CHAPTER 10

GENERAL PRINCIPLES IN EVALUATING THE OCCUPATIONAL ENVIRONMENT

Andrew D. Hosey

INTRODUCTION

Evaluating the occupational environment requires a multidisciplined approach. A fundamental need exists for the input of the knowledge of engineers, chemists, health physicists, physicians, toxicologists, nurses, production supervisors, and others in the elimination of hazards which threaten workers. The most successful approach coordinates these many disciplines and incorporates effective communication between the employer and employee for the recognition, evaluation and control of potential hazards.

Obviously it is not always practical to enlist such a group of workers, management, and highly skilled professionals in Industrial Hygiene for most plants. It is essential, however, that each person evaluating the work environment be knowledgeable of the contributions of other professions to the solution of specific problems. For example, an engineer studying ventilation control for benzene should know the chemistry of benzene and the influence of benzene upon man. Likewise, the physician studying the work environment should have a knowledge of the engineering requirements for control, as well as the chemical sampling and analytical techniques used.

GENERAL PRINCIPLES

The general principles in evaluating the occupational environment concern recognition of potential hazards, preparation for field study, conducting the field study, and interpretation of the survey results.

The recognition of potential hazards includes becoming familiar with the process s, maintaining an inventory of physical and chemical agents encountered, periodically reviewing the different job activities of a work area, and studying the existing control measures. The procedures in the preparation for a field study embrace the selection of proper instruments, calibration of equipment, and the development of the required analytical methods. Factors to consider in conducting a field study are all related to sampling; where, when, how long, and how many samples, as well as the merits of general area versus breathing zone sampling should be weighed. Once the survey has been conducted, the industrial hygienist must interpret the results. Health standards and previous data are available for comparison. Knowledge of proper corrective measures is an integral part of the industrial hygienist's responsibilities.

This chapter presents the guidelines to be considered by an industrial hygienist in planning a strategy for evaluation of the occupational environment.

RECOGNITION OF POTENTIAL HAZARDS

The investigator must become familiar with all processes used in the particular plant or other establishment. He must learn what chemicals or substances are used and produced and the intermediate products, if any. This information may be obtained by asking questions during the survey, by visual observation, and by a study of process flow sheets usually contained in technical books that describe the particular operation. It is of utmost importance that a list of all chemicals and products used be obtained for future reference during the evaluation of the environment. The variety of substances capable of causing occupational diseases increases steadily. New products are constantly being introduced which require the use of new raw materials or new combinations of older substances, and new processes. It has been estimated that new (and some potentially toxic) substances are introduced into industry at the rate of one every 20 minutes and that about 10,000 such materials are in use today. New uses for physical agents in industrial processes are increasing at a rapid rate. Examples include the use of lasers, microwaves, supersonic welding equipment, and many others. These, too, are potentially hazardous unless proper control measures are instituted.

Toxicity of Raw Materials and Products

It is important for the investigator to recognize that the toxicity of a substance is not the sole criterion, or necessarily the most important, of the existence of a health hazard associated with a particular industrial operation. The terms "toxicity" and "hazard" are not synonymous. The nature of the process in which the substance is used or generated, the possibility of reaction with other agents (physical or chemical), the degree of effective ventilation control or the extent of enclosure of the process materials all relate to the potential hazard associated with each use of a given chemical agent (see Chapter 9). Such an assessment must be made along with due consideration of the type and degree of toxic responses the agent may elicit in both the average and, possibly, hypersusceptible workers.

After the list of chemicals used and produced is obtained, it is necessary to determine which of these are toxic and to what degree. Information of this nature can be found in the latest texts and in scientific journals, Hygienic Guides published by the American Industrial Hygiene Association (A.I.H.A.),[1] the Z-37 Standards published by the American National Standards Institute (A.N.S.I.),[2] and by correspondence with toxicologists, technical information centers, and manufacturers. *Toxic Substances,* a recent publication by the National Institute for Occupational Safety and Health[3] contains over 8000 substances. The list, which is revised annually, gives the concentration at which each substance is known to be toxic and should serve as an excellent reference source in the area of toxicology. Many companies publish a list of toxic materials used in their plants for use by safety personnel, foremen, and others. Similar information should be obtained also on the potential hazards of physical agents in use. A number of guides, standards, and texts are available for this purpose.

Sources of Air Contaminants

Many potentially hazardous operations can be detected by visual observation during the preliminary survey. The most dusty operations can be easily spotted, although this does not necessarily mean they are the most hazardous. It must be remembered that the dust particles which cannot be seen by the unaided eye are the most hazardous because they are of respirable size. Furthermore, dust concentrations must reach extremely high levels before they are readily visible in the air. Thus the absence of a visible dust cloud does not mean necessarily that a dust-free atmosphere exists. However, those operations that generate fumes, such as welding, can be spotted visually.

Reference to the list of raw materials, products and byproducts will indicate possible air contaminants. In any burning operation, a knowledge of the fuels used will indicate the air contaminants generated. Separation processes can produce chemicals or particulates which are potentially hazardous.

The presence of many vapors and gases can be detected by the sense of smell. Trained observers are able to estimate rather closely the concentration of a limited number of solvent vapors and gases in the workroom air by the odor level. For many substances, however, the odor threshold concentration is greater than the permissible exposure levels. For example, if the odor of carbon tetrachloride vapor is barely perceptible, this indicates the amount is generally too great for a continuous exposure. In fact, concentrations of some vapors and gases may be present in concentrations considerably in excess of the permissible level, but may not be detectable by their odor.

New Stresses — Changes in Processes

As indicated above, new chemical products and physical agents are continually being introduced and used in industrial processes. The investigator must be aware of these and must ascertain the potentially hazardous nature of these before they are used so that any necessary safeguards can be inaugurated. Many companies, especially the larger ones, have such information available and will generally make it accessible to the investigator. Furthermore, the employer should inform employees of these potential hazards and should establish controls for their protection.

Job Activities Review

A review of the worker's routine job requirements should be made. Changes in his job requirements or modifications of techniques to accomplish his work can have a profound effect upon his exposure to health hazards. Overtime requirements for particular jobs should be determined so that the contribution of overtime and the related prolonged exposure of workmen to health hazards can be evaluated.

Control Measures in Use

The preliminary survey would not be complete unless the types of control measures in use and their effectiveness are noted. Control measures include local exhaust and general ventilation, protective respiratory devices, protective clothing, and shielding from radiant heat, ultraviolet light, or other forms of radiant energy. General guides to effectiveness include the presence or absence of dust on floors and ledges; holes in ductwork, fans not operating or rotating in the wrong direction (the latter has been found to occur in many plants and it should be noted that, even though a blower is operated backward, it will still exhaust some air, but not the required amount); or the manner in which personal protective devices are treated by workmen. During the preliminary survey it may be desirable to conduct a check on local exhaust ventilation systems in use to determine if sufficient airflow is provided to remove the contaminants from the workers' breathing zone. The manual, *"Industrial Ventilation,"*[4] will serve as a useful guide for this purpose since it describes test procedures and contains examples of many types of systems with the recommended airflows.

Adequate notes must be made during an evaluation of the environment. The speed and accuracy of preparing a report of an investigation will depend largely on information recorded in the form of notes.

SELECTION OF INSTRUMENTS TO EVALUATE THE WORK ENVIRONMENT

Sampling instruments used to evaluate the environment for occupational health hazards are generally classified according to type as follows: (1) direct reading; (2) those which remove the contaminant from a measured quantity of air; and (3) those which collect a known volume of air for subsequent laboratory analysis.

Most of the equipment used by industrial hygienists is found under the first two types. The third group includes various types of evacuated flasks, plastic bags, or other suitable containers for collecting known volumes of contaminated air to be returned to the laboratory for analysis.

The choice of a particular sampling instrument depends upon a number of factors. Among these are: (1) portability and ease of use; (2) efficiency of the equipment or device; (3) reliability of the equipment under various conditions of field use; (4) type of analysis or information required; (5) availability; and (6) personal choice based on past experience and other factors.

No single, universal sampling instrument is available and it is doubtful if such an instrument will ever be developed. In fact, the present trend is the development of a greater number of specialized instruments such as the direct reading gas and vapor detectors.

In evaluating a worker's exposure or the environment in which he works, an instrument must be used that will provide the necessary sensitivity, accuracy, reproducibility, and, preferably, rapid results. Detailed discussions of instruments used for sampling for particulates are given in Chapter 13, for gases and vapors in Chapter 15, and for direct reading instruments for aerosols, gases and vapors in Chapter 16, as well as in "Air Sampling Instruments for Evaluation of Atmospheric Contaminants" published by the American Conference of Governmental Industrial Hygienists.[5] Instruments for assessing noise exposure and for other physical agents are discussed in subsequent chapters of this manual. One of the older, but still valid, discussions on this subject is "Sampling and Analyzing Air for Contaminants" by Silverman.[6] Those whose responsibilities include the collection and analysis of samples will find this publication a worthwhile reference.

The use of continuous monitoring devices to evaluate the working environment has increased tremendously in recent years. While these devices are normally not designed for field use, many are available in sizes that are convenient for this purpose. In general, however, many industries install these devices in areas where exposures to certain gases or vapors may vary considerably. Examples include the use of continuous monitors for carbon monoxide in tunnels or plant areas where this gas is produced or used, monitors for chlorinated hydrocarbons such as in the production of carbon tetrachloride or trichloroethylene, and monitors for certain alcohols. Many of these continuous detecting and recording instruments can be equipped to sample at several remote locations in a plant and record the general air concentrations to which workers may be exposed during a shift. Many large plants have added computerized equipment to the recorders so that the data may be readily available and summarized for instant review. However, as is the case with other instruments, continuous monitors must be calibrated periodically and the interferences known.

After selecting the instrument, the industrial hygienist, compliance officer, or other person collecting samples must become familiar with the device and its limitations. He must know, for example, whether or not the particular instrument is specific for the contaminant to be determined, what other substances interfere with the test, and the accuracy and sensitivity of the device. He must also be familiar with the response time, which is the time interval from the instant samples are taken to the time the instrument shows a reading or the chemical reaction takes place in a detector tube. Furthermore, in the case of detector tubes, the readings must be made under good lighting conditions, preferably in daylight.[7,8,9,10,11]

CALIBRATION OF INSTRUMENTS

Instruments and techniques used in calibrating sampling equipment are discussed in detail in Chapter 11. This brief discussion is included to stress the necessity for following recommended procedures in order that the data resulting from the analysis of field samples (whether by direct reading devices in the field or by equipment that collects samples for subsequent laboratory analysis) will truly represent concentrations in the environment, and particularly concentrations to which the worker is exposed.

Since the amount of sample, whether collected by means of a filter, an impinger, or a bubbler or indicated by a direct reading instrument, depends upon the volume of air sampled and its duration, it is essential that the device operate at a known rate of airflow. Thus, the equipment must be calibrated against a standard airflow measuring device both before and after use in the field. The exact rate of airflow must be recorded so that when it is multiplied by the sampling time, the total volume of air sampled or collected will be known. This volume of air is used in calculating the concentration of contaminant to which the worker was exposed. Furthermore, direct reading instruments and detector tubes must be calibrated against a known concentration of the substance for which they are used. Results obtained during a survey or study are no more accurate than the instruments used to obtain the data. In some situations the investigator must do his own calibrating, but more frequently this is done by others at a central laboratory.

ESTABLISHING PROPER ANALYTICAL METHODS

The use of accurate, sensitive, and reproducible analytical methods is equally as important as the proper calibration of the sampling equipment. In evaluating the occupational environment the concentration of contaminant in the ambient air is generally small. In fact, the direct reading instruments and other devices used to collect samples for subsequent analysis are required to detect quantities of substances in the microgram or part-per-million range. Thus, a sufficient quantity of sample must be collected to enable the analyst to determine accurately this small amount of substance.

When available, standard methods of analysis should always be used. Unfortunately, only a few such methods have been tested under various situations and conditions. In the field of industrial hygiene the A.C.G.I.H. has available a "Manual of Analytical Methods" that contains about 20 methods.[12] Many of the nearly 200 A.I.H.A. Hygienic Guides[1] contain recommended methods of analysis. This same organization also publishes Analytical Guides, which to date cover 61 methods of analysis. The American Public Health Association as prime contractor with the National Air Pollution Control Administration, and through the Intersociety Committee, has been developing methods for air sampling and analysis; the first 60 of these have been published as a manual entitled "Methods of Air Sampling and Analysis," American Public Health Association, 1015 Eighteenth Street, NW Washington, D.C., 1972.[13] While these methods were developed primarily for the field of air pollution, most of them can be used for sampling and analysis of environmental conditions in plants.

The American Society for Testing and Materials[14] initiated Project Threshold in March, 1971 to validate test methods in the field of air pollution. Many of these methods can be used also for sampling and analyzing contaminants in the workplace. Several methods have been developed and tested, the latest of which is a tentative fluorescent method for beryllium.

The reason for this lack of tested standard methods is the tremendous amount of time and personnel required to perform the necessary testing. There are nearly 500 substances included in the latest TLV list (A.C.G.I.H.) but there are perhaps less than 100 standardized methods available to determine compliance or non-compliance with the U.S. Department of Labor's regulations under the Occupational Safety and Health Act of 1970. This does not mean that methods other than the standard methods cannot be used. However, these other methods must also be tested and calibrated against known concentrations of the substance in question. Many analytical methods have been published in the literature and the methods should be evaluated in the laboratory prior to performing an analysis.

MAKING THE FIELD SURVEY

The nature of the substance or condition to which workers may be potentially exposed will usually have been determined during the preliminary survey. The problem, then, is to determine the intensity of exposure and to do this one must collect samples of the air or use direct reading instruments. Every effort must be made to obtain samples that represent the worker's exposure. To decide what constitutes a representative sample, the investigator must answer these five basic questions: (1) where to sample; (2) whom to sample; (3) how long to sample (sampling duration); (4) how many samples to take; and (5) when to sample — day or night, what month or season.

Where to Sample

Where the purposes of the sampling are to evaluate a worker's exposure and to determine his daily, time-weighted average exposure, it is necessary to collect samples at or as near as practical to his breathing zone and also in the area adjacent to his normal work station, or general room air. Sometimes it is necessary to sample at the operation itself because of the difficulties of placing a sampling device at his breathing zone or attaching it to his person. On the other hand, if the purpose of sampling is to define a potential hazard, to check compliance with regulations, or to obtain data for control purposes, samples representative of the worker's exposure must be collected. In some cases it is necessary to sample the general room air also to define certain exposures.

Whom to Sample

Personnel exposure is best determined by monitoring the different job tasks in a suspect area. Personnel monitors properly attached to workers directly exposed should give a representative sample to actual breathing zone exposure. Actual exposure sources can be documented with the proper number of personnel samples *combined* with the results from stationary sampling points. Job descriptions for area personnel and the time spent at each task are of primary importance in determining potential exposure.

How Long to Sample

The volume of air sampled and duration of sampling is based upon the sensitivity of the analytical procedure or direct reading instrument; the estimated air concentration; and the Standard or TLV of the particular contaminant. Thus, the volume of air sampled may vary from a few liters, where the estimated concentration is high, to several cubic meters where low concentrations are expected. Knowing the sensitivity of the method, the TLV, and the sampling rate of the particular instrument in use, the minimum sampling time can be determined. The above applies to devices that collect a known volume of air for later analysis. The duration of sampling should represent some identifiable period of time — usually a complete cycle of an operation — to determine an operator's exposure. Another technique is to sample on a regular schedule, for example, so many minutes of each hour. This procedure usually requires more samples than cyclic-type sampling but, when used in conjunction with the cyclic-type sampling, gives more confidence in the results and recommendations.

Evaluation of worker's daily time-weighted average exposures is usually best accomplished when analytical methods will permit, by allowing the worker to work his full 7- or 8-hour shift with a personal breathing zone sampler attached to his person. Techniques have been developed in recent years that allow full shift sampling for many dusts, fumes, gases and vapors. These techniques, which include the use of filters and miniature cyclones to sample airborne dusts and activated charcoal to sample many gases and vapors have been developed successfully in recent years for many airborne contaminants. The concept of full shift integrated personal sampling is much preferred to that of short term or general area sampling if the results are to be compared to standards based on time-weighted average concentrations. When methods that permit full shift integrated sampling are not applicable, time-weighted average exposures can be calculated from alternative short term or general area sampling methods by applying the general formula explained in Chapter 3.

The first step in calculating a worker's or group of workers' daily, time-weighted exposure is to again study the job descriptions obtained for the persons under consideration and ascertain how much time out of each day they spend at various tasks. Such information is usually available from the plant personnel office or foreman on the job. In many situations the investigator must make time studies himself to obtain the correct information. Even though this information was obtained from plant personnel, it should be checked by the investigator because in many situations what the investigator observes and the times given by plant personnel do not agree. From this information and the results of the environmental survey, a daily, time-weighted average 8-hour exposure can be calculated. This assumes that a sufficient number of samples have been collected or readings obtained with direct reading instruments under various plant operating conditions to give a true picture of the exposure.

Where sampling for the purpose of comparing results with airborne contaminants whose toxicological properties warrant short term and ceiling limit values, it is necessary to use short term or grab sampling techniques to define peak concentrations and estimate peak excursion durations. For purposes of further comparison, the time-weighted average 8-hour exposure can be calculated using the values obtained by short term sampling.

How Many Samples to Take

There is no set rule to determine the number of replicate samples that are necessary to evaluate a worker's exposure, provided that a minimum number are taken to characterize the exposure in time and space. A single sample will never suffice even if the investigator believes that this concentration would be maintained throughout the work shift. If the indicated concentration is near or above the TLV or Standard, repeated sampling should be done. Ordinarily, contaminants are not generated at a constant rate, and the concentration can vary considerably from time to time.

Only rarely does an operation release contaminants into the workroom air at a fairly constant rate. Chapters 13 and 15 describe sampling procedures for particulates, gases, and vapors, including information on the number of samples needed. The concentration found in single sample may have been too high or too low due to a number of factors and if the sample had been collected at another time, the results could very well be considerably different. Several dozen samples may be necessary to define accurately a daily, time-weighted average exposure for a worker who performs a number of tasks during the shift.

When to Sample

Another area to be considered in sampling is *when* to sample — a determination of the work shift or seasonal period during which samples should be collected. If, for example, an operator continues working for more than one shift, samples should be collected during each shift that he works. It has been found that in many situations airborne concentrations of toxic substances or exposure to physical agents may be different for each shift. Furthermore, and this applies to plants located in areas where large temperature differences occur during different seasons of the year, samples should be collected during summer and winter months. Normally, there is more general ventilation during the summer months than in winter, a factor which tends to dilute the concentration of the contaminant.

INTERPRETATION OF FINDINGS

Interpretation of the analyses of samples collected or from direct reading instruments is the final step in evaluating the environment. A great deal of common sense and judgment must be used in interpreting the results of an environmental study. Before an investigator determines that a worker or group of workers is exposed to a hazard injurious to health, he must have the following facts: (1) nature of substance or physical agent involved; (2) intensity (concentration) of exposure; and (3) duration of exposures, which will have been determined from the preliminary survey and the results of air sampling done during the environmental study. In many cases, adverse effects from exposure to toxic materials or physical agents do not appear until the exposure has occurred for several years. The purpose of TLVs or Standards is to protect against the future appearance of such symptoms.

Comparison of Results with Standards

Results of the environmental study must be compared with standards before an employer can be cited for a violation or control measures can be recommended. It must be emphasized again that the samples collected during the study must be representative of the worker's daily, time-weighted average exposure, if there is a standard for such exposure, before a comparison can be made.

In connection with the enforcement of the Occupational Safety and Health Act, the standards for exposure to gases, vapors, dust, ionizing and non-ionizing radiation are contained in the Code of Federal Regulations (CFR), Title 29, Part 1910, Occupational and Environmental Health Standards. These were first published in the Federal Register, Vol. 26, No. 105, May 29, 1971 and are subject to revision. At this writing, most of these standards are the same as the A.C.G.I.H. 1970 TLVs, but about 20 are the latest A.N.S.I. Z-37 Standards. In 1971, for the first time A.C.G.I.H. published a combined list of Threshold Limit Values for airborne contaminants and physical agents.[15] Included in the latter are guidelines (TLVs) for noise, lasers, microwaves, ultraviolet radiation, and heat stress. Basic Radiation Protection Criteria[16] should be consulted for standards on ionizing radiation. Other guidelines in this area include the A.I.H.A. Hygienic Guides[1] A.N.S.I. Standards,[2] and the A.S.H.R.A.E. Guide[17] for temperature and humidity.

Many states have adopted standards in the above area, some of which are more stringent than those referred to above. Since a state may qualify to administer and enforce a State Occupational Safety and Health Program under provisions of the Federal Act, the standards in effect in a particular state must be consulted by the investigator. Federal standards adopted to date (1972) are minimum legal requirements and they will no doubt be modified from time to time as new data become available. State standards must be "*at least* as effective" as Federal standards. When state standards are applicable to products distributed or used in interstate commerce, they must be such as are required by compelling local conditions and do not unduly burden interstate commerce.

Comparison of Results with Previous Data

As indicated earlier in this discussion, many of the larger industrial establishments utilize continuous monitors to maintain a record of concentrations of various gases and vapors in certain areas of their plants. These data must be related to worker exposure. Other companies that employ industrial hygienists ordinarily have data on exposures of workmen to various toxic substances as well as certain physical agents. If at all possible, the investigator should make every effort to study these data and compare them with the results of his study. In many cases the data may not be the same and there may be good reasons for the discrepancy. In many instances the data on exposures will be more complete and detailed when taken from company records than when obtained by an investigator from a one- or two-day investigation of certain hazardous operations in that plant. Thus, considerable embarrassment can be avoided if the above suggestion to check other recorded data is followed.

In addition to data available from company records, other sources of such information include the results of previous studies conducted by Federal, state and local agencies, some insurance companies, and consultants. Here again, results of these studies may be different than those obtained by the investigator so great care must be exercised in making comparisons.

SUMMARY

The conduct of environmental surveys and studies is only one phase in the over-all effort in determining occupational health hazards. Such surveys are valuable only if all environmental factors relating to the workers' potential exposures are included. In evaluating workers' exposures to toxic dusts, fumes, gases, vapors, mists, and physical agents, a sufficient number of samples must be collected, or readings made with direct reading instruments, for the proper duration to permit the assessment of daily, time-weighted average exposures and evaluate peak exposure concentrations when needed.

It is essential that the proper instrument be selected for the particular hazard under study and that it be calibrated periodically to insure that it is sampling at the correct rate of airflow and, in the case of direct reading instruments, that they have been calibrated against known concentrations of the contaminant in question. For those samples to be analyzed in the laboratory, a method must be used that is accurate, sensitive, specific, and reproducible for that particular contaminant.

Adequate notes taken during environmental studies are a necessity. An investigator or inspector cannot rely upon his memory after a study is completed to provide the detailed information necessary for the preparation of a report.

Finally, sound judgment should be exercised both during the actual survey and while preparing the report.

References

1. AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. *A.I.H.A. Hygiene Guide Series*, 66 South Miller Rd., Akron, Ohio 44313.
2. AMERICAN NATIONAL STANDARDS INSTITUTE. *Minimum Requirements for Sanitation in Places of Employment*, A.N.S.I. Z-4.1, New York, N.Y. (1968).
3. CHRISTENSEN, HERBERT E. (Ed.). *Toxic Substances — Annual List 1971*, U.S. Dept. Health, Education & Welfare, HSMHA, NIOSH, Rockville, Md. (1971).
4. AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS COMMITTEE ON INDUSTRIAL VENTILATION. *Industrial Ventilation — A Manual of Recommended Practice*, P.O. Box 453, Lansing, Michigan, 48902, 12th ed. (1972).
5. AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS. *Air Sampling Instruments for Evaluation of Atmospheric Contaminants*, 1014 Broadway, Cincinnati, Ohio 45202.
6. SILVERMAN, L. *Air Conditioning, Heating & Ventilating*, "Sampling and Analyzing Air for Contaminants;" (Aug. 1955).
7. MORGENSTERN, A. S., R. N. ASH and J. R. LYNCH. *American Industrial Hygiene Association Journal 31*: 630 "The Evaluation of Gas Detector Tube Systems: I. Carbon Monoxide (1970).
8. ASH, R. N. *Trans. 32nd Annual Meeting of American Conference of Governmental Industrial Hygienists*, "The PHS Detector Tube Study: A Progress Report," Detroit, Michigan (May 10-12, 1970).
9. ASH, R. N. and J. R. LYNCH. *American Industrial Hygiene Association Journal 32*: 410, "The Evaluation of Gas Detector Tube Systems: II. Benzene," (1971).
10. ASH, R. N. and J. R. LYNCH. *American Industrial Hygiene Association Journal 32*: 490, "The Evaluation of Gas Detector Tube Systems: III. Sulfur Dioxide," (1971).
11. AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS — AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. Joint Committee, *American Industrial Hygiene Association Journal 32*: 488, "Direct Reading Detecting Tube Systems." (1971).
12. AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS. *Manual of Analytical Methods*, P.O. Box 1937, Cincinnati, Ohio 45201.
13. "Methods of Air Sampling and Analysis," American Public Health Association, 1015 Eighteenth Street, NW, Washington, D.C. (1972).
14. AMERICAN SOCIETY FOR TESTING AND MATERIALS. *Project Threshold*, 1916 Race Street, Philadelphia, Pa. 19103.
15. AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS. *Threshold Limit Values for Airborne Contaminants and Physical Agents with Intended Changes Adopted by A.C.G.I.H. in 1971*, P.O. Box 1937, Cincinnati, Ohio 45201 (1971).
16. NATIONAL COMMITTEE ON RADIATION PROTECTION. *Basic Radiation Protection Guide*, NCRP Report No. 39, P.O. Box 4687, Washington, D.C. 20008.
17. AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS. *A.S.H.R.A.E. Guide*, 345 E. 47th Street, New York, N.Y. 10017 (Published annually).

Preferred Reading

1. American Industrial Hygiene Association Journal.
2. Archives of Industrial Health.
3. Environmental Science and Technology.
4. Journal of the Air Pollution Control Association.
5. Journal of Occupational Medicine.
6. British Journal of Industrial Hygiene.
7. Bulletin of Hygiene (London).
8. Heating, Refrigeration and Air Conditioning.
9. Analytical Chemistry.
10. Industrial Hygiene Digest.
11. Journal of Laboratory and Clinical Medicine.
12. Noise Control.
13. Toxicology and Applied Pharmacology.
14. New England Journal of Medicine.
15. Air Sampling Instruments Manual (ACGIH).
16. Encyclopedia of Chemical Technology (Interscience Publishers).
17. Handbook of Chemistry and Physics (Chemical Rubber Pub. Co.)
18. I.E.S. Lighting Handbook (Illuminating Engineering Society).
19. Handbook of Dangerous Materials (Sax).