DISCUSSION PAPER

FOR AN

ASTM STANDARDS DEVELOPMENT PROJECT

FOR

INDOOR AIR QUALITY MONITORING

PREPARED BY

HAL LEVIN
CENTER FOR ENVIRONMENTAL DESIGN RESEARCH
UNIVERSITY OF CALIFORNIA, BERKELEY

DECEMBER 10 1984

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OUTLINE OF TOPICS

1.0 INTRODUCTION

Indoor air quality monitoring activities have increased substantially during the past eight years. Under its health hazard evaluation program, NIOSH has conducted a large number of investigations in offices, schools and other public buildings during this interval (Melius, 1984). Sexton of the State of California Indoor Air Quality Program reports that a surprisingly large number of laboratories surveyed by his agency are conducting indoor pollution investigations which are neither for legal compliance nor for purely research purposes.

Most of these studies are conducted for the purposes of determining the source of discomfort or health problems, "building sickness," reported by building occupants. The present author and others have been involved in preventative monitoring efforts intended to characterize indoor air quality prior to new building occupancy as well as efforts to remedy problems in buildings.

The symptoms of "building sickness" include eye, nose and throat irritation; sensation of dry mucous membranes and skin; erythema (reddening of the skin); mental fatigue; headaches; high frequency of airway infections and cough; nausea; and dizziness. Reports of "building sickness" have intensified efforts to understand the causes including the conduct of many air quality monitoring projects (WHO, 1982a).

Nagda and Rector (1983) have made a distinction between research and investigation methods. It is necessary to distinguish between monitoring methods utilized for building investigations, methods for determining compliance with legal limits, and methods intended for research purposes. Monitoring used for building investigation differs from compliance monitoring since it often focuses on low levels of a large number of substances. It usually includes investigation of building mechanical equipment and the operating protocols and maintenance procedures employed in conjunction with this equipment. Some investigators also examine thermal parameters, humidity, and other factors which might contribute to the set of symptoms known as "building sickness."

Standard methods and protocols for building air quality investigations do not exist. In general, equipment, methods, and protocols derived from ambient air quality monitoring and industrial hygiene are employed, frequently by individuals trained in those disciplines. While the failure of many investigators to determine the causes or sources of the complaints and health effects may be partially due to the application of methods developed for other purposes, the absence of protocols to assist investigators in designing monitoring programs may also contribute to the lack of success.

In most reported cases, specific pollutants are not found present in sufficiently large concentrations to explain the complaints and symptoms reported. Some investigators hypothesize that the synergistic effects of low concentrations of large numbers of substances are involved in the etiology of the health effects (Hollowell and Miksch, 1981). No concensus has developed around the mechanism of action, the nature of the chemical mixture responsible, or action other than improved ventilation to ameliorate the problem. Most investigators recommend ventilation system improvements or operational changes.

It is necessary to develop protocols for assessing ventilation as part of indoor pollution monitoring work. Mechanical ventilation systems and natural ventilation found in most residences, offices, schools, and other non-industrial indoor environments differ substantially from industrial ventilation. There is no existing set of guidelines or methods for their thorough investigation. Normal "air balance" procedures for new buildings are intended to adjust the distribution of air amongst supply and return registers and to set supply and exhaust fan volumes to conform to specifications. They do not, in fact, serve to quantify or evaluate ventilation.

The actual performance of the ventilation system with respect to pollutant removal, adequacy of mixing within the conditioned spaces, variations from room to room, etc. are generally not evaluated. It is assumed that these are addressed adequately during system design. Experience does not validate this assumption (Levin, 1984a). Investigations conducted to date conclude that ventilation system problems are responsible in a significant number of cases (Melius, 1984).

In many cases of asbestos monitoring, mechanical ventilation systems are not operated during sampling. This often occurs because monitoring takes place on weekends or during school vacations and holidays to avoid disruption of school activities. Even when ventilation systems are operated, ventilation rates are normally not measured or estimated, nor are they reported. This raises questions regarding the validity of the monitoring data in assessing airborne asbestos levels (Levin, 1984b).

While new methods and protocols are necessary for ventilation system evaluation and monitoring, there are large numbers of investigations, many of them reported in the literature, from which to draw information for the formulation of guidelines for such procedures. There are many researchers and professionals whose experience can contribute to an effective standards development process. And there are many new instruments and techniques developed explicitly for indoor air quality work which can provide alternatives to cumbersome, costly or inappropriate ones developed for ambient or industrial environmental monitoring.

In sum, it appears that the need and the ability to develop standards and protocols for indoor air quality monitoring now exist, that the potential participants appear willing, and the methods and techniques are available for developing standards. And, it appears that such standards would assist those who research, investigate or regulate the indoor environment in accomplishing their goals of understanding, improving or controlling air quality indoors.

2.0 CONSIDERATIONS IN SELECTING POLLUTANTS FOR STANDARDS DEVELOPMENT

2.1 Level of concern

2.1.1 Risk posed by the pollutant in indoor air to building occupants.

2.1.1.1 Occurrence indoors (knowledge, concentrations of concern, sources)

2.1.1.2 Hazardousnous (acute, chronic; mutagenic, carcinogenic, teratogenic).

2.1.2 Existence of standards for exposure limits (OSHA, NIOSH, EPA, HUD, AIHA, ACGIH, ASHRAE, NAAQS, state standards).

2.1.3 Irritant or mild nervous system effects

2.1.4 Odor perception at indoor levels

2.2 Feasibility of monitoring

2.2.1 Existing standard methods applicable to indoor air monitoring

2.2.2 New methods available for IAQ monitoring

2.2.3 Acceptable costs of monitoring

2.2.4 Reliability/accuracy of method(s) including analysis
2.2.5 Portability of equipment used in the field

2.3 Feasibility of developing acceptable standard
2.3.1 Existing standard(s) applicable
2.3.2 Potential to develop standard for established or new methods
2.3.3 Extent of use to date, potential to develop necessary information.

3.0 LIST OF POLLUTANTS
(or types of pollutants) which may be considered for standards.

3.1 Asbestos and other fibrous aerosols
ASTM has published a standard for asbestos monitoring, D 4240 - 83. Additional information might be added for topic areas not contained in that standard but listed in the topical headings developed for other indoor pollutants (See Section 5.0 Outline of topics for standards.) It is important that guidelines for the design of ventilation monitoring and reporting protocols be developed to accompany asbestos monitoring as part of an indoor air quality asbestos monitoring standard.

3.2 Biologic aerosols
Increasing attention to these components of indoor air has resulted from the work done to identify P. legionella. As a result, investigations have shown that airborne concentrations of viable organisms frequently correlate with physiologic reponses and complaints. Symptoms including pulmonary manifestations, muscles aches, chills, fever, headache and fatigue have been attributed to biologic agents. Attack rates in affected office buildings have been from 1 to over 50%. Disease has been attributed to thermophilic actinomycetes, non-pathogenic amoebae, fungi, and Flavobacterium spp. or their endotoxins (Morey, 1984). Some bulk materials sampling may accompany air sampling routinely in future building investigations, research and compliance monitoring. Increased attention to collection and analysis of such samples along with air sampling methods and protocols for biologic aerosols will be required in the next few years.

3.3 Carbon monoxide
Sources of carbon monoxide found indoors include tobacco smoke, gas and fossil fueled appliances, and adjacent garages and roadways. Monitoring is more frequent in residential than other indoor environments, although offices, schools and other non-residential buildings are subject to contamination. Direct reading portable analyzers and larger real-time instantaneous instruments are available.

3.4 Carbon Dioxide
Direct reading portable analyzers as well as stationary and portable sampling devices can be utilized for CO_2 monitoring. CO_2 measurements can provide indirect measures of ventilation rates in densely-occupied structures of known area and occupancy. Such measurements can be used for preliminary evaluations in building, both for compliance and for building investigation procedures. Work to date indicates that CO_2 is an excellent indicator of the relationship between occupancy and ventilation. All-outside-air ventilation can reduce by half the airborne CO_2 level compared with normal building ventilation operations (Turiel, 1983).

It has also been reported that levels above 1000-1200 ppm are frequently associated with complaints related to building sickness symptoms (Rajhans, 1983). Thus, measures of this sort can result in identification of the need for bulding ventilation investigations and corrective action prior to extensive chemical sampling and analysis which may be substantially more costly than ventilation measurements. Tracer gases and other means can be used to validate CO_2 findings, if necessary, for research or compliance purposes.

3.5 Formaldehyde

This contaminant is probably the best known indoor air pollutant award. Its fame is due to its widespread use in building materials, especially plywood, panelling and particle board. It is used as an adhesive or binder in these and other wood products as well as a host of other building products, furnishings and consumer items. Indoor levels of 0.1 ppm are considered problematic and often are exceeded in new homes with low air exchange.

These levels are often associated with serious health problems and complaints of discomfort. The potential carcinogenicity of formaldehyde has been identified. The Interagency Regulatory Liason Group, in its report to the Consumer Products Safety Commission, expressed concern about formaldehyde in combination with other substances found indoors. In particular, the ILRG cited chlorine, present indoors from vapors of hot water, which combines with formaldehyde to form phosgene gas (ILRG, 1980). Formaldehyde is monitored with active and passive devices, and its measurement is almost routine in indoor pollution investigations.

Information on the sources and source strengths of formaldehyde emissions has been developed by several researchers including Matthews, Pickrell, and Meyer. While such information is leading to changes in products and their uses, existing sources now in place will continue to contribute formaldehyde to indoor air for some time to come. Furthermore, many formaldehyde-containing building products, furnishings and consumer products continue to be used indoors (Meyer, 1984).

3.6 Inhalable particulate matter

Smoking, other combustion, and re-entrained dust appear to be important sources of inhalable particulate matter (IP) indoors. Indoor and outdoor concentrations and compositions differ significantly. The importance of IP exposures is accepted, but the measurement of indoor concentrations has resulted in increased emphasis on size distribution. Chemical adsorption on particulate surfaces is receiving additional attention as the organic chemical composition of indoor air becomes better documented.

While sampling instruments are available, they are quite noisy and may be unacceptable in many indoor air monitoring situations.

3.7 Metals and other inorganic particulate constituents

Lead, mercury, arsenic and other heavy metals found in indoor air are usually constituents of particulate matter (discussed below).

3.8 Nitrogen dioxide

NO_2 produced by combustion can be present in levels exceeding annual NAAQS. Many current research projects are monitoring NO_2, and the results will determine the extent of further work required. Work already completed indicates that NO_2 monitoring will continue to be an important component of indoor air quality work. Passive samplers and real-time instantaneous reading instruments are available.

3.9 Ozone

Office copiers and air cleaners are considered important sources of ozone indoors. Measured average levels of ozone may be low due to the reactivity of ozone and the normal abundance of organics. Levels near the ozone sources may be extremely high and require special protocols to provide the desired level of protection from excessive exposure. Care is also required in sampling when results will be the basis for comparing levels to other data.

3.10 Pesticides and other semi-volatile organics

Contamination of residential and non-residential environments by pesticides and other semi-volatile organics is not uncommon. Monitoring where severe contamination exists is often critical to decisions regarding occupancy of affected buildings. Protocols for monitoring environmental conditions, for determining the extent of sampling, for determination and verfication of ventilation system operation, and for assessing other relevant factors are necessary to provide the information used in making important personal and economic decisions. Such protocols are lacking currently with the result that uncertainty and conflict can occur. (Levin, 1984a, Hahn et al, 1984.)

3.11 Polyaromatic hydrocarbons and other organic particulate constituents

PAHs are complex organic substances including known and suspected carcinogens. Benzo-a-pyrene (BaP) is often measured to indicate PAH concentrations although the relationship is not well-defined. They are produced indoors by incomplete organic combustion including tobacco smoking, wood-burning, and cooking. PAHs occur in vapor and condensed forms. Usually, only the particulate (condensed) form is measured (NAS, 1981).

3.12 Radon and radon progeny

Radon continues to be an indoor pollutant of concern as local researchers discover high levels. Monitoring must involve ventilation considerations. Passive and active monitors are available.

3.13 Sulfur dioxide

Kerosene heaters appear to be the major source of SO_2 indoors. Due to the extensive use of these devices for residential heating, monitoring is likely to continue.

3.14 Volatile organics

Current EPA-sponsored research focused on volatile organic compounds (VOCs) indicates the number of compounds usually present is higher than previously believed. Furthermore, indoor-outdoor ratios are consistently greater than unity (Wallace, 1984). There is general agreement that VOCs are important indoor pollutants and that they present complex barriers to effective, affordable monitoring. State-of-the-art methods can be the subject of standards to assist the research community as further work will likely occur primarily at that level.

3.15 Complex mixtures

Tobacco smoke, exhaled human breath, cooking by-products, gas-combustion, and other indoor air constituents are composed of complex mixtures often including varieties of organic and inorganic vapors as well as particulates. These mixtures change over time and through space after generation as they mix with room air, combine chemically, and undergo physical changes. Source monitoring provides the basis for understanding their environmental fate. As more sophisticated control measures are considered, deeper understanding of complex mixtures will be required.

3.15.1 Tobacco smoke.

Much of the literature and research on indoor pollution focuses on tobacco smoke as an important source of indoor pollution. Tobacco smoke is considered to pose serious health threats to "innocent parties," i.e., non-smokers. As a result of both the health and irritant properties of tobacco smoke as well as increased office employment and reduced ventilation in office environments, a great deal of attention has been focused on passive or "involuntary" smoking. Legislation at the local level has been enacted or considered in a growing number of communities, most notably in San Francisco and neighboring municipalities in the Bay Area. As a result, employers are seeking ways to protect non-smokers from the cigarette smoke of others and to discourage smoking in the work environment.

Characterization of cigarette smoke has been done for purposes of clinical and laboratory toxicity studies and epidemiology. However, little work has been done on the fate of the constituents of tobacco smoke in the indoor environment. It is likely that such monitoring will be done in the coming years as regulatory and technical developments focus increasing attention on tobacco smoke as an indoor air pollutant and health hazard.

Efforts to identify effective means for controlling tobacco smoke concentrations have relied on measurements of specific components, usually particulates and carbon monoxide, occasionally formaldehyde and other organics, and, for special purposes, certain other constituents. However, insufficient study has been devoted to the measurement of tobacco smoke components at spatial or temporal distances sufficiently removed from the source to evaluate the effectiveness of various control measures. Yet ventilation standards are being developed which distinguish between smoking and non-smoking occupancy in determining outside air requirements varying by factors from five to many times that in some recent risk analyses. (ASHRAE, 1981; Repace & Lowery, 1984; Weber, 1984).

3.15.2 The environmental degradation products of many substances present indoors pose very serious health hazards. Included, for example, are the dioxins and furans which are formed when PCBs or PCPs are exposed to high temperatures. Since these chlorinated compounds are often contaminated with dioxins and furans during the manufacturing process, their hazardous by-products are present at low concentrations in most residential and office environments (MacLeod, 1979). Emerging knowledge on the occurrence and hazards of these substances has already led to increased efforts to monitor them in instances such as the transformer explosions at Binghamton. N.Y. and San Francisco (Hahn, 1984).

4.0 NON-POLLUTANT MEASUREMENTS AND DATA

Indoor air quality monitoring can be of little or no practical value where information on the environmental conditions, building operating conditions, building use patterns, and other factors affecting source strength and dilution are not reported. It is recommended that general requirements for background data or environmental conditions be reported with all indoor air quality monitoring - research, compliance or problem building investigation. The factors listed below are suggested as parameters for which standards be developed or adapted (where applicable standards already exist, as they do in many instances.)

4.1 Thermal environment

The significance of the thermal environment for indoor air quality evaluation is acknowledged (WHO, 1982; Meyer, 1983). Yet monitoring of the thermal environment is not always reported in conjunction with indoor pollution monitoring. Furthermore, the thermal complexity of the indoor environment presents difficulties which must be considered in the design of monitoring programs. Air temperatures vary vertically within spaces, from air to surfaces, and within materials. These differences can have important consequences for both the thermal comfort of occupants as well as for the vapor pressures of substances being emitted into the air. Protocols for the monitoring of thermal parameters should accompany standards for measurement and reporting.

4.2 Relative Humidity

The moisture content of air significantly affects the release rate of many pollutants, the concentrations in air, and the potential to affect biological organisms and physical systems. A large number of devices exist which can economically and accurately monitor indoor air humidity within acceptable limits of cost.

4.3 Air movement

Air currents within buildings areextremely complex and subject to the influence of a large number of factors. These include mechanical system functional characteristics, building plan, location and configuration of furnishings, activities, openings between interior spaces, openings in the exterior envelope, temperature differences between supply air and building air, and other factors.

Development of useful air sampling strategies and interpretation of results from monitoring require data on air movements within sampled spaces. Such data is necessary but difficult to acquire. A multiple tracer gas system may be developed to accomplish this. Further work is required. The following are some of the parameters which should be characterized:

- Velocity
- Direction
- Spatial patterns
- Volumes at supply and return registers in area monitored

4.4 Air exchange rates

There are a number of methods now in use for determing air exchange rates and they vary greatly in cost, applicability and reliability. These methods range from the use of tracer gas (i.e. SF6) to the use of pressurizing systems (often used in smaller structures, particularly houses, in conjunction with energy-related research.) In addition, there are methods used by mechanical engineers and air balance specialists to measure air volumes at registers and fans in building mechanical systems. Then, by computation, overall outside air volumes are derived. Standardization of techniques for acquiring and reporting data are essential to make results reports comparable amongst buildings and investigations. Amongst the factors which can be chartacterized are the following:

1) Ventilation rate - air volume supplied to a building volume or area or occupant load; and,

2) Air exchange rate, outside air intake, exhaust air, infiltration/ exfiltration.

4.5 Wind

The important parameters include the following:
1) Direction and velocity; and,
2) Variations at the perimeter of building.

4.6 Building Characteristics

Different types of investigations generate different needs for data on building characteristics. Standardization in the use of terms and the measurement practices involved in building characterization will improve the comparability of results and assist in the development of more systematic assessments. The list of topics which follows is not exhaustive but illustrates the categories of data often sought in research and building investigation activiities.

4.6.1 Indoor/outdoor relationships
1. Openings in building envelope
2 Nature of operational barriers (doors, windows, vents, screens, dampers, filters, fans, etc.
3. Timing and use characteristics of openings
4. Control
5. Monitoring
6. Envelope materials permeability to light, heat, particles, gases

4.6.2 Occupancy
1. Density and distribution of population
2. Population characteristics
3. Activities
4. Schedules

4.6.3 Maintenance
1. Activities
2. Schedules
3. Materials

4.6.4 Mechanical system
1. Description: design, configuration, components
2. Operations: timing, modes, control
3. Maintenance: frequency, procedures, evaluation, verification
4. Performance: measured air volumes, temperatures, humidity

5.0 OUTLINE OF TOPICS FOR STANDARDS

The following lists topics which are commonly found in existing workplace sampling methods standards. Topics may not be the same for all indoor air quality sampling methods standards. However, it is desirable that a set of guidelines be developed to provide consistency where deemed practical. A coordinating group might be charged with developing such guidelines for sub-groups working on specific standards.

5.1 List of topics

Scope
Applicable Documents
Summary of Method
Significance and Use
Constraints on method
Definitions of Terms Specific to this Standard

Interferences
General Method Description
Apparatus and Materials
Reagents
Safety Precautions
Sampling
Handling and Storage of Sample
Calibration and Standardization
Procedure
Calculations
Sampling and Analytical Errors
Protocols
Precision and Accuracy

6.0 PROTOCOLS

The diversity of disciplines involved in indoor air quality work, the rapid increase in interest in the subject, and the complexities and difficulties of developing effective monitoring protocols create the need for standards regarding the development of protocols. These may divided into two classification systems: 1) type of investigation, and 2) suspected pollutants or sources.

The type of investigation will play a major role in determining the requirements of the protocol. Research, compliance, and building investigations each have separate requirements for protocols. Different pollutants or sources also determine protocol design. The following sections describe some considerations in the development of protocols and will form the basis for discussions on the incorporation of protocols into indoor air quality monitoring standards.

Additionally, where particular sources are suspected, or where monitoring is conducted for determining product emission rates, special protocols are required.

6.1 General Considerations.

6.1.1 Introduction:

"The aim of sampling is to provide a miniature reproduction of the larger portion of the environment which is to be examined, but on a scale that will enable the sample to be manipulated in the laboratory" (NAS, 1975).

Sampling in enclosed environments (industrial and non-industrial workplace, indoor non-workplace) differs from outdoor sampling in several aspects. Amongst the most important are the introduction of ventilation air through mechanical or natural means, the diversity of pollutant sources, the very large number of sources and contaminants of concern, and the imperfect mixing of indoor air resulting in special difficulties. Of these difficulties, representation of the larger indoor environment of which the sample(s) is (are) to be representative requires attention to temporal and spatial variations.

Even where indoor conditions are closely controlled by mechanical equipment, variations in meteorology and outdoor source strength can significantly affect distributions and concentrations of pollutants indoors. The most careful and thorough planning of monitoring activities will often be undermined by changes in occupant behavior (not smoking, different activity patterns, etc.) or climatic variations. Mixing can be less complete indoors than outdoors due to the limited volumes, large surface area variations, and the action of natural and mechanical ventilation systems.

Sampling in indoor air may present special problems due to the unacceptability of invasive sampling equipment and personnel. Noise, diplacement of objects, restrictions on movement or activities, modifications to normal air handling protocols, etc. are often unacceptable aspects of indoor air sampling. The same problems often apply to the collection of data on other environmental parameters.

Operating conditions of the building cannot always be modified to provide the desired test conditions - worst case, typical case, best case, 100% outside air, minimal outside air supply, standard temperatures or humidities. Thus, testing must often be done under conditions which might differ significantly from desired conditions.

The tendency for many pollutants to adsorb onto the very large surface areas presented in indoor environments results in dynamics which limit the ability to compute or infer concentrations under conditions other than those at which testing was performed. Furthermore, factors affecting pollutant concentrations prior to monitoring must be ascertained and, to the degree possible, controlled to assure steady state and, therefore, well-defined concentrations have been reached at the time of monitoring.

Reports of monitoring for several indoor pollutants show substantial diurnal, seasonal, and annual variations due to meteorolgical factors, building operational factors, and source strength factors (Meyer, 1983).

6.2 Indoor air quality research:

Some monitoring will be done for the purpose of determining the efficacy of monitoring protocols, instruments, analytical techniques, or other aspects of indoor air quality. Other investigators are interested in estimating population exposure to indoor pollutants. This work includes that done for purposes of characterizing indoor pollutants in various building types and work done to assist in the development and validation of models used for predictive or policy purposes. Other work is conducted to estimate source strengths (product emission rates) or to determine the efficacy of various control measures.

Due to the purpose and use of research work, quality assurance and quality control measures must be rigorously applied. Furthermore, reports of results must be more comprehensive and detailed including data on related factors such as environmental conditions indoors and outdoors, concentrations of other pollutants, characteristics of the building being monitored, and other factors which may affect the interpretation or replicability of the results by other researchers or by policy-makers.

6.3 Compliance monitoring:

Monitoring conducted to determine compliance with legal limits or consensus standards must be done under standardized conditions or ones which can be referenced to standardized conditions to avoid false negatives or positives. Prevailing restrictions on funding of public agencies ordinarily involved in compliance monitoring require that methods be as economic as possible. The potential significance of the results on building owners, occupants and users require that the results be reliable and replicable. Quality assurance and quality control require thorough documentation.

6.4 Investigations of problem buildings:

Investigations are conducted by professionals and technicians with a wide range of backgrounds, interests and skills. Investigations are conducted under widely varying circumstances. Weather, occupancy, operation of building equipment, etc. which can have significant impacts on monitoring results can vary substantially from one building to another and from one day to another in a single building. The purpose of such investigations is to determine the source of dissatisfaction with indoor air quality or of health effects.

Since both the problems being investigated and the building environment can vary so widely from case to case, it will not be possible to develop universal protocols. However, there are guidelines which can be provided to assist in the design of protocols and assessment of monitoring results. Due to the variations between buildings and the personnel involved in investigations, it is important that guidelines be provided to reduce useless or misleading monitoring. It is also important that variables (other than the concentrations of indoor air pollutants) which may contribute to the problem be considered systematically, preferably before monitoring is conducted.

The experience of investigators who fail to identify the specific source(s) of complaints indicates that there may either be synergistic effects of various pollutants and other environmental factors or that investigations may systematically fail to monitor effectively. One strong possibility emerging from the literature on investigations is that investigators arrive too long after episodic pollution which may originate in new materials, furnishings or equipment. Particularly important may be volatile, low molecular weight organic compounds which are present in some materials. The long lag time between onset of symptoms leading to complaints and the reports of complaints or the initiation of investigations have hampered investigations in the past.

A major issue which must be resolved concerns the conditions under which sampling is done. Do we specify them or only the methods for monitoring and reporting them?

6.5 Materials Evaluations

There is a growing demand for data on the emission rates of chemicals from building materials, furnishings and equipment. Private industry trade associations and public and private laboratories are conducting tests. A small number of test methods have gained favor. These include vacuum extraction, desiccator tests, head space tests, and environmental chamber tests. Standards for test methods already exist to a limited degree for some of these tests. Others are completely without standardization. ASTM would make a valuable contribution by developing such standards.

7.0 INSTRUMENTS

A variety of instruments have been developed in recent years which are applicable to indoor air quality work. Many of them have been developed explicitly for indoor pollution monitoring. Others were developed for other purposes but may be applicable.

Instruments available for indoor air quality monitoring were reviewed in 1980 by Sandia and again in 1982 by Geomet which is currently preparing updates for their earlier report. A review of instruments including the following topics will be useful as part of the general documentation which accompanies the completed standards compendium (Nagda and Rector, 1982; NIOSH, 1977). Some categories for review or analysis of instruments for use indoors are given below.

1. Personal, Portable or Stationary
2. Sensitivity/limits of detection
3. Cost of instrument

4. Calibration requirements and procedures
5. Accuracy within operating range
6. Power requirements, service time
7. Versatility for more than one pollutant
8. Integrated or direct reading
9. Recording capability
10. Obtrusiveness: noise, visibility, space requirements
11. Active or passive
12. Analyzer or collector
13. Availability
14. Travel considerations

8.0 ANALYTICAL METHODS AND CONSIDERATIONS

Major innovations in analytical methods have been made, particularly for organic compounds and asbestos fibers. However, there are controversies as well as developments concerning the analysis of these substances and others found in indoor air. It is important to the overall value of the standards that broad participation and state-of-the-art methods be considered and evaluated in the standards development process (EPA, 1984; Nagda and Rector, 1983; NAS, 1975; NAS, 1976; WHO; 1982b).

9.0 QUALITY ASSURANCE AND QUALITY CONTROL

Existing standards and methods commonly contain guidelines for QA/QC procedures, criteria and standards. This information can be modified to make it suitable to the indoor air quality monitoring activity at hand: research, compliance or building investigation. While there may be differences in the rigor applied in each type of monitoring, the provision of standards will establish guidelines and the basis for adoption of more rigorous QA/QC practices where applicable (EPA, 1976; Nagda and Rector, 1982; NIOSH, 1977).

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