, ammonia, carbon disulfide, carbon monoxide, hydrogen sulfide, acids, nitrogen oxides, and many others. It does not respond to noble gases, vapor-phase metals, and chemicals that are made up of two atoms of the same element, such as oxygen (O<sub>2</sub>), nitrogen (N<sub>2</sub>) and chlorine (Cl<sub>2</sub>). Water vapor and carbon

dioxide are frequent interferences. IR spectroscopy may be deployed in several different configurations.

### Active Open-path Fourier transform IR

Active open-path Fourier transform IR (Active open-path FTIR or active OP-FTIR) may be deployed for fence line or perimeter monitoring or worker exposure monitoring. The technique relies on instruments placed in two different fixed locations in sight of one another. In this configuration, it can measure an average concentration of contaminants across the straight-line path between the two instruments. Measurements down to the low parts-per-billion can be achieved.

### Passive Open-path Fourier transform IR

Passive open-path Fourier transform IR (Passive open-path FTIR or passive OP-FTIR) is operated as a portable “point and shoot” instrument that can be used to detect, but not measure, chemical releases. It also cannot tell the difference between different chemicals. The technique relies on an infrared source in the environment, such as the sun, instead of generating its own infrared source, as active OP-FTIR instruments do. Its detection limits are higher than for active OP-FTIR, in the range of hundreds of ppm, but its range is longer, up to a mile or more.

### Handheld Fourier transform IR for solid and liquid identification

Handheld Fourier transform IR (FTIR) units are available for identification of unknown solids and liquids. They can work from a library of over 10,000 chemicals to identify substances including chemical warfare agents, explosives, toxic industrial chemicals, narcotics, suspicious powders and other dangerous chemicals. Analysis is performed by placing a small amount of unknown substance onto the interface.

### Ion Mobility Spectrometry Instruments

Portable ion mobility spectrometry (IMS) instruments can be used to identify airborne chemicals. The instruments utilize built-in pumps to draw air through the instrument. Substances that can be identified include chemical warfare agents, toxic industrial chemicals, narcotics and explosives. These instruments utilize an ionization source, which may or may not be radioactive, to put a positive or negative charge on a chemical. The ion mobility spectrum of the chemical is compared to the spectra of known chemicals to identify the unknown. Substances that will interfere with the reading include menthol, oil of wintergreen, perfumes, food flavorings and engine exhaust. It is sensitive down to parts



per billion of a chemical, but may not detect at levels below the IDLH for chemical warfare agents.

### Surface Acoustic Wave

Surface acoustic wave (SAW) instruments utilize vibrating piezoelectric crystals to detect and identify airborne chemicals. Chemicals adsorbed onto the crystal surface change the frequency of the vibration. The change is compared to the change for known substances to identify the unknown chemical. These instruments may be calibrated to detect chemical warfare agents. Like IMS instruments, SAW instruments cannot usually detect chemical warfare agents below IDLH levels, but they are less susceptible to interference from other chemicals.



The NRL SAW sensor.

usually detect chemical warfare agents below IDLH levels, but they are less susceptible to interference from other chemicals.

### Raman Spectroscopy

Raman spectroscopy utilizes laser light scattering to detect and measure chemicals. It can be used in an open-path mode, similar to open-path FTIR, but unlike IR methods, water and carbon dioxide do not interfere with the readings. Portable systems generally have a range of less than 50 yards, but large, fixed systems can cover up to 6 miles at night. A wide range of airborne, solid, or liquid chemicals can be measured, with detection limits from the low ppm to percent levels, although better detection limits can be achieved.

### Gas Chromatography

Gas chromatography (GC) uses a stationary phase and a mobile phase to separate contaminants based on how strongly they are attracted to the stationary phase. It can be employed for site characterization, source testing and monitoring, employee exposure monitoring, fence line or perimeter monitoring and emergency response. A large number of different detectors can be used with this technique. Depending on the detector, different volatile and semi-volatile organic chemicals can be detected and measured, sometimes at levels as low as parts per billion. When a mass spectrometer is used as the detector, the technique is called GC-mass spec, or GC-MS.

### Metal Oxide Sensors

While not new, these semiconductor sensors are used in special applications (generally when the contaminant is known). The sensor will react to a variety of chemicals and is

therefore non-specific. Calibration is done for a specific chemical, but it will detect other contaminants if present.

### **Radiation Exposure Monitoring**

No single instrument can measure all forms of ionizing radiation. Where radiation sources are present, a specific monitoring program will be included in the Site Safety and Health Plan detailing the type of hazard, how monitoring devices were selected, and exposure control methods.

Area monitors (for example, the Geiger counter and the Cutie Pie survey meter) are available. Personal monitors include the film badge and thermoluminescence detectors.

Pancake monitors such as Geiger counters which use a thin-window pancake-shaped detector are best for monitoring particle and energy wave emissions.

- Used for measuring alpha and beta.
- Sensitive for gamma rays, but not generally preferred for determining exposure rates because of the irregularity of the thickness and density of the walls and the energy response curve.

The Geiger-Mueller is sometimes equipped with the external probe for alpha and beta radiation and an internal probe for gamma radiation.

- When the amount of radiation is higher, the surveyor switches to the internal probe that will pick up background radiation which should be minimal.

Pancake detectors are used when surveying for contamination. The detector is housed in an aluminum casing; the thin mica window of the detector is protected by a stainless-steel screen.

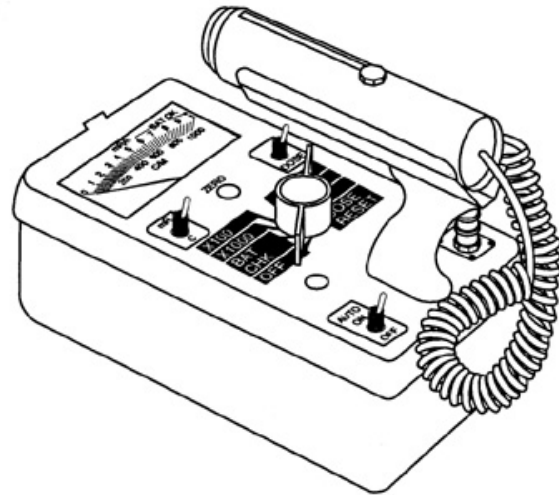
Another type of instrument often referred to as a “hot dog” detector is useful for measuring background levels of gamma radiation. The detector is used for surveying direct radiation. The detector has a rotary shield which is used to differentiate between beta and gamma radiation. When the shield is closed, only gamma can be detected.

A description and illustration of a Geiger-Mueller detector follows.

### Geiger-Mueller Tube

#### Use:

- The tube is filled with gas. When radiation enters the tube, it reacts with the gas, causing the release of energy.
- Used to scan surfaces rapidly.
- Detects beta, gamma, and X-rays; can detect alpha only with the cap removed.



#### Readout:

Clicks per minute. The amount of energy released is related to the number of counts per minute. Rad units: R, m/R, M/R

#### Notes:

- Audible “clicks” alert user to changes in amount of radiation detected
- Wide range and sensitive
- Area monitor only
- Not a measure of dose
- Not accurate at high exposure rates
- Rugged instrument
- Utilize inverse square law to minimize dose to internal organs when monitoring

## Noise Monitoring

---

A Sound Level Meter (SLM) is a direct-reading instrument. Some models have additional features such as:

- measure sound in small bands across the entire spectrum of sound, called octave bands
- data-logging for future analysis

Use:

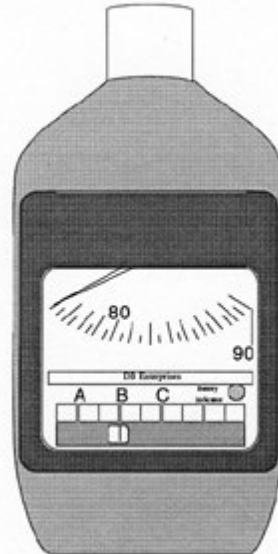
To monitor noise exposure in the area

Read-out:

Decibels (dB) usually on the A scale

Notes:

- A-Scale used for occupational exposure
- A-Scale developed to mimic the way the human ear responds to noise.
- Requires calibration before and after each use.
- Some instruments require manually changing the range of noise that can be measured.
- Battery must be checked before use.
- General-purpose meters are designed to measure continuous noise only (sounds which last at least 1 second).
- Personnel must be trained to use the instrument.



Tip: Personal noise dosimeters are also available for routine operations. These instruments are worn by the employee during the entire shift and give a time-weighted average exposure.

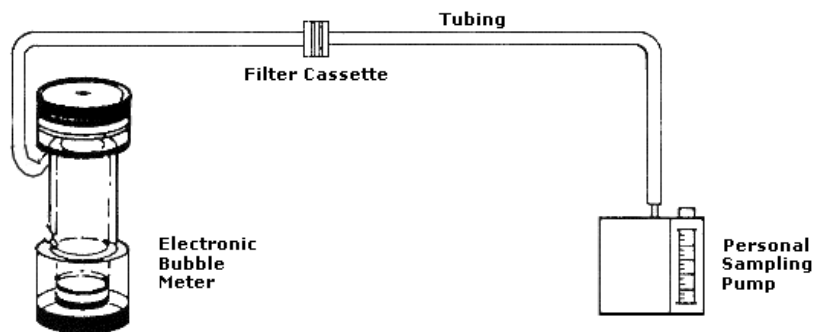
Tip: iPhone and Android apps are available for noise monitoring with your phone.

## Personal Air Monitoring

Personal monitoring protocols generally include the following:

### 1. Calibrate (pumps and alarms)

Check with the safety officer to be sure that it has been properly calibrated. If a personal pump is to be used, this will ensure that the amount of air flow through the sampling media matches the method being used. Calibration will also be conducted after sample collection to determine the total volume (duration x flow rate). If the flow rate has changed by more than 5%, resampling may be required. Consult the method cited in the sampling plan. If a personal alarm is to be used, this will ensure that the monitor responds according to manufacturer specifications.



Calibration set up for personal sampling pump, with filter cassette in-line

### 2. Sampling lines

If you will use tubing to connect a pump and a collection filter/tube, ensure that you have different lengths of tubing (for different heights of workers) and methods to keep the tubing close to the wearer's clothing (tape or pins). Sampling lines can separate from the pump and may result in loss of a sample. Loose or floppy tubing can be a safety hazard to the wearer.

### 3. Know the demands of work, and the schedule

Wearing a sampling device is an imposition. If you know the work demands, you can better ensure that it will not interfere with usual activities. For example, fork lift operators will not want a pump positioned in the small of the back. Women often need a belt to hold a pump—so be ready to provide a belt, as needed. Folks who want to leave the workplace at lunch will not wait for you to come when it is time to leave. You may jeopardize sample collection if it is removed and placed on a contaminated work surface.



### 4. Tell each person what to expect

Go over the reason for sampling, how the equipment works and what will happen after the collection. Ask if the equipment is comfortable (or as much as possible) and if there are any other questions.

### 5. Let workers know where you will be

Let each person know how to reach you during the shift if he/she has a question or a problem. Most pump protocols require at least hourly observation, so you will need to be on site for the entire shift.

### 6. Have maintenance guidelines been followed?

All equipment is supplied with a recommended maintenance schedule. Follow it. Should any indication of malfunction be noted during routine checks or usage, report them to the safety officer.

### 7. Assemble supplies for Chain of Custody for any sample to be shipped to detect any tampering when outside your control. Wrap seals around entry/exit plugs or caps.



Air sampling cassette for particles ready for shipment

Individual worker exposure is generally measured during routine or scheduled operations because the equipment is specific to the exposure. Provides the most accurate measurement of a worker's actual exposure, because it goes where the worker goes and can be placed in the breathing zone (near the nose).

- Results can be compared with a TWA or STEL set by OSHA, ACGIH, NIOSH or the company.
- Documents an individual's exposure without regard to protective equipment.

In some instances, personal monitoring may be done during an emergency.

In planning to conduct personal air monitoring for exposure assessment, identify a published method and laboratory that is experienced in the analytical procedure you want used. Methods are shown at NIOSH and OSHA websites.

Specific storage requirements may be needed for some samples. Whenever collecting a sample to characterize exposure to a contaminant for the first time, always discuss the method you will use with the laboratory in advance. The laboratory personnel will alert you to the number of blanks required and discuss other issues such as the collection media and turn-around time. When the media is rarely used, it may be obtained from the laboratory, rather than purchasing a larger quantity from a vendor.

### Gas and vapor sampling

Use:

- Measure gas or vapor exposure

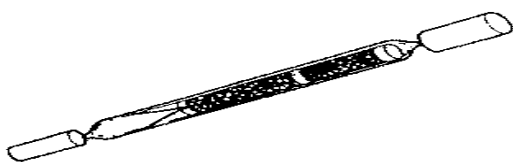
Readout:

- None immediately
- Laboratory reports result

Notes:

- Sampling media selected for specific hazard. Generally a solid sorbent in a glass tube is used. An example use of several types are:
  - Coconut shell charcoal – acetone
  - Silica gel - sulfuric acid
  - XAD-2 (2-hydroxymethyl piperidine) - acetaldehyde
  - Soda lime - hydrogen sulfide

Each glass tube has two sections of solid sorbent. The larger part is generally twice the volume of the smaller (back up) section. The ends of the tube are broken off, the tube is placed in a 'tube holder' and connected to the pump, with the air flowing in the direction shown on the tube. Caps are supplied to cover the ends of the tube when sampling is complete.



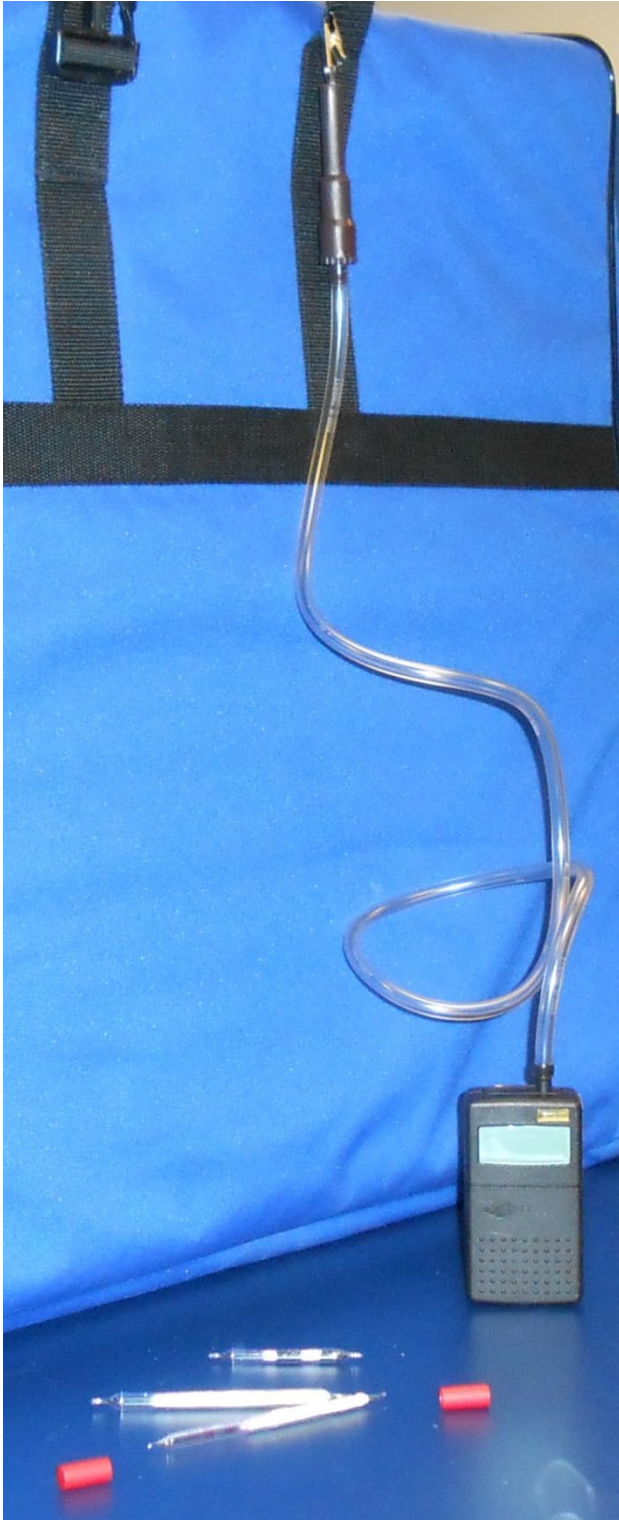
see examples with the sampling train (pump, tubing, holder) below

- Battery operated pump must be calibrated before and after use
- One or more tubes is taken into the field, opened and capped and submitted to the lab as a field blank.
- Sampling personnel must be trained
- Use care in breaking the glass tubes (use a tube cutter and wear safety glasses)
- Dispose of any glass ends or broken tubes to minimize cuts to personnel handling trash
- Position the sample holder near the breathing zone; ensure pump does not hinder work
- Monitor pump operation during use to prevent loss of sample due to malfunction
- Have back up pumps and media
- Match media to the contaminant by following an available air sampling/analysis method
- Match duration of sampling to exposure guideline (TWA, STEL, C)
  - Use multiple tubes for TWA, as needed
  - If collected over several hours, result cannot be compared with STEL or C
- Media are dated for service life; some are temperature-sensitive
- Calculate sample volume/flow rate based on expected concentration
- Resample if needed due to questionable/invalid result

Tip: Personal air samples for some contaminants can be collected by using a passive monitor. This device is a badge clipped to the worker's collar which collects one or more contaminant in the air without using a pump. The monitor is sent to a laboratory for analysis. VOCs and mercury are often measured with a passive badge.



Personal monitoring sampling train for gas or vapor



Tubes containing media; ends are broken for sample collection then sealed with the red caps before shipping to a laboratory.

### Particle/Particulate/Fiber/Dust Sampling

Dust, fibers, flakes and mists are particles or particulates; the shapes are not all the same, and mists are liquids, not solids. For air sampling, they can be grouped, as the collection method is generally a filter.

Use:

- Measure exposure to solids in the air

Readout:

- None immediately
- Laboratory reports result

Notes:

- The filter is selected for the contaminant and the analysis method. Several examples of filters and use are:
  - MCE (mixed cellulose ester) - Lead, Asbestos (analysis by polarized light microscopy)
  - PVC (poly vinyl chloride) - Lead Chromate
  - Quartz filter - diesel particulate
  - Polycarbonate - Asbestos (analysis by transmission electron microscopy)
- The filter is held in a two- or three-piece cassette and supported by a back-up pad that rests on the part of the cassette that has ridges; air flows across the filter, through the back up pad and to the pump. Plugs removed just prior to sampling are replaced when sampling is complete.
- One or more cassettes is taken into the field, plugs removed and immediately reinserted and submitted to the lab as a field blank.
- Sampling personnel must be trained
- Battery operated pump must be calibrated before and after use
- Monitor pump operation during use to prevent loss of sample due to malfunction
- Have back up pumps and media
- Match media to the contaminant by following an available air sampling/analysis method

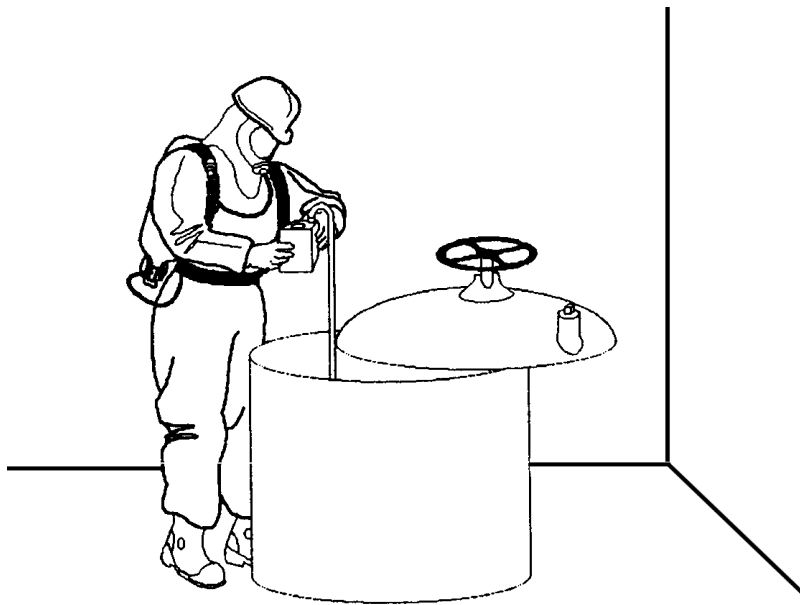
- Match duration of sampling to exposure guideline  
    Use multiple cassettes if overloading is possible
- Media are dated for service life
- Calculate sample volume/flow rate based on expected concentration
- Resample if needed due to questionable/invalid result

Tip: There are exceptions to filters being used to sample solids. Example: ozone is captured on two nitrite-impregnated glass filters.

### Area Air Monitoring

---

Many of the direct reading instruments described in detail in this manual are used for area air monitoring. For example, testing of a confined space is illustrated below:



**Real-Time, Area Monitoring**

Considerations for the sampling protocol for use of each of these direct-reading instruments are covered above.

Always lower tubing, not monitor. Use the 2+2 rule for confined space.

### Area Monitoring for Particles/Fibers/Dust

Potential movement of particulate contaminants from the work site to the perimeter boundary or beyond may require sampling. To do this a pump with large capacity is needed.

Use:

- Measure exposure to solids in the air at the perimeter fence

Readout:

- None immediately
- Laboratory reports result

Notes:

- Requires electric power source
- Noisy, may have to be housed in noise-absorbing box if residents nearby
- Flow rates of 1 cfm or more
- Sampling personnel must be trained
- Requires calibration or use of a flow regulator that is calibrated
- Monitor pump periodically for proper function
- Match filter media to contaminant by following available air sampling/analysis methods



**High volume area sampling pump**

## **Water Sampling**

---

Contaminants may be in surface water, run off from production process or in wells. An overview of equipment for water sampling is provided. There are several types of water samples, as described below.

Readout:

- None immediately
- Laboratory reports result

Type 1: Grab sample from the surface

Use:

- Collect water samples at or just below the surface to test for contaminants or environmental parameters (such as pH, conductivity, oxygen)

Notes (Grab sample from the surface)

- On-site or laboratory testing
- Ensure that sample container is correct for contaminant/test  
(stainless steel, glass, plastic)
- Do not contaminate sample with your hand - wash before collecting; wear gloves
- Follow requirements for sample preservations (chemical, temperature)
- Decontaminate between samples

Type 2: Below the surface using Bomb Discrete Sampler, Van Dorn-style Bottle, Kemmerer-style, Peristaltic and Vacuum pumps

Uses:

- Evaluate for specific contaminant(s)

Notes:

- On-site or laboratory testing



- Ensure that sample container is correct for contaminant/test  
(stainless steel, glass, plastic)
- Do not contaminate sample with your hand—wash before collecting; wear gloves
- Follow requirements for sample preservations (chemical, temperature)
- Decontaminate between samples
- Follow site specific water safety SOP as necessary

### Type 3: monitoring well sampling using

Bailers (hand or pump)

Samplers (hand, vacuum, pneumatic, peristaltic, battery or 120V electric powered, submersible)

Liquid level indicators (meters available to indicate the level of an organic such as gasoline floating on the water and the level of the organic/water interface)

### Uses:

- Monitor water levels in wells and collect samples for analysis

### Notes:

- On-site or laboratory testing
- Well depth and size may dictate/limit types of equipment to be used
- Ensure that sample container is correct for contaminant/test (stainless steel, glass, plastic)
- Do not contaminate sample with your hand—wash before collecting; wear gloves
- Follow requirements for sample preservations (chemical, temperature)
- Decontaminate between samples or use dedicated equipment to prevent cross contamination.
- Follow site specific water and electrical safety SOP(s) as necessary

Submersible pump and apparatus





An interface meter: Used to determine the light (floating on water) phase and the dense (sinking) phase

Tip: Permanent soil water samplers may be installed in the vadoze zone (above the water table). Two tubes from the buried sampler allow water samples to be taken with pressure/vacuum.

Tip: Initial soil water investigations may be done with a piezometer, a device driven directly into the ground or down a small bore hole; a ground water sample is retrieved through tubing.

## **Soil Sampling**

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Contaminants in soil at the surface, or below the surface may be evaluated. Sampling at each location is described here.

### At the surface

Readout:

- None immediately
- Laboratory reports result

Type:

- Surface sampling using trowel, spoon, spade

Use:

- collect soil from the surface for testing in the lab

Notes:

- Decontaminate the tool between samples to prevent cross contamination
- Use wide-mouth, non-reactive containers for ease in transfer
- Send to a laboratory for chemical analysis

Below the surface—manual collection

Readout:

- None immediately
- Laboratory reports result

Type:

- Below surface sampling—hand held, manual collection using  
Soil Recovery Probe, Auger or push type

Use:

- Collect Grab or Undisturbed soil sample below the surface, typically up to 24 inches

Notes:

- Select auger head for soil type
- Decontaminate the tool between samples to prevent cross contamination
- Use wide-mouth, non-reactive containers for ease in transfer
- Send to a laboratory for chemical analysis
- Soil type may dictate/limit sampler type
- Must use plastic liner to take an undisturbed soil sample/profile; may not be compatible with some organic chemicals

#### Below surface Sampling - mechanized

Readout (Types A and B):

- None immediately
- Laboratory reports result

Type A:

- Below surface sampling, mechanized using  
Augers-electric powered, gas powered hand-held and mechanized

Use:

- Collect at greater depths than manual tools allow

Notes:

- Auger may be used to access the sample depth, then a different soil sampler is used to collect the sample.
- Soil type and depth guide decision on sampler used

- Soil type and condition may increase possibility of contamination with soils closer to the surface. Training is required to recognize and prevent/reduce this contamination and may require consideration in selecting the collection tools.
- Decontaminate the tool between samples to prevent cross contamination
- Use wide-mouth, non-reactive containers for ease in transfer
- Send to a laboratory for chemical analysis
- Must use plastic liner to take an undisturbed soil sample/profile; may not be compatible with some organic chemicals
- Mechanized equipment hazards

### Type B:

- Below surface sampling using

Split Spoon

### Use:

- Collect soil sample cores at extended depths or in 'hard, compacted' ground.

A hole is augured with a mechanical device and

Then the spoon is attached to replace the auger and driven into the soil to collect a profiled soil sample.

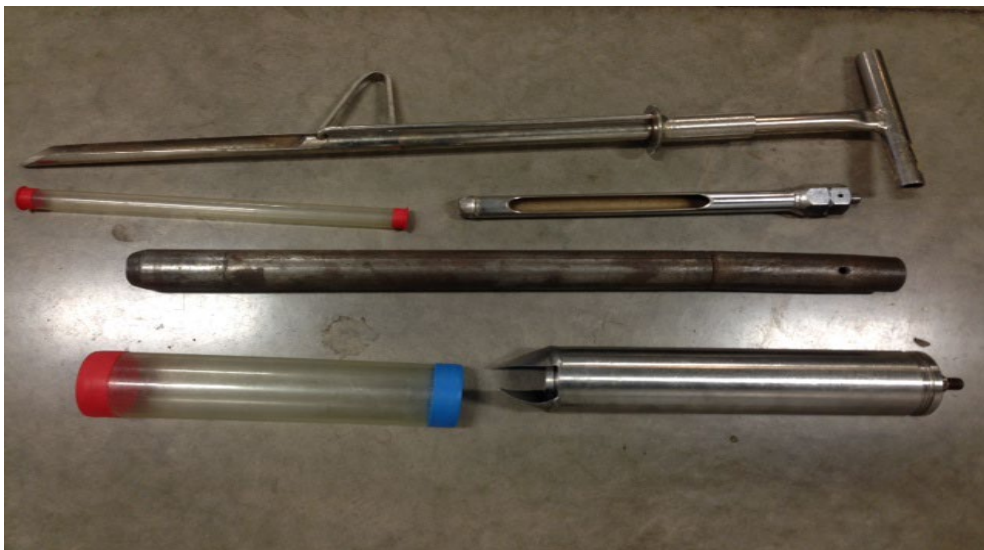
(Alternatively, drive the spoon down without auguring, collecting samples in series.)

The spoon is extricated and split open to remove the core, typically 12-24 inches.

### Notes:

- Soil type and depth guide decision on sampler used
- Soil type and condition may increase possibility of contamination with soils closer to the surface. Training is required to recognize and prevent/reduce this contamination and may require consideration in selecting the collection tools.

- Decontaminate the tool between samples to prevent cross contamination
- Use wide-mouth, non-reactive containers for ease in transfer
- Send to a laboratory for chemical analysis
- Must use plastic liner to take an undisturbed soil sample/profile; may not be compatible with some organic chemicals
- Mechanized equipment hazards; heavy equipment hazards may result from need for drilling and pounding of the split spoons. Site-specific OJT may be required.



Soil sampling tools (from the top)

Metal sampling tool, for collecting in shallow areas, up to two feet

Plastic attachments (liner) to contain sample; metal extender

Split spoon sampler

Plastic liner sample container and metal probe that fits over liner

## Surface Contamination Sampling

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Possible contamination of surfaces is of interest for several reasons, including:

- Evaluating decontamination of PPE and tools
- Identification of possible spread of contaminants
- Document possible need for cleanup or additional cleanup

There are some published guidelines regarding allowable contamination (e.g., lead, radiation), but many determinations are made on present (above the limit of detection) and not present (below the limit of detection). Commercial kits are available for some contaminants of interest.

Use:

- Determine surface contamination

Readout:

- None for chemicals; laboratory report needed
- Radiation evaluated with direct-reading instrument

Notes:

- Consult with laboratory personnel
  - Collection media (filter, swipe)
  - Need for bulk material
  - Packing and shipping requirements
- Consult with laboratory personnel if bulk material is required for analysis
  - Packing and shipping requirements
- Follow a protocol carefully
  - Collection media
  - Area swiped
  - Direction and pressure of swiping
- Document location
  - Written notes
  - Photos, if possible



## **Monitoring at an Emergency**

It is important to carefully monitor the atmosphere during response to an unexpected release. Failure to recognize toxic, explosive, or oxygen-deficient atmospheres could result in serious damage to life and property. The ERP provides a plan for monitoring as part of the emergency response. Some general considerations follow.

### **Preplanning**

- Monitoring equipment appropriate for anticipated hazards should be selected by site or plant management.
- Members of the emergency response team who are expected to use the equipment must be trained in its use.
- Emergency response team members should practice using the equipment during emergency response drills.
- Equipment must be properly maintained and stored so it is ready for use during an emergency.
- Spare parts should be available to repair the equipment in case it is damaged during response activities.
- Someone on each shift should be trained to make emergency repairs.

### **During an Emergency Response**

Before use:

- Allow adequate warm-up time as appropriate.
- Calibrate equipment as appropriate.
- Cover with plastic to prevent contamination as appropriate.

### **During size-up (risk assessment)**

- Enter upwind from the spill or release.
- Begin monitoring at a distance where no contamination is expected.
- Monitor for oxygen first, then flammable/explosive limits and toxic substances.
- Continue to take readings as the spill or release is approached.
- Take readings at ground level, a few feet from the ground, and higher in the air.

- Take readings at the entry and throughout a confined space. Do not enter if there is inadequate oxygen or an explosive or toxic atmosphere.
- Leave the area immediately if readings indicate that PPE is inadequate.

### During response actions

- Continuously monitor all areas near the source of the spill where response activities are occurring; conditions can change rapidly.
- Retreat immediately if readings indicate that PPE is inadequate.
- Decontaminate the equipment properly.

### After response

- Recharge power sources and replace any damaged or expended parts.
- Store monitors properly to be ready for any future use.
- Reorder any needed disposable supplies or damaged parts.

**Note:** Detailed information on air monitoring must be included in each company's ERP to ensure adequate training, appropriate use, and proper storage and maintenance of equipment.

## Summary - Monitoring

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When there are questions of employee or off-site residents' exposure to substances, monitoring is done to evaluate the level of exposure and provide input to control plans.

Toxic chemicals, fire and explosion hazards, oxygen-enriched and oxygen-deficient atmospheres, radioactivity, and biological hazards can be monitored at the site. Sampling water, soil and surfaces provides additional information regarding the extent of contamination and groups that may be at risk of exposure.

There are several ways to describe evaluation of exposures using a variety of sampling instruments and tools:

- **Where performed**

**Personal sampling** is used to measure the amount of a toxic chemical in the air to which a worker is exposed, and it requires laboratory support. Personal sampling (when the worker wears a small pump all day and the sample is taken in the breathing zone) gives the best information on a worker's exposure.

**Area monitoring** gives you a measurement of the air concentration of a substance at a particular place.

- **What can be sampled**

**Air**

**Water**

**Soil**

**Surfaces**

- **Information obtained**

**Detect** a hazard means that it is present; detect a hazardous substance means that it is present in an amount greater than the limit of detection.

**Measure** a substance means that a concentration is determined.

- **Immediate result (yes/no)**

**Direct-reading or real-time instruments** provide a reading of air contamination at the moment you are using the equipment. Direct-reading instruments may be used to detect IDLH conditions, flammable vapors, oxygen, and toxic materials.

**Laboratory Analysis.** If laboratory analysis is needed, the results will not be available for some time. Consult with the lab regarding time needed for analysis.

Personnel taking samples for exposure assessment must be trained and use calibrated and maintained equipment. A written sampling plan is used for routine operations and planning for emergencies must include procedures to ensure that any equipment that would be needed in an unexpected situation is always ready for use.

### Exercise - Monitoring

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During this exercise, you will have the opportunity to use a combustible-gas indicator, indicator tubes, and an oxygen meter. There are three stations, in which you will:

1. Measure ethyl alcohol with a combustible-gas indicator at three distances: 1 inch, 6 inches, and 2 feet.
2. Measure ammonia with indicator tubes at three distances: 1 inch, 6 inches, and 2 feet.
3. Exhale into an empty bag and measure the percent oxygen in the bag.

Use the sampling data sheets provided to record your readings from the instruments.

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## **CLOSING AND EVALUATION**

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Thank you for participating in this program.

This is an opportunity to ask any questions you may have, or to discuss how the knowledge and skills learned can be used at work. Were all of your initial questions answered?

Please take the next 10 minutes to complete the program evaluation forms. These are important for improving the program. The Midwest Consortium does take your comments seriously and has made changes in content and the skill exercises based on feedback. Your comments are anonymous.

We hope to see you at another Midwest Consortium program in the future