

CHAPTER 1

BACKGROUND TO MONITORING EMPLOYEE EXPOSURE TO OCCUPATIONAL ATMOSPHERES

1.1 OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970

Although the first recognized and recorded occupational disease occurred in the 4th century B.C., there was little concern for protecting the health of workers before the 19th Century. It was in 1833 that the Factory Acts of Great Britain were passed. Although these acts were directed more toward providing compensation for accidents than to preventing and controlling their causes, they are considered the first effective legislative acts in industry that required some concern for the working population.

It was not until 1908 that the United States passed a compensation act for certain civil employees. Then in 1911, the first state compensation laws were passed, and by 1948, all States had some form of workmens' compensation. However, it has been in the most recent decade that Federal legislation has had a dramatic impact on the occupational safety and health of the American worker. The Federal Coal Mine Health and Safety Act of 1969 (P.L. 91-173) was directed to the health, protection of life, and prevention of diseases in miners and persons who, although not miners, work with or around the products of coal mines.

The Occupational Safety and Health Act of 1970 (P.L. 91-596) is one of the most far-reaching federal laws ever enacted, in that it applies to all employees of an employer engaged in a business affecting commerce, except for government employees and employees and employers at employment sites being regulated under other federal laws. Quoting from the preamble to the Act, its purpose is:

"To assure safe and healthful working conditions for working men and women; by authorizing enforcement of the standards developed under the Act; by assisting and encouraging the states in their efforts to assure safe and healthful working conditions; by providing for research, information, education, and training in the field of occupational safety and health; and for other purposes."

With respect to the above, the Act specifies the employer's obligations to furnish to each employee a place of employment free from the recognized hazards that are causing or likely to cause death or serious physical harm, and to comply with standards promulgated by OSHA. Court decisions defining the employer's duty have already been made, and there is little doubt that the final responsibility for compliance with the provisions of the Act rests with the employer. This responsibility includes the determination of whether a hazardous condition exists in a workplace, the evaluation of degree of the hazard, and where necessary, the control needed to prevent occupational illness.

But what are the employee's obligations under the Act? The employee also has to comply with the safety and health standards as they relate to his performance and actions on the job. Although no provisions exist in the law to issue citations to or to penalize an employee, good practice would dictate that he (a) notify the proper authority when certain conditions exist that may cause personal injury; and (b) observe all safety rules, make use of all prescribed personal protective equipment, and follow procedures established to maintain a safe and healthful work environment.

1.2 FEDERAL OCCUPATIONAL SAFETY AND HEALTH STANDARDS (29 CFR 1910, Subpart Z)

On April 28, 1971, the Occupational Safety and Health Act came into effect. The first compilation of health and safety standards promulgated by the Department of Labor's OSHA was derived from existing Federal standards and national consensus standards. Thus, many of the 1968 Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH) became Federal standards because they had been included in an earlier Federal law. Also, certain workplace quality standards of the American National Standards Institute (ANSI) were incorporated as Federal health standards in 29 CFR 1910.1000 (Table Z-2) because they were considered national consensus standards.

The health regulations dealing with toxic and hazardous substances were originally codified under Subpart G, Occupational Health and Environmental Control, of 29 CFR Part 1910. The term "29 CFR 1910" refers to Title 29 (Labor) of the Code of Federal Regulations available from the Superintendent of Documents, U.S. Government Printing Office. The 1910 refers to Part 1910 of Title 29, which contains the Occupational Safety and Health Standards. The majority of the Federal toxic substances occupational exposure standards were contained in 29 CFR 1910.93, Air Contaminants, Tables G-1, G-2, and G-3. On May 28, 1975, OSHA announced recodification of the air contaminant standards into Subpart Z, Toxic and Hazardous Substances. The following two paragraphs are a modified version of that announcement.

On September 29, 1974, in 39 FR 33843, OSHA announced its intention to initiate rule-making proceedings to issue more complete standards for each of the substances listed in Tables G-1, G-2, and G-3 of 29 CFR 1910.93. As a result, it is expected that approximately 400 additional standards dealing with toxic substances will be promulgated.

Regulations dealing with toxic substances are contained in Subpart G of Part 1910. This subpart contains only a few sections and additional serially numbered sections cannot be added

without completely renumbering the subparts which follow. Therefore, new standards dealing with individual toxic substances have in the past been inserted following section 1910.93 by the addition of letter suffixes (e.g., section 1910.93a-Asbestos; section 1910.93b-Coal tar pitch volatiles).

Although such numbering is satisfactory for limited use, it is not suitable for a large group of new sections, because of the complex multiple-letter suffixes that result. Therefore, in view of the fact that OSHA contemplates promulgating a large number of standards dealing with toxic substances, this numbering system could not be continued. Consequently, the toxic substance standards contained in Subpart G of Part 1910 were recodified and placed in a new Subpart Z of Part 1910, beginning at section 1910.1000. This recodification will simplify the manner in which standards for toxic substances may be referenced and will eliminate unnecessary confusion.

The following table sets forth the recodification of Title 29 Part 1910, Sections 1910.1000 through 1910.1017, respectively.

Old Section No. (Subpart G)	New Section No. (Subpart Z)	
1910.93	1910.1000	Air contaminants
1910.93a	1910.1001	Asbestos
1910.93b	1910.1002	Interpretation of term coal tar pitch volatiles
1910.93c	1910.1003	4-Nitrobiphenyl
1910.93d	1910.1004	alpha-Naphthylamine
1910.93e	1910.1005	4,4'-Methylene bis (2-chloroaniline)
1910.93f	1910.1006	Methyl chloromethyl ether
1910.93g	1910.1007	3,3'-Dichlorobenzidine (and its salts)
1910.93h	1910.1008	bis-Chloromethyl ether
1910.93i	1910.1009	beta-Naphthylamine
1910.93j	1910.1010	Benzidine
1910.93k	1910.1011	4-Aminodiphenyl
1910.93l	1910.1012	Ethyleneimine
1910.93m	1910.1013	beta-Propiolactone
1910.93n	1910.1014	2-Acetylaminofluorene

1910.93o	1910.1015	4-Dimethylaminoazobenzene
1910.93p	1910.1016	N-Nitrosodimethylamine
1910.93q	1910.1017	Vinyl chloride

Tables G-1, G-2, and G-3 of section 1910.93 (new redesignated section 1910.1000) are redesignated as Tables Z-1, Z-2, and Z-3, respectively. All references in new section 1910.1000 to Tables G-1, G-2, and G-3 are revised to correspond with this redesignation.

A convenient paperback volume of the 29 CFR 1910 standards, available as OSHA publication 2206, contains information current to January 1, 1976.

1.3 ACGIH THRESHOLD LIMIT VALUES (TLVs)

In the field of industrial hygiene, control of the work environment is based on the assumption that, for each substance, there exists some safe or tolerable level of exposure below which no significantly adverse effect occurs. These levels are referred to in the generic sense as threshold limit values. However, the term threshold limit values also specifically refers to occupational exposure limits published by a committee of ACGIH that are reviewed and updated each year to assimilate new information and insights (1-1). They are commonly referred to as "TLVs," and the list (1-1) is known as the "TLV Booklet." The ACGIH periodically publishes a documentation of TLVs in which it gives the data and information upon which the TLV for each substance is based (1-2). This documentation (1-2) can be used to provide the industrial hygienist with insight to aid professional judgment when applying the TLVs.

Several important points should be noted concerning TLVs. First, the term "TLV" is a copyrighted trademark of the ACGIH. It should not be used to refer to Federal or other standards. Since the TLVs are updated annually, the most current "TLV Booklet" should always be used. When referencing an ACGIH value, the year of publication should always preface the value as "The 1974 TLV for nitric oxide was 25 ppm." Second, TLVs are not mandatory Federal or State employee exposure standards. TLVs are updated annually and generally reflect the most current professional recommendations

concerning employee exposures to specific substances. If a TLV happens to be lower than a Federal or State health standard, the employer should strive to limit employee exposure to the TLV even though his legal obligation is not to exceed the Federal or State standard.

The following informative material concerning TLVs is quoted from the preface of the 1976 TLV Booklet with the permission of the ACGIH:

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness. . . .

Time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday. In some instances it may be permissible to calculate the average concentration for a workweek rather than for a workday. The degree of permissible excursion is related to the magnitude of the threshold limit value of a particular substance as given in Appendix D. The relationship between threshold limit and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which threshold limits may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations — even for short period — produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All factors must be taken into consideration in arriving at a decision as to whether a hazardous condition exists.

Threshold limits are based on the best available information from industrial ex-

perience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance or other forms of stress may form the basis for others.

The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the precision of the estimated TLV is also subject to variation and the latest *DOCUMENTATION* should be consulted in order to assess the extent of the data available for a given substance.

The committee holds to the opinion that limits based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote or accelerate physical impairment through interaction with other chemical or biologic agents. In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline. They are not intended for use, or for modification for use, (1) as a relative index of hazard or toxicity, (2) in the evaluation or control of community air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods, (4) as proof or disproof of an existing disease or physical condition, or (5) for adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ. . . .

1.4 PROPOSED OSHA HEALTH STANDARDS

Since January 1974, the National Institute for Occupational Safety and Health (NIOSH) and

OSHA have had underway a joint NIOSH/OSHA Standards Completion Program (SCP). Federal regulations 29 CFR 1910.1000, Tables Z-1, Z-2, and Z-3 (formerly 1910.93, Tables G-1, G-2, and G-3) establish permissible exposure limits for approximately 400 chemical substances. OSHA proposes to amend 29 CFR 1910 with health standards that, if adopted, will establish detailed requirements for each chemical substance regarding such areas as:

1. measurement of employee exposure,
2. medical surveillance,
3. methods of compliance,
4. handling and use of liquid substances,
5. employee training,
6. recordkeeping,
7. sanitation and housekeeping.

As of September 1976, toxic substance health standards had been published as proposed rules in the Federal Register for the following substances (in chronological order):

- 8 May 1975 - ketones (6), including 2-butanone, 2-pentanone, cyclohexanone, hexone, methyl n-amyl ketone, and ethyl butyl ketone
- 3 Oct. 1975 - lead
- 6 Oct. 1975 - toluene
- 8 Oct. 1975 - general (11), including alkyl benzenes (p-tert-butyltoluene, cumene, ethyl benzene, alphas-methyl styrene, styrene, and vinyl toluene); cyclohexane; ketones (camphor, mesityl oxide, and 5-methyl-3-heptanone); and ozone
- 9 Oct. 1975 - asbestos
- 17 Oct. 1975 - beryllium
- 20 Oct. 1975 - trichloroethylene
- 24 Nov. 1975 - sulfur dioxide
- 25 Nov. 1975 - ammonia

As stated in the preface, one of the primary intents of this Occupational Exposure Sampling Strategy Manual is to detail the intent and purpose of the employee exposure monitoring requirements of the proposed health regulations. This Manual also contains recommendations concerning ways to comply with the

proposed regulations. IT IS IMPORTANT TO NOTE THAT SOME PROCEDURES PRESENTED IN THIS MANUAL EXCEED MINIMUM REQUIREMENTS OF THE PROPOSED OSHA REGULATIONS. In particular, the proposed regulations do not require employers to maintain the upper confidence limit (UCL) on employee averages below the applicable permissible exposure limit. The only reference to statistics in the proposed regulations occurs where the method of measurement used must meet accuracy requirements at a confidence level of 95%. The method of measurement refers solely to the sampling device (as the pump used to draw air through a filter, sorbent tube, or impinger) and the chemical analysis procedure used to determine the amount of chemical substance.

However, it is believed that the well-intentioned employer will want to use the statistical procedures contained in Chapter 4. In Table 1.1 are the sections of this Manual that apply to specific portions of the proposed regulations for 2-pentanone as published on May 8, 1975, in the Federal Register. This section is almost identical in the majority of the toxic substance health standards.

Figure 1.1 provides a generalized flowchart of the proposed OSHA employee exposure determination and measurement strategy for the proposed regulatory requirements of Table 1.1.

1.5 STATISTICS AND OCCUPATIONAL EXPOSURE MEASUREMENTS

One of the most important objectives of any industrial hygiene program is to accurately assess employees' occupational exposures to airborne contaminants, where necessary, by exposure measurements. The use of statistics in this assessment process is necessary because all measurements of physical properties contain some unavoidable random measurement error. That is, because of the effect of random measurement errors, any exposure average for an employee calculated from exposure measurements is only an estimate of the true exposure average. This section will discuss several statistical concepts as they apply to occupational exposure sampling. Then the sources of measurement variation will be elaborated.

Before getting into the terminology of sta-

tistics, a basic question should be answered: "Why should industrial hygienists even bother with statistics?" Simply because of measurement errors? Won't statistical techniques take the professionalism out of the industrial hygiene profession? Absolutely not! First, realize that statistics deals with the entire field of techniques for collecting, analyzing, and most importantly making inferences (or drawing conclusions) from data. Snedecor and Cochran (1-3) have stated:

"Statistics has no magic formula for doing this in all situations, for much remains to be learned about the problem of making sound inferences. But the basic ideas in statistics assist us in thinking clearly about the problem, provide some guidance about the conditions that must be satisfied if sound inferences are to be made, and enable us to detect many inferences that have no logical foundation."

Armitage (1-4) may be paraphrased regarding the rationale for the proper application of statistical techniques. The variation of occupational exposure measurements is an argument for statistical information, not against it. If the industrial hygienist finds on a single occasion that an exposure is less than a desired level, it does not follow that all exposures will be less than the target level. The industrial hygienist needs statistical information that the exposure levels are consistently low enough. The "professional experience" often referred to is likely to be, in part, essentially statistical comparisons derived from a lifetime of industrial practice. The argument, then, is whether such information should be stored in a rather informal way in the industrial hygienist's mind or whether it should be collected and reported in a systematic way. Very few industrial hygienists acquire, by personal experience, factual information over the whole range of occupational exposure situations, and it is partly by the collection, analysis, and reporting of occupational exposure statistical information that a common body of knowledge is built and solidified. Now to the discussion of terminology used in the statistical procedures.

A *statistical population* is an entire class of items about which conclusions are to be drawn. Usually it is impossible, or impractical, to take measurements on all items in the population.

TABLE 1.1. PROPOSED OSHA REGULATIONS AND RELATED SECTIONS OF THIS MANUAL

2-Pentane

(a) *Definitions.* (1) "Permissible exposure" means exposure of employees to airborne concentrations of 2-pentanone, not in excess of 200 parts per million (ppm) or 700 milligrams per cubic meter (mg-cu m) averaged over an eight-hour work shift (time weighted average), as stated in § 1910.93, Table G-1.
 (2) "Action level" means one half (1/2) of the permissible exposure for 2-pentanone.

(b) *Exposure determination and measurement.* (1) Each employer who has a place of employment in which 2-pentanone is released into the workplace air shall determine if any employee may be exposed to airborne concentrations of 2-pentanone at or above the action level. The determination shall be made each time there is a change in production, process, or control measures which could result in an increase in airborne concentrations of 2-pentanone.
 (2) A written record of the determination shall be made and shall contain at least the following information:

- (i) Any information, observation, or calculations which may indicate employee exposure to 2-pentanone.
 - (ii) Any measurements of 2-pentanone taken;
 - (iii) Any employee complaints or symptoms which may be attributable to exposure to 2-pentanone; and
 - (iv) Date of determination, work being performed at the time, location within the work site, name, and social security number of each employee considered.
- (3) If the employer determines that any employee may be exposed to 2-pentanone at or above the action level, the exposure of the employee in each work operation who is believed to have the greatest exposure shall be measured. The exposure measurement shall be representative of the maximum eight-hour time weighted average exposure of the employee.

(4) If the exposure measurement taken pursuant to paragraph (b)(3) of this section reveals employee exposure to 2-pentanone at or above the action level, the employer shall:

- (i) Identify all employees who may be exposed at or above the action level; and
- (ii) Measure the exposure of the employees so identified.

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(5) If an employee exposure measurement reveals that an employee is exposed to 2-pentanone at or above the action level, but not above the permissible exposure, the exposure of that employee shall be measured at least every two months.
 (6) If an employee exposure measurement reveals an employee is exposed to 2-pentanone above the permissible exposure, the employer shall:

- (i) Measure the exposure of the employee so exposed monthly;
- (ii) Institute control measures as required by paragraph (d) of this section; and
- (iii) Individually notify, in writing, within five days, every employee who is found to be exposed to 2-pentanone above the permissible exposure. The employee shall also be notified of the corrective action being taken to reduce the exposure to at or below the permissible exposure.

(7) If two consecutive employee exposure measurements taken at least one week apart reveal that the employee is exposed to 2-pentanone below the action level, the employer may terminate measurement for the employee.

(8) For purposes of this paragraph employee exposure is that which would occur if the employee were not using a respirator.

(c) *Methods of measurement.* (1) An employee's exposure shall be obtained by any combination of long term or short term samples which represents the employee's actual exposure averaged over an eight-hour work shift (see Appendix B-IV) of this section for suggested measurement methods).

(2) The method of measurement shall have an accuracy, to a confidence level of 95 percent, of not less than that given in Table 1.

TABLE 1

Concentration:	Required accuracy (percent)
Above permissible exposure	±25
At or below the permissible exposure and above the action level	±35
At or below the action level	±50

SECTION 3.1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 3

APPENDIX D

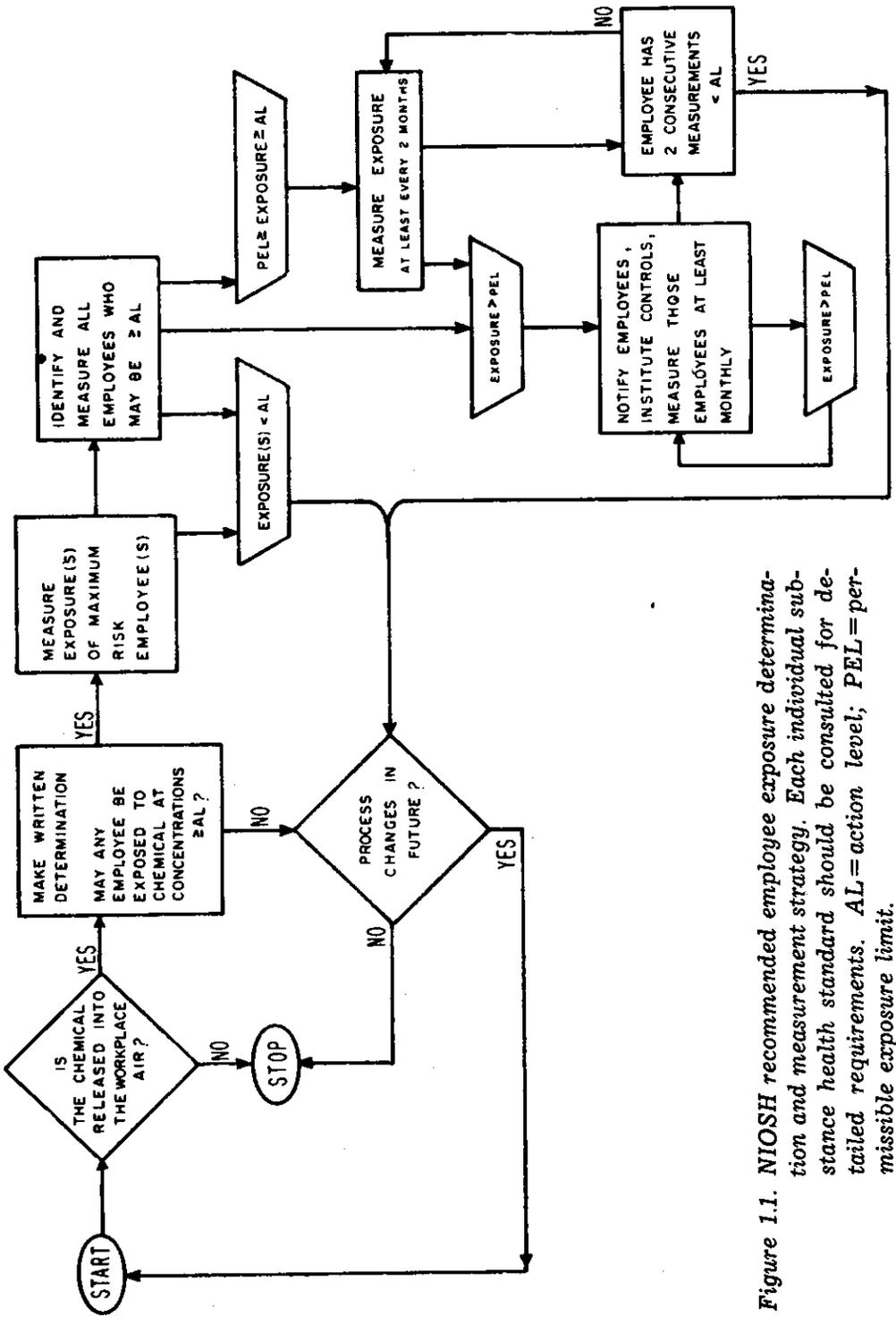


Figure 1.1. NIOSH recommended employee exposure determination and measurement strategy. Each individual substance health standard should be consulted for detailed requirements. AL=action level; PEL=permissible exposure limit.

Thus, we usually take measurements on several items comprising a *statistical sample* drawn from the population. The findings from the sample are generalized to obtain conclusions about the whole population. After taking measurements on items on the statistical sample, the measurements can be ranked in groups either in a table or graphically. One then recognizes that the measurements have some *distribution*.

The next step in data reduction is finding where the measurements are centered (or where the bulk of the measurements lie). There are several statistical *measures of central location* (or central tendency). The two used here are the arithmetic mean and geometric mean. The computations for these are demonstrated in Chapter 4. Lastly, how the measurements are distributed about the center value is determined. Several *measures of dispersion* give an idea of the scatter or variation of the measurements. The three used here are the geometric standard deviation, the normal standard deviation, and the coefficient of variation (or relative

standard deviation). The methods of calculating these are given in Chapter 4.

The use of the word "sample" in this Manual might be a source of confusion. In the strict statistical sense, a sample consists of several items, each of which has some characteristic measured. In the industrial hygiene sense, however, a sample consists of an airborne contaminant(s) collected on a physical device (as a filter or charcoal tube). Industrial hygiene sampling is usually performed by drawing a measured volume of air through a filter, sorbent tube, impingement device, or other instrument to trap and collect the airborne contaminant. But in the sense of this Manual, an occupational exposure sampling strategy combines both the concept of a statistical sample and the physical sample that is chemically analyzed. In Table 1.2 are some examples of types of populations that may be encountered in occupational exposure sampling. Refer to Technical Appendix M, Normal and Lognormal Frequency Distributions, for a discussion on the application of these distributions.

TABLE 1.2. OCCUPATIONAL EXPOSURE SAMPLING POPULATIONS

Example population	Example of statistical sample used to estimate population parameters	Measure of central location of the distribution	Measure of dispersion	Best distribution model for fitting data
The airborne concentration values of a contaminant an employee is exposed to on one 8-hour workshift.	Grab sample measurements during the 8-hour workshift	(a) Arithmetic mean (8-hour TWA) (b) Geometric mean	Geometric standard deviation (intraday variability)	Lognormal
The daily (8-hour TWA) exposure averages of an employee obtained over many days.	Several measured daily exposure averages	(a) Long-term geometric mean (b) Long-term arithmetic mean	Geometric standard deviation (intraday variability)	Lognormal
The daily (8-hour TWA) exposure averages of all employees in an occupational group of similar expected exposure risk on a particular day.	Measured daily exposure averages for several employees in the group	(a) Group geometric mean (b) Group arithmetic mean	Geometric standard deviation (operator or intragroup variability)	Lognormal
Many replicate analyses performed on an industrial hygiene sample (as a filter or charcoal tube).	Several replicate analyses performed on the one IH sample	Arithmetic mean sample value	Coefficient of variation of analytical method	Normal
Many measurements of a calibrated contaminant test concentration obtained by a particular sampling and analytical procedure (as a low volume pump and charcoal tube with subsequent analysis by gas-liquid chromatography).	Several charcoal tubes exposed to the calibrated concentration	Arithmetic mean sample value	Coefficient of variation of sampling and analytical method	Normal

The following list details the primary sources of variation that affect estimates of occupational exposure averages:

1. Random sampling device errors (as random fluctuations in pump flowrate),
2. Random analytical method errors (as random fluctuations in a chemical laboratory procedure),
3. Random intraday (within day) environmental fluctuations in a contaminant's concentration,
4. Random interday (between days) environmental fluctuations in a contaminant's concentration,
5. Systematic errors in the measurement process (improper calibration, improper use of equipment, erroneous recording of data, etc.), and
6. Systematic changes in a contaminant's airborne concentration (as due to the employee moving to a different exposure concentration or shutting off an exhaust fan).

The random errors and fluctuations (1) through (4) are sometimes called statistical errors since they can be accounted for (but not prevented) by statistical analysis. Systematic errors under (5) include both instrumental errors and goofs or blunders of the fallible human using the equipment! Random errors under (1) and (2) are quantified and their effects minimized by the application of statistically based quality control programs. The quality control programs also enable one to get a good idea of the typical variation (coefficient of variation) of a sampling and analytical procedure. Refer to Technical Appendix D, Coefficients of Variation and Accuracy Requirements for Industrial Hygiene Sampling and Analytical Methods, for a further discussion of these types of errors.

Random intraday and interday environmental fluctuations in a contaminant's airborne concentration are most likely influenced primarily by the physical process that generates the contaminant and the work habits of the employee (spatial and temporal). There is no reason to believe the fluctuations are influenced by the chemical nature of a contaminant, but it is probable they are affected by its physical nature (dust, mist, gas).

It is important to note that the random environmental fluctuations of a contaminant in a plant may greatly exceed the random variation of most sampling and analytical procedures (often by factors of 10 to 20). Figure 1.2 shows actual environmental fluctuations for carbon monoxide. Figure 1.2 is a section of paper from a CO analyzer strip chart recorder. The vertical scale is zero to 100 ppm and the horizontal time scale contains a 15-minute period between any two vertical lines. A 1-inch distance represents 1 hour. The variability of the instrument is measured by a coefficient of variation of about 3%. Thus, the 95% confidence limits on a particular data point are approximately $\pm 6\%$ of the measured concentration at any particular time. More about this in Chapter 4.

Systematic errors can either remain constant through a series of samples (because of improper calibration) or vary abruptly following some change in the process. Systematic errors cannot be accounted for statistically. If they are detected in the course of a measurement procedure, the data must first be corrected before the statistical analysis is performed. Many times, however, they go undetected and introduce much larger variation into the data than would be caused by the expected random errors and fluctuations. In the statistical sense, a systematic error (or change in the middle of a series of measurements) creates a second statistical population with a different average. If the systematic change goes undetected, the two "side by side" populations are analyzed as one, with a consequently much larger variation. The statistical procedures presented in this Manual will not detect and do not allow for the analysis of highly inaccurate results because of systematic errors or mistakes. Control of systematic errors is primarily a technical rather than a statistical problem.

Systematic changes in the contaminant exposure concentration for an employee can occur due to:

1. Employee moving to a different work area (as going from a solvent room to a warehouse),
2. Closing plant doors and windows (in cold seasons),
3. Decreases in efficiency or abrupt failure (or plugging) of engineering control equipment such as ventilation systems,

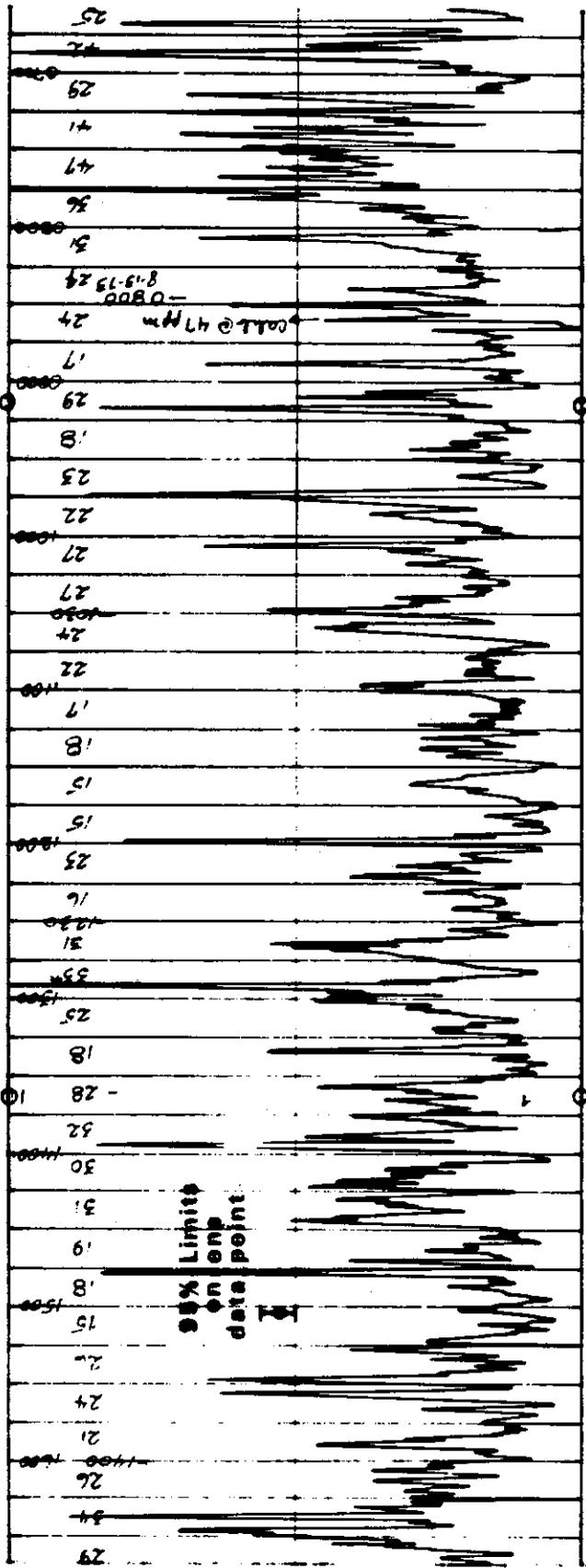


Figure 1.2. Actual industrial hygiene data showing intraday environmental fluctuations. Range of carbon monoxide data on chart is 0 to 100 ppm.

4. Changes in the production process or work habits of the employee.

One of the most important reasons for periodically measuring an employee's exposure every few months is to detect trends or systematic changes in the long-term exposure average. A secondary benefit is a better estimate of the variation of the exposures over extended periods, but this is not the primary purpose of periodic exposure measurement. Periodic measurements are one of the most informative ways to detect hazardous shifts in exposure levels or to indicate that hazardous levels are being approached.

1.6 STATISTICS AND COMPLIANCE ENFORCEMENT

Mandatory occupational exposure standards have been promulgated in the United States (29 CFR 1910, Subpart Z) with the intent of most adequately ensuring, to the extent feasible, that no employee will suffer material impairment of health or functional capacity. With these mandatory health standards has come the reality of necessary governmental enforcement. Duncan (1-5) has broadly defined enforcement as all those steps taken by a governmental agency to attain the desired level of quality. For OSHA, under the Occupational Safety and Health Act of 1970, these steps consist of proceedings, engineering judgment, court proceedings, and recommended voluntary compliance programs.

A simplistic legal approach toward the enforcement of these mandatory occupational health standards proceeds as follows. A sampling and analytical test method for the measurement of an employee's exposure to a particular hazardous substance is developed. The test method is used to measure a particular employee's exposure. If that measurement exceeds the standard, there has been a violation of the law. This simple point of view neglects the number and duration of samples that were taken from the random variation of the sampling and analytical method. Finally, there is no consideration of how many samples will be required of the enforcement agency or the employer to attain a specified level of effectiveness for the sampling program.

For example, if a compliance officer found an average air concentration of 105 ppm based on

five samples taken over an entire workshift at a location in a plant and the standard was 100 ppm, then by the purely legal approach, he would be obligated to issue a citation. Suppose the citation was contested and the compliance officer was asked under cross examination whether he was certain his measurements have shown the standard has been exceeded. If he was aware of the statistics that underlies environmental sampling, he would have to answer legally, "Yes," but in actuality, "I don't know." It is essential that the sampling of the occupational environment should be performed utilizing appropriate statistically based sampling plans and statistical decision procedures so that the data can support the decision making processes regarding compliance or noncompliance with the mandatory health standards.

Tomlinson (1-6) in 1957 applied the concept of sequential testing to the problem of compliance monitoring, concerning a TWA standard, in British coal mines. Tomlinson recognized the large within-shift and shift-to-shift variation of the average airborne dust concentration. Roach (1-7, 1-8) introduced the concept of utilizing the upper confidence limit on the arithmetic mean of a group of short-term (grab) samples to determine the compliance status of an occupational environment. Roach, however, assumed a normal distribution for the samples, and later work has shown that it is better to assume the lognormal distribution for grab sample data. Roach made the very important point that any sampling procedure, no matter how carefully performed, can only estimate the true average concentration that existed in the occupational environment.

NIOSH first proposed the use of statistics for compliance monitoring in the carbon monoxide criteria document (1-9). Unfortunately, the procedure given for grab sample data was based on the assumption of normally distributed data and was inappropriate.

There is precedent in Federal regulations for including and referencing of statistical methods in mandatory product and health standards. Methods have been given both for governmental enforcement and private industry compliance monitoring programs. The Consumer Product Safety Commission (CPSC) has included very specific sampling and decision plans in several

of its product standards. The FF 4-72 Flammability Standard for Mattresses (1-10) gives details for a manufacturer's compliance program and allows submission of alternate sampling plans by industry. The commission believed that these plans would protect the public against unreasonable risk and that they were reasonable, technologically practicable, and appropriate. These are goals that any sampling and decision plan must achieve. The Commission accepted the concept that the enforcement agency must assume the burden of demonstrating noncompliance by showing, with a high level of statistical confidence, that noncompliance did in fact exist. The CPSC included a sequential sampling plan in its test for Eye Irritants (16 CFR 1500.42) (1-11) and a table for lot size, sample size, and failure rate for testing clacker balls in 16 CFR 1500.86 (1-12).

The U.S. Public Health Service has issued a Drinking Water Standard (42 CFR 72, Subpart J) that specifies a minimum sampling frequency and sequential decision plan. The Food and Drug Administration's eyeglass impact standards (21 CFR 3.84) state that the manufacturer shall test a statistically significant number of lenses from each production batch.

In the field of industrial hygiene, NIOSH requires that manufacturers of certified gas detector tube units must maintain a quality control program similar in many respects to that described in MIL-Q-9858A "Quality Program Requirements," but adds the requirement to use sampling plans from MIL-STD-105D or MIL-STD-414. The Institute's certification procedures are based, in part, on the use of these sampling systems. The Institute has also proposed that similar quality control requirements would be extended to manufacturers of personal protective devices (42 CFR 83) and sound-level meters (42 CFR 82).

It appears that the Environmental Protection Agency (EPA) has never included or referenced statistical techniques for data analysis in air quality or water quality regulations. However, Larsen (1-13) of EPA has discussed the problem in an EPA technical report. Russell Train, EPA Administrator, expressed a desire to see standard statistical techniques for determining the validity of sample results become common to environmental standards (1-14). He believes that the methodology of statistical quality con-

trol charts has a place in environmental quality control.

An article in *Electrical World* (1-15) questioned the precision of Ringelmann chart smoke readings by a single observer. The conclusion was that poor precision led to poor reliability for enforcement purposes when regulatory controls were strict. A table of citation probabilities (%) was given for actual smoke density (RN — Ringelmann Number) versus maximum density allowed. More of this type of article based on statistics will probably appear in the literature as the statistical aspects of enforcing air concentration standards are more closely examined.

It is important to emphasize that the proposed OSHA health regulations (see section 1.4) DO NOT require the employer to use the statistical procedures in Chapter 4 of this Manual when making decisions regarding measured exposures of his employees. It is believed, however, that **THE WELL-INTENTIONED EMPLOYER WILL WANT TO USE THESE PROCEDURES FOR THE ADDITIONAL PROTECTION THEY WILL AFFORD HIS EMPLOYEES.** OSHA is considering adopting some statistical procedures for their noncompliance determinations.

Lastly, it is believed statistical procedures will appear more frequently in legal cases that involve sampling: an article by Katz (1-16) considered the practical aspects of statistics in the courtroom, and Corn (1-17) discussed applying statistics to determine noncompliance with the Federal coal dust exposure standard.

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 - 1-17. Corn, M.: Remarks on Determination of Non-compliance with the Respirable Dust Standard, Federal Coal Mine Health and Safety Act of 1969. American Industrial Hygiene Association Journal, 36:404-407, 1975.

SUGGESTED READINGS FOR CHAPTER 1

Specific ANSI Standards as follows:

- Benzene (Z37.4-1969)
- Beryllium and beryllium compounds (Z37.5-1970)
- Cadmium dust (as Cd) (Z37.5-1970)
- Cadmium fume (as Cd) (Z37.5-1970)
- Carbon disulfide (Z37.3-1968)
- Carbon tetrachloride (Z37.17-1967)
- Ethylene dibromide (Z37.31-1970)
- Ethylene dichloride (Z37.21-1969)
- Formaldehyde (Z37.16-1967)
- Hydrogen fluoride (Z37.28-1969)
- Fluoride as dust (Z37.28-1968)
- Lead and its inorganic compounds (Z37.11-1969)
- Methyl chloride (Z37.18-1969)
- Methylene chloride (Z37.23-1969)
- Organo (alkyl) mercury (Z37.30-1969)
- Styrene (Z37.12-1969)
- Tetrachloroethylene (Z37.22-1967)
- Toluene (Z37.12-1967)
- Hydrogen sulfide (Z37.2-1966)
- Chromic acid and chromates (Z37.3-1971)
- Mercury (Z37.8-1971)

Source: American National Standards Institute, 1430 Broadway, New York, N. Y. 10018

U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health: Registry of Toxic Effects of Chemical Substances. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, published annually.

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CHAPTER 2

DETERMINATION OF NEED FOR EXPOSURE MEASUREMENTS

The proposed OSHA health regulations discussed in section 1.4 require, for establishments where any of the regulated substances are released into the workplace air, that the employer make a written exposure determination. This determination is an estimate of whether any employee may be exposed to concentrations in excess of the action level. This written determination must be made even if the results are negative — that is, even if the employer determines that there is little chance that any employee may be exposed above the permissible exposure limit. This determination is the first step in an employee exposure monitoring program that minimizes employer sampling burden while providing adequate employee protection. Only if this exposure determination is positive (e.g., indicates that an employee may be exposed above the action level) is the employer required to measure (take airborne concentration samples of) employee exposures as detailed in Chapter 3. Refer to Technical Appendix L for a discussion of the action level.

The employer must consider relevant information from insurance companies, trade associations, and suppliers. In establishments having more than one work situation involving a regulated substance, a written determination must be made for each situation. For example, in a plant where a regulated substance is used in both dip tank and spray finishing operations, a written determination must be made for each operation.

Finally, a new written determination must be made each time there is a change in production, process, or control measures that could result in an increase in airborne concentrations of the regulated substance. However, this requirement applies only if the original written determination did not consider the changes.

Therefore, the first written determination can specify production variables over ranges of anticipated operation for which the determination is negative or positive. Also, a “separate determination” does not necessarily imply (or require) a separate piece of paper. One sheet may consider several operations, several chemicals, and the associated operating condition ranges for which the determination applies. The following sections of this chapter give guidelines for considerations to be used in making the determination.

2.1 PHYSICAL STATES OF OCCUPATIONAL ENVIRONMENTAL CONTAMINANTS

Airborne contaminants can be present in the air as particulate matter in the form of liquids or solids; as gaseous material in the form of a true gas or vapor; or in combination of both gaseous and particulate matter. Most often airborne contaminants are classified according to physical state and physiological effect on the human body. Knowledge of these classifications is necessary for proper evaluation of the work environment, not only from the standpoint of how they affect the worker, but also so that correct exposure sampling methods can be employed. In addition, we must consider the route of entry and action of the contaminant.

2.1.1 Gases

Gases are defined as formless fluids that occupy a space or enclosure and that can be changed to the liquid or solid state only by the combined effect of increased pressure and decreased temperature. Examples: carbon monoxide, fluorine, hydrogen sulfide, and chlorine. Their size is molecular.

2.1.2 Vapors

Vapors are the gaseous form of substances that are normally in the solid or liquid state at

normal temperatures and pressures. They can be condensed to these states only by either increasing the pressure or decreasing the temperature. Examples: trichloroethylene vapors, carbon tetrachloride vapors, and mercury vapors. Their size is molecular.

2.1.3 Dusts

Dust is a term used in industry to describe airborne solid particles that range in size from 0.1 to 25 micrometers (0.000004 to 0.001 inch) in diameter. Dusts are generated by physical processes, such as handling, crushing, or grinding of solid materials. Examples: silica, asbestos, and lead dusts.

2.1.4 Fumes

Fumes are solid particles that are generated by condensation of materials from the gaseous state, generally after volatilization from the molten state. The formation of fumes is often accompanied by chemical reaction, such as oxidation. Examples: lead oxide fume, iron oxide fume, and copper fume. Gases and vapors are not fumes, although they are often incorrectly called that, such as gasoline fumes, or carbon monoxide fumes. Fumes typically occur in the size range 0.01 to 5 micrometers (0.000004 to 0.0002 inch).

2.1.5 Mists

Mists are suspended liquid droplets generated by condensation from the gaseous to the liquid state or by dispersing a liquid, by splashing, foaming, or atomizing. Examples: oil mists produced during cutting and grinding operations, acid mists from electroplating, and pesticide mists from spraying operations.

2.2 PHYSIOLOGICAL CLASSIFICATION OF TOXIC EFFECTS

2.2.1 Irritants

Irritants are corrosive in action. They inflame the moist mucous surfaces of the body. Airborne concentration is of far greater importance than length of time of exposure. Examples of irritant materials that exert their effects primarily on the upper respiratory tract are aldehydes, alkaline dusts and mists, acid mists, and ammonia. Materials that affect both the upper respiratory tract and lung tissues are chlorine, bromine, and ozone. Irritants that affect primarily the terminal respiratory passages are nitrogen dioxide and phosgene. There are also skin irritants.

2.2.2 Asphyxiants

Asphyxiants exert their effects on the body by interfering with the oxygenation of the tissues. They are generally divided into two classes: simple asphyxiants and chemical asphyxiants.

The *simple asphyxiants* are physiologically inert gases that dilute the available atmospheric oxygen below the level required to support life. Examples of simple asphyxiants: methane, ethane, hydrogen, and helium.

The *chemical asphyxiants* exert their action on the body by chemical action, by preventing either oxygen transport in blood or normal oxygenation of the tissues. Examples: carbon monoxide, hydrogen cyanide, and nitrobenzene.

2.2.3 Anesthetics and Narcotics

Anesthetics and narcotics exert their action on the body as simple anesthesia through a depressant action on the central nervous system. Examples: acetylene, ethylene, and ethyl ether.

2.2.4 Systemic Poisons

Systemic poisons are materials that cause injury to particular organs or body systems. The halogenated hydrocarbons (such as carbon tetrachloride) can cause injury to the liver and kidneys whereas benzene and phenol may cause damage to the blood-forming system. Examples of materials classified as nerve poisons: carbon disulfide, methyl alcohol, tetraethyl lead, and organic phosphorus insecticides. Lead, mercury, cadmium, and manganese are examples of metallic systemic poisons.

2.2.5 Chemical Carcinogens

Chemical carcinogens are chemicals that have been demonstrated to cause tumors in mammalian species. Carcinogens may induce a tumor type not usually observed, or induce an increased incidence of a tumor type normally seen, or induce such tumors at an earlier time than would otherwise be expected. In some instances, the worker's initial stages of exposure to the carcinogen and the tumor appearance are separated by a latent period of 20 to 30 years.

2.2.6 Lung Scarring Agents

Lung scarring agents are particulate matter other than systemic poisons that slowly produce damage to the lung. The damage occurs by lung scarring rather than by immediate irritant action. Chronic exposure to irritants can also produce these effects.

Fibrosis-producing dusts include crystalline silica and asbestos. Other dusts, such as coal dust, can produce pneumoconiosis, which has long been a concern in the mining industry.

2.2.7 Chemical Teratogens

Chemical teratogens are chemicals that produce malformation of developing cells, tissues, or organs of a fetus. These effects may result in growth retardation or in degenerative toxic effects similar to those seen in the postnatal human.

2.3 ROUTE OF ENTRY AND RATE OF EXPOSURE

Contaminants enter the body principally in three ways:

1. Skin absorption (through the skin),
2. Ingestion (through the digestive tract), and
3. Inhalation (through the respiratory tract).

The respiratory tract is by far the most common access for airborne contaminants to the body because of the continuous need to oxygenate the tissue cells and because of intimate contact with the body's circulatory system.

The effect of inhaled particulate material on the body depends strongly on the particle size. As can be seen in Figure 2.1, typical airborne contaminant particle sizes range from less than 0.01 micrometer to over 25 micrometers (0.0000004 to 0.001 inch). The diameter of particles of concern as a health hazard is generally considered to be below 10 micrometers. This is because the larger airborne particles, particularly those greater than 10 micrometers in diameter, have a much greater probability of being captured in the upper passages of the respiratory system. Particles down to about 0.5 micrometer (0.00002 inch) in size, such as smoke or fumes, penetrate deeper but are usually collected on the mucous lining of the airway ducts. Aerosol particles less than about 0.5 micrometer can reach the lung air exchange walls deep in the lungs. It is here that the lung is most vulnerable to damage.

The rate effect of exposure to toxic agents is usually generalized into acute and chronic.

Acute exposure is characterized by exposure to high concentration of the offending material over a short time span. The exposure occurs

quickly and can result in immediate damage to the body. For example, inhaling high concentrations of carbon monoxide gas or carbon tetrachloride vapors will produce acute poisoning.

Chronic exposure occurs when there is continuous absorption of small amounts of contaminants over a long period of time. Each dose, taken independently, would have little toxic effect but the quantity accumulated over a long period (months to years) can result in serious damage. The toxicants can remain in the tissues causing steady damage. Chronic poisoning can also be produced by exposure to small amounts of harmful material that produce irreversible damage to tissues and organs so that the injury rather than the poison accumulates. An example of such a chronic effect of a toxicant is the disease known as silicosis, which is produced by inhaling crystalline silica dust over a period of years.

2.4 WORKPLACE MATERIAL SURVEY

The primary purpose of a survey of raw material is to determine if potentially harmful materials are being used in a work environment, and if so, the conditions under which these materials are being used.

The first step in the survey is to determine and tabulate all materials that may be used or produced in the work operations or manufacturing processes under investigation and that may be released into the workplace atmosphere or contaminate the skin. In many instances, this information may be obtained from purchasing records. Tabulating this information by process area or operation is useful. This could be done during the Workplace Observations of section 2.6, which is sometimes referred to as a "plant survey."

Many raw materials used in industrial operations will be identified by trade name rather than by chemical composition. In this case, the employer should obtain from the supplier (or the manufacturer) the composition of the raw materials so that each constituent may be identified and properly evaluated.

This information is conveniently recorded on a Material Safety Data Sheet. Two examples of useful formats are the OSHA form and the proposed NIOSH form. Note that the two-page OSHA Form 20, shown as Figure 2.2, is required

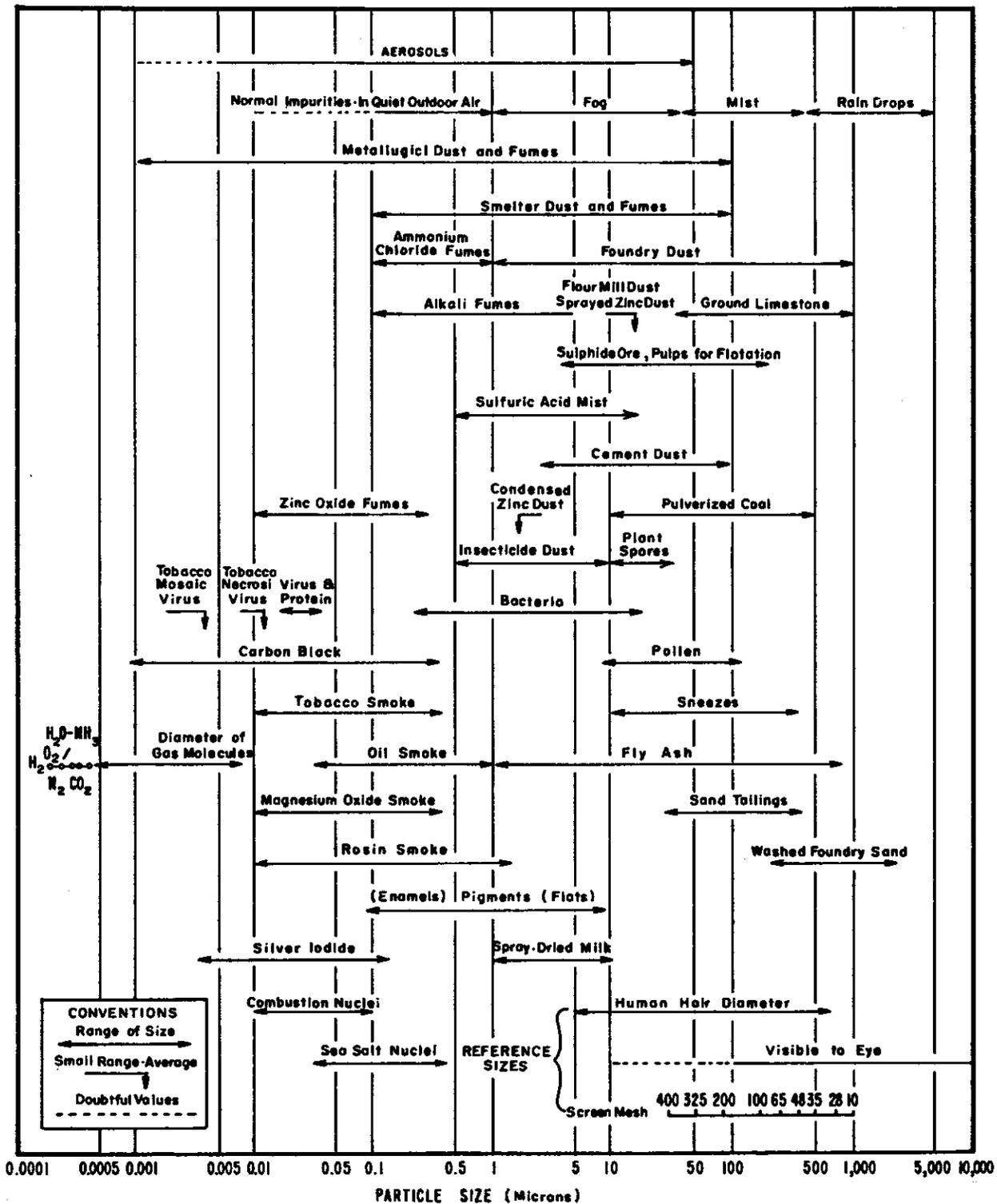


Figure 2.1. The size of airborne contaminants. (Chart reproduced by courtesy of the Mine Safety Appliances Company.)

only in the maritime industry for ship repairing, shipbuilding, and shipbreaking (29 CFR 1915, 1916, and 1917, respectively). Locations having this form of employment are the only locations for which a Material Safety Data Sheet has to be provided by law. Reference 2-1 gives instructions and an explanation of the terms used for preparing OSHA Form 20. The use of the proposed four-page NIOSH form, shown as Figure 2.3, is discussed in Reference 2-2. When using these forms, be sure to check if any of the material components are federally regulated under 29 CFR 1910. If so, there may be specific use regulations for these components, including informative appendices of the proposed OSHA regulations. The appendices are a convenient source of data for the specific properties of these substances.

When these forms are completed, they should be compared with the tables of substances published in the Occupational Safety and Health Standards, 29 CFR 1910. This procedure will allow employers to determine if they are subject to the provisions of Federal regulations by the use of, or the possession of, the substances listed in the published standards. Even if the toxic substances are not federally regulated, the same exposure monitoring, control procedures, etc., that apply to similar substances that are federally regulated should be instituted. Professional industrial hygiene consultation should be employed.

2.5 PROCESS OPERATIONS AS A SOURCE OF CONTAMINANTS

The processes and work operations using materials known to be toxic or hazardous must be investigated and understood. In this regard, there are many processes and work operations that should be suspect with respect to their potential for releasing toxic materials into the work environment and exposing employees to concentrations above the action level. The following are a few examples:

- Any process or operation that involves grinding, sanding, sawing, cutting, crushing, screening, sieving, or any manipulation of material that generates dust.
- Any process involving combustion.
- Processes that involve melting of metals that would release metal fumes and oxides.

- Any liquid or spray process involving the use of solvents or products that contain solvents, such as mixing wet materials, degreasing operations, spray painting, or drying operations. These may generate solvent vapors or mists.
- Processes that involve treatment of metal surfaces such as pickling, etching, acid dipping, and cleaning operations. These may release into the work environment acid or alkaline mists or various gases and vapors as a result of chemical reactions.

These processes and operations are only examples of the many that may be encountered in the wide variety of industries in our society. Some additional examples of potentially hazardous operations and air contaminant examples are given in Table 2.1.

2.6 WORKPLACE OBSERVATIONS

The previous sections generally indicate potential hazards that may be present in a workplace. They provide little or no insight into actual exposures to toxic materials. Their only intention is to provide an indicator as to the existence of potentially exposed employees. Thus, with information about the physical state and effects upon the human body of hazardous materials, the chemistry of products and by-products, and a thorough knowledge of the process and operations involved, the survey is continued by a visit to the workplace to observe work operations. It is here that potential health hazards may be identified and a determination made as to whether an employee may be exposed to hazardous airborne concentrations of materials released into the work environment.

Some potentially hazardous conditions and sources of air contaminants can be visually identified, such as dusty operations. But the dusts or fumes that cannot be seen pose the greatest hazard to workers because they are in the size range that is most readily respirable. Respirable dust is considered that portion of the dust able to reach the nonciliated deep portions of the lungs such as the respiratory bronchioli, alveolar dusts, and alveolar sacs — dust with particle diameters less than about 10 micrometers. Refer to Reference 2-3 for a discussion of sampling devices used to estimate the health hazard due to inhalation of insoluble particulates.

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MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION	
MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.
ADDRESS	
TRADE NAME	
SYNONYMS	
II HAZARDOUS INGREDIENTS	
MATERIAL OR COMPONENT	%
III PHYSICAL DATA	
BOILING POINT, 760 MM HG	MELTING POINT
SPECIFIC GRAVITY (H ₂ O=1)	VAPOR PRESSURE
VAPOR DENSITY (AIR=1)	SOLUBILITY IN H ₂ O, % BY WT.
% VOLATILES BY VOL.	EVAPORATION RATE (BUTYL ACETATE=1)
APPEARANCE AND ODOR	

IV FIRE AND EXPLOSION DATA			
FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE	
FLAMMABLE LIMITS IN AIR, % BY VOL.	LOWER	UPPER	
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARD			
V HEALTH HAZARD INFORMATION			
HEALTH HAZARD DATA			
ROUTES OF EXPOSURE			
INHALATION			
SKIN CONTACT			
SKIN ABSORPTION			
EYE CONTACT			
INGESTION			
EFFECTS OF OVEREXPOSURE ACUTE OVEREXPOSURE			
CHRONIC OVEREXPOSURE			
EMERGENCY AND FIRST AID PROCEDURES			
EYES			
SKIN:			
INHALATION:			
INGESTION:			
NOTES TO PHYSICIAN			

Figure 2.3. Proposed NIOSH form, Material Safety Data Sheet.

TABLE 2.1 POTENTIALLY HAZARDOUS OPERATIONS AND AIR CONTAMINANTS

Process types	Contaminant type	Contaminant examples
<i>Hot operations</i>		
Welding	Gases (g)	Chromates (p)
Chemical reactions	Particulates (p)	Zinc and compounds (p)
Soldering	(dust, fumes, mists)	Manganese and compounds (p)
Melting		Metal oxides (p)
Molding		Carbon monoxide (g)
Burning		Ozone (g)
		Cadmium oxide (p)
		Fluorides (p)
		Lead (p)
		Vinyl chloride (g)
<i>Liquid operations</i>		
Painting	Vapors (v)	Benzene (v)
Degreasing	Gases (g)	Trichloroethylene (v)
Dipping	Mists (m)	Methylene chloride (v)
Spraying		1,1,1-trichloroethylene (v)
Brushing		Hydrochloric acid (m)
Coating		Sulfuric acid (m)
Etching		Hydrogen chloride (g)
Cleaning		Cyanide salts (m)
Dry cleaning		Chromic acid (m)
Pickling		Hydrogen cyanide (g)
Plating		TDI, MDI (v)
Mixing		Hydrogen sulfide (g)
Galvanizing		Sulfur dioxide (g)
Chemical reactions		Carbon tetrachloride (v)
<i>Solid operations</i>		
Pouring	Dusts	Cement
Mixing		Quartz (free silica)
Separations		Fibrous glass
Extraction		
Crushing		
Conveying		
Loading		
Bagging		
<i>Pressurized spraying</i>		
Cleaning parts	Vapors (v)	Organic solvents (v)
Applying pesticides	Dusts (d)	Chlordane (m)
Degreasing	Mists (m)	Parathion (m)
Sand blasting		Trichloroethylene (v)
Painting		1,1,1-trichloroethane (v)
		Methylene chloride (v)
		Quartz (free silica, d)
<i>Shaping operations</i>		
Cutting	Dusts	Asbestos
Grinding		Beryllium
Filing		Uranium
Milling		Zinc
Molding		Lead
Sawing		
Drilling		

Operations that generate fumes may sometimes be visually identified, since the melting of metals, such as in welding, may result in visible smoke emissions. In electroplating and other operations, where metallic surfaces are subjected to a variety of treatments by immersion in heated tanks of acids, alkalies, and degreasing agents, there are often visible mists in the form of steam.

Some sources of air contaminants in work operations can be determined by the sense of smell. Gases and vapors may often be detected by their distinct odors, tastes, or irritating effects, such as burning sensations in the nose, throat, and lungs. However, the ability to identify and detect their presence will vary widely with individuals. Caution is advised in this method of detection because of olfactory fatigue in some cases. Also, many gases and vapors have odor thresholds higher than the permissible exposure levels, so it would be possible for an overexposure to occur before the offending material could be detected by smell. Tables of odor threshold data are very hard to find in the literature and often contain conflicting data.

However, one can check each Federal health standard (29 CFR 1910) and examine the permitted Respiratory Protection Table for the substance. If OSHA specifically allows either a chemical cartridge or gas mask respirator for an organic vapor (without requiring an end-of-life indicator), it can be assumed that the organic vapor has some warning property (generally odor or irritation) at levels below that permissible exposure. One should then refer to Appendix A (Substance Safety Data) and Appendix B (Substance Technical Guidelines) of the particular substance standard for further information on what these warning properties may be. Finally, keep in mind that the senses such as sight, smell, and taste may help to detect contaminants, but they are not dependable in recognizing all health hazards.

Employee location in relation to a contaminant source is also an important factor in determining if an employee may be significantly exposed to a hazardous substance. It should be apparent that in most instances the closer a worker is to the source of an air contaminant, the higher the probability that a significant exposure will occur. In some instances, it may be necessary to investigate air flow patterns within a work

establishment since many contaminants can be dispersed long distances from the source of evolution. Thus, it could be possible to significantly expose workers who are not in close proximity to the contaminant source.

The procedures or methods the worker uses to perform his job should also be analyzed. Exhaust ventilation equipment for degreasing tanks, which is designed to prevent or control the release of toxic materials into the worker's environment, may not perform its intended function if the worker bends directly over the tank to perform his job. In this same respect, a worker's habit of not using or improperly using control equipment may cause significant exposure to hazardous materials. Also, careless handling of toxic materials, whether intentional or unintentional, could cause situations in which significant exposures could occur.

Improper design, installation, or maintenance of control equipment can many times cause exposure situations. Far too often employers (or their contractors) ignorant of the principles of local exhaust ventilation will design and install ineffective control systems. The principles of design and measurements to determine system effectiveness contained in Reference 2-4 should be followed.

There are other characteristics of the workplace that should be considered in relation to how contaminant concentrations can be affected. Certainly high-temperature locations would give rise to higher evaporation rates of toxic solvents. The location of open doors and windows provides some natural ventilation that tends to disperse or dilute materials released in the workroom. Attention should also be directed toward general room ventilation that might provide some measure of control.

2.7 CALCULATION OF POTENTIAL EXPOSURE CONCENTRATIONS

By knowing the ventilation rate in a workplace and the quantity of material generated, calculations can often be made to determine if standards might be exceeded. For example, suppose 4 gallons of methyl ethyl ketone are used (evaporated) at a work station in 8 hours and the ventilation rate in the workplace is 600,000 cubic feet per hour dilution air. The dilution ventilation equations of Reference 2-4 can be modified to give:

Steady-state exposure concentration estimate
(in ppm) = $\frac{(403) (a) (10^6) (b) (K)}{(c) (d)}$

where:

- a = specific gravity of solvents
- b = pints solvent/hr
- c = molecular weight of solvent
- d = ventilation rate in cubic ft/hr

Molecular weights and specific gravities of many common solvents are contained in Reference 2-4. Also certain substances regulated in 29 CFR 1910 have an Appendix B (Substance Technical Guidelines) that contains molecular weight and specific gravity data.

K is a safety factor that must be included to take into account poor mixing of the material into the entire room, locations of fans in the workroom, proximity of employees to the work operation, etc. Reference 2-4 states that K values of 3 to 10 are usually chosen for dilution ventilation work. For our purposes, however, these may not be large enough. The factor K can be thought of as the approximate ratio of breathing zone concentration at the operation to the general room air concentration.

Gonzales, et al. (2-5) performed a study where DOP aerosol was released as a point source at one end of a 20- by 20- by 8-foot room. Ventilation conditions consisted of 6, 9, and 12 room air changes per hour with the entering air uniformly distributed across the entire wall with the outlet air plenum identically constructed. Under all conditions of ventilation, aerosol concentrations ranging up to 4% of the DOP generator concentration occurred within the probable breathing zone at distances 4 to 10 feet from the leak source. At the same time, close to and 2 feet above the leak, where the general concentration might be measured, concentrations ranged from 0.04 to 0.6% of source concentration. Ratios of 100 for breathing zone concentration near the source to fixed room samples concentration (and, thus, general air) were not uncommon.

Therefore, if the employee stays relatively close to the source (within a 10-foot radius), particularly if located downwind from the source, a K factor of 100 would be justifiably conservative. For other situations, K = 10 could be used. The preceding applies only if ade-

quately designed and operated local exhaust ventilation is not used and mixing with room air is relied upon.

If K = 10 was used for the ketone example above, the equation would be:

$$\frac{(403) (0.81) (10^6) (4) (10)}{(72) (600,000)} = 300 \text{ ppm}$$

The TWA standard for methyl ethyl ketone (MEK) is 200 ppm. Definitely a maximum risk worker (typically the one closest to the source, such as a tank or solvent tray, of MEK) should be chosen for the measurement, and an exposure measurement representative of the maximum probable exposure should be obtained as detailed in Chapter 3. Judgments based on the previous equation should be very conservative since a value of K = 1 assumes (unattainable) perfect mixing in the room, and concentrations 10 to 100 times the average room concentration can easily occur near the solvent source.

If the room is "closed" or if the ventilation rate is unknown (or very low), a conservative assumption of one effective room change per hour can be made. Since the room air would probably be poorly mixed, it is best to assume K = 50. The previous equation becomes:

Steady-state exposure concentration estimate
(in ppm) =

$$\frac{(403) (10^6) (\text{specific gravity of solvent}) (\text{pints solvent/hr}) (50)}{(\text{molecular weight of solvent}) (\text{room volume in cubic ft})}$$

Suppose the MEK is used in a nonventilated room at the rate of 1 pint per 8-hour shift. The room is 20 feet long by 20 wide by 10 high, or 4000 cubic feet:

$$\frac{(403) (10^6) (0.81) (0.125) (50)}{(72) (4000)} = 7100 \text{ ppm}$$

Definitely in this case we should proceed with maximum-risk-employee exposure measurements as detailed in Chapter 3.

Hemeon (2-6) provides more sophisticated equations for conventional dilution at sources such as point, area, and strip sources. These equations are very useful for estimating concentrations that prevail in the breathing zone of workers if they are engaged in tasks that in-

volve evaporation only a short distance (a few feet) from their breathing zone. In this case, the local breathing zone concentrations may be high whereas the average concentration in the room is low. Hemeon (2-6) has also provided estimates of typical solvent application rates where the solvent rate information is lacking. The following list of solvent application rates in certain typical individual operations is from Hemeon.

<u>Operation</u>	<u>Pints/minute/ worker</u>
Manual, small-brush cementing	0.02-0.03
Manual, large-brush applications	0.02
Manual, gross application, maximum use rate by hand (unusual)	$\frac{3}{4}$ - $1\frac{1}{2}$
Mechanical coating operations	$\frac{1}{3}$ -2
Spray painting machinery	$\frac{1}{4}$ - $\frac{1}{2}$

The best information on solvent usage is, however, obtained from the employee or shop foreman.

2.8 EMPLOYEE COMPLAINTS OR SYMPTOMS

Employee complaints or symptoms that may be attributable to significant exposure to a chemical substance must always be considered in determining the need for exposure measurements. An employer can obtain information on the common symptoms of exposure to a substance from the Health Hazard Data section in Appendix A of a proposed substance standard (of the type discussed in Section 1.4) and the Signs and Symptoms section in Appendix C of the proposed standard. Any occupational health nurse or physician seeing the employees should be consulted in this aspect.

2.9 OCCUPATIONAL ENVIRONMENTAL DETERMINATION REPORT

The goal of the previous sections is to obtain a written report with a determination stating whether any employee may be exposed to airborne concentrations of a hazardous chemical substance. Refer to appropriate Federal regulations (29 CFR 1910 Subpart Z) to determine minimum required information for this report. The following guidelines provide recommenda-

tions concerning what a comprehensive report should contain. The report can be organized for convenience by either employee or work operation. It is compatible with proposed Federal health standard requirements.

1. Date of report.
2. Name and social security number of each employee considered at a work operation.
3. Work operations performed by the employee at the time of the report.
4. Location of work operations within the worksite.
5. Chemical substances to which the employee may be exposed at each work operation.
6. Any information, observations, and estimates that may indicate exposure of this employee to a chemical substance. List any exposure measurement data and calculations.
7. Federal permissible exposure limits and/or ACGIH TLV for each chemical.
8. Complaints or symptoms that may be attributable to chemical exposure.
9. Type and effectiveness of any control measures used. For mechanical ventilation controls, list measurements taken to demonstrate system effectiveness.
10. Operating condition ranges for production, process, and control measures for which the determination applies.
11. Determination summary including any further action required.

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SUGGESTED READINGS FOR CHAPTER 2

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