

THE JOURNAL OF Allergy AND Clinical Immunology

August 1994, part 2 • Volume 94 • Number 2

The problem of the “sick” building—Facts and implications: Identifying and measuring indoor nonbiologic agents

Yehia Y. Hammad, ScD [[MEDLINE LOOKUP](#)]

- *Tampa, Florida*

Sections

- [Technical Terms and Units](#)
- [Indoor Air Quality Investigations](#)
- [Sampling for Nonbiologic Agents](#)
- [Evaluation Criteria](#)
- [References](#)
- [Publishing and Reprint Information](#)

- [Previous article](#) in Issue
- [Next article](#) in Issue
- [Drug links](#) from Mosby's DrugConsult
- [Genetic information](#) from OMIM
- Citation of this Article
 - View on [PubMed](#)
 - Download in [citation manager format](#)
 - Download in [Medlars format](#)
- [Related articles](#) in PubMed

ASHRAE	American Society of Heating, Refrigeration, and Air-conditioning Engineers
CFM	Cubic feet per minute
EPA	Environmental Protection Agency
HVAC	Heating, ventilation, and air conditioning
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration

The energy crisis of the 1970s resulted in modifications in heating, ventilation, and air-conditioning (HVAC) equipment to minimize air-handling costs by limiting the amount of outside air brought into a building. The standard for the amount of outside air per person supplied by HVAC dropped from 20 to 30 cubic feet per minute (CFM) per person to 5 CFM per person. This value was recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in their Standards 62-73¹ and 62-81.²

Architectural practices and decorating styles also changed during this period. Examples include the use of sealed instead of openable windows, extensive use of wall-to-wall carpeting, and expanded use of particle board. Equipment within buildings, particularly nonindustrial buildings, changed during this same period with the introduction of copying machines, laser printers, personal computers, and other electric devices. These changes in the indoor environment were associated with the introduction of contaminants such as volatile organic compounds from carpets, solvents from paints and varnishes, ozone from copying machines, ammonia from blueprint machines, acetic acid from photographic equipment, and formaldehyde from particle boards used for wall paneling and the construction of desks, cabinets, and other furniture.

Other important sources of airborne contaminants are the materials used for building maintenance such as cleaning solutions, disinfectants, carpet shampoos, and floor waxes. Routine human activities also introduce chemicals and particulates in the indoor environment. Examples are cigarette smoke, carbon monoxide, carbon dioxide, oxides of nitrogen generated from cooking activities that use natural gas combustion, and bioeffluents released by human metabolism, such as carbon dioxide, methane, ammonia, hydrogen sulfide, acetaldehyde, pyruvic acid, lactic acid, and butyric acid.

The significant drop in outside air requirements, together with the introduction or increase in the large number of new sources of airborne contaminants, have contributed to potential problems with indoor air quality. ASHRAE has subsequently modified the ventilation guidelines, published in 1990 in Standard 62-1989,³ with the flow rate of outdoor air recommended at 15 to 20 CFM per person. The above discussion focused on the indoor sources and their relationship to the activities and equipment that existed inside the buildings. Obviously, indoor air quality can also be influenced by contaminants that are generated outdoors and enter the building through various pathways such as the shell or "skin" of the building or through fresh air intakes.

The National Institute for Occupational Safety and Health (NIOSH) has been asked to perform what is known as health hazard evaluations in the indoor environment. NIOSH has conducted more than 500 of these evaluations in buildings with indoor air quality complaints. The problems were attributed to inadequate ventilation in 53% of the cases, inside contaminations in 15%, and outside contamination in only 10%. About 5% of the problems were attributed to building material contamination and another 5% to microbial contamination.⁴

Technical Terms and Units

TOP

In this section some of the important technical terms and units encountered during the evaluation of air quality will be introduced and discussed.

CFM of outdoor air per person

This is the unit of air flow specified in ASHRAE Standard 62-1989.³ It is the air flow rate of outside air delivered to the building divided by the number of persons occupying the space.

CFM of outdoor air per square ft

This is another way to specify ventilation rate of outdoor air. It is expressed in net occupiable area and not gross area of the building. This unit is also used in the ASHRAE standard.³

Air changes per hour

This is the conventional way to express the total actual dilution ventilation rate of a specific space. It is equal to the ventilation air flow rate in CFM divided by the volume of ventilated space in cubic feet. However, it can also be used to express air changes per hour of outdoor air.

Concentration of gases and vapors

A gas is a substance that is in the gaseous phase at normal temperature and pressure. A vapor is the gaseous phase of a material that is a solid or a liquid at normal temperature and pressure. The concentration can be expressed in units of parts of contaminant per million parts of air by volume (parts per million) or in weight of contaminant (milligrams) per unit volume of air (cubic meters).

Concentration of particulates

Concentration of particles is usually expressed as weight of dust (milligrams) per unit volume of air (cubic meters). Under some circumstances the concentration of dust that can be tolerated is very low, such as in clean rooms used in electronics and the space industry or in the case of asbestos fibers in indoor air. Concentration is expressed in these situations as number of particles or fibers per milliliter of air.

Indoor Air Quality Investigations

TOP

Investigations into building complaints should be approached in a systemic fashion similar to that used in industrial hygiene surveys. The first step is to collect and review available documents and records regarding design, construction, floor plans (blueprints), space modifications and remodeling, history of HVAC maintenance, and finally documented complaints by the building's occupants. The next step is a walkthrough survey conducted to search for indicators and sources of air pollutants, such as odors, staining, mold growth, signs of water damage, and sanitation problems. It is also important to inspect the activities in the immediate vicinity of the building to identify other possible causes for the complaints, such as the presence of car parking facilities.

Although radon and asbestos are considered the two major indoor air pollutants, short-term health effects are not associated with these two contaminants. The symptoms will most probably be

related to biologic and other nonbiologic agents. The main nonbiologic contaminants and their sources are shown in ■Table I.

TABLE I. Main nonbiologic contaminants and their sources

Contaminant	Sources
Acetic acid	Photographic and x-ray development equipment, and silicone caulking compounds
Carbon dioxide	Unvented gas and kerosene appliances, processes producing combustion products, and human respiration
Carbon monoxide	Tobacco smoke, engine exhausts, unvented gas, and kerosene appliances
Formaldehyde	Off-gassing from urea formaldehyde foam insulation, plywood, particle board, paneling, carpeting and fabric, glues, and combustion products including tobacco smoke
Nitrogen oxides	Combustion products from appliances and tobacco smoke, welding, and gas and diesel engine exhaust
Ozone	Copy machines, laser printers, electrostatic air cleaners, and smog
Volatile organic	Paint, cleaning compounds, glues, copy machines, silicone caulking compounds material, insecticides, and combustion products including tobacco smoke, carpeting
Miscellaneous	Microfilm equipment, window cleaners, acid drain cleaners, blueprint gases including equipment, and outdoor sources ammonia, hydrogen sulfide, sulfur dioxide
Man-made	Fibrous glass and mineral wool used in thermal insulation and HVAC mineral fibers ducts

The third step is to conduct comprehensive personal interviews of the occupants. The history of the complaints, the patterns of symptoms, the spatial locations, and the timing of complaints can be of significant help to identify the area of the problem.

The final step in this investigation is environmental monitoring. It is conducted either to identify the agent or to measure and evaluate the extent of the problem when the agent is already identified.

Sampling for Nonbiologic Agents

TOP

Air sampling may seem to be the logical response to an indoor air problem. However, measurement of a specific agent may be misleading as well as very expensive. It should be performed when all the investigations previously described are completed and decisions are reached on location of sampling, time of sampling, and appropriate analytic procedure. Subsequent use of the results should also be considered before the samples are taken. For example, the results can be used to

relate indoor concentrations to outdoor conditions, to compare concentrations obtained in complaint areas with those collected in which no symptoms are reported, and to compare the results with specific air quality standards.

A sufficient amount of the contaminant must be collected during sampling to perform subsequent qualitative and quantitative analytic procedures. The amount collected will be proportional to the airborne concentration, sampling flow rate, and duration of sampling. Air sampling can be performed to obtain either area or personal samples. The selection of the sampling method depends primarily on the airborne contaminant, the purpose of the survey, and subsequent sample analysis. One should ascertain if a particular situation is covered by statutory requirements by a federal, state, or local regulatory agency before any sampling program is undertaken. If the situation is regulated, then the decision to diverge from the official regulatory agency procedure is a major one, because the individual carries the burden of proof to prove the equivalence of the selected unofficial method. Sampling and analytic techniques are described in adequate details in several publications by the Environmental Protection Agency (EPA)* and NIOSH.⁵ Comprehensive descriptions of air sampling equipment are in several recent publications.⁶⁻⁹

Aerosol sampling

Samples of particles may be collected by various techniques, including filtration, electrostatic precipitation, and impaction. Particle collection can be obtained with or without size separation. Collection without size separation is used to obtain total suspended particulate matter for subsequent gravimetric, chemical, or physical analysis. Collection with size segregation is used for many purposes such as determination of particle size distribution of airborne dust and determination of a specific fraction of the dust cloud that will deposit in the various compartments of the respiratory tract. Examples are the respirable fraction required by the Occupational Safety and Health

Administration (OSHA) standards¹⁰ and the mass of particles less than 10 μm fraction required by the EPA's Air Quality Standards.¹¹

Sampling of gases and vapors

Sampling of gases and vapors can be conducted to obtain grab, intermittent, or continuous samples. Each sampling procedure will provide data representing a range of averaging times. Grab samples can be collected by gas sampling bags, evacuated bottles, gas syringes, and gas detector tubes. Intermittent samples can be obtained by absorbing the gases in liquid media contained in bubblers and impingers or adsorption of gases on solid media such as charcoal and silica gel. A popular new technique is passive dosimetry. Gases and vapors are allowed to diffuse into the collection medium of the dosimeter, and therefore the use of an air moving device such as an air pump is not needed. Another category of detection device is the direct reading instruments that are used extensively in field evaluations. They can be operated intermittently or in a continuous mode to provide real-time sampling and readout. A major disadvantage of these latter types of instruments is their high cost, which limits the number of available sampling units and makes frequent sampling impractical.

The enforcement of OSHA's safety and health standards in the work environment is possible because of the clearcut relationship between industrial processes and concentrations of airborne contaminants. The exposed population is principally healthy adults who are willing to accept the risks associated with the exposure limited to the work day, which is usually 8 hours. This is not the case with indoor air quality problems that occur in the home, office, schools, and public buildings. The exposed population includes all age group from infants to the elderly. In addition, persons with allergies, diseases of the heart and lungs, and other diseases are at potential risk. Hence the development and enforcement of comprehensive indoor air quality standards is much more difficult.

OSHA permissible exposure limits,¹⁰ ACGIH threshold limit values,¹² and NIOSH recommended exposure limits¹³ are derived from the industrial setting and should not be used as evaluation criteria for indoor air quality. The only standards that seem to be applicable currently are those published by ASHRAE,³ which are derived from recommendations by the World Health Organization.¹⁴

Building owners and managers concerned about the possibility of indoor air quality problems in their property may consult the "Guide for building owners and facility managers" published by the EPA and NIOSH.¹⁵

References

[TOP](#)

1. ASHRAE Standard 62-73. Standard for natural and mechanical ventilation. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc, Atlanta, Georgia, 1977.
2. ASHRAE Standard 62-81. Ventilation for acceptable indoor air quality. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc, Atlanta, Georgia, 1981.
3. ASHRAE Standard 62-89. Ventilation for acceptable indoor air quality. American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc, Atlanta, Georgia, 1990.
4. Congressional testimony of J. Donald Millar, Director, before the Subcommittee on Superfund, Ocean, and Water Protection, Committee on Environment and Public Works, U. S. Senate, on May 26, 1989. In: NIOSH indoor air quality, selected references. US Department of Health and Human Services, Centers for Disease Control, 1989.
5. NIOSH manual of analytical methods. 4th ed. Washington, D.C.: Government Printing Office, 1990.
6. ACGIH. Air sampling instruments for evaluation of atmospheric contaminants. 7th ed. Cincinnati, Ohio, 1989.
7. Lodge JP, ed. Methods of air sampling and analysis. 3rd ed. Chelsea, Michigan: Lewis Publishers, 1989.
8. Ness SA. Air monitoring for toxic exposure. New York: Van Nostrand Reinhold, 1991.
9. Maslansky CJ, Maslansky SP. Air monitoring instrumentation. New York: Van Nostrand

Reinhold, 1993.

10. U.S. Department of Labor, Occupational Safety and Health Administration. OSHA safety and health standards 29 CFR 1910, No. 1910.1000.

11. U.S. Code of Federal Regulations. 40 CFR, Pt 50. Washington, D.C.: Government Printing Office, 1989.

12. ACGIH, 1993-1994, TLV's for chemical substances and physical agents and biological exposure indices. Cincinnati, Ohio, 1993.

13. NIOSH guide to chemical hazards. U.S. Department of Health and Human Services, CDC, DHHS (NIOSH) publication No. 85-114, 1989.

14. WHO. Indoor air quality research, report on a WHO meeting, Stockholm, August 27-31, 1984. Copenhagen: World Health Organization.

15. U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Atmospheric and Indoor Air Programs, Indoor Air Division, Building Air Quality. A guide for building owners and facility managers, 1991.

Publishing and Reprint Information

TOP

- *From the College of Public Health, University of South Florida.*
- *Reprint requests: Yehia Y. Hammad, ScD, College of Public Health, 13201 Bruce B. Downs Blvd., Tampa, FL 33612. J ALLERGY CLIN IMMUNOL 1994;94:389-93.*
- *Copyright © 1994 by Mosby–Year Book, Inc.*
- **8091-6749/94 \$3.00 + 0 1/0/56023**