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Objectives

- ◆ To understand the purposes of sampling
- ◆ To learn calibration procedures for high flow pumps, low flow pumps, noise dosimeters and sound level meters
- ◆ To use methods of sampling for gases and vapors, aerosols and noise
- ◆ To apply analytical methods and interpret degree of accuracy

Resources Available from the Division of Safety & Hygiene (DSH) Libraries

(800) 644-6292 (614) 466-7388

library@bwc.state.oh.us

www.ohiobwc.com

Safety training:

- Safety talks, outlines and scripts - DSH Safety leader's discussion guide, Training Center's One-hour safety presentations, reference books, web resources
- Videos – hundreds of safety and health topics
- Books and articles on training techniques

Machine and equipment safety:

- Safety standards (ANSI, NFPA, CGA)
- Books and articles on power presses, material handling equipment, lockout/tagout, etc.

Sample written programs:

- DSH program profiles and sample written programs
- Reference books
- Internet resources

Illness and injury statistics:

- Statistics from the U.S. Bureau of Labor Statistics
- National Safety Council's *Injury Facts*
- National Institute of Occupational Safety & Health (NIOSH) studies

Hazard communication and chemical safety:

- Chemical safety information
- Material safety data sheets (MSDSs)
- Sample written programs
- Videos
- Internet resources

Safety standards

- American National Standards Institute (ANSI) standards (including standards for construction, machinery and equipment, personal protective equipment)
- National Fire Protection Association (NFPA) fire codes (including the Life Safety Code and the National Electrical Code)
- Compressed Gas Association (CGA) standards

Other topics of interest (books, articles, magazines, videos and standards):

- Confined spaces
- Electrical safety
- Job safety analysis
- New employee orientation
- Powered industrial trucks
- Respiratory protection
- Scaffolds
- Spill response

Directories and lists of vendors of safety equipment

Occupational Safety & Health Administration (OSHA) regulations

Manual of Uniform Traffic Control Devices (MUTCD)

Recommendations of useful Internet sites

BWC publications

Saving You Time and Research

Requests for copies of OSHA standards, information on starting a safety committee, a video on accident investigation techniques -- these are some of the thousands of inquiries BWC's Division of Safety & Hygiene (DSH) libraries receive each year.

DSH has two libraries to serve you:

- The central library in the William Green Building in downtown Columbus;
- The resource center and video library located at the Ohio Center for Occupational Safety and Health (OCOSH) in Pickerington.

Both libraries are open 8 a.m. to 4:45 p.m., Monday through Friday. Your need for information does not require a visit to the library. You can phone, fax, or e-mail your requests and receive a quick response.

The central library provides free information services on the topics of occupational safety and health, workers' compensation and rehabilitation.

The OCOSH resource center provides similar services for those who visit OCOSH for meetings and training center classes.

The video library offers an extensive collection of videotapes to supplement your organization's safety and health training program. It is a convenient and popular source for Ohio employers to borrow quality occupational safety- and health-related training aids.

Visit our Web site at **www.ohiobwc.com**.

Central library
30 W. Spring St., Third Floor
Columbus OH 43215-2256
1-800-OHIOBWC
(614) 466-7388
(614) 644-9634 (fax)
library@bwc.state.oh.us

OCOSH resource center
13430 Yarmouth Drive
Pickerington OH 43147
1-800-OHIOBWC
Resource center (614) 728-6464
Video library (614) 644-0018

**INTERNET WEB SITES
FOR
OCCUPATIONAL SAFETY & HEALTH INFORMATION
April 2005**

GENERAL

NATIONAL SAFETY COUNCIL (NSC)

<http://www.nsc.org/>

The NSC has a user friendly web site for innovative and current information on home, farm and community, on the road and workplace safety and as well statistical data and charts.

NORTH DAKOTA WORKFORCE SAFETY & INSURANCE

<http://www.workforcesafety.com/>

For workplace safety, North Dakota's WSI site puts forth their "safe operating procedures" page where they give information on accident and near miss reports, substance abuse, material handling and storage, walking and working surfaces, and safety program development and orientation.

OCCUPATIONAL & INDUSTRIAL SAFETY RESOURCES

<http://www.khake.com/page59.html>

Maintained by a Vocational Information Center, this web site provides links to occupational and industrial safety with lists of directories, national centers, hotlines and help lines as well as specific area coverage such as emergency, disaster and natural hazards, and tool, machine and equipment safety options.

OKLAHOMA STATE UNIVERSITY

<http://www.pp.okstate.edu/ehs/>

The Department of Environmental Health & Safety at OSU offers an online safety resource library that is constantly being updated with topics from A-Z including specific areas of safety such as fire, construction, HAZCOM and training. Go to the "Links Library" option.

SAFETY DIRECTORY

<http://www.safetydirectory.com/>

Safety Directory.com is an Internet gateway to occupational health & safety sites. This web site is indexed with information on industry specific topics, training, illness and injury, as well as safety publications and resources.

FEDERAL GOVERNMENT

CENTERS FOR DISEASE CONTROL & PREVENTION (CDC)

<http://www.cdc.gov/>

The CDC is always a good resource for current medical issues throughout the United States. Health topics from A-Z give an in-depth look at most communicable diseases as well as topics such as safe driving, violence, and air pollution, and workplace safety and health topics.

FEDERAL EMERGENCY MANAGEMENT ASSOCIATION (FEMA)

<http://www.fema.gov/>

For up-to-date information on active disasters and emergencies nationwide access this web site first. Publications include options for emergency preparedness and prevention, response and recovery, disaster fact sheets, and public awareness information.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY & HEALTH (NIOSH)

<http://www.cdc.gov/niosh/homepage.html>

NIOSH's web site provides current information on many services as well as safety research, including ergonomics programs, respirators, and mining safety. At the chemical page you will find databases and other helpful resources, information on personal protective equipment, as well as government agency web sites of interest.

OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION (OSHA)

<http://www.osha.gov>

OSHA'S official web site includes media releases, online publications, statistics, standards & directives, "Technical Links," training center courses, "hot topics," and "what's new" as well a very useful A-Z index page.

INTERNATIONAL RESOURCES

HEALTH & SAFETY EXECUTIVE (HSE)

<http://www.hse.gov.uk/>

The United Kingdom has an international safety web site with a good deal to offer on occupational safety & health. Drop down boxes offer A-Z industry information, health and safety topics, tools, research, as well as publications and statistics.

ERGNET

<http://www.sunderland.ac.uk/~ts0qli/ergnet.htm>

The University of Sunderland in the UK is an international web site directory of "places for ergonomics and human factors". Featuring lists of sources such as societies, organizations, government bodies, institutes, centers and laboratories, this site also gives links to journals, a research database and other general ergonomic sites.

OHIO

OHIO EPA (OEPA)

<http://www.epa.state.oh.us>

At the official web site for Ohio's Environmental Protection Agency; use the "Topic Index" to find regulations and information on permits, hazardous waste, pollution prevention, wastewater, wetlands, and much more.

OHIO STATE LIBRARY/OHIOLINK

<http://winslo.state.oh.us>

At **OhioLink**, a statewide library and information network, you can search the State Library of Ohio's collection for the BWC's Division of Safety & Hygiene library books as well as other Ohio College and university library collections. Also available at this web site are searchable versions of Ohio Administrative laws and rules, electronic databases, and other Ohio library directories.

SPECIFIC (BY SUBJECT)

CONSTRUCTION

<http://www.cdc.gov/elcosh/index.html>

CDC's **eLCOSH** is a comprehensive library of construction-related safety information presented in both English and Spanish with items listed under trade, hazard, job site, and others. Also see: The Construction Industry Safety Council, a Center to Protect Workers' Rights resource center at <http://www.buildsafe.org/RSC.htm> for OSHA publications in PDF and hazard alerts.

ERGONOMICS

<http://www.ergoweb.com>

ERGOWEB provides current information on ergonomics and human factor science. Offered are: research, case studies, reference material and a forum for questions, answers and discussion.

LABORATORY SAFETY

<http://safety.science.tamu.edu/>

Texas A&M University College of Science is an optional choice for safety in the laboratory information. From hazard identification to waste disposal this web site offers thorough coverage of laboratory safe practices.

MATERIAL SAFETY SHEETS

<http://www.ilpi.com/msds/index.html>

This web site offers many solutions for finding MSDS (100 free sites) as well as chemical manufacturers and suppliers, pesticides including fertilizers, government sites, and other miscellaneous locations for chemical data. Also check any toxicological effects at <http://www.atsdr.cdc.gov/toxprofiles/> and health and safety information on household chemical ingredients at <http://householdproducts.nlm.nih.gov/>.

MOTOR CARRIER SAFETY PROGRAMS

<http://www.fmcsa.dot.gov/safetyprogs/saftprogs.htm>

The Federal Motor Carrier Safety Administration (FMCSA), an administration within the U.S. Department of Transportation, regulates and supports the Nation's interstate commercial carrier industry. The FMCSA web page offers several safety programs in PDF format such as brake safety, fatigue, HAZMAT safety, speed management, sharing the road safely, and other insurance and licensing information.

RADIATION

<http://www.physics.isu.edu/radinf/>

The Radiation Information Network offers a web site that is in-depth with information on radiation topics and issues. In addition to what's new in the field and general information there are regulatory, organizational and society links as well as research and educational resources available to access.

SAFETY STATISTICS

<http://stats.bls.gov/>

Occupational health and safety statistics by industry and occupation can be researched for injuries, illnesses, and fatality data at this web site starting with the "Overview of BLS Statistics on Worker Safety and Health" page.

SAFETY BRIEFINGS, MANUALS, PRODUCTS & PROGRAMS

OSHA POWERPOINT SAFETY PRESENTATIONS

<http://esf.uvm.edu/siript/powerpt.html>

An extensive safety PowerPoint presentation library is available at this web site featuring A-Z topics such as accident investigations, bomb threats, chemical spills, construction, electrical, hand tools, emergency response, fire safety, forklifts, JSA, laser, OSHA compliance, PPE, razor knife safety, safe lifting, and many more.

SAFETY PUBLICATIONS & VIDEO RESOURCES

<http://www.cbs.state.or.us/external/osha/standards/pub.htm>

A valuable resource for safety resources, the Oregon State's Department of Consumer and Business Publications web site is packed with downloadable information. Areas covered are agriculture, asbestos abatement, occupational exposures, HAZCOM, HAZMAT, HAZWOPER, safety practices, writing manuals and programs, tools of the trade, workers' compensation and ergonomics.

Ohio Bureau of Workers' Compensation, Div. of Safety & Hygiene Library
 30 W. Spring St., L-3, Columbus, OH 43215-2256
 (800) 644-6292, press option 2 - 2
 (614) 466-7388/ (614) 644-9634 (fax)
 E-Mail: library@bwc.state.oh.us

MONITORING INTRODUCTION

Why do we Monitor?

Industrial hygiene monitoring is mainly performed to provide information regarding the type and relative quantity of contaminant(s) present in the work environment.

There are many different reasons for collecting this information:

1. Compliance with Regulations

- OSHA air standards: Generic and Substance specific
- Medical monitoring
- Respiratory protection program
- Hazard communication

2. Evaluation of Engineering Controls

- Ventilation measurements
- Before and after installation

3. Determination of Health Effects

- Workers' Compensation claims
- Epidemiological studies
- Employee complaints

4. Selection of Personal Protection Equipment

5. Source Identification

6. Clearance

- Asbestos

Representative Samples

To have confidence in the sample results, the sample must be representative of the environment of concern and reflect the actual conditions and exposure.

To ensure representative samples, the following questions must be considered when formulating a sampling strategy:

1. What do I need to sample for?
2. Who/where do I need to sample?
3. How many people need sampled or how many samples do I collect?
4. How long do I need to sample?
5. When do I need to sample?

The answers to these questions will often depend on the reasons for doing the sampling but the following are things to consider:

1. What do I need to sample for?

- Agents specific to the operation and materials used
- Chemical by-products

2. Who/where do I need to sample?

- Specific operations
- People/locations near the operation(s) of concern
- Personal samples versus Area Samples
- Maximum risk employee(s)
- Random selection

3. How many people do I sample or how many samples do I need?

- Maximum risk employee(s)
- Random selection
- Statistical sampling

4. How long do I need to sample?

- Dependent on duration of the job, type of contaminant, activities performed, or sampling method
- Full-shift
 - ⇒ **Full-shift consecutive samples:** A series of samples collected consecutively throughout a shift. This strategy provides some insight into the variations in concentration during the shift. Often it is possible to identify specific activities which give rise to the highest exposures. Cost is sometimes a limiting factor to this approach.
 - ⇒ **Full-shift single sample:** A single sample collected during a shift. This strategy does not provide insight into the variations in concentration during the shift. More cost effective but potential to lose a full day of sampling if something happens to the sample.
 - ⇒ **Partial period consecutive samples:** Samples collected throughout the shift but with some of the shift unsampled. Can be beneficial if performing short-term exposure monitoring. The problem with this strategy is how to handle the unsampled portion of the shift. In theory the measurements are only valid for the duration of the sampling periods. However, professional judgment may allow for inferences to be made concerning exposures during the unsampled periods. Reliable knowledge of the process and good documentation are required to make this judgment.
- Short-term – typically 15-minute samples collected because the contaminant has a STEL and the process or activity performed dictates that high exposures will be encountered for short periods of time.
- Instantaneous (Grab) – typically taken because the contaminant has a ceiling exposure limit or contaminant identification is being attempted. Timing of sample collection is critical and often questionable. Direct reading instrumentation is typically involved.

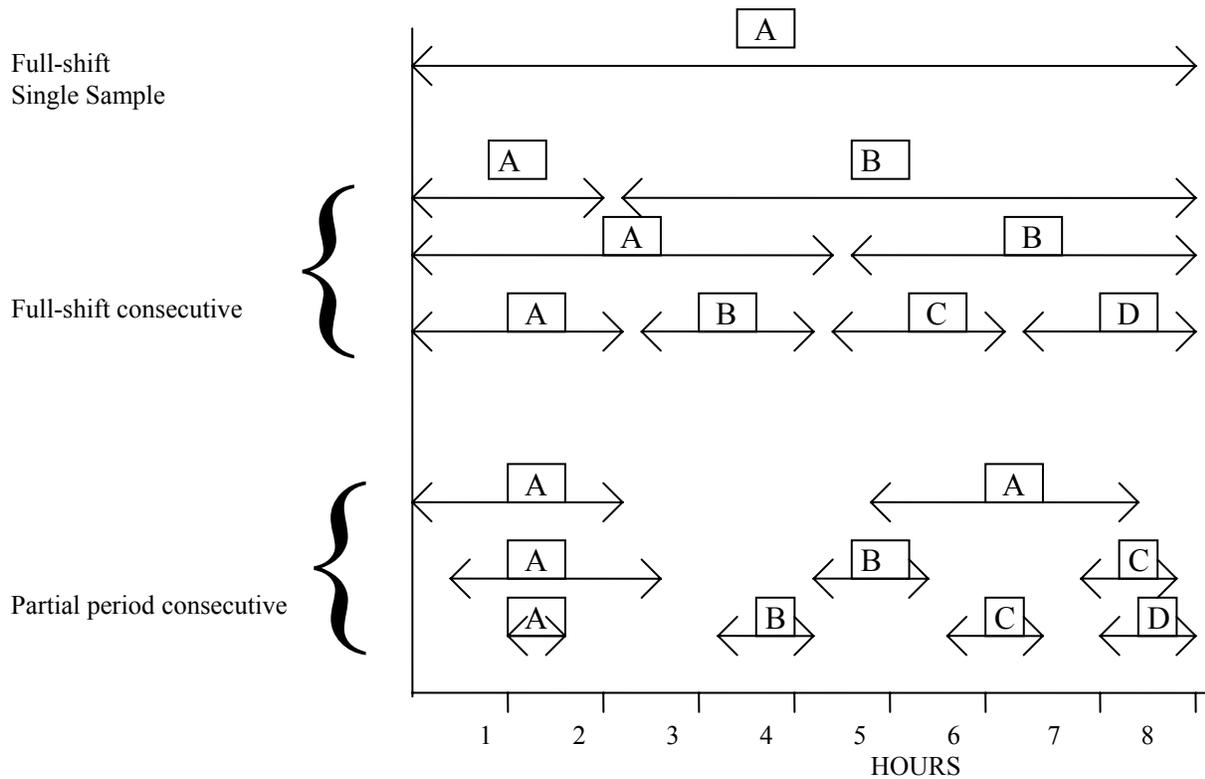


Figure 2.1 – Full-Shift Sampling Strategies

5. When do I sample?

- It is a large leap of faith to sample one day and extrapolate the results to the rest of the year. Variations are to be expected from day-to-day and person-to-person. Exposure variations can be due to:
 - ⇒ seasonal variation
 - ⇒ work load
 - ⇒ products produced
 - ⇒ process or material changes
 - ⇒ individual work practices

1. Personal Samples

- Monitoring equipment is attached directly to the individual
- Sample taken in the breathing zone or hearing zone
- Sample the “true” exposure of mobile individual
- Comparison to exposure limits

2. Area Samples

- Generally obtained to identify “worst case” exposure scenarios
- Locate sources of contaminants
- Cannot be used for comparison to exposure limits

Air Monitoring

Two primary methods of sample collection:

1. Laboratory Supported

- Active sampling involves the use of a pump to pull the air being sampled through or into the sampling media.

⇒ **Advantages:**

- methods extensively tested and validated
- often the method used by compliance officials
- calibrated, measured airflow for accuracy of sample volume
- collection of contaminants in multiple phases (e.g., vapor and aerosol) with one pump
- defined method for detecting and accounting for sample breakthrough when sampling gases/vapors

⇒ **Disadvantages:**

- equipment can be cumbersome and interfere with worker
- preparation can be time consuming
- training is often necessary
- as pumps age they become less reliable
- up front cost for pumps

- Passive diffusion sampling relies on the principle of diffusion to allow the air being sampled to contact the sampling media.

⇒ **Advantages:**

- easier to use allowing less training
- less expensive when compared to the cost of pumps and calibrators
- less obtrusive to the wearer

⇒ **Disadvantages:**

- very few OSHA or NIOSH methods to reference
- fixed sampling rate
- reverse diffusion
- stagnant air will cause starvation
- high face velocities and turbulent effects
- method error is greater than active sampling

2. Real Time (Direct Reading)

- Electronic monitors employ a wide variety of technologies and are designed to achieve a wide variety of purposes. Most instruments are limited to instantaneous area type monitoring but personal full-shift monitoring is becoming more common through the use of data logging capabilities.
- Colorimetric methods employ the use of indicating tubes to determine airborne concentrations. Colorimetric methods can be both active (i.e., hand pump) or passive for certain contaminants.

The main advantage to using real time instrumentation is the elimination of the lag time encountered when samples are collected on media and analyzed in a laboratory. A disadvantage could be the expense if a large variety of contaminants need to be analyzed necessitating many different instruments.

Air Sampling Pumps

The primary device used in active sampling to collect the air is the air sampling pump. Air sampling pumps are often classified by their flow rate.

<u>Type</u>	<u>Flow Rate</u>
<i>Low-flow pump</i>	0.5 - 200 milliliters per minute (ml/min)
	<ul style="list-style-type: none">• primarily used for gas/vapor sampling
<i>High-flow pump</i>	1 - 4 liters per minute (LPM)
	<ul style="list-style-type: none">• typically used for aerosol sampling but can be used for gases/vapors
<i>High-volume pump</i>	8 - 30 LPM
	<ul style="list-style-type: none">• uses include environmental sampling and clearance sampling

The basic operation of any air sampling pump must consider:

- On/Off switch
- Sampling ports
- Battery charging
- Battery capacity
- Maintenance

Pump Calibration

The accuracy of any air measurement depends on the precise determination of the mass of contaminant collected as well as the volume of air sampled. The accuracy and precision of any air sampling procedure can be only as good as the sampling and analytical error associated with the method. The difference between the air concentration reported for an air contaminant and the true concentration at that time and place represents the overall error of the measurement.

In active air sampling the largest portion of the sampling error is often due to the flow rate of air and, ultimately, the underestimation or overestimation of the total volume of air that has passed through the sampling device. Therefore, to obtain the best estimate of the true concentration of a contaminant, one must have a thorough understanding of both the setting and maintaining of calibrated flow rates.

Before any air sampling device can be relied on as accurate, it must be calibrated. This goes for pumps as well as direct reading instrumentation.

COMMON SAMPLING ERRORS

- | | |
|------------------------|----------------------------------------|
| - Improper calibration | - Improper media selection/preparation |
| - Flow rate variation | - Field blanks not submitted to lab |
| - Improper flow rate | - Improper sample handling |

Minimizing sampling and analytical errors will help to ensure accuracy and precision.

Accuracy: The closeness of a measured value to its true value.

Precision: The degree to which replicate measurements differ from one another.

Calibrator Classifications

The distinction between the different classifications of calibrators is based solely on accuracy. Calibrators are classified as:

- **Primary standards**
 - ⇒ accuracy is considered to be $\pm 1\%$ or better
 - ⇒ most common type for field use is the inverted burette (bubble meter), however, the Dry-Cal is now used extensively
 - ⇒ manual calibration vs. electronic calibration

- **Secondary standards**
 - ⇒ accuracy is considered to be $\pm 5\%$ or better
 - ⇒ most common type for field use is the precision rotometer
 - ⇒ must periodically be calibrated against a primary standard
 - ⇒ pump rotometers are not precision rotometers

Standard industrial hygiene practice is to calibrate with representative media in-line, before and after each sampling period, and under pressure and temperature conditions similar to those at the sampling location.

Temperature and Pressure: Air volume is directly affected by temperature and pressure. If the conditions during air sampling are significantly different from those during calibration, then a correction factor must be used when calculating the sample air volume (field volume). This can be done using the following equation:

$$V_{field} = V_{calibration} \times \frac{T_{field}}{T_{calibration}} \times \frac{P_{calibration}}{P_{field}}$$

- where:**
- V_{field} = air sample volume in liters obtained during sampling period
 - $V_{calibration}$ = air sample volume in liters obtained by multiplying the calibrated airflow rate by the elapsed sampling time
 - T_{field} = absolute temperature during sampling in degrees Kelvin or Rankin
 - $T_{calibration}$ = absolute temperature during calibration in degrees Kelvin or Rankin
 - $P_{calibration}$ = atmospheric pressure during calibration in mmHg or inches of water
 - P_{field} = atmospheric pressure during sampling in mmHg or inches of water

As a rule of thumb pressure differences are negligible and temperature differences of less than 30° F are also negligible and will not greatly affect the sampled air volume.

Pump Calibration Procedure Electronic Calibrator

1. Select appropriate pump(s) and sampling media.
2. Turn on the pump(s) and allow to run at least five minutes.
3. Record date, time of day, pump type and number, calibration device and number, and type of collection media on the *Pump Calibration Record and/or Field Sampling Data Sheet*. If the calibration air temperature will be significantly different than the sampling air temperature this should also be recorded.
4. Start calibration device.
5. Attach media to pump with Tygon tubing.
6. Attach the other side of the media to the calibrator with Tygon tubing.
7. With the pump still running, start the calibration. Verify the flow rate with at least 3-5 samples, preferably 10 samples. Record the average flow rate on the *Pump Calibration Record and/or Field Sampling Data Sheet*.
9. Check the flow rate after the air sampling is completed to verify the flow rate has not drifted.

Standard industrial hygiene practice is to calibrate with representative media in-line, before and after each sampling period, and under pressure and temperature conditions similar to those at the sampling location.

Sampling and Analytical Methods

There are many sources for air monitoring methods. The key to selecting a method is ensuring its validity. Validated methods consider:

- Sampling rate
- Sample volume
- Temperature and humidity
- Interferences
- Accuracy and Precision
- Analytical sensitivity
- Sample stability

Many validated methods are published by NIOSH and OSHA. Other sources include EPA, AIHA, ASTM, or industry. Often there is more than one method available for a given contaminant and the proper selection of a method will sometimes depend on the environment in which the sampling will take place. However, **an IH sampling guide has been developed by most accredited laboratories that list specific methods and their sampling parameters for specific contaminants.**

Sampling Documentation

Accurate sampling documentation is critical for the support and interpretation of the results. Document forms may be found in TAB 6 of this manual.

- Industrial Hygiene Field Sampling Data Sheet
- Lab Analysis Sheet
- Air Sample Table
- Calibration Form

In addition to recording information pertinent to the actual sampling (e.g., start/stop time, pump identification, sample identification), it is important that the work performed by the employee be documented. Documentation should include the type of equipment used, the feeds, speeds, heats, etc., of equipment, the presence and condition of control equipment, and whatever other information may be necessary to assure meaningful interpretation of the results. It can also be of value to document the details of the operation performed for future reference. This enables a determination to be made as to whether or not the work method has changed in such a manner as to have an effect upon exposures. Such information can also prove useful from a legal viewpoint. Disagreements based upon hearsay can be avoided if dependable documentation of the sampling parameters, work method(s), tools, controls, etc., that were present during the monitoring is available.

Time-Weighted Average Calculations

The time-weighted average (TWA) concentration of a contaminant can be determined on an eight-hour basis or for the actual time sampled. If the total sample time is less than eight-hours, calculating the eight-hour TWA assumes zero exposure for the unsampled portion of the eight-hour period. Unless zero exposure can be documented for the unsampled period, a more conservative approach is to calculate the TWA for the actual time sampled and assume the result is representative of the eight-hour TWA. The following equations calculate both an eight-hour TWA concentration and a TWA for the time sampled using the same data in the example below:

Eight-Hour TWA:
$$TWA_{8Hr.} = \frac{(C_1)(T_1) + (C_2)(T_2) + (C_3)(T_3) \dots + (C_n)(T_n)}{8}$$

Time Sampled TWA:
$$TWA_{timesampled} = \frac{(C_1)(T_1) + (C_2)(T_2) + (C_3)(T_3) \dots + (C_n)(T_n)}{T_{total}}$$

- C_n = contaminant concentration measured in time period T_n
- T_n = time sampled (hours) to determine C_n (if the denominator is in minutes then units for T are in minutes)
- T_{total} = total sample time ($T_1 + T_2 + T_3 \dots + T_n$)

Example: Monitoring is conducted to determine a full-shift exposure to toluene. (ACGIH 50 ppm, OSHA 200 ppm, NIOSH 100 ppm) To best characterize the exposure, two samples are collected in the morning and two samples are collected in the afternoon for a total of four samples. Each sample is analyzed separately and the 8-hour TWA concentration can be determined from the following data:

	<u>Time Sampled</u>	<u>Concentration Determined</u>
Sample 1:	1.5 hours	58 ppm
Sample 2:	1.5 hours	80 ppm
Sample 3:	2.5 hours	25 ppm
Sample 4:	1.5 hours	150 ppm

$$TWA_{8Hr.} = \frac{(58\text{ppm})(1.5\text{hrs.}) + (80\text{ppm})(1.5\text{hrs.}) + (25\text{ppm})(2.5\text{hrs.}) + (150\text{ppm})(1.5\text{hrs.})}{8\text{hrs.}} = 62\text{ppm}$$

$$TWA_{timesampled} = \frac{(58\text{ppm})(1.5\text{hrs.}) + (80\text{ppm})(1.5\text{hrs.}) + (25\text{ppm})(2.5\text{hrs.}) + (150\text{ppm})(1.5\text{hrs.})}{7\text{hrs.}} = 71\text{ppm}$$

EXPOSURE LIMITS

Air monitoring results are typically compared to applicable exposure limits. The more common exposures limits are:

- OSHA Permissible Exposure Limit
- ACGIH Threshold Limit Value
- NIOSH Recommended Exposure Limit
- AIHA Workplace Environmental Exposure Limit
- MAK Maximum Concentration Value
- Manufacturers' Recommendations

OSHA – The Occupational Safety and Health Administration's permissible exposure limits (OSHA PEL) are found in Tables Z-1, Z-2, and Z-3 of the OSHA General Industry Air Contaminants Standard (29 CFR 1910.1000). They are the legally enforced standards in the United States. Unless noted otherwise, PELs are time-weighted average (TWA) concentrations that must not be exceeded during any 8-hour work shift of a 40-hour workweek. A short-term exposure limit (STEL) is designated by "ST" preceding the value and is measured over a 15-minute period. OSHA ceiling concentrations (designated by "C" preceding the value) must not be exceeded during any part of the workday; if instantaneous monitoring is not feasible, the ceiling is assessed as a 15-minute TWA exposure.

ACGIH – American Conference of Governmental Industrial Hygienists' Threshold Limit Values (ACGIH TLV), unless noted otherwise, are TWA concentrations for an 8-hour workday and a 40-hour work week and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. A short-term exposure limit (STEL) is designated by "ST" preceding the value and, unless noted otherwise, is a 15-minute TWA exposure that should not be exceeded at any time during a workday; should not occur more than four times per day; and there should be at least 60 minutes between successive exposures in this range. A ceiling TLV is designated by "C" preceding the value; unless noted otherwise, the ceiling value should not be exceeded at any time. The TLVs are intended for the use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and no other use such as proof or disproof of an existing disease or physical condition. The TLVs are not fine lines between safe and dangerous concentrations, nor are they a relative index of toxicity.

Typically, concentrations are given in parts per million (ppm) for gases and vapors, and milligrams per cubic meter (mg/m^3) for aerosols. A "skin" designation indicates the potential for dermal absorption; skin exposure should be prevented as necessary through the use of good work practices and gloves, coveralls, goggles, and other appropriate equipment.

Air Monitoring for Gases and Vapors

Gas: a state of matter which (at normal temperature and pressure (25° C and 760 mm mercury) has very low density and expands or contracts to occupy the space of enclosure in which it is confined relative to changes in temperature and/or pressure.

Examples: carbon monoxide, chlorine, oxygen, nitrogen

Vapor: an air dispersion of molecules of substances which is a liquid in its normal state. Evaporation is the process by which a liquid is changed into the vapor state. Solvents with low boiling points will evaporate readily.

Examples: formaldehyde, benzene, isopropyl alcohol

Principles of Collection

- Adsorption
- Absorption
- Derivatization
- Capture

Adsorption: adherence of the gas or vapor onto the surface of another substance, called the adsorbent. Adsorption can be obtained through active or passive diffusion sampling.

Adsorbents are typically enclosed in glass tubes that contain two separate sections of media. Adsorbents are typically specific for groups of compounds (e.g., alcohols, amines, hydrocarbons) and one adsorbent will not work with all compounds. The most common types of adsorbent media include:

⇒ activated charcoal

⇒ silica gel

⇒ porous polymers (Tenax[®], Poropak[®], Chromo-sorbs[®], and Amberlite[®] XAD resins)

Collection Efficiency of Solid Sorbent Tubes

Validated air sampling methods will specify a sorbent material that will effectively trap the contaminant(s) of interest. But the following factors will affect the collection efficiency of solid sorbents:

- **Temperature:** adsorption efficiency decreases at higher temperatures
- **Humidity:** As water vapor is adsorbed by a sorbent, the capacity for the contaminant(s) of interest may decrease. This effect is most pronounced for sorbents such as charcoal and silica gel.
- **Sampling Rate:** Higher flow rates lower the collection efficiency of solid sorbents. For sorbents whose capacity is significantly reduced by high humidity, reducing the sample flow rate may improve the collection efficiency.
- **Other Contaminants:** The presence of significant concentrations of air contaminants (other than the one of interest) may reduce the collection efficiency of the sorbent for the target contaminant. This is most pronounced for contaminants within the same chemical family. Some classes of compounds can displace other less tightly adsorbed analytes in mixed atmospheres and cause breakthrough or losses.

Sampling Concerns for Solid Sorbent Tubes

- **Breakthrough:** Most commercially available sampling tubes consist of two sections of sorbent separated by glass wool or polyurethane. These two sections are desorbed and analyzed separately in the laboratory. Breakthrough occurs when the front section of the tube is saturated and enough contaminant accumulates on the back-up section that it begins to exit the tube. As a guideline, if 10% or less of the amount of the contaminant collected on the front section is found on the back section, breakthrough has probably not occurred. If greater than 25% is detected, breakthrough is probable and the results should be reported as the minimum amount present. Between 10%-25%, be suspicious.

Sampling Concerns for Solid Sorbent Tubes

- **Migration:** Occurs when the contaminant collected on the front section diffuses to the back section over an extended storage period or during improper storage. Migration can give a false indication of breakthrough. Migration can be minimized by refrigerating or freezing the samples as soon as possible after sampling and keeping the samples chilled during shipment to the laboratory.
- **Channeling:** Occurs when the sorbent media is oriented so that clear channels form and allow air to pass directly through the tube without contacting the sorbent. If this occurs there is no way of indicating if sample loss has occurred. Channeling is prevented by orienting the sorbent tube vertically and not horizontally.
- **Media Shelf Life:** Most media (not just sorbent tubes) has a shelf life associated with it. Be sure to use media whose shelf life has not expired.

Sample Compatibility

Once a contaminant has adsorbed onto a solid sorbent it has to be desorbed in the laboratory for analysis. Air contaminants are desorbed from solid sorbents using solvent extraction or thermal desorption techniques. Solvent desorption is the most frequently used technique and carbon disulfide is the most common desorption solvent because it has a high desorption efficiency for many organic compounds and produces minimum interference in gas chromatography analysis using flame ionization detection. In some cases, however, the desorption efficiency is poor when using carbon disulfide and other desorbing solvents have to be used.

It is important to note that more than one contaminant can often be collected and analyzed on the same media at the same time if the desorbing solvent is the same. Which contaminants can be collected concurrently on the same media can be determined by contacting the laboratory that will be analyzing the sample.

SAMPLING INSTRUCTIONS: SOLID SORBENT TUBES

Use these instructions for active sampling (i.e., pump involved) for substances which are retained on solid sorbents such as activated charcoal, silica gel, porous polymers, etc.

1. Calibrate each personal sampling low flow pump at the desired flow rate with a representative solid sorbent tube in-line.
2. Label sorbent tube with sample identification. Break the ends of the solid sorbent tube immediately before sampling to provide an opening at least one-half the internal diameter at each end.
3. Connect the solid sorbent tube to a calibrated personal sampling pump with flexible tubing with the smaller sorbent section (backup section) nearer to the pump (if the tube has an arrow on it the arrow should be pointing toward the pump). Do not pass the air being sampled through any hose or tubing before entering the sorbent tube.
4. Position the solid sorbent tube vertically during sampling to avoid channeling and/or premature breakthrough. Place in breathing zone for a personal sample.
5. Collect the sample at an accurately known flow rate and for the specified air volume as specified in the sampling guide for the substance being sampled. If possible check the flow rate during sampling to ensure the flow rate is being maintained.
6. Record pertinent sampling data (e.g., start/stop times, sample location, air temperature, etc.) and prepare field blanks. Field blanks should consist of unused sorbent tubes from the same lot used for sample collection. Handle and ship the field blanks exactly as the samples (e.g., break ends and seal with plastic caps) but do not draw air through the field blanks. Label field blanks.
7. At the completion of sampling seal the ends of the sorbent tube with plastic caps. Post calibrate each pump and calculate the total air volume sampled using the average flow rate of the pre- and post calibration runs. If sampling problems preclude the accurate measurement of air volume, discard the sample. The pre- and post calibrated flow rates should be within $\pm 10\%$ (preferably $\pm 5\%$). If this is not the case it should be noted on the field data sheet.
8. Complete the laboratory analytical request form. Securely pack samples and ship to laboratory.

Absorption: penetration of one substance into the inner structure of another. The collection media is usually a liquid.

The most common sampling device used for collecting a sample by absorption is the liquid impinger. Other less common liquid absorbing sampling devices include spiral and helical absorbers, fritted bubblers, and glass-bead columns. Using a liquid sampling media may involve absorption based on solubility or a reaction of the contaminant with the sampling solution.

Liquid Impingers

The design function of a liquid impinger is to provide sufficient contact between the sampled air and the liquid surface to allow complete absorption or reaction of the gas or vapor with the sampling solution.

When using a liquid impinger the flow rate needs to be maintained low enough (1.0 LPM) so the solution does not bubble out of the impinger or excessive losses of the solution occur due to evaporation.

Liquid impingers are versatile and good for sampling reactive gases and vapor. The disadvantages, however, of using liquid impingers are many and may include:

- they are cumbersome and bulky and not well suited for personal sampling
- the solution may be hazardous and pose an exposure concern
- evaporation of the solution poses problems with sample loss
- there is no real means to monitor overloading

Because of the disadvantages associated with liquid impingers, their use has declined in favor of solid sorbent tubes or chemically treated filters.

Derivatization: the process of converting a reactive compound into a distinct, more stable compound.

Derivatization media may include various types of chemically treated filters, tubes, and solutions which act to stabilize very reactive or difficult to analyze compounds upon their collection. This helps with preventing sample loss during storage or shipment and provides a more stable compound for analysis. Aldehydes and isocyanates are common compounds collected through derivatization.

When compared to using liquid solutions, chemically treated filters or sorbent tubes are less cumbersome and safer to use in the field and can provide improved collection efficiency for some compounds. In addition, sample loss is more easily verified from the front/back section of tubes or by using backup filters.

Capture: collecting a sample of air using a pump and bag or direct capture using an evacuated cylinder.

Applications may include:

- Field applications where samples will be analyzed on-site using portable direct reading instrumentation. Example: sulfur gas
- Leak, spill, or other emergency situations requiring quick sample and analysis so control measures can be implemented
- Measurement of peak concentrations from specific tasks or operations
- Collection of highly volatile compounds for which media is not available or efficient
- Useful for environmental assessments and contaminants found at extremely low levels (evacuated flasks)

The major drawbacks in the use of sampling bags include:

- potential instability of the gas or vapor mixture in storage
- sample loss through rupture or leakage in transport and handling
- sample loss due to reaction of the contaminant adsorption of the contaminant onto the bag material, or diffusion of the contaminant through the bag material

There are different chemical compositions of bag material available so be sure the bag you use is compatible with the contaminant you will be collecting.

Air Monitoring for Aerosols

Aerosols

An aerosol is an assemblage of solid or liquid particles dispersed in a gaseous medium such as air. Aerosols are encountered in several forms in the industrial environment. The most common being:

Dust - Solid particles generated by handling, crushing, grinding, rapid impact, detonation, or decrepitation (breaking apart by heating) of materials such as rock, ore, metal, coal, wood, and grain. Dusts do not tend to flocculate, except under electrostatic forces; they do not diffuse in air but settle under the influence of gravity. They range in size from 0.1 to 25 micrometers (also called microns and each micron is one-one millionth of a meter) in diameter. A person with normal eyesight can see dust particles as small as 50 microns. Dusts are physically divided into two categories: total and respirable. Total dust particles include the entire range of dust particle sizes. Respirable particulates nominally range in size from 1 to 10 microns.

Fume - an aerosol which is formed when the material from a volatilized solid condenses in air. Two of the most commonly encountered fumes are metal and polymer fumes. Fume particle sizes are generally less than 1 micron in diameter.

Mist - an aerosol of liquid droplets suspended in air, usually generated by the breaking up of a liquid by splashing, atomizing, or forming. Examples include oil/coolant mists, acid mists.

Fibers - solid particles which are longer than 5 microns and have a length to diameter ratio of 3 to 1 or greater. Examples include asbestos, glass fibers, ceramic fibers, carbon fibers.

Sampling With Filters

The general objective of aerosol sampling is to obtain information about aerosol properties at a given location over a specified length of time. Of the many aerosol properties that can be assessed, the most common are the mass per unit volume of air (concentration) and the particle size characteristics. These are important because the toxic properties of aerosols and the associated regulatory standards are most often expressed in terms of one or both of these properties.

The most common sampling techniques for workplace evaluation of aerosol exposures are:

- filtration based - porous membrane filters (cellulose ester, polyvinyl chloride), fiber filters (cellulose, glass, quartz), or capillary membrane filters (polycarbonate, polyester)
- sedimentation based - centrifugal, horizontal elutriator, electrostatic and thermal precipitation
- impaction based - jet and plate impactors, cascade impactors
- optical based - microscopy, various direct reading instruments

Of the above techniques, filtration is by far the most common one encountered. Many types of filter media are available, and the choice of media will depend on the aerosol characteristics and the analytical technique to be used. In personal sampling, conventional practice is to use a 25-millimeter (mm), 37-mm, or 47-mm diameter filter cassette containing a filter supported by a backup pad. If the total mass of contaminant is the concern then the cassettes are typically used closed-faced because the even distribution of the aerosol on the filter is not critical. If the analytical technique involves microscopy then even distribution of the aerosol on the filter is critical and the cassette should be used open-faced.

Excessive filter loading is the greatest concern when sampling with filters due to potential analytical problems and the pumps ability to maintain a stable flow rate.

AIR SAMPLING INSTRUCTIONS FOR FILTER MEDIA

Use these instructions for active sampling of total aerosols which are retained on filter media.

1. Calibrate each personal high flow sampling pump at the desired flow rate with a representative filter in-line.
2. Remove the plugs from the filter cassette and attach the filter to pump with flexible tubing placing the end of the cassette with the filter closest to the pump. The air being sampled should not be passed through any hose or tubing before entering the cassette.
3. Position the filter so the open end of cassette is facing down to prevent large particles from falling into the cassette. Place in breathing zone for a personal sample.
4. Collect the sample at an accurately known flow rate and for the specified air volume as specified in the sampling guide for the substance being sampled. If possible check the flow rate during sampling to ensure the flow rate is being maintained. Observe the filter frequently and change filter or terminate the sampling at first evidence of excessive filter loading.
5. Record pertinent sampling data (e.g., start/stop times, sample location, air temperature, etc.) and prepare field blanks. Field blanks should consist of unused filters from the same lot used for sample collection. Handle and ship the field blanks exactly as the samples but do not draw air through the field blanks. Label field blanks.
6. At the completion of sampling replace the plugs on the filter cassette. Post calibrate each pump and calculate the total air volume sampled using the average flow rate of the pre- and post calibration runs. If sampling problems preclude the accurate measurement of air volume, discard the sample. The pre- and post calibrated flow rates should be within $\pm 10\%$ (preferably $\pm 5\%$). If this is not the case it should be noted on the field data sheet.
7. Complete the laboratory analytical request form. Securely pack samples and ship to laboratory.

Inhalation of aerosols results in partial deposition throughout the respiratory tract. The site of deposition and the amount deposited are functions of:

- airborne concentration
- duration of exposure
- density of the particles
- ventilation rate
- tidal volume
- particle size and shape

Once deposited the aerosols may react with or be absorbed through tissues to cause adverse health effects. The site of deposition can be an important determinant of the rate of clearance and the ultimate toxic effect. Depending on factors such as the site of deposition and chemical composition the health effects may range from simple irritation to terminal disease.

To better assess the potential health effects of airborne particulate matter, exposure guidelines have typically been issued for different sizes of particles. Over the past several years, new size-selective exposure guidelines have been adopted by agencies around the world, including the ISO, ACGIH, and ASTM. OSHA is still following the old guidelines. The old and new guidelines are as follows:

OLD GUIDELINES	NEW GUIDELINES
<ul style="list-style-type: none">• Total Dust - Both non-respirable and respirable material that can be collected into a 37-mm cassette. Particle sizes up to 100 microns.• Respirable Dust - materials which can penetrate to the alveolar (gas exchange) region of the lung. Particle sizes up to 10 microns.	<ul style="list-style-type: none">• Inhalable Particulate Mass - materials that are hazardous deposited anywhere in the respiratory tract. Particle sizes up to 100 microns.• Thoracic Particulate Mass - materials that are hazardous deposited within the lung airways and the gas exchange region. Particle sizes up to 25 microns.• Respirable Particulate Mass - materials that are hazardous when deposited in the gas exchange region. Particle sizes up to 10 microns.

Traditional “total dust” sampling under the old guidelines using a closed-faced cassette does not meet the sampling criteria for sampling inhalable particulate mass. To date, two sampling devices, the IOM sampler and the GSP sampler, have been designed to meet inhalable particulate mass sampling criteria. If sampling is performed using the traditional closed-faced cassette the results can still be compared to applicable OSHA standards since they haven’t adopted the new guidelines. If, however, the results are going to be compared against ACGIH TLVs care must be taken to assure that the TLV is not for inhalable mass.

Traditional “respirable dust” sampling under the old guidelines using a filter and standard 10-mm cyclone at a flow rate of 1.7 LPM is still considered to meet the new respirable dust sampling criteria.

Frequently Tested Compounds with Current Inhalable and Respirable TLVs

INHALABLE TLVs	RESPIRABLE TLVs
• asphalt (bitumen) fume	• cadmium, elemental
• flour dust	• coal dust
• cadmium, elemental	• diquat
• magnesium oxide	• graphite
• synthetic vitreous fibers	• kaolin
• silica, amorphous (diatomaceous earth)	• mica
• nickel (elemental, soluble & insoluble compounds)	• paraquat
• nickel subsulfide	• particulate not otherwise classified (PNOC)
• particulate not otherwise classified (PNOC)	• silica (amorphous, fume, fused, & crystalline)
• soapstone	• soapstone
• wood dust, hard & soft woods (proposed)	• talc
	• vanadium pentoxide

Noise Monitoring

Noise Induced Hearing Loss

The precise impact of noise exposure on the auditory system is complex. Effects depend upon such variables as the frequency pattern of the noise, sound level, exposure duration, and whether or not it is continuous or impulse noise. Apart from acoustic trauma, such as from an explosion, noise has two main effects on hearing: an acute effect known as a temporary threshold shift (TTS) and a chronic effect known as noise-induced permanent threshold shift (NIPTS). In this context, the terms acute and chronic do not refer to the rapidity of onset of the effect, but to the duration of the effect. A TTS is a reversible condition and NIPTS is irreversible.

In general, prolonged exposure to excessively loud noise first injures, and then destroys, the hair-like cells (cilia) which line the cochlea in the inner ear. The cilia are responsible for transforming the mechanical energy of sound from the middle ear to electrical energy in the inner ear, which is transmitted to the auditory nerve. Damage typically occurs to cilia cells responsible for the perception of sound between 3000 and 6000 hertz (Hz), but most often at the 4000 Hz location. With continuing exposure to excessive noise levels, the damage broadens, producing ever increasing losses at neighboring frequencies, while continuing to worsen at 4000 Hz. The damage continues to spread with continued exposure and eventually leads to hearing losses in the 500 to 2000 Hz range, which encompasses the speech frequencies. Until the damage reaches these frequencies, an individual may not even realize that permanent damage has occurred. The progression of damage to the speech frequencies is gradual and may take years to develop, depending on the duration and level of noise exposure. Detecting early damage through a hearing conservation program is the key to preventing it from spreading to the speech frequencies.

Hearing loss is not the only adverse effect of excessive noise. Noise may affect one's job by causing increased errors and reduced quality. Noise has also been associated with increased fatigue, stress, and cardiovascular disorders.

Why Conduct Noise Monitoring?

- Identify potential noise hazards that may produce a permanent noise-induced hearing loss
- Regulatory compliance
- Input to a company's hearing conservation program (HCP)
- Safety considerations regarding communication

OSHA Noise Standard

To determine the hazard associated with a noise exposure the duration of exposure is a critical factor. For this reason the OSHA noise standard (29 CFR 1910.95) is based on an eight-hour time-weighted average (TWA) exposure (or noise levels and corresponding exposure times that are equivalent to an eight-hour exposure). The standard actually consists of the following two exposure limits:

- **Permissible exposure limit (PEL) = 90 decibels, A-weighted (dBA):** feasible engineering controls must be initiated if the TWA exposure exceeds this level (for most jurisdictions the requirements for engineering controls are not enforced until TWA exposures exceed 100 dBA). If engineering controls cannot lower the exposure below 90 dBA then hearing protection is mandatory.
- **Action level (AL) = 85 dBA,** if the TWA exposure equals or exceeds this level then a hearing conservation program is required.

The OSHA noise standard is based on a 5 dB exchange rate. This means that as the sound level is increased 5 dB above the PEL, the allowable exposure time is decreased by 50%.

Exposure to continuous steady-state noise is limited to 115 dBA while impulse or impact noise is limited to 140 dBA.

Noise Measurement Devices

The two basic instruments used to evaluate noise exposures are the:

- Sound Level Meter
- Noise Dosimeter

Sound Level Meter (SLM)

The main function of the sound level meter is to determine instantaneous or real time sound pressure levels. It is often used to identify areas of high noise exposure that may need a more detailed evaluation. It may also be used to verify noise dosimeter results. The basic components of a sound level meter consist of the:

- **microphone**
 - ⇒ converts pressure variations to an electrical signal
 - ⇒ weakest link in the system
- **processing unit**
 - ⇒ amplifies the signal received from the microphone
 - ⇒ performs the conversion of sound pressure to decibels
 - ⇒ electronic filters (A, B, & C weighting)
- **display/readout**
 - ⇒ digital or analog
 - ⇒ fast/slow response

Considerations for using a sound level meter in the field include:

- **Where to measure**
 - ⇒ for the purpose of evaluating personal noise exposures the sound level needs to be measured in the area where the employee spends the majority of time
 - ⇒ measurement needs to be measured at ear height
 - ⇒ meter needs to be at arms length from body
 - ⇒ the measurement distance from the source should always be noted
- **Meter response (slow/fast) and weighting**
 - ⇒ OSHA requirements call for the meter to be set to slow response and A-weighted
- **Microphone orientation**
 - ⇒ dependent on the type of microphone
 - ⇒ most meters in the U.S. are equipped with random incidence microphones which require the microphone not be pointed directly at the source. A good rule of thumb is to orient the microphone at a 70° angle to the source
- **Wind**
 - ⇒ wind blowing across a microphone can cause a positive error
 - ⇒ error can be eliminated by using a wind screen
- **Calibration**
 - ⇒ For accurate measurements the sound level meter should be calibrated before each set of measurements and after the measurements are complete

Noise Dosimeters

Due to high worker mobility and variable noise levels obtaining accurate average exposures with a sound level meter can be difficult. Noise dosimeters are basically sound level meters with a built in time function. They allow for personal sampling by clipping the microphone on the shoulder and clipping the processing unit onto the belt. Through the integration of time and sound levels they calculate a noise dose (% of the allowable exposure) and the average noise exposure. Based on an eight-hour exposure a dose of 100% is equivalent 90 dBA and a dose of 50% is equivalent to 85 dBA. This is based on the following equation:

- $\text{Sound level} = 90 + 16.61 \log(\text{dose}/100)$

The following terms are associated with noise dosimeters:

- **Criterion level:** the continuous equivalent A-weighted sound level that equals 100% of the allowable exposure.
- **Exchange rate:** the increase in sound level necessary to reduce the exposure by 50%.
- **Instrument Threshold:** the A-weighted sound level at which the instrument begins to integrate

For OSHA compliance monitoring the dosimeters must be set at a criterion level of 90 dBA, and an exchange rate of 5 dBA. The threshold setting will depend on the purpose of the monitoring. For determining the need for engineering controls the threshold setting must be at 90 dBA and for determining the need for a hearing conservation program the threshold setting must be set at 80 dBA. Older model dosimeters will only allow one threshold setting at a time but newer models can monitor with both threshold settings and indicate results corresponding to each setting.

Concerns when Using a Noise Dosimeter:

- **microphone orientation**
 - ⇒ preferably midway between the head and end of shoulder
 - ⇒ always pointing up
 - ⇒ preferably on the side nearest the ear receiving the highest sound
- **temperature**
 - ⇒ check manufacturer's literature
- **wind** (e.g., fans, tow motor operator)
 - ⇒ wind blowing across a microphone can cause a positive error
 - ⇒ error can be eliminated by using a wind screen
- **magnetic fields**
 - ⇒ can cause error by inducing current in instrument's circuitry
 - ⇒ most newer models are shielded, however, still do not always offer protection

Types of Surveys

- **Basic screening survey**
 - ⇒ typically performed when an area is surveyed for the first time
 - ⇒ conducted to identify areas where noise may exceed 85 decibels
 - ⇒ if noise is not highly variable the data collected here may be sufficient to satisfy the measurement objectives of the HCP
 - ⇒ typically involves the use of a sound level meter
- **Detailed survey**
 - ⇒ required where noise exposures are variable or workers are mobile
 - ⇒ typically involves the use of a sound level meter and dosimeter
- **Engineering control survey**
 - ⇒ conducted when specific equipment is identified as the major contributor to an exposure
 - ⇒ also conducted on new equipment to verify noise specifications
 - ⇒ involves more advanced instrumentation such as octave band analyzers and sound intensity meters

LAB 1 PROBLEM SET

(Answers are to be provided on a separate piece of paper)

1. You take a series of personal samples for xylene throughout an employee's eight-hour work shift. The sample times are as follows:

- Sample 1: 120 minutes
- Sample 2: 120 minutes
- Sample 3: 80 minutes
- Sample 4: 160 minutes

The lab results are as follows:

- Sample 1: 310 ppm
- Sample 2: 225 ppm
- Sample 3: 515 ppm
- Sample 4: 130 ppm

What is the employee's eight-hour time-weighted average exposure to xylene?

2. Answer the following questions based on the following information:

You sample for acetone with a low-flow pump using activated charcoal.

Pre-calibrated flow rate = 55 ml/minute
Post-calibrated flow rate = 53 ml/minute

A morning and afternoon sample is collected during the following sample times:

<u>Morning</u>	<u>Afternoon</u>
Pump Start: 6:15	Pump Start: 11:00
Pump Stop: 10:15	Pump Stop: 3:00

The lab reports a mass of 150 micrograms (μg) of acetone for the morning sample, and 250 μg acetone for the afternoon sample.

- a) What is the sampling time in minutes for each sample?
- b) What is the volume of air in liters collected for each sample?
(These volumes are reported to the lab)
- c) What is the result of each sample in milligrams of contaminant per cubic meter of air (mg/m^3)?
- d) What is the result of each sample in parts of contaminant per million parts of air (ppm)?
MW of acetone = 58
- e) What is the employee's 8-hour time-weighted average exposure?

3. A given quantity of gas has a volume of 34.0 liters at 13°C and 748 mmHg. What would its volume (in liters) be at 21°C and 757 mmHg?
4. The volume of air collected during sampling was 150 ft^3 at 90°F and 770 mmHg. What is its volume (in liters) at 10°C and 750 mmHg?

Calibration Form

PUMP CALIBRATION RECORD

COMPANY: _____

SURVEY DATE: _____

Pre-Calibration Date: _____

Post-Calibration Date: _____

Pump#	Flowrate				Avg.

Pump#	Flow rate				Avg.

Pump#	Avg. Flow rate

COMPANY: _____

SURVEY DATE: _____

Pre-Calibration Date: _____

Post-Calibration Date: _____

Pump#	Flow rate				Avg.

Pump#	Flow rate				Avg.

Pump#	Avg. Flow rate

COMPANY: _____

SURVEY DATE: _____

Pre-Calibration Date: _____

Post-Calibration Date: _____

Pump#	Flow rate				Avg.

Pump#	Flow rate				Avg.

Pump#	Avg. Flow rate

*All calibrations performed with a BIOS Dry-Cal calibrator.

*All flow rates in LPM

Industrial Hygiene Field Sampling Data Sheet

<p>Pump (high/low) #: _____ Sample ID: _____ Media type: _____ Name: _____ - Work Location: _____ Cal Flow Rate: _____ / _____ / _____ (Bios Dry-cal lite) pre post avg Min/Max volume: _____ / _____ Time On: _____ On: _____ Min: _____ Off: _____ Off: _____ Liters: _____ Lunch time: _____ Air temp: _____ Count On: _____ Count Off: _____ <u>Comments:</u> work performed, equip used, feeds/speeds, control equip, ppe</p>	<p>Pump (high/low) #: _____ Sample ID: _____ Media type: _____ Name: _____ - Work Location: _____ Cal Flow Rate: _____ / _____ / _____ (Bios Dry-cal lite) pre post avg Min/Max volume: _____ / _____ Time On: _____ On: _____ Min: _____ Off: _____ Off: _____ Liters: _____ Lunch time: _____ Air temp: _____ Count On: _____ Count Off: _____ <u>Comments:</u> work performed, equip used, feeds/speeds, control equip, ppe</p>
<p>Pump (high/low) #: _____ Sample ID: _____ Media type: _____ Name: _____ - Work Location: _____ Cal Flow Rate: _____ / _____ / _____ (Bios Dry-cal lite) pre post avg Min/Max volume: _____ / _____ Time On: _____ On: _____ Min: _____ Off: _____ Off: _____ Liters: _____ Lunch time: _____ Air temp: _____ Count On: _____ Count Off: _____ <u>Comments:</u> work performed, equip used, feeds/speeds, control equip, ppe</p>	<p>Pump (high/low) #: _____ Sample ID: _____ Media type: _____ Name: _____ - Work Location: _____ Cal Flow Rate: _____ / _____ / _____ (Bios Dry-cal lite) pre post avg Min/Max volume: _____ / _____ Time On: _____ On: _____ Min: _____ Off: _____ Off: _____ Liters: _____ Lunch time: _____ Air temp: _____ Count On: _____ Count Off: _____ <u>Comments:</u> work performed, equip used, feeds/speeds, control equip, ppe</p>

Air Sample Table

COMPANY: XYZ Corporation
 SURVEY DATE: December 31, 2005

SURVEYOR: Ken Wilson, CIH
Ohio Bureau of Workers' Comp.
Division of Safety & Hygiene

TABLE 1

AIR MONITORING RESULTS

NAME	JOB	CONTAMINANT	TIME SAMPLED (Hrs: min.)	CONCENTRATION DETERMINED (mg/m ³)	OSHA PEL (mg/m ³)	ACGIH TLV (mg/m ³)
Don Bentley	Cut-off Saws & Grinders -Panther PA10 cut-off saw & bench top grinders LEV present on grinders	Chromium	8:03	0.00026	0.5	0.5
		Nickel		0.00026	1	N.A.L.

- OSHA PEL - Occupational Safety and Health Administration Permissible Exposure Limit
- ACGIH TLV - American Conference of Governmental Industrial Hygienists
- mg/m³ - Milligrams of contaminant per cubic meter of air
- N.A.L. - No Applicable Limit
- LEV - Local exhaust ventilation

OSHA Standard 29 CFR 1910.1020 provides employees and their designated representatives a right of access to relevant exposure and medical records. Each employee must be informed upon first entering into employment, and annually thereafter, of 1) their right of access to such records, 2) the existence, location, and availability of such records, and 3) the person responsible for maintaining and providing access to such records.

Formulas & Calculations

Standard Temperature & Pressure (STP):

- the designation given to an ambient condition in which the barometric pressure (**P**) is:

1 atmosphere
760 mm Hg
14.70 psia
0.00 psig
1.013.25 millibars
760 Torr

and the ambient temperature (**T**) is:

0° C
32° F
273° K
460° R

Normal Temperature and Pressure (NTP):

-the designation given to an ambient condition in which the barometric pressure (**P**) is:

1 atmosphere
760 mm Hg
14.70 psia
0.00 psig
1.013.25 millibars
760 Torr

and the ambient temperature is:

25° C
77° F
298° K
537° R

Kelvin and Rankin are considered absolute temperatures

Temperature Conversions:

$$^{\circ}\text{R} = ^{\circ}\text{F} + 460$$

$$^{\circ}\text{K} = ^{\circ}\text{C} + 273$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.556$$

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Concentrations:

Parts per million (ppm) by volume: The concentration of gases and vapors is usually expressed in parts of contaminant per million parts of air. This is a volume-to-volume relationship.

$$ppm = V_{gas} / V_{air} \times 10^6$$

$$ppm = V_p / V_{atm} \times 10^6$$

Percent by volume:

$$\text{Volume \%} = V_{gas} / V_{air} \times 100$$

Relationship between ppm and % volume

$$ppm = 10,000 \times \text{Volume \%}$$

Sometimes concentrations are expressed in milligrams per cubic meter (mg/m^3), a mass-to-volume relationship. The following formula is used to convert between mg/m^3 and ppm at NTP:

$$ppm \times MW = \text{mg}/\text{m}^3 \times 24.45$$

Since the gas molar volume is affected by temperature and pressure an adjustment must be made if ambient conditions differ from NTP.

$$(ppm)(MW/24.45)(298^\circ K/T_2)(P_2 / 760 \text{ mmHg}) = \text{mg}/\text{m}^3$$

Sometimes conditions are such that one can calculate the vapor concentration of a known amount of material in an area by applying the following formula:

$$C = \frac{(V_m)(\rho)(24.45)(T_2)(760)(10^6)}{(V_T)(MW)(273)(P_2)}$$

V_m = volume of material in ml

ρ = density in g/ml

T_2 = temperature in K

V_T = total volume of area in liters

MW = molecular weight in grams per mol

P_2 = pressure in mmHg

Air Sampling

Time-weighted Average (TWA) concentration:

$$C_{TWA} = \frac{C_1 T_1 + C_2 T_2 + C_3 T_3 \dots + C_n T_n}{T_{total}}$$

C_n = measured concentration in time interval n

T_n = amount of time in time interval n

T_{total} = total time (usually 8 hours)

Sampling Flow rate:

$$R = V/T$$

R = flow rate in liters per minute

V = volume of air sampled in liters

T = sampling time in minutes

From this you can determine the sample volume also.

Corrected Sample Volume (or Flow rate):

$$V_2 = V_1 \times (P_1 / P_2) \times (T_2 / T_1)$$

V_1 = volume collected at sampling location

V_2 = volume corrected to NTP

P_1 = pressure at sampling location

P_2 = 760 mmHG

T_1 = temperature at sampling location

T_2 = 298⁰ K

This assumes calibration was conducted at NTP.

Glossary

ACGIH	American Conference of Governmental Industrial Hygienists.
Accuracy	The closeness of a measured value to its true value.
Action Level (AL)	In general, the level of a pollutant which specified actions or counter measures are to be taken.
Active Sampling	Involves the use of a pump to pull the air being sampled through or into the sampling media.
Adsorption	Adherence of the gas or vapor onto the surface of another substance, called the adsorbent.
Aerosols	Liquid droplets or solid particles with a fine enough particle size to stay dispersed in the air for a prolonged amount of time.
Agents	Elements in a workplace such as chemicals, physical and biological items.
AIHA	American Industrial Hygiene Association.
Air Monitoring	The sampling for and measuring of contaminants in air.
Air Sampling Pump	The primary device used in active sampling to draw air through sampling media. Air sampling pumps are often classified by their flow rate.
Calibrate	To check adjust, or systematically standardize the flow rate of an air sampling pump.
Ceiling Limit (c)	The concentration of airborne contaminant that should never be exceeded at anytime during a work shift.
Clearance Sampling	Air sampling performed to verify decontamination of an area is sufficient enough for re-occupancy.
Derivatization	The process of converting a reactive compound into a distinct, more stable compound.
CIH	Certified Industrial Hygienist.
Dusts	Solid particles which are created when materials (e.g. Rock, metal, wood, grain, ore, etc) are crushed, ground, detonated and faced with rapid impact. They can also be created through material handling.
f/cc	Fibers per cubic centimeter.
Fibers	Solid particles which are longer than 5 microns and have a length to diameter ratio of 3 to 1 or greater. Examples include asbestos, glass fibers, ceramic fibers, carbon fibers.
Full-shift Consecutive Sample	A series of samples collected consecutively throughout a work shift.
Full-shift Single Sample	A single sample collected during a work shift.
Fumes	An aerosol which is formed when the material from a volatized solid condenses in air. Fumes are not vapors. Fumes can often be found around welding operations due to the reactions of the metals to the heat.

Gas	A state of matter which (at normal temperature and pressure, 25 degrees C and 760 mm mercury) has very low density and expands or contracts to occupy the space of enclosure in which it is confined relative to changes in temperature and/or pressure. Examples: carbon monoxide, chlorine, oxygen, nitrogen.
Hazard	A possible source of danger or risk.
High-flow Pump	1 – 4 liters per minute (LPM). Typically used for aerosol sampling but can be used for gases/vapors.
High-volume Pump	8 – 30 (LPM). Uses include environmental sampling and clearance sampling.
IDLH	Immediately Dangerous To Life and Health.
Impinger (midget)	A small glass bottle normally filled with a specific liquid that will absorb airborne chemicals when air containing the contaminant is bubbled through it.
Inhalable Particulate Mass	Materials that are hazardous deposited anywhere in the respiratory tract. Particle sizes up to 100 microns.
Instantaneous (Grab) Sample	A sample taken within a short time period, generally to determine the contaminants at a specific time or during a specific event.
Low-flow Pump	0.5 – 200 milliliters per minute (ml/min). Primarily used for gas/vapor sampling.
Mg/M3	Milligrams per cubic meter.
Mists	An aerosol of liquid droplets suspended in air, usually generated by the breaking up of a liquid by splashing, atomizing or forming. Examples include oil/coolant mists, acid mists.
NIOSH	National Institute for Occupational Safety and Health.
OSHA	Occupational Safety and Health Administration.
Partial Period Consecutive Sample	Samples collected throughout a work shift but with some of the shift not sampled.
Passive Diffusion Sampling	Air sampling that relies on the principle of diffusion to allow the air being sampled to contact the sampling media.
Permissible Exposure Limit (PEL)	Legally permissible concentration of a contaminant, established by OSHA, that one shall not be exposed above during the course of their work.
Personal Protective Equipment	Specialized clothing or equipment worn by an employee for protection against a hazard. General work clothes (e.g., uniforms, pants, shirts or blouses) not intended to function as protection against a hazard are not considered to be personal protective equipment.
PPE	Personal Protective Equipment. This includes things like gloves, respirators, aprons, boots etc.
PPM	Parts Per Million. A unit of measurement.

Precision	The degree to which replicate measurements differ from one another.
Pump Calibration	See “calibrate.”
Real Time Monitoring	The use of instrumentation to detect and quantify air contaminants. Also known as direct-reading instruments.
Respirable Dust	Materials which can penetrate to the alveolar (gas exchange) region of the lung. Particle sizes up to 10 microns.
Respirable sampling	Air monitoring for respirable dust that utilizes a particle separator known as a cyclone.
Rotometer	A flow meter consisting of a transparent tube with a solid float inside.
Short Term Sample	Typically, 15-minute samples collected because the contaminant has a STEL and the process or activity performed dictates that high exposures will be encountered for short periods of time.
Short Term Exposure Limit (STEL)	Maximum airborne concentration for continuous 15-minute period. Allowed four times a day, with at least 60-minutes between exposures.
Thoracic Particulate Mass	Materials that are hazardous deposited with the lung airways and the gas exchange region. Particle sizes up to 25 microns.
Threshold Limit Values (TLV)	The maximum recommended concentration of a contaminant, established by ACGIH, that one should be exposed to during the course of their work.
Time Weighted Average (TWA)	Average exposure for an individual over a given working period, as determined by sampling at given times during the period.
Total Dust	Both non-respirable and respirable material that can be collected into a 37 mm cassette. Particle sizes up to 100 microns.
Toxic Effect	Harmful effects on the body as a result of contact with a hazardous substance.
Toxicity	The capacity of a material to harm or injure a living organism.
Vapors	An air dispersion of molecules of substances which is a liquid in its normal state. Often confused with fumes, vapors are actually the volatile form of substances that are generally found in a solid or liquid state in the proper environment. Vapors are caused by the evaporation of the material in question.