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Standard Guide for Air Sampling Strategies for Worker and Workplace Protection[1]

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1. Scope

1.1 ~~To provide~~ This guide describes criteria to be used in defining air sampling strategies for workplace health and safety monitoring or ~~evaluation, such as:~~evaluation. Sampling criteria such as duration, frequency, number, location, method, equipment, and ~~timing.~~ timing are all considered.

1.2 ~~When sampling is done to determine if the conditions in the workplace are in compliance with regulations of the U.S. Occupational Safety and Health Administration (OSHA), many of these criteria, for specific hazardous substances, are stated in 29 CFR 1910.~~Where air sampling is prescribed by law or regulation, this guide is not intended to take the place of any requirements that may be specified in such law or regulation.

1.3 Guidance for surface sampling strategies for metals and metalloids is provided in Guide D7659.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
D1356 Terminology Relating to Sampling and Analysis of Atmospheres
D4840 Guide for Sample Chain-of-Custody Procedures
D7659 Guide for Strategies for Surface Sampling of Metals and Metalloids for Worker Protection
E1542 Terminology Relating to Occupational Health and Safety
2.2 ~~*Other Documents:*~~*ISO Standards:*[3]
~~29~~ISO 7708 ~~CFR 1910~~Particle Size Fraction Definitions for Health-Related Sampling
ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories
EN 1540 Workplace Exposure—Terminology

3. Terminology

3.1 For definitions of terms relating to occupational health and safety, see Terminology E1542.

3.2 For definitions of terms relating to atmospheric sampling and analysis, see Terminology D1356.

3.3 *Definitions:*

3.3.1 *alarm sampler*—sampling device that produces an alarm (audible, visible, or both) when the concentration of a substance exceeds a pre-set value.

3.3.2 *exposure (by inhalation)*—situation in which a chemical or biological agent is present in the air that is inhaled by a person.
EN 1540

3.3.3 *occupational exposure limit*—upper bound on the acceptable concentration of a hazardous substance in workplace air.

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

[3] ~~Code of Federal Regulations, available from U.S. Government Printing Office, Washington, DC 20402.~~Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

3.3.3.1 *Discussion—*

Typically established by national authorities in efforts to protect workers' health.

3.3.4 *professional judgment—*application and appropriate use of knowledge gained from formal education, experience, experimentation, inference, and analogy. **D7659**

3.3.4.1 *Discussion—*

The capacity of an experienced professional to draw correct inferences from incomplete quantitative data, frequently on the basis of observations, analogy, and intuition.

3.3.5 *sampling excursion—*duration of time during which active sampling is not being performed, typically between two durations of active sampling.

4. Significance and Use

4.1 ~~To describe~~ This guide describes standard approaches used to ~~determine~~formulate air sampling strategies before ~~any~~ actual air sampling occurs.

4.2 For ~~the majority of the purposes for sampling,~~ most workplace air sampling purposes, and for the majority of ~~the~~ materials sampled, air sampling strategies are matters of choice. Air sampling in the workplace may be done for single or multiple ~~purposes. Conflicts~~ purposes, such as health impact, hazard or risk assessment, compliance assessment, or investigation of complaints. Problems can arise when a single air sampling strategy is expected to satisfy multiple diverse purposes.

4.2.1 ~~Limitations of~~ Proper consideration of limitations of cost, space, power requirements, equipment, analytical methods, training and personnel ~~requirements~~ result in ~~an optimum~~ a best available strategy for each purpose.

4.2.2 A strategy designed to satisfy multiple purposes must be a compromise among several alternatives, and will not be optimum for any one ~~purpose.~~purpose; however, the strategy should be appropriate for the intended purpose(s).

4.2.3 The purpose or purposes ~~of~~for sampling should be explicitly stated before a sampling strategy is ~~selected. Good~~ selected in order to ensure that the sampling strategy is appropriate for the intended use. Good sampling practice, legal requirements, cost of the sampling program, and the ~~usefulness~~utility of the results may be markedly different for different ~~purposes of sampling.~~intended sampling purposes.

~~4.3 This guide will not aid in the evaluation of air sampling data.~~

4.3 This guide is intended for use by those who are preparing to evaluate ~~the~~ air quality in a work environment of a location by air sampling, or who wish to obtain an understanding of what information can be obtained by carrying out air sampling.

4.4 This ~~work was commissioned by the committee on Occupational Health and Safety because there was no document available that drew together in one place the many diverse pieces of information about air sampling covered within it. This guide cannot~~ guide should not be used as a stand-alone document to evaluate any given ~~air borne contaminant.~~airborne contaminant(s).

4.5 This guide cannot take the place of sound professional judgment in development and execution of any sampling strategy. In most instances, a strategy based on a standard practice or method will need to be adjusted due to conditions encountered in the field. Documentation of any professional judgments applied to development or execution of a sampling strategy is essential.

5. Air Sampling—General

5.1 ~~Air sampling results are~~ Results from air sampling are but one of many sources of information about workplace health and safety of ~~conditions in a workplace.~~ conditions. Air sampling should not be used to the exclusion or absence of other pertinent information.

5.2 Bioassay and biomonitoring results, clinical observations, visual observation, quality and process control data, and material balance studies, where applicable, should always be used in conjunction with air sampling data.

5.3 Qualitative agreement among separately obtained sources of information ~~should~~ will typically increase confidence in the interpretation of workplace hazard or risk assessments. Disagreement among information sources or data should be cause for concern, and ~~provoke efforts to find out why the disagreement occurred.~~will result in investigation into the source(s) of disagreement.

6. Purposes ~~of~~ for Air Sampling

6.1 *Risk Evaluation—*To estimate the expected, or maximum, or both contaminant concentrations in the workplace. The information obtained is used to recommend worker protection requirements and to assess the probability of sensitization or hypersensitivity reactions.

6.2 *Exposure Estimation*—To measure the actual concentrations of contaminant to which one particular worker is exposed. The concentrations measured may or may not be hazardous. In many cases, it is sufficient to show that any exposures are less than half of applicable limits or standards. It may be necessary to show that an exposure does not exceed an applicable limit value within a stated degree of confidence.

6.3 *Exposure Documentation*—To provide the data base necessary for epidemiological studies, when the existence of a health hazard is postulated. It is similar to exposure estimation, but is focused more on job categories or job titles, rather than on an individual worker, and requires the use of instruments and methods that minimize the likelihood of obtaining results that are below the limits of detection.

6.4 *Facility Characterization*—To determine the levels of the analyte or analytes of interest within a facility at an initial or baseline point, during or after process operations, or as part of facility decommissioning.

6.5 *Selection of Engineering Controls*—To determine, for contaminants that are not totally contained, the collection or capture efficiencies of control devices necessary to bring specific contaminant concentrations below applicable limits at specific locations.

6.6 *Evaluation of Engineering Controls*—To measure the quantities of contaminants passing or escaping from a control device due to leaks, wear, damage, inadequate maintenance, overloading, or accidents.

6.7 *Selection of Personal Protective Equipment*—To determine the protection factor required for personal protective equipment in order for a ~~worker~~person to ~~inhabit~~ work in a contaminated or potentially contaminated area for a specific period of time.

6.8 *Selection of Bioassay or Biomonitoring Procedures, or Both*—To determine the applicability of bioassay methods that estimate an individual's total dose or body burden of a material and biomonitoring methods that estimate an ~~individual's~~individual's rate of exposure or rate of uptake of a material.

6.9 *Compliance with Regulations and Standards*—To obtain the measurements required to satisfy legal requirements, or to determine if exposures in the workplace are below legal limits.

6.10 *Source Identification*—To single out the contribution of each of many potential sources of contamination, based on ~~its unique characteristics,~~ each contaminant's unique characteristics and other factors, such as emission fluctuations, wind direction and variability, dispersion conditions, and the presence or absence of distinct trace materials.

6.11 *Process Control*—To ensure that the process being monitored is proceeding according to design, that valuable materials are not being lost through leaks or side reactions, and that only those effluents expected, in the quantities expected, are being produced. This type of sampling can be used to detect and halt process changes before hazardous air concentrations are produced.

6.12 *Education and Taining*—To educate workers in the importance of sound control practices (for example, engineering controls, personal protective equipment, good housekeeping).

6.13 *Investigation of Complaints*—To resolve ~~doubts and document the seriousness of reported hazardous releases.~~ concerns expressed by workers, management, or other stakeholders.

7. Air Sampling Plans—General Considerations

7.1 Sampling plans should be fit for the intended purpose or purposes. In general, this means that the outcome of the sampling campaign will be a set of data that meets data quality objectives and can be evaluated to provide the intended information. The intended purpose or purposes should be explicitly stated before evaluating sampling options or selecting a sampling strategy. Sampling should, to the extent practicable, be representative of the exposure being assessed.

7.2 Principles of good practice, as well as applicable regulatory or legal requirements, should be considered and addressed during development of the sampling plan.

7.3 Limitations of the sampling plan should be considered and addressed. These include, but may not be limited to, the following:

7.3.1 Ability to collect samples at desired sampling locations;

7.3.2 Resource limitations such as time, cost, equipment, or trained personnel;

7.3.3 Ability of the analytical laboratory to detect and report the analyte or analytes of interest in the given sample matrix, with the required data quality objectives at the anticipated concentration range; and

7.3.4 Ability to evaluate the data, especially from a statistical perspective.

7.4 Due to one or more of the limitations described in 7.3, it may be necessary to develop a single sampling plan intended to accomplish multiple purposes (see 6.2). When this is the case, conflicts may emerge with one or more of the criteria given in Sections 9 – 11, and compromises will typically be required to optimize the overall sampling strategy. When this occurs, the resulting strategy may not be optimal for any one purpose.

7.5 Whether to collect a single sample, or a set of samples, is a key decision. Collection of a set of samples, rather than a single sample, is normally recommended for proper data evaluation. A set of samples, rather than a single sample, is normally required in the following instances:

7.5.1 When a comparison of "hot spots" to background locations is needed;
7.5.2 When required to meet regulatory requirements;
7.5.3 When a statistical evaluation of the data is needed.

7.6 The following are examples of when a single sample may be appropriate:
7.6.1 When physical limitations, such as collecting a sample on a small item or accessibility limitations, prevent the collection of multiple samples;
7.6.2 When multiple operations are being performed simultaneously; in this instance, it may not be possible to collect more than one sample per operation.

7.7 In cases where sampling is performed in response to an emergency or other urgent situation, the sampling plan typically will be based primarily on professional judgment, since planning time is at a minimum.

7.8 The sampling plan should include appropriate quality assurance measures that will provide documentation, throughout the sampling event and subsequent collection and evaluation of data from the samples, that appropriate quality standards have been met.

7.9 Documentation of how the sampling plan was developed is of great benefit in the event that issues arise in collecting or analyzing the samples, or in evaluating the data. Considerations include, for example, whether the sampling plan was statistically based.

8. ~~Where to Sample~~ Factors Affecting Air Sampling

8.1 Some of the factors affecting contaminant air concentrations include the velocity and direction of air movement, contaminant sinks, movement of personnel and equipment, source strength, and distance from the source. Small differences in location can have major ~~effects.~~influences.

8.1.1 The volume of air movement affects dilution of the ~~source.~~contaminant(s). The more air that passes the source of contaminant per unit of time, the lower the ~~plume concentration~~ contaminant concentration per unit volume is likely to be.

8.1.2 The direction of air movement determines areas of heaviest exposure ~~downwind,~~downstream, and may prevent any exposure ~~upwind. Variation in wind direction~~ upstream. Variation indirection of air movement determines the total area exposed. Where there is slow air movement, eddy currents, or air recirculation, there may be an increase in air ~~concentration with time.~~contaminant concentration with time (or pockets of higher contaminant concentrations).

8.1.3 Contaminants may be lost in a variety of sinks. Aerosol particles are subject to gravitational settling; vapor contaminants can condense on surfaces or aerosol particles; gases can be adsorbed on various surface and particles; and all can react with each other, surfaces, or normal air components.

8.1.4 Movement of personnel and equipment can change local air flow patterns significantly. Movement tends to increase the number and size of eddy currents present, ~~to resuspend~~can re-suspend settled aerosols, and ~~to~~can deflect contaminants away from local exhaust ventilation, such as hoods.

8.1.5 The rate and velocity of contaminant evolution also affects local air movement. Large or high velocity emissions ~~tend to~~ can overwhelm local airflow, while small or low velocity emissions have ~~much less effect. Emission sources of high concentration, or with compositions or temperatures, or both, that differ greatly from the surrounding air,~~ a smaller effect. High concentration emissions, emissions with compositions that differ significantly from surrounding air, or emissions whose temperatures vary significantly from surrounding air, or combinations of these factors, , may resist mixing with the air for considerable times and distances downwind.

8.1.6 Distance from the emission source is ~~very important.~~ an important factor. Contaminants usually become more dilute with ~~distance.~~ distance from the source. Samples taken outdoors usually show more variation with distance ~~than~~ from the source compared to those taken indoors, due to ~~greater~~ the greater air volume to consider, greater variations in air temperature, air pressure, wind speed, wind direction, and precipitation washout. Outdoor samples can also be distributed and diluted over a much greater range of vertical and horizontal distance. Even indoor contaminant concentrations may vary more than two orders of magnitude between ~~the floor~~ floors and ~~ceiling,~~ceilings, or between two locations more than a meter apart in any direction (**1**, **2**).[4] Samples taken from within the open face of local exhaust ventilation, with the sample inlet facing into the moving air, will almost always indicate higher concentrations than the same type of sample taken at or beyond the edge of the opening (**3**).

8.2 It is essential that air samples be taken as close as possible to the location of interest, as determined by the purpose of sampling.

8.2.1 Samples taken for the purpose of selection of engineering controls, evaluation of engineering controls, source identification, or process control should usually be taken downwind of the source, and as close to it as possible.

8.2.2 Samples taken for the purpose of risk evaluation, exposure estimation, selection of personal protective equipment, selection of bioassay or biomonitoring procedures, and investigation of complaints should be taken ~~as close as possible to~~ within the breathing zone of the person affected.

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

8.2.3 Where a worker's activities ~~influence~~cause the emission of a contaminant, breathing zone samples will usually indicate concentrations up to one order of magnitude higher than nearby fixed location samples (**2, 4**).

8.2.4 If the worker's activities do not ~~influence~~cause emission, then breathing zone samples will usually indicate concentrations the same as, or lower than, nearby fixed location samplers (**1**). The worker's exposure will usually be lower than the concentration indicated by fixed location samplers, if the worker is in and out of the contaminated area and does not affect emissions.

8.2.5 When personal breathing zone samples are appropriate but do not provide adequate sensitivity, fixed or portable samplers with higher sensitivities must be used and should be placed at about breathing height above the ground or floor.

8.3 Alarm samplers are a special case. They may produce false ~~as~~(as well as ~~true~~true) alarms.

8.3.1 Use of a large number of alarm samplers should be avoided. When used, they must be placed where there is a high probability they will warn personnel of a contaminant or control equipment failure that results in hazardous contaminant air concentrations.

8.3.2 A good practice is to place indoor alarm samplers in or very near exhaust ventilation. They may not sample the highest concentrations at this location, but they are more likely to be exposed to some increase in concentration if a release occurs anywhere in the room.

8.3.3 Outdoor alarm samplers should be placed far enough downwind of potential sources to allow mixing eddies to diffuse the plume enough to detect ~~some concentration~~the contaminant(s) at the sampler.

8.4 Samples taken for ~~the purpose of compliance~~ compliance purposes should use the rules of good practice to the maximum extent possible, while complying with all specific ~~requirements of the regulations.~~ regulatory requirements. The user may also sample in additional locations, with additional types of samplers, or with additional analytical ~~methods.~~methods, as necessary.

9. What to Sample

9.1 For most ~~purposes of sampling, the contaminant~~sampling purposes, the contaminant(s) of concern should be ~~sampled.~~sampled using collection apparatus and media that will not alter the composition(s) or concentration(s) of the contaminant(s).

9.2 ~~The number and types of analytical methods available will~~ Appropriate analytical methods that are fit for purpose will be used to determine the results that can be obtained.

9.3 In some cases, such as source identification, selection of engineering controls, and evaluation of engineering controls, a marker material other than the contaminant of interest may be sampled with greater ease or sensitivity, or both, as long as the marker material concentration is proportional to the ~~source strength of the contaminant.~~contaminant source strength.

10. How to Sample

10.1 ~~How samples should be taken depends on~~ Sampling procedures are dependent upon the type of sampling ~~instruments~~equipment available, analytical methods employed, and the ~~purpose~~purpose(s) of sampling. Other ~~factors~~ factors, such as staff training and available resources, may also be important.

10.2 Sampling instruments can influence sampling strategy, due to their size, space requirements, and mass. For example:

10.2.1 *Vertical Elutriator*—used in cotton dust sampling is too large to be placed on the worker.

~~9.2.2 *A Small Pump and Sample Collector*— can be placed on the worker, but the worker may object to its noise and bulk.~~

10.2.2 *Dosimeter Badge*—can be placed on the individual, over the entire shift, with little or no complaint from nor hinderance to the worker.

10.2.3 *Detector Tubes*—designed for taking very short term samples.

10.2.4 *Personal Sampling Pumps*—designed for ~~long term sampling.~~either long-term or short-term sampling, or both.

NOTE 1—~~Some~~Many sampling instruments are capable of ~~measuring~~collecting more than one contaminant simultaneously.

10.3 Selection of appropriate air sampling media is essential. Considerations for selection of sampling media include the following:

10.3.1 Suitability for the application;

10.3.2 Compatibility with the analyte or analytes of interest;

10.3.3 Suitability for the analytical method which will be used.

10.4 Analytical methods affect sampling strategy by placing limits on minimum and maximum collection durations for each sample. Also, multiple contaminants may have to be sampled separately, on different collection media. Even for materials sampled in the same medium, separate samples may be necessary, due to different methods of ~~desorption and extraction and different instrument conditions~~ sample preparation and analysis in the analytical laboratory.

10.5 The purpose of sampling will profoundly affect how sampling is ~~approached.~~carried out.

10.5.1 Selection and evaluation of engineering controls, selection of respiratory protection or bioassay/biomonitoring techniques, or both, source identification, and process control samples are not usually ~~compared~~correlated to health standards.

10.5.2 Risk evaluation, exposure estimation, exposure documentation, and compliance samples are usually compared to health standards, such as the ~~OEL (Occupational Exposure Limit), PEL (Permissible Exposure Limit) or TLV (Threshold Limit Value),~~ applicable occupational exposure limit (OEL), and are usually best collected with personal samplers.

10.6 For sampling of particulate matter, many OELs invoke a size-selective sampling criterion, based on conventions in ISO 7708. Where applicable, such criteria should be considered in selection of the sampling instrument.

10.7 In addition, the potential for a fraction of the sampled particulate to deposit on interior walls of some sampling devices should be taken into account; see references **(5-7)** for more information.

11. When to Sample

11.1 Air sampling ~~should~~shall be ~~done~~ carried out when required by law or regulation.

11.2 Air sampling ~~should be~~is typically done when there is a probability that any individual will be exposed to significant airborne concentrations of a hazardous material, and when there is an analytical method ~~of~~for determining the quantity of the hazardous material ~~on~~on/in a sampling ~~media.~~medium.

11.3 The following five considerations are important in deciding when to sample.

11.3.1 *Type of Operation*—~~Most actual~~ In practice, most operations generate conditions that are combinations of two or three of the following:

11.3.1.1 *Repetitive Operations,* such as production lines, where the same operation or cycle of operations is carried out day after day, with very little change.

11.3.1.2 *Non-repetitive or Irregular Operations,* such as maintenance or ~~research,~~construction, where each operation is essentially unique.

11.3.1.3 *Enclosed Operations or Processes,* where there is little or no human contact with any hazardous material present, unless a leak or spill occurs.

11.3.2 *Start Time*—Sampling ~~should start~~ is best initiated at the time the risk of significant exposure or release begins, or as soon as feasible thereafter. In most cases, sampling should start at the beginning of a ~~workshift,~~ work shift, or at the beginning of the first cycle capable of producing significant exposures or emissions.

11.3.3 *Duration of Sampling*—Influenced by many things including:

11.3.3.1 ~~*Influence of the* Purpose of Sampling on Duration~~—If the purpose of sampling is to determine compliance with a standard, then the sampling duration ~~should~~shall be the same as that specified in the ~~standard.~~standard **(58)**~~)~~**.** Most ~~OELs, PELs, and TLVs are~~ OELsare based on an 8 h exposure, but some are based on 10 h. ~~OSHA recommends a minimum sample duration of 7 h for compliance samples, where feasible. Most ceiling PELs, ceiling TLVs~~ Most ceiling OELs and short term exposure limits (STELs) are based on 15 min exposures, but some are based on ~~5~~ 5, 10 or ~~10~~30 min exposures.

11.3.3.2 *Equipment Limitations*—Samples should not be so large that they overload the collector, ~~and should not be so small they are less than the threshold of detection of the analytical method.~~but should, whenever possible, be large enough for the analyte or analytes of concern to be detected by an analytical method that is fit for purpose.

11.3.3.3 *Characteristics of the Operation Sampled*—Brief periods of high exposure, followed by periods of significantly lower exposure, might be sampled only during the peak exposures. Full shift samples would be adequate for repetitive operations with relatively constant exposure levels. Alarm samplers might be run continuously.

11.3.3.4 *Statistical Considerations*—When more than one sample must be taken, the duration of each sampling period should be held constant, because the variability of a sample is a function of its duration **(69)**. That is, longer sampling durations result in smaller confidence limits for the mean, while shorter durations result in larger confidence limits, on the average, assuming sampling durations do not vary in step with cycles in the operation. If different sampling durations must be used for multiple samples of the same process or operation, then each sample must be weighted in proportion to its duration when calculating the mean.

11.3.3.5 ~~*Convenience*—~~*Practical Considerations*—It is often not ~~usually convenient~~ practical to run personal samplers beyond one shift, or to run static samplers beyond 24 h. In some cases, it may satisfy the purpose of sampling to show that the concentration sampled did not exceed ~~10 %~~ a percentage (for example 10 %) of any applicable ~~standard.~~OEL.

11.3.4 *Number of Samples*—Factors that should be considered include:

11.3.4.1 *Purpose of Sampling*—For compliance with a regulation or standard, the minimum number of samples required may be specified in the standard.

11.3.4.2 *Equipment Limitations*—The duration of the operation sampled, and the minimum and maximum feasible durations for a single sample, determined by limitations of the sampling and analytical methods, set outside limits on the number of samples that can be taken. For example, an 8-h workshift could be sampled with one 8-h sample, two 4-h samples, four 2-h samples, or eight 1-h samples, depending on the characteristics of the equipment available.

11.3.4.3 *Characteristics of the Operation Sampled*—For relatively constant exposures, fewer samples are needed. Cyclic or irregular exposures should initially be sampled during each identifiable phase of the operation, in order to gain understanding of the pattern of exposure.