4.4 Indoor Air Quality

4.4: (1 Credit: Implement 3 of 4)

- Indoor air quality system is designed based on a detailed user needs assessment.
- Air contamination sources are reduced by achieving objectives 2-5 in ASHRAE guide.
- Air contamination pathways are reduced by achieving objectives 6-8 in ASHRAE guide.
- Indoor air quality systems are commissioned as per ASHRAE guide.

1. Overview

In the early 20th Century, indoor air quality (IAQ) studies were a subset of ventilation and thermal comfort research and were considered to be only indirectly related to human health[1]. In the 1960s, research began to focus on the impacts of tobacco smoke, allergens, radon, and formaldehyde; through these investigations IAQ and its impact on health gained credibility in the health community. Since that time, building scientists and health professionals have refined their research related to the above topics, but have also begun to investigate biologics like bacteria and mold (Figure 1)[1] and defined minimum ventilation rates to reduce short- and long-term health risks.

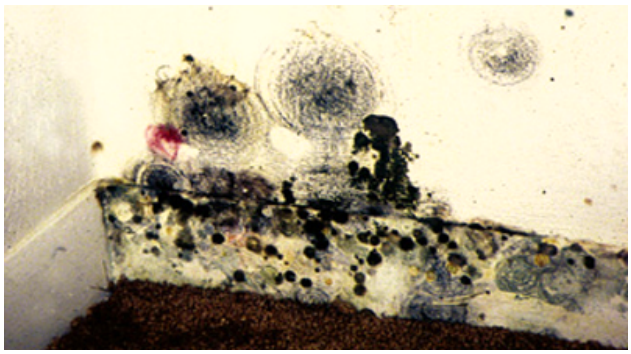

Figure 1: Extensive mold growth on the wall of a house caused by leaking water. Mold and other biologics can cause significant IAQ issues in a building. Photo by Terry Brennan, image courtesy of the U.S. EPA Mold Image Library.

In 1973, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) published one of the first IAQ Standards, Standard 62—Ventilation for Acceptable Indoor Air Quality. The purpose of this standard was to establish minimum ventilation rates for occupied spaces that would satisfy 80% of a building's occupants[2]. At the time the standard was published, the United States was experiencing a surge in energy prices due to an oil embargo; this scarcity led to the tightening of building envelopes to increase energy efficiency[3]. This had an unintended consequence as incidences of "sick building syndrome" (or SBS) increased.

However, infiltration and ventilation rates are not the only factors that determine IAQ. The quality of indoor air is related to interactions among four factors:

1. Pollution from occupant activities (e.g., cooking, cleaning, painting, etc.)[4],
2. Pollution from building materials or other sources (e.g., off-gassing of furniture, etc.)[4]
3. Filtration (e.g., systems to capture contaminants before the enter a building), and
4. Infiltration and ventilation rates[5, 6].

IAQ is a critical issue for universal design because the configuration of the envelope, building systems, and the choice of materials can lead to pollution concentrations that are between 2 and 100 times greater than they are outdoors[7]. Compounding the problem, people in industrialized countries spend as much as 90% of their time indoors[8]. Finally, many people have chronic respiratory or cardiovascular diseases exacerbated by certain toxins[9]; if they have limited mobility they may be disproportionately exposed to poor IAQ.

2. Issues to Consider

At Risk Populations: A number of populations like children, the elderly, people with preexisting medical conditions like asthma or heart disease, and those with allergies are particularly sensitive to common pollutants found in buildings. Understanding and communicating these risk factors are an important first step in the design or substantial renovation of a facility.

To assist in this process, organizations like the U.S. Environmental Protection Agency (EPA) and the American Society for Healthcare Engineering (ASHE) have developed guidance for specialized facilities like schools[10], health care environments[11], and the home[12]. These tools help: identify common IAQ issues found in these building types, develop communication plans to link occupants with operations and maintenance staff, provide guidance on how to assess and address potential problems, and encourage ongoing evaluation of IAQ (Figure 2).

Figure 2: The Framework for Effective School Indoor Air Quality Management developed by the U.S. EPA. The framework includes specific guidance for mitigating IAQ issues in schools.

Ongoing Operations and Maintenance: Ensuring good IAQ does not end with the conclusion of construction; it is a process of continuing maintenance. Frequently, IAQ issues are identified by complaints from building occupants. These complaints can then be used to track down possible issues like water damage, new sources of pollution (e.g., new furniture, new convenience copier or printer, etc.), and problems with the ventilation of a space. Addressing complaints immediately can prevent larger IAQ issues from emerging. A survey, like the one developed by the New York State Department of Health, can be a useful diagnostic tool during this process. In addition, focus groups with occupants and building management can help to determine how people use a building or the capabilities of operations to conduct preventative maintenance.

Outdoor Air Quality vs. IAQ: Frequently, issues of IAQ in a building are caused by problems with the outdoor air. In many cities, particulate matter and ozone are above recommended levels; these pollutants are concentrated indoors by the envelope and building systems. In addition, supply air intakes into a building can be contaminated by vehicle exhaust, back of house services, or the exhaust from the building. Careful thought about the placement of supply and exhaust louvers, filtration media, and building operations can help to prevent these issues.

Conflicts with Energy Efficiency: Tightening of the building envelope to reduce infiltration and exfiltration improves energy efficiency, but reduces the quantity of air available for ventilation. It is possible to balance the need for a tight envelope with IAQ, however it increases the importance of building systems design, construction, operations, and preventative maintenance. In addition, because it may be necessary to utilize newer systems like demand-controlled ventilation and energy recovery ventilators to balance energy and IAQ concerns, it is especially important that maintenance personnel understand how to operate and maintain this equipment.

Climate Change: Changing temperatures, precipitation, and humidity levels can strain mechanical equipment, increase the risk of mold growth indoors, and change vapor

transmission through the envelope. Designers should consider how the building envelope and mechanical systems will perform over time as the atmosphere continues to warm[13, 14].

Pollutants, Sources, and their Potential Health Effects:

Pollutant:	Source:	Potential Health Effects:
Asbestos	Insulation and other building materials such as floor tiles, dry wall compounds, reinforced plaster	Not a source of acute health effects; asbestosis, mesothelioma, fibrosis, cancer.
Biological Contaminants	Air handling system condensate, cooling towers, water damaged materials, high humidity indoor areas, hot water systems, outdoor excavations, plants, animal excreta	Chills, fever, muscle ache, chest tightness, headache, cough, sore throat, diarrhea, and nausea, allergic reactions, infections, death.
Carbon Dioxide	Unvented gas/ kerosene devices, improperly vented combustion devices, human respiration	Eye, respiratory and mucous membrane irritation
Carbon Monoxide	Tobacco smoke, fossil-fuel engine exhausts, improperly vented combustion devices	Dizziness, headache, nausea, cyanosis, cardiovascular effects, and death
Formaldehyde	Foam insulation, plywood, particle board, and paneling; carpeting and fabric; glues and adhesives; and combustion products	Hypersensitive or allergic reactions; rashes; respiratory and mucous membrane irritation
Miscellaneous Inorganic Gases	Blueprint/microfilm equipment, cleaning solutions, acid drain cleaners, combustion products, tobacco smoke	Eye, respiratory tract, mucous membrane irritation, aggravation of chronic respiratory diseases
Nitrogen Oxides	Combustion byproduct from furnaces and appliances; tobacco smoke, welding, fossil-fuel engine exhausts	Eye, respiratory and mucous membrane irritation
Ozone	Copy machines, electrostatic air cleaners, electrical arcing, smog	Eye, respiratory tract, mucous membrane irritation; aggravation of chronic respiratory diseases
Radon	Ground beneath buildings, building materials, and groundwater	Chronic exposure may lead to increased risk of lung cancer from alpha radiation
Tobacco Smoke	Cigars, cigarettes, pipe tobacco	Eye and nasal irritation, coughing, wheezing, sneezing, headache, lung cancer
Volatile Organic Compounds (VOCs)	Paints, cleaning compounds, moth-balls, glues, photocopiers, caulk, insecticides, herbicides, combustion products, asphalt, gasoline, tobacco smoke, cosmetics	Nausea, dizziness, eye, respiratory tract, and mucous membrane irritation, headache, fatigue

3. Related Standards

ANSI/ASHRAE Standard 62-2016—Ventilation for Acceptable Indoor Air Quality specifies minimum ventilation rates and other measures for new and existing commercial buildings that are intended to provide IAQ that is acceptable to human occupants and that minimizes adverse health effects. ANSI/ASHRAE 62.2 specifies similar information for residential structures. It is adopted, by reference, in the International Mechanical Code.

ASHRAE 180-2012—Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems provides the standard practices for inspection and maintenance of commercial HVAC systems to improve thermal comfort, energy efficiency, and IAQ. It is adopted, by reference, in the International Mechanical Code.

ASHRAE Indoor Air Quality Guide summary guidance for best practices for all aspects of IAQ building design, commissioning and construction, including designing for maintainability; tools and material for demonstrating the value of IAQ to clients. The Guide was developed in cooperation with the American Institute of Architects, The U.S. Green Building Council, the Builders and Owners Management Association International, the Sheet Metal and Air Conditioning Contractors of North America, and the U.S. Environmental Protection Agency.

ASHRAE Guideline 24-2015—Ventilation and Indoor Air Quality in Low-Rise Residential Buildings is a companion document to the ASHRAE Indoor Air Quality Guide, providing information on achieving good IAQ in low-rise buildings that may go beyond minimum requirements. It also provides information relevant to ventilation and IAQ on envelope and system design, material selection, commissioning and installation, and operation and maintenance. This guideline applies to ventilation and IAQ in residential buildings three stories or fewer in height above grade, including manufactured and modular houses.

Environmental Law Institute Database of State Indoor Air Quality Laws is a compilation of laws that reflects a wide range of state policy strategies to improve IAQ. The Database only contains enacted state laws. In many cases, regulations or guidance documents established pursuant to individual laws are noted. The Database does not include federal or local IAQ laws.

Centers for Disease Control and Prevention (CDC) Indoor Air Quality State Map provides links to offices or programs identified by each state as dealing with indoor air-related health inquiries.

Indoor Air Quality in Commercial and Institutional Buildings is an Occupational Safety and Health Administration (OSHA) Document that outlines federal statues and standards, including:

- Occupational Safety and Health Act of 1970
- 29 CFR 1904, Recording and Reporting Occupational Injuries and Illnesses
- 29 CFR 1910, Occupational Safety and Health Standards
    - 29 CFR 1910.94, Ventilation
    - 29 CFR 1910.1000, Air Contaminants
    - 29 CFR 1910.1048, Formaldehyde
    - 29 CFR 1910.1450, Occupational exposure to hazardous chemicals in laboratories

ISO 16814:2008—Building environment design (Indoor air quality) specifies methods to express the quality of indoor air suitable for human occupancy, and to allow several acceptable target levels of indoor air quality, depending on local requirements, constraints, and expectations.

Other standards and projects under the direct responsibility of the ISO/TC 205 Secretariat include general principles for indoor environmental design, guidance for air purity requirements, and methods for expressing the quality of indoor air for individuals.

4. Measurement and Verification

The identification and measurement of IAQ problems is a complex task because of the potential number of gases, compounds, and biologics (e.g., carbon monoxide, VOCs, dust mites, etc.) that can impact human health. Because monitoring all potential pollutants at all times is not feasible, ASHRAE and other authorities recommend three overlapping approaches for IAQ:

1. *Pollutant reduction:* limiting infiltration and outdoor air ventilation if ambient air quality does not meet certain criteria; locating indoor air intakes away from contamination like vehicle exhaust; locating building intakes and exhaust away from each other; eliminating tobacco smoking indoors or near building air intakes; identifying potential contaminants that may be brought into a building by occupants; identifying interior materials, furniture, fixtures, or equipment which may off-gas harmful compounds (e.g., VOCs, formaldehyde, etc.) Guidance on these issues, including measurement protocols, are provided in Section 4 and Appendices B, F, and I of ASHRAE 62.1-2016.
2. *Pathway interruption:* for particulate matter and certain gaseous compounds like ozone, it is possible to pass both outdoor and recirculated air through filtration media to reduce the concentration of a pollutant in supply air. ASHRAE Standard 62.1 requires filtration of outdoor air if a building is located in an area where the national standards for particulate matter, ozone, or other compounds are exceeded. The standard also provides guidance on the minimum efficiency of filtration required. Other standards, like ASHRAE Standard 180, provide guidance on maintenance of IAQ systems.
3. *Adequate ventilation rates:* measuring ventilation rates to ensure that pollutants are adequately exhausted is done in accordance with Sections 5 through 8 of ASHRAE Standard 62.1-2016. The standard also provides guidance on minimum ventilation rates that are needed depending on use, interior contaminants, and/or number of occupants.

5. Design Considerations

- *Indoor air quality system is designed based on a detailed user needs assessment.* The ASHRAE Indoor Air Quality Guide discusses the importance of understanding not only who is going to be occupying a building but what the capabilities are of operations and maintenance staff to ensure IAQ. Surveys and focus groups can help to determine how people plan to use the building and if there are any preexisting IAQ issues. These considerations should be included in the Owner's Project Requirements (OPR) and an IAQ Basis of Design (BoD) used for design, construction, and occupancy phases.
- *Air contamination sources are reduced by achieving objectives 2-5 in ASHRAE guide.* Objectives 2 through 5 of the ASHRAE Indoor Air Quality Guide provide strategies to control moisture, limit entry of contaminants into a building, and limit contamination from interior materials. This is not a one-time process undertaken only during construction; it requires ongoing vigilance by operations and maintenance personnel.
- *Air contamination pathways are reduced by achieving objectives 6-8 in ASHRAE guide.* Objectives 6 through 8 of the ASHRAE Indoor Air Quality Guide outline methods to exhaust contaminants from buildings, to reduce interior contamination through adequate ventilation, and to apply advanced ventilation concepts like demand-controlled ventilation that reduce airflow to unoccupied spaces to increase energy efficiency.
- *Indoor air quality systems are commissioned as per ASHRAE guide.* Strategy 1.2 in the ASHRAE Indoor Air Quality Guide describes the commissioning process for IAQ which spans from pre-design through occupancy. This includes creating a detailed OPR and BoD document which is used for commissioning, warranty reviews, and annual testing.

6. Definitions

The following definitions are adapted from ASHRAE Standard 62.1-2016.

Acceptable indoor air quality	Air in which there are no known contaminants at harmful concentrations and with which 80% or more of the occupants exposed do not express dissatisfaction.
Air-cleaning system	A device or combination of devices applied to reduce the concentration of airborne contaminants.
Ambient air	The air surrounding a building; the outdoor air brought into a building.
Conditioned space	A part of a building that is heated or cooled for occupants.
Contaminant	An unwanted airborne constituent that reduces acceptability of air.
Demand-controlled ventilation	Any means by which the breathing zone outdoor airflow can be varied to the occupied space or spaces based on the actual or estimated number of occupants and/or ventilation requirements.
Exfiltration	Uncontrolled outward air leakage from conditioned spaces through unintentional openings in ceilings, floors, and walls to unconditioned spaces or the outdoors.
Exhaust air	Air removed from a space and discharged to outside and building by means of mechanical or natural ventilation systems
Indoor air	The air in an enclosed occupiable space.
Infiltration	Uncontrolled inward air leakage to conditioned spaces through unintentional openings in ceilings, floors, and walls from unconditioned spaces or the outdoors.
Makeup air	Outdoor and/or transfer air replacing exhaust air and exfiltration.
Mechanical ventilation	Ventilation provided by mechanically powered equipment, such as motor-driven fans and blowers, but not by devices such as wind-driven turbine ventilators and mechanically operated windows.
Natural ventilation	Ventilation provided by thermal, wind, or diffusion effects through doors, windows, or other intentional openings in a building.
Outdoor air	Ambient air that enters a building through a ventilation system, through intentional openings for natural ventilation, or by infiltration.
Primary air	Air supplied to a ventilation zone prior to mixing with re-circulated air.
Recirculated air	Air removed from a space and reused as supply air.
Return air	Air removed from a space to be re-circulated or exhausted.
Supply air	Air delivered by mechanical or natural ventilation to a space and composed of either outdoor air, re-circulated air, or transfer air.
Ventilation	The process of supplying/removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature.
Ventilation air	The portion of supply air that is outdoor air plus any re-circulated air that has been treated for to maintain acceptable IAQ.

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