INTERNATIONAL

Designation: E 1370 – 96

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

This standard is issued under the fixed designation E 1370; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

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

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.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1356 Terminology Relating to Sampling and Analysis of Atmospheres[2]

E 1542 Terminology Relating to Occupational Health and Safety[2]

2.2 *Other Documents:*

29 CFR 1910[3]

3. Terminology

3.1 For definitions of terms relating to occupational health and safety, see Terminology E 1542.

3.2 For definitions of terms relating to atmospheric sampling and analysis, see Terminology D 1356.

4. Significance and Use

4.1 To describe standard approaches used to determine air sampling strategies before any actual air sampling occurs.

4.2 For the majority of the purposes for sampling, 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 arise when a single air sampling strategy is expected to satisfy multiple purposes.

4.2.1 Limitations of cost, space, power requirements, equipment, analytical methods, and personnel requirements result in an optimum 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.

4.2.3 The purpose or purposes of sampling should be explicitly stated before a sampling strategy is selected. Good practice, legal requirements, cost of the sampling program, and the usefulness of the results may be markedly different for different purposes of sampling.

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

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

4.5 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 be used as a stand-alone document to evaluate any given air borne contaminant.

5. Sampling—General

5.1 Air sampling results are one of many sources of information about health and safety of conditions in a workplace. Air sampling should not be used to the exclusion of other information.

5.2 Bioassay and biomonitoring results, clinical observations, 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 increase confidence in the interpretation of workplace hazard assessments. Disagreement should be cause for concern, and provoke efforts to find out why the disagreement occurred.

6. Purposes of 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

[1] This guide is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.04 on Workplace Atmospheres.

Current edition approved Jan. 10, 1996. Published March 1996. Originally published as E 1370 – 90. Last previous edition E 1370 – 90.

[2] *Annual Book of ASTM Standards*, Vol 11.03.

[3] Code of Federal Regulations, available from U.S. Government Printing Office, Washington, DC 20402.

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.

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 *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.

6.5 *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.

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

6.7 *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 rate of exposure or rate of uptake of a material.

6.8 *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.

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

6.10 *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.

6.11 *Investigation of Complaints*—To resolve doubts and document the seriousness of reported hazardous releases.

7. Where to Sample

7.1 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.

7.1.1 The volume of air movement affects dilution of the source. The more air that passes the source per unit of time, the lower the plume concentration is likely to be.

7.1.2 The direction of air movement determines areas of heaviest exposure downwind, and may prevent any exposure upwind. Variation in wind direction 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.

7.1.3 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.

7.1.4 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 settled aerosols, and to deflect contaminants away from local exhaust ventilation, such as hoods.

7.1.5 The rate and velocity of contaminant evolution also affects local air movement. Large or high velocity emissions tend to 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, may resist mixing with the air for considerable times and distances downwind.

7.1.6 Distance from the emission source is very important. Contaminants usually become more dilute with distance. Samples taken outdoors usually show more variation with distance than those taken indoors due to 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 concentrations may vary more than two orders of magnitude between the floor and ceiling, 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)**.

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

7.2.1 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.

7.2.2 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 the breathing zone of the person affected.

7.2.3 Where a worker's activities influence 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)**.

7.2.4 If the worker's activities do not influence emission,

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

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.

7.2.5 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.

7.3 Alarm samplers are a special case. They may produce false as well as true alarms.

7.3.1 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 air concentrations.

7.3.2 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.

7.3.3 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 at the sampler.

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

8. What to Sample

8.1 For most purposes of sampling, the contaminant of concern should be sampled.

8.2 The number and types of analytical methods available will determine the results that can be obtained.

8.3 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.

9. How to Sample

9.1 How samples should be taken depends on the type of sampling instruments available, analytical methods employed, and the purpose of sampling. Other factors may also be important.

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

9.2.1 *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.

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

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

9.2.5 *Personal Sampling Pumps*—designed for long term sampling.

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

9.3 Analytical methods affect 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 in the analytical laboratory.

9.4 The purpose of sampling will profoundly affect how sampling is approached.

9.4.1 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 to health standards.

9.4.2 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), and are usually best collected with personal samplers.

10. When to Sample

10.1 Air sampling should be done when required by law or regulation.

10.2 Air sampling should be 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 determining the quantity of the hazardous material on a sampling media.

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

10.3.1 *Type of Operation*—Most actual operations generate conditions that are combinations of two or three of the following:

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

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

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

10.3.2 *Start Time*—Sampling should start 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, or at the beginning of the first cycle capable of producing significant exposures or emissions.

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

10.3.3.1 *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 be the same as that specified in the standard. **(5)** Most OELs, PELs, and TLVs are 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 and short term exposure limits (STELs) are based on 15 min exposures, but some are based on 5 or 10 min exposures.

10.3.3.2 *Equipment Limitations*—Samples should not be so large they overload the collector, and should not be so small they are less than the threshold of detection of the analytical method.

10.3.3.3 *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.

10.3.3.4 *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 **(6)**. 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.

10.3.3.5 *Convenience*—It is not usually convenient 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 % of any applicable standard.

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

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

10.3.4.2 *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.

10.3.4.3 *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.

10.3.4.4 *Economics*—The minimum number of samples required to accomplish the purpose of sampling is the optimum number to take. It is easier to decide where to add one or two samplers than it is to decide where to take one out.

10.3.4.5 *Manpower Limitations*—The more samples that are taken, the more man-hours of work will be required. Care must be taken to ensure that the available personnel can carry out the work required.

10.3.4.6 *Statistical Considerations* **(6, 7)**—One sample of any operation is rarely adequate, because the uncertainty of a single sample value is large. For long duration operations, 2 to 4 samples may be enough. For short duration samples, from grab samples up to those of 1, 4 to 7 samples of the same operation or phase are the minimum required. Other considerations being equal, more short duration samples are better than fewer long duration samples covering the same total sampling period, because they provide more information. For example, the full shift exposure can be estimated from a number of back-to-back short duration samples taken over the entire shift, and the fluctuations in exposure levels during the day can be seen. A single full shift sample would also estimate the full shift exposure, but would shed no light on fluctuations. For repetitive operations, conducted over a prolonged period of time, the question is not how many total samples to take, but how many samples to take each day, week, month, or year. In general, initial sampling should be done as though the operation was not repetitive. After initial sampling, the number of samples taken should be based on the observed variations and on the purpose of sampling. Experience shows that a minimum of 10 samples is required to observe a periodicity or trend. That is, if daily variations are important, you will need 10 samples per day. If seasonal variations are important, you will need 10 samples per calendar quarter.

10.3.5 *Termination of Sampling*—Sampling should be terminated at the end of a shift, or when there is no longer any risk of significant exposures or emissions from the contaminant being evaluated. Most operations should be sampled at least annually. The frequency should be increased if the degree of hazard, lack of availability or reliability of alarm samplers, or experience with the operation indicates that the contaminant levels have changed.

11. Long Term Sampling (Measurement of Average Concentrations)

11.1 Long term sampling refers to the measurement of an average concentration of air contaminant over a specified duration. PELs and TLVs are usually specified as time weighted average (TWA) concentrations over 8 h. The weighted mean is a basic statistical calculation.

11.1.1 In statistics, sampling refers to measurement of a small portion of a population, in order to estimate a population parameter.

11.1.2 In air monitoring, sampling refers to measurements of mean contaminant concentration over a stated duration. The TWA calculation averages these mean concentrations over some stated interval. The general formula for a TWA is:

$$C = \frac{(C_1T_1 + C_2T_2 + ... + C_nT_n)}{(T_1 + T_2 + ... + T_n)} \quad (1)$$

where:

C_n = Average air concentration for the duration T_n.

11.2 Two things must be borne in mind during any sampling strategy discussion: (*1*) a TWA standard (PEL or TLV) is designed to protect the worker only from exposures incurred