Air Monitoring Equipment – Quick Tips

When workers are exposed to hazardous materials, it's important to make sure they are not overexposed – which is why air monitoring is an important part of any safety program. This document discusses the various types of available air monitoring equipment and defines some basic terms.

Air can be monitored in several ways. To sample worker exposure (personal sampling), diffusion-detector tubes, vapor-monitoring badges, or personal air-sampling pumps are all potential options. The most widely used and preferred option is to connect a battery operated pump to a filter medium (tubes and filters) to collect the contaminant so it can be analyzed and exposures levels determined. To monitor specific areas (area sampling), detector tubes and pumps, hand-held electronic monitors, or fixed wall-mounted electronic monitors are used.

The physical state of the analyte (gas, aerosol, vapor, or combination thereof) plays an important role in the air monitoring equipment selection process.

The following are basic definitions used around monitoring equipment and a description of each type of monitor.

Definitions

- **Area sampling (General) –**Sampling done to evaluate a designated work area that is considered to have a hazardous atmosphere present during the workday. The sampling device is placed in the area for a period of time to establish a baseline of exposure for that area.
- **Ceiling –**Airborne contaminant concentration that must not be exceeded during any part of the workday.
- **Immediately dangerous to life or health (IDLH) –**Conditions that pose an immediate threat to life or health, or conditions that pose an immediate threat of severe exposure to contaminants.
- **Lower-explosive level (LEL) –**The lower limits of flammability of a gas or vapor at ordinary ambient temperature expressed in percentage of the gas or vapor in air by volume.
- **Milligrams per cubic meter (mg/m3) –**Unit used to measure air concentration of dust, gases, mists and fumes.
- **Parts per million (PPM) –**Parts of air by volume of vapor, gas or other contaminant.
- **Permissible exposure limit (PEL) –**The Occupational Safety and Health Administration's (OSHA's) time-weighted average airborne contaminant concentration that must not be exceeded during any eight-hour work shift of a 40-hour workweek. PELs are found in 29 CFR 1910.1000 in the Z-1A or Z-2 tables.

- **Personal sampling –**Sampling done to evaluate a worker's exposure during the workday. Workers usually wear the sampling device in their breathing zone.
- **Short-term exposure limit (STEL) –**Airborne contaminant concentration measured over a 15-minute period unless otherwise noted, that cannot be repeated more than four times per day and there must be at least 60 minutes between exposure periods.
- **Time-weighted average (TWA) –**Concentrations of airborne contaminants that have been weighted for a certain time, usually eight hours.
- **Threshold-limit value (TLV) –**Eight-hour TWA airborne contaminant concentration set up by the American Conference of Governmental Industrial Hygienists (ACGIH). They are used as a recommended level.
- **Upper-explosive level (UEL) –**The highest concentration, expressed in percentage of vapor or gas in the air by volume, of a substance that will burn or explode when an ignition source is present.

Diffusion-Detector Tubes

Several manufacturers make diffusion-detector tubes, which have limited applications. Diffusion tubes can be used to determine a TWA or a STEL. They usually consist of a glass tube with a chemical reagent impregnated in a silica layer. One end is broken off and the tube is placed in a tube holder. If the tube has a clip, it is often hung on the worker's lapel, near the breathing zone to get an accurate reading of the worker's exposure. To calculate an accurate level, the sampling start time must be recorded on the writing area of the tube. The indicating area has a calibrated scale. This is where the reaction with the sample gas or vapor takes place, causing a discoloration that can be read off the scale.

When the workday is complete, the tube is taken off the worker and the stop time recorded. The tube is read by looking at the discoloration and recording the unit of measure on the tube, typically (ppm, mg/m3, or percent) and value from the scale. The TWA is obtained by dividing the scale value by the total amount of time sampled in hours.

Advantages: They give an immediate reading, meet OSHA guidelines, and you don't have to wait for lab results.

Disadvantages: There are often chemical-cross sensitivities and they tend to be less accurate than vapor badges and personal sampling pumps.

Vapor-Monitor Badges

Vapor-monitor badges are a good way to monitor a worker's breathing zone to determine the worker's exposure. They work through the simple principle of diffusion. The worker is given the badge, which clips onto the collar. The exposure time, temperature, relative humidity, date exposed, employee and monitor number must be recorded. This information is needed to correctly calculate the exposure level. The badges can be used to determine an eight-hour TWA or a 15-minute STEL.

Badges are available for organic vapors, formaldehyde, ethylene oxide, mercury, nitrous oxide and a few other compounds. Some of the badges are sold with a prepaid analysis. All the employer has to do is have the worker wear the badge, and then return it in the addressed mailer to the laboratory to be analyzed. Some of the badges can be purchased without the analysis, requiring the analysis to be done by the employer's laboratory of choice. Analysis is usually done by desorbing the vapors trapped on the badge. The desorbed vapor is then run through a gas chromatograph to determine the level.

Advantages: The results are more accurate than those of diffusion tubes.
Disadvantages: Badges have to be sent away for analysis, and results cannot be given immediately. They are often more expensive than diffusion tubes. Badges are also only available for a limited number of chemicals.

Personal Air-Sampling Pumps

Personal air-sampling pumps are a little more difficult to use. They consist of a small pump that pulls a constant amount of air (usually in liters per minute), a charcoal tube, a filter cassette or other sampling devices like a cyclone or liquid impinger to collect the contaminant, and a clip for attaching the collection media near the worker's breathing zone.

These pumps require calibration before each use and must have the flow rate set to the correct level depending on what is being monitored. The worker usually wears the pump and the collection media for the entire day. Once the day is finished, the charcoal tube, filter cassette, or liquid media is sent to the laboratory of choice to be analyzed.

Advantages: The results are usually more accurate than other methods and allow for a broader sampling of chemicals. It is also one of the few ways to get a TWA for dusts in the air.
Disadvantages: Requires knowledge of National Institute for Occupational Safety and Health (NIOSH) sampling methods, as well as which type of filter or tube to use. It is also more bulky and cumbersome than other sampling methods, so workers might not warm up to it as easily. If a person is not experienced in this type of work, it may be beneficial to get a consultant to help.

Detector Tubes and Pumps

Detector tube and pump systems are a very effective way to do on-the-spot air monitoring and meet the OSHA requirements of 25% error. They are accurate enough to get an idea of the hazards in the workplace. Detector tubes are typically used when surveying an area, and can also give an idea of worker exposure in ppm or percent volume.

Two main types of pumps are available: piston and bellows. The piston style requires the user to pull a piston to pull air through the tube. With the bellows style, the user squeezes the bellow, and upon release, air is pulled through the tube as the bellow opens.

Several types of tubes are used to get a measurement:

- **Scale tube**—Typical units found on the tube are ppm, mg/m3, and percent (%) scales that are read by measuring the length of discoloration.
- **Qualitative tube**—This tube does not give a quantitative reading, but it lets the user know that the gas or vapor is present.
- **Pretube**—For some chemicals, a test that produces a simple color change is not available, so a pretube is required. It is used to convert the test gas or vapor into another compound that can be detected in the indicating tube by a color change.
- **Color-matching tube**—The sample is taken until the color of the sample matches the color intensity of the control tube. The number of pump strokes taken to match the color of the control tube is then looked up on a chart to calculate the concentration of the test gas or vapor.
- **Color comparison**—This method compares the intensity of the discoloration on the sample tube with a control tube. The comparison tube has three color intensities

to compare with three levels.

Advantages: Allow for quick sampling of an area. They are relatively inexpensive for quick monitoring.
Disadvantages: The tubes are limited in the types of chemicals they can pick up. Certain chemicals can also interfere with the tubes and give false readings, so it is important to check for interferences.

Respirable Silica and Pumps

In March 2016, OSHA issued a final rule to control exposure to respirable crystalline silica in general industry. Control of silica will start with employers identifying and quantifying respirable silica exposure. Appendix A to 29 CFR 1910.1053 identifies the methods to follow for a collection of a respirable silica sample. Each method incorporates the use of a cyclone sampler. The cyclone separates the respirable fraction (approximately 12 micron and below) of the particulate from the atmosphere drawn through it. The cyclone sampler is designed so that smaller particles are carried onto the filter paper inside the cassette and larger unwanted particles drop into the grit pot. The dust cyclone sampler is used with a sampling pump at a flow rate of 1.7 liters per minute (lpm) to 2.5 lpm depending on the type of cyclone used to give the correct performance.

Advantages: Meets the requirement of the standard to separate the smaller respirable size silica particles that pose a hazard to the body from the larger size silica particles.
Disadvantages: Additional cost of equipment and knowledge of how to set it up with an air monitoring pump.

Hand-Held Electronic Monitors

Continuous hand-held monitors come in a variety of shapes and sizes. They can vary from a relatively simple single-gas monitor to a complex datalogging multi-gas monitor. They all make a quantitative analysis that is displayed on a digital or analog readout. Some also have the capabilities to store information, which can be downloaded to a computer.

Advantages: The readout is immediate. There is no waiting for a color change or waiting for a lab to analyze the results of a badge. The monitors also give real-time readout. What is being read on the display is what the contaminant concentration is at that time. Most hand-held meters also have a visible or audible alarm or both that will alert the user if the contaminant is above a safe level.
Disadvantages: This type of meter is usually calibrated with one type of gas, and interference from similar gases could alter the readings. The operator must have adequate training to interpret the information that the monitor is providing, and also be familiar with calibration and limitations of the device. In comparison with other types of monitors, they are often more expensive.

Fixed-Air Monitors

This type of monitor is very similar to a hand-held electronic monitor, except it is permanently mounted and an operator is not required. Fixed monitors use sensors similar to those of hand-held monitors. They often do not have a wide selection of chemicals that they can monitor. This type of monitor ranges from a simple carbon monoxide monitor to a very expensive multisensory system.

Fixed monitors operate at all times, and are used for area sampling and not personal sampling. They often have alarms to alert workers to a dangerous situation. Some of

the more complex systems can start a ventilation blower when contaminant concentrations are too high, or even sound an alarm in another part of the plant.

Advantages: Immediate continuous readout of a designated area. It does not require a person to be present to collect the samples. Also can be used in conjunction with other equipment such as ventilation equipment that can be activated to control the level of the contaminant if it exceeds a set point.

Disadvantages: Calibration or problems with the monitor can go unnoticed since it is primarily used without daily interaction with the operator. The operator must have adequate training to interpret the information that the monitor is providing, and also be familiar with calibration and limitations of the device. These types of monitors typically have the greatest up front cost.

Conclusion

Whatever type of system you choose, make sure you understand what the monitor will and will not do. Most of these monitors are for surveying and not for accurate readings. OSHA only requires a 25% error, so do not plan to use any of these monitors for laboratory analytical work. Air monitoring is a very important part of any safety program, so make sure you get all of the details before sending your workers into a hazardous area.

Commonly Asked Questions

Q: How do I know what air monitoring equipment to use?

A: It will depend on what you are sampling and how accurate you want to be. If you prefer a quick, but less accurate result, the diffusion detector tube is your answer. If you prefer more accuracy but less cost, than personal sampling pumps and personal badges are the answer. For the highest level of accuracy and variety of chemicals to sample for, personal air sampling with sampling pumps is best. When using sampling pumps with collection media, the correct sampling method must be used. The sampling method identifies what equipment and collection media is needed. There are two main sources to reference to determine what method should be used. The first is the NIOSH Manual of Analytical Methods (NMAM) and the second is OSHA’s Sampling and Analytical Methods.

Q: How often is calibration required?

A: Always consult your owner’s manual for recommended calibration frequency. General bump testing and calibration guidelines are provided in Quick Tip 378.

Q: What type of monitor should I have for entering a confined space?

A: The first thing to know is what types of hazards you expect to encounter. Most importantly, you need to monitor for oxygen, then combustible gas, and then any toxic gases that might be present, such as carbon monoxide. This can usually be done with a three- or four-gas monitor with a sample draw pump to test the space before entry.

Q: How do you convert mg/m^3 to ppm?

A: PPM = (mg/m^3 x 24.45) / molecular weight.

Q: What does it mean when a tube reads out in percent volume?

A: 1% = 10,000 ppm.

Sources

NIOSH Pocket Guide To Chemical Hazards, U.S. Department of Health and Human Services, 2016.
Fundamentals of Industrial Hygiene, 6th Edition, Abbreviated National Safety Council, 2012.
Air Sampling Instruments, 9th edition, ACGIH
Personal Sampling for Air Contaminants, OSHA Technical Manual, Section II, Chapter 1
NIOSH Manual of Analytical Methods (NMAM), 5th Edition 29 CFR 1910.1053