Air Monitoring Guide

A Special Insert Contributed by

Dennis Ertel

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American Institute for Conservation of Historic & Artistic Works
1717 K Street, NW • Suite 200 • Washington, D.C. 20006
(202) 452–9545; Fax: (202) 452–9328; info@aic-faic.org; http://aic.stanford.edu

Introduction

Monitoring environmental conditions in the workplace or in the outdoor environment is an important tool in assessing potential hazards or exposures to various chemical compounds, biological agents and physical parameters. Monitoring can be done in many media, to include air, water, soil, dust and food. This guide will focus on sampling in only one medium, namely air.

Air sampling is the process of capturing some aspect of the air or a portion of the environment, which will hopefully represent the environment as a whole. The environment can be either an outdoor area or a smaller enclosed space such as workplace, residence or other space. Traditionally air sampling is done in the outdoor air by environmental scientists and in the workplace, or indoor environment, by industrial hygienists. While the tools are similar for monitoring workplaces and monitoring environments (including environments inside museums, such as display cases or galleries), the precise applications and response levels vary. Since conservators may find themselves in many different environments, it is appropriate to be aware of how and when the air should be monitored and in certain situations and conservators may find that they need to perform their own monitoring.

This guide is organized to introduce the conservator to the principals and purposes of air sampling, air sampling instruments, sampling issues and interpreting air-monitoring results. There are sidebars to this guide that define technical terms and abbreviations, as well as outline sources for monitoring equipment and reference materials.

Purpose: Exposure Assessment

There are a number of reasons to conduct air sampling or air monitoring. The overriding reason to monitor and conduct assessments is to evaluate the potential hazards in the workplace air as part of a comprehensive health and safety program. Based on the specifics of the environment, monitoring might include assessing exposure to chemical compounds, biological agents (such as fungi or molds, anthrax, or dust mites) or physical characteristics of the environment (such as temperature, humidity or airflow). These various chemical compounds, biological agents or physical characteristics will be referred to in this guide as "agents or characteristics." The primary reasons to monitor are:

- Evaluate compliance with regulations and laws
- Estimate exposure for protection of staff
- Estimate exposure for protection of the public
- Estimate concentration for protection of collections, objects, or artifacts
- Estimate effectiveness of ventilation or other contaminant controls

The decision to monitor can be based on a number of issues, including those listed above, and may take other reasons or factors into account. If there is a reasonable chance that conditions or concentrations will exceed occupational exposure levels—such as the Permissible Exposure Level (PEL) published by the Occupational Safety and Health Administration (OSHA)—there is an obligation under the OSHA regulation to evaluate the conditions, and this is routinely done by monitoring the air.

A workplace evaluation normally begins with a close look at the operations, especially the materials or products used in the immediate workplace, adjacent areas and the ambient environment. This evaluation may include a review of processes, equipment used, chemicals or products used (which often calls for a review of material safety data sheets or MSDSs), and other factors affecting the workplace environment. The evaluation could consist of the following steps:

1. Determine the agents or characteristics that will be monitored. For example, is the stressor a chemical, biological hazard, etc.
2. Obtain the sampling and analytical methods available for this stressor. Sampling and analytical methods are available from the National Institute for Occupational Safety and Health (NIOSH), OSHA, the US Environmental Protection Agency (EPA) and other agencies and private laboratories. Review the method(s) to determine the best approach to sample for this stressor. The type of samples to be collected may influence the method selected. Limitations on sampling time may also dictate that a method with a low limit of detection be utilized.
3. Once the sampling method is determined, the sampling strategy should be designed. Designing a sampling strategy is discussed below.
4. Conduct the sampling, survey, or monitoring.
5. Analyze samples, if necessary. (not applicable for sampling with direct-read instruments)
6. Interpret sampling results.
7. Make recommendations or implement controls, based on the results.

8. Document the assessment and results of the analyses.

Sampling Strategy: Selecting What Agents and Characteristics To Sample

The end results of the workplace evaluation may lead to the decision to conduct further assessment of workplace agents or characteristics that are of concern. For example, extensive use of a toluene-based solvent in a process with limited ventilation is likely to lead to the decision to perform workplace air monitoring for toluene. The specific hazard will define the sampling and analytical method to be used. Do several agents or characteristics have to be monitored simultaneously? Sometimes it is not possible to sample the contaminant in question, but another agent can be sampled and the data used to determine the maximum level of the contaminant in question.

If the decision to conduct air monitoring is made, a number of issues will have to be considered, based on the specific concerns or situation. The goal of an air-monitoring program is to quantify exposure conditions. A sufficient number and types of samples must be taken to permit the determination of the range of exposure to agents or characteristics on a daily basis. That number will depend on the variability of work conditions that affect exposures. The sampling or monitoring can be done in a number of ways. Air monitoring would normally be done in one of the following manners:

- Breathing Zone (BZ) or personal samples: a monitor is placed in the immediate vicinity of an individual's breathing zone. Traditionally a sample tube or filter is attached to the individual's shirt collar.
- Area samples: Monitoring is conducted in the general area of the individuals or operations of concern. This type of sampling would also be appropriate for evaluating the contact or exposure of objects or collections to "agents or characteristics."
- Source samples: Monitoring done in the immediate vicinity of a source of "agents or characteristics." In the toluene-based solvent example, this could be sampling done in the immediate vicinity of the container of toluene.

The length of time that monitoring is performed is also a consideration. Whether or not exposure is expected to be consistent throughout a time-period of interest will play a large role in this decision. Full-shift sampling may be done for agents or characteristics that are expected to be present throughout a "work-shift." Short-term or "Grab" sampling may be done for exposures of short duration, especially if the majority of the anticipated exposure is likely to occur in a very short time frame.

The duration of monitoring may also be influenced by the need for analytical sensitivity of the methods employed during the monitoring—with some methods longer monitoring periods may be needed to collect enough air to reach an acceptable analytical sensitivity. Longer term monitoring, greater than a work-shift to many weeks, may be appropriate in evaluation of some environmental conditions, especially if little is known about the concentrations or likely timing of exposure.

Sampling Strategy: Selecting When To Sample

The decision about when to sample will also need to be considered. The initial basis should come from the workplace evaluation. If it is determined that an unacceptable exposure is likely only during a "worst case" situation, or if it is unclear if an excessive exposure may occur, then monitoring should be arranged to evaluate the "worst case" (please remember that "worst case" is very subjective and somebody else may be able to imagine a worse "worst case"). If no overexposures are found under "worst case" sampling conditions, then it is unlikely that other work cases will result in excessive exposures.

If exposures are likely to be at consistent levels and no "worst case" situation exists, or if there are elevated exposures detected during "worst case" sampling, sampling under routine conditions should be conducted. Routine sampling will help determine if there is a likelihood of potentially unacceptable exposures during everyday activities. Periodic sampling may be necessary if levels of agents or characteristics are detected but slightly below unacceptable exposures.

Sampling Strategy: Who should do sampling?

The decision of who should do sampling or monitoring should be made depending on the level of sophistication of a sampling strategy and the experience of the potential sampling personnel. If compliance with OSHA or EPA regulations, injuries to members of the public, or litigation are possible, experienced, and preferably certified, industrial

Definitions

ACGIH: American Council of Government Industrial Hygienists

Aerosol: Solid or liquid of microscopic size dispersed in a gaseous medium, solid or liquid, suspended in air (e.g., dust, fumes, fog and smoke) (from DiNardi)

Analytical Methods: Detailed laboratory procedures that specify how to measure the amount of chemicals collected on the sampling media (from DiNardi)

Calibration: The establishment of a relationship between various calibration standards and the measurements of them obtained by a measurement system, or portions thereof (from DiNardi)

CIH: Certified Industrial Hygienist

Detection Limit: The lowest level at which an analysis can reliably identify the chemical compound of interest.

EPA: Environmental Protection Agency

Grab Sampling: The direct collection of an air-contaminant into a device such as a sampling bag, syringe, or evacuated flask, over a few seconds or minutes (from DiNardi)

MSDS: Material Safety Data Sheet

NIOSH: National Institute for Occupational Safety and Health

OSHA: Occupational Safety and Health Administration

Oxygen Deficient Atmosphere: An atmosphere containing less than 19.5% oxygen by volume (OSHA) (from DiNardi)

PEL: Permissible Exposure Limit

RBC: Risk Based Concentration

TLVs: Threshold Limit Values (published by the ACGIH)

Sorbent Tube: A small glass tube normally filled with two layers of a solid sorbent material that will adsorb specific chemical for subsequent elution and laboratory analysis (from DiNardi)

VOCs: Volatile Organic Compounds: Any organic compound that participates in atmospheric photochemical reactions. (from DiNardi)

hygienists or environmental scientists are recommended. Although environmental scientists or an industrial hygienists are the individuals with the most experience performing monitoring or sampling, in some situations other professionals in the conservation or museum community could perform necessary sampling or monitoring. If a conservator or museum staff member decides to conduct sampling, it is essential that they be familiar with the techniques to collect the samples, how to interpret the data, and very comfortable with how to use the sampling equipment and instruments.

Air Sampling Instruments

Air sampling can be performed using a large variety of different instruments. Air sampling pumps can be connected to various sample collection containers (such as filters, sorbent tubes and canisters). Instruments that provide an instantaneous or direct-reading capability can be used to measure various agents or characteristics. Passive monitoring equipment can also be used to measure or quantify various agents or characteristics. Passive monitoring and air sample collection usually provides results presented as time-weighted averages and direct read instruments usually give instantaneous concentrations or measurements.

Direct Read Instruments

Direct-read instruments, also known as real time monitors, are available to measure chemical concentrations and many physical characteristics of the air. Many direct read instruments can also be used in a long-term monitoring mode that allows data-points to be stored over an extended period of time. The following list outlines many direct read instruments:

- Gas Monitors: Instruments are available to measure concentrations of many chemical compounds, to include carbon monoxide, carbon dioxide, hydrogen sulfide, ethylene oxide, volatile organic compounds (VOCs) and many more compounds. Some instruments are specific to one compound, others have sensors for many compounds and some are non-specific to a certain type of chemical compound (such as VOCs). These instruments have the capability to detect concentrations as low as one part per million (ppm) for many compounds and as low as 10 parts per billion (ppb) for VOCs. Gas monitors typically employ an electro-chemical sensor to measure chemical concentrations. Oxygen monitors are also available and very important when entering oxygen-deficient atmospheres and confined spaces.

- Dust/Aerosol/Particle Monitors: These instruments evaluate particle counts in the air. While the "particles" measured are non-specific, if the sampler knows what type of particles are likely to be in the air, one can make some assumptions about the particles detected with these instruments. Some particle counters can detect levels as low as 0.1 milligrams (of particles) per cubic meter of air (mg/m^3). Particle counters typically employ a light scattering device and an optical sensor to measure particle concentrations.
- Temperature and Relative Humidity Meters: Instruments are available to measure temperature and relative humidity. Many models offer both the ability to collect grab sample type measurements and long-term monitoring. The temperature and relative humidity meters usually use electrochemical sensors to determine temperature and relative humidity.
- Air Flow Meters: Used to measure airflow in specific areas and is commonly used to evaluate ventilation effectiveness. Most air flow meters operate by either measuring a temperature change in a sensor relative to the speed of the airflow or by simply measuring the movement of a vane (like a small fan blade) within the instrument.

With all direct-read instruments, it is important to understand the proper use of the instrument, the limitations of the instrument and the maintenance and calibration requirements of the instrument. Often direct-read instruments will be used in conjunction with the use of other sampling methods, such as air sample collection and analysis.

Air Sample Collection and Analysis

Air samples can be collected and analyzed to determine the concentrations of certain chemical or biological agents. Samples are traditionally collected by drawing a known volume of air through a sample media or filter at a specific airflow rate. Agents are then absorbed, adsorbed, captured, or collected on to the sample media which can then be analyzed by laboratory analyses. Laboratory analytical techniques are published by many entities, including NIOSH, OSHA and the EPA. The laboratory methods for most chemical analyses are available on-line through these organizations, and outline sample collection techniques (such as media, air flow rates, sample collection times and analytical sensitivity) in addition to the laboratory techniques.

Different types of air sample media are used for different types of agents. The following list describes some of the more common media.

- Sample Filters: Sample filters are typically used to collect chemical agents that are present in the air as dusts/particles/aerosols, fibers, fumes, mists or other materials that act like particles. Filters made of different materials, depending on the use, and may include the following materials: cellulose fibers, glass, PVC, quartz and others. Results from filter sampling are typically reported as a weight per volume of air, such as mg/m^3. Accessories, such as cyclones and elutriators, may be used in conjunction with filters to perform sampling of specific size ranges of particulates.
- Sample Sorbent Tubes: Tubes are typically used to sample gases and vapors. The sample tubes are usually made of a cylinder of adsorbent material that is inside of a glass tube. As the air is drawn through the tube chemical compounds are adsorbed to the media. When the media is analyzed at the laboratory, the chemical compounds are desorbed from the media and then analyzed using various analytical tools. Sample tube media may be made of activated charcoal, coconut shell charcoal, silica gel or other proprietary compounds. Results from tube samples are typically reported in ppm or ppb.
- Indicator Tube Sampling: Indicator tubes are similar to sample sorbent tubes in size and materials but have different chemical media that will provide an observable reaction to the chemical compound of interest. The colorimetric reaction, or change in color of the media, is observable and the area that has changed color corresponds to marks on the side of the tube that provide an estimate of the chemical concentration. This is a simple alternative to sample sorbent tubes, but is less precise, likely has a higher detection limit and indicator tubes are not available for as many compounds as sample sorbent tubes.
- Passive Monitors: Passive monitors are also available to measure air concentrations of various agents. Passive monitors are usually made-up of a sorbent media field that is exposed to the environment. Air diffuses across the media without the use of an air-sampling pump. The media comes as a sample tube, badge, paper or test stick

(looks like a cotton swab). The agents present in the air that passively reacts with the media is adsorbed or absorbed to the media. Some passive sample media show a colorimetric reaction and others require laboratory analysis.

- Bioaerosol Sampling: According to the American Council of Government Industrial Hygienists (ACGIH), "bioaerosols include microorganisms (culturable, non-culturable, and dead microorganisms) and fragments, toxins, and particulate waste products from all varieties of living things." Bioaerosols would include fungi and molds. Air samples are primarily collected using air-sampling pumps with either impactor samplers and Petri dishes with agar media, or filter cassettes with tacky slides. Analyses can be performed for either the viable portions of bioarosols or for total spore counts. Results are usually presented in units of either colony forming units of organisms per cubic meter of air or in spores per cubic meter of air.

For all air sampling, the individuals collecting samples should be knowledgeable about the use and limitations of the sampling equipment, methods and applicability. Appropriate and uncontaminated sample media should be used. Laboratory analysis should be performed by experienced laboratories, preferably labs that are approved or accredited for the specific analysis required.

Other Sampling Issues

Calibration: Calibration, a systematic check to ensure that sampling equipment is providing reliable measurements, is an essential step in air monitoring. Air monitoring and air sampling equipment should be calibrated as recommended by manufacturer's instructions. Direct-read equipment normally requires annual calibration and routine calibration checks. Air sampling pumps are typically calibrated before and after air sampling.

Quality Control: Quality control steps should be included in air monitoring. Depending on the type of monitoring, quality control procedures might include the use of blank samples, measurements in areas with known concentrations and multiple means of conducting various measurements. It is also a good idea to review quality control information from both manufacturers of equipment and laboratories.

Interpreting Results

For many agents or characteristics, there are occupational exposure levels (OELs), environmental regulations, guidelines or other resources that provide guidance. These requirements or guidelines are usually based on established information from a mix of applicable scientific disciplines including epidemiology, toxicology, ecology, materials science and other health sciences. Some OELs, such as permissible exposure levels (PELs), published by OSHA or the Mine Safety and Health Administration (MSHA), have regulatory and legal requirements for compliance. Other OELs, such as the Recommended Exposure Limit (REL), published by NIOSH, and the Threshold Limit Values (TLVs), published by the American Conference of Governmental Industrial Hygienists (ACGIH), are based on more current scientific studies, but do not carry the regulatory or legal requirements of the PELs.

For non-occupational exposure, there are guidance levels published by EPA regions, such as Region 3's Risk Based Concentrations (RBCs), and other guidance levels from other EPA sources, the World Health Organization (WHO), and other entities. The non-occupational risk levels, such as the RBCs, are typically based on lifetime risk levels to the most sensitive members of the population, and may not be appropriate for use in all situations.

There are also some situations where there are no guidelines to rely on for data interpretation. A good example is the situation of mold or fungi. Fungi are generally evaluated with respect to two factors: concentration and the types of organisms present. Indoor concentrations should be at levels near or below outdoor levels. Indoor levels in excess of outdoor levels suggest an indoor source of fungi or bacteria contamination. In the case of fungi or chemical in which there has only been limited or no research, data interpretation requires more specialized personnel that can evaluate limited data, data from similar agents, or in some case a full risk assessment or research effort may be required. The lack of an appropriate limit does not permit concluding that the agents or characteristics do not pose a potential health risk.

For situations where there is no obvious or regulatory driven guidance on acceptable exposure, conservators should work with various parties involved in the project or at the institution to determine how to establish an acceptable exposure level. These situations may require involvement and advice from environmental or occupational health specialists, such as industrial hygienists or occupational physicians, legal representatives, risk or insurance representatives, public affairs personnel and other appropriate parties.

There may also be airborne concentrations of certain agents or characteristics that are acceptable or desirable for collections, objects or museum materials that will not be the same as those from the occupational exposure and environmental health fields. Some of these studies have been published in various journals and publications from the fields of conservation and museum studies. The listed reference, *Pollutants in the Museum Environment*, by Pamela Hatchfield, lists many concentrations of chemical compounds that are believed to be damaging to various museum materials.

For additional information on the subject of air monitoring, please consult the references and contacts listed in this guide. Other reference and links are provided in the Health and Safety area of the AIC website.

—Dennis Ertel, member of the AIC Health and Safety Committee, 839 Quince Orchard Blvd., Suite E, Gaithersburg, Md., 20878; (301) 519-6880, dennysoma@yahoo.com

References

Dillon, H. K. 1996. *Field Guide for the Determination of Biological Contaminants in Environmental Samples.* American Industrial Hygiene Association Press.

DiNardi, Salvatore R. 1997. *The Occupational Environment: Its Evaluation and Control.* American Industrial Hygiene Association Press.

Hatchfield, Pamela. 2002. *Pollutants in the Museum Environment.* Archetype Publications.

Maslansky, Carol J., and Steven P. Maslansky. 1993. *Air Monitoring Instrumentation.* John Wiley & Sons.

Plog, Barbara A. 1996. *Fundamentals of Industrial Hygiene.* National Safety Council.

Wight, Gregory D. 1994. *Fundamentals of Air Sampling.* Lewis Publishers.

Sources for Air Monitoring Equipment

Draeger Safety, Inc. (detector tubes and accessories, direct-read instruments)
101 Technology Dr.
Pittsburgh, PA 15275
(412) 787-8383
Fax: (412) 787-2207
(800) 615-5503
www.draeger.com/ST/internet/US/en/Products/Detection/detection.jsp

Lab Safety Supply (direct-read instruments and accessories)
P.O. Box 1368
Janesville, Wis. 53547-1368
(800) 356-0783
Fax: (800) 543-9910
www.labsafety.com/home.htm

Mine Safety Appliances Company (MSA) (direct-read instruments and accessories)
P.O. Box 426
Pittsburgh, Pa. 15230
(800) MSA-2222
www.msanet.com/day/1.html

Quest Technologies (direct-read instruments and accessories)
1060 Corporate Center Dr.
Oconomowoc, Wis. 53066
(800) 245-0779
(262) 567-9157
www.quest-technologies.com/index.htm

RAE Systems (direct-read instruments and accessories)
1339 Moffett Park Dr.
Sunnyvale, Calif. 94089
(877) 723-2878
(408) 752-0723
Fax: (408) 752-0724
www.raesystems.com

Sensidyne, Inc. (sampling pumps and accessories, direct-read instruments)
16333 Bay Vista Dr.
Clearwater, Fla. 33760
(727) 530-3602
Fax: (727) 539-0550
(800) 451-9444
www.sensidyne.com

SKC Inc. (sampling pumps and accessories, direct-read instruments)
863 Valley View Rd.
Eighty Four, Pa. 15330-9613
(724) 941-9701
(800) 752-8472 (USA only)
Fax: (724) 941-1369
www.skcinc.com

TSI Incorporated (direct-read instruments and accessories)
500 Cardigan Rd.
Shoreview, Minn. 55126-3996
(651) 483-0900
Fax: (651) 490-2748
www.tsi.com