IAQ 2013 Tools Topic Overview

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Introduction

The complex relationships between indoor and outdoor environmental conditions, coupled with the impacts of climate change, make it more important than ever before that buildings be comfortable and healthy for the occupants yet also energy efficient. New and enhanced building design, construction and operation tools for use by developers, policymakers, architects, engineers, building owners and operators will help achieve these goals.

In the context of this discussion, such tools include:

- Standards and guidelines (such as ASHRAE Standards 189.x, 62.x, and 90.x and the ASHRAE Indoor Air Quality Guide),
- Programs and codes (such as LEED, ENERGY STAR, ASHRAE bEQ and IgCC),
- Design and analysis software (such as energy and indoor air quality (IAQ) simulation models, including their coupled application),
- Occupant surveys (e.g., health questionnaire, physiological measurements, absentee data), and
- Performance verification tools (ranging from measurement methods and capabilities to verification checklists).

The ASHRAE IAQ 2013 Conference included a Tools track to examine questions relating to the needs, development, verification and application of these tools. The session included papers on a wide range of related issues such as a review of indoor environmental quality (IEQ) measurement methods, a description of IEQ survey tools, descriptions of IEQ sensing options, and a proposal for a graphical approach to evaluating energy, IEQ and other performance aspects of buildings.

Types of Tools

The following sections discuss the development of new tools, innovative use of existing tools, and evaluation of the quality of information from new or existing tools to study the integrated IEQ/health and energy performance of buildings.

Codes, Standards, Programs and Guidelines

Green and sustainable building programs, standards and guidance documents (e.g., ASHRAE 2013; USGBC 2009; GBI 2010; ICC 2010, Architecture 2030) are driving the trend towards low energy buildings, and the manner in which they consider (or fail to consider) IAQ is critical to achieving energy efficient buildings with good indoor environments. As described in the ASHRAE Indoor Air Quality Position Document (ASHRAE 2011), green building efforts directly impact the decisions made during design, construction, operation and maintenance of a building through requirements or options that accrue points towards a rating. These programs may be well-intentioned, but for the most part are not based on thorough consideration of all the many parameters impacting IEQ and those that do not have the potential to negatively impact IEQ as an unintended consequence of some measures implemented to save energy and other resources. This potential for negative consequences is greatest when the goal is to achieve netzero or very low energy. In the worst cases, providing good IEQ may be taken for granted or seen as a roadblock to the other goals. One of the key recommendations of the position document is “Sustainable (green) building performance codes, programs and standards should be based on thorough consideration of the many parameters impacting IEQ to ensure that limited resources are used effectively and IEQ is not compromised for other goals.”

Persily and Emmerich (2012) reviewed the manner in which many of these green and sustainable building programs, standards and guidance documents address IAQ and concluded that a strong case exists for a more comprehensive and demanding approach to IAQ. One reason cited for this includes the documents’ reliance on ASHRAE Standard 62.1, which is intentionally a set of minimum requirements for code compliance and therefore leaves out guidance that advances IAQ beyond the minimum. Some specific areas that a comprehensive, high-performance IAQ standard needs to address better than Standard 62.1 are moisture control, material emissions, poor outdoor air quality and the typical “silo” approach (i.e., addressing different aspects of building performance separately) to building design, and operations and maintenance practices.

In 2009, ASHRAE published the Indoor Air Quality Guide, which presents best practices for design, construction, and commissioning, and addresses many of the critical issues highlighted by Persily and Emmerich (2012) in substantial detail. However, it contains practices and examples that are specific to commercial and institutional buildings and is not directly applicable to residential buildings in which people spend the majority of their time and where IAQ improvements have the potential to yield the largest health benefits. There is a critical need for such a document providing guidance on actions to take throughout the process of building design, construction, commissioning, operation and maintenance. The need is even more critical for low energy residential buildings because currently there is no residential equivalent to ASHRAE Standard 189.1, although a project committee (SPC 189.2) was recently formed to begin development of a Standard for the Design of High-Performance, Sustainable Low-Rise Residential Buildings.

An important lingering question is whether buildings designed and constructed to meet the requirements of green building codes and standards have indoor environmental quality that is better than, worse than or no different from conventional buildings. Unfortunately, the limited studies done to date are typically too small to draw any firm conclusions. A review by Birt & Newsham (2009) concluded that, in general, occupants of green buildings had higher satisfaction with air quality and thermal comfort, whereas satisfaction with lighting showed little or no improvement and there was a trend towards a decrease in acoustic satisfaction associated with green buildings. More recently, Newsham et al. (2013) found in a post-occupancy evaluation (POE) study of 12 green and 12 conventional buildings in Canada and the northern U.S. that green buildings exhibited superior performance in environmental satisfaction, satisfaction with thermal conditions, satisfaction with the view to the outside, aesthetic appearance, less disturbance from heating, ventilation and air-conditioning (HVAC) noise, workplace image, night-time sleep quality, mood, physical symptoms, and reduced number of airborne particulates. They also concluded that green building rating systems might be improved via credits related to acoustic performance, a greater focus on reducing airborne particulates, enhanced support for the interdisciplinary design process and development of POE protocols. However, with tens of thousands of green buildings in North America and tens of billions of dollars annually spent on green building construction, further study of many more buildings is needed and easily justified by the potential benefits.

Modeling and Simulation

While energy efficiency and IAQ are sometimes viewed as contradictory goals, design processes and building systems that are integrated can lead to high performing buildings that are both energy efficient and have good IAQ (ASHRAE IAQ Guide, ASHRAE IAQ Position Document; Persily and Emmerich 2012; Levin and Emmerich 2013). Modeling and simulation tools improve the abilities of designers to achieve coordinated and integrated systems. Passive design features (i.e. the architectural and envelope aspects) can be optimized to reduce the need for active design strategies (i.e., HVAC systems) for thermal conditioning. Source control can be implemented as a fundamental approach to reducing contaminant levels inside buildings thus reducing the need for removal via ventilation and air cleaning.

More advanced building modeling capabilities could simultaneously account for interactions among building temperatures, humidities, airflows and contaminant concentrations and thus facilitate innovative design including natural ventilation and demand controlled ventilation (DCV). True demand controlled ventilation could be based not just on the number of occupants, but also on contaminant levels from people, building materials and contents. Dols et al. (201x) describe the development of one such new simulation tool combining multizone building heat transfer, airflow and contaminant transport modeling capabilities. Other similar tool development efforts are also underway (e.g., Feng et al. 2012). Rackes and Waring (2013) presented an analysis approach that can optimize IAQ and energy performance.

Building energy simulation studies analyze the impacts of revised energy standard requirements on reducing building energy use but often no consideration is given to the potential IAQ impacts of such requirements. Recently, however, Ng et al. (2012) described the creation and potential use of a set of multizone airflow and IAQ models of the DOE reference buildings described by Deru et al. (2011). These models enable parallel energy and IAQ analysis of factors such as varying ventilation rates and contaminant source strengths, similar to the simulation study described by Ng et al. (2013).

One critical step in developing and using simulation tools is validating their accuracy and range of applicability. Several published validation efforts have been targeted at multizone IAQ models (Emmerich 2001) and building energy simulation models (Ryan and Sanquist 2012), but models for interactions between temperature, humidity, airflow and contaminant concentration have yet to receive similar attention.

Measurement and Performance Verification

Another critical area of tool development and application is the measurement and verification of the IEQ and energy performance of buildings, including those that are low-energy.

Commissioning is a quality control process to identify and correct deviations of building performance from its intended function. Its strengths include the ability to make effective corrections, due in part to the considerable resources available and attention paid during the design and construction process. One weakness of commissioning is that it is often performed during a limited time period prior to and during building startup. Continuous or periodic re-commissioning efforts have the potential to be more useful and there is evidence that they are cost effective.

ASHRAE Standard 55 identifies temperature, humidity, air speed and radiant heat as the four thermal comfort metrics of the interior environment that need to be measured to validate building performance. However, even these relatively limited measurements are not simple because they must be measured over various conditions in multiple locations. This must be combined with data about occupant metabolic rate and clothing insulation, which can be done only by a human observer and may change daily and even change typically during the course of a single day.

On a limited basis, central building control and monitoring systems are often used to identify and assess thermal comfort problems in buildings. However, the number of measurement points and measured parameters is often limited and may be insufficient to provide adequate data. Though at present it is rarely done, these systems could be supplemented with measurement of temperature, humidity, air speed and radiant heat in more locations using portable or fixed apparatuses connected to a central data system or that individually collect and store data.

Sensors to measure individual chemical contaminants are expensive, and there is no evidence yet that they would be effective in predicting or preventing IEQ problems. Nevertheless, there is hope that sensor cost will come down in the future. This might even be facilitated as an adjunct to the development of such devices for military and civil defense purposes.

Occupant surveys have the advantage of directly assessing occupant perceptions. Surveys may include thermal comfort as well as other aspects of IEQ. For thermal comfort, there are accepted methods of surveying that are described in ASHRAE Standard 55-2010. For other subjective aspects of IAQ, such as odor, irritation and building related illness there is a broad range of survey tools but little standardization. For aspects of noise, and light, there are objective measurements that can be made but little agreement on standard survey tools. For aspects of IEQ such as views to the outdoors, décor, aesthetic design, artwork and ergonomics, there is even less available to support a metric. The building occupants themselves and their perceptions and comfort are relatively sources of information. Because human behavior can play such a large role in building energy and IEQ performance, taking advantage of occupant experience is a potentially valuable approach to detecting and preventing undesirable conditions and behavior.

It is a large challenge to balance the practicality and cost of measurements and metrics against making them meaningful. In general, there is no accepted and standardized, comprehensive set of IEQ metrics to compare building performance over time or to compare one building to another. For all the above reasons, measurement and performance verification of IEQ is more challenging than for energy. Reflective of this, many of the IAQ 2013 conference papers address various aspects of measurement and performance verification.

Newsham et al. (2013) recommend developing an objective and subjective IEQ measurement kit and protocol to supplement the mechanisms already in place to require on-going quantitative energy performance, noting that this could lead to improved post-occupancy performance.

Zhai and McNeil (2013) review and evaluate currently existing protocols and reveal the gaps to be studied. They acknowledge the expense of the powerful protocols such as that used for the EPA BASE study (EPA 2003) and recommend that further consideration be placed on the use of occupant satisfaction surveys. They also note that simplified, accessible computer protocols could evaluate building IEQ performance, in a similar way that those used by the Energy Star rating system and CIBSE Technical Memorandum 22 (CIBSE 2006) to evaluate energy.

In an attempt to create a means to consolidate and present the results of measurements, Teichman and Emmerich (2013) describe a graphical approach to describing the performance of high-performing buildings based on four key attributes of high-performing buildings: energy use, indoor air quality, water consumption, and waste generation.

Summary

This overview discusses the tools available, and those still needed, for achieving environmental health in low energy buildings including Codes, Standards, Programs and Guidelines, Modeling and Simulation, and Measurement and Performance Verification. While there are many standards and programs aimed at creating low energy buildings, these standards need to include environmental health requirements based on more thorough consideration of the many parameters impacting IEQ. The effectiveness of the current standards and programs requires further study. The simulation tools aimed at predicting both IEQ and energy performance require validation. Standard post-occupancy evaluation protocols need to be developed and validated.

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