Indoor Air Quality in High Performance Building: What is and isn't in ASHRAE/ IES/ USGBC standard 189.1

Andrew Persily

Engineering Laboratory, National Institute of Standards and Technology
100 Bureau Drive Gaithersburg, MD 20899

Content submitted to and published by:
Proceedings of 13th International Conference on
Indoor Air Quality and Climate, Indoor Air 2014, July 7-12, 2014 Hong Kong
Paper number: HP1014

U.S. Department of Commerce
Penny Pritzker, Secretary of Commerce

National Institute of Standards and Technology
Willie E. May, Acting Director

Indoor Air Quality in High Performance Buildings: What is and isn't in ASHRAE/IES/USGBC Standard 189.1

SUMMARY

While most discussions of high performance buildings (HPB) include site impacts, water use, energy, materials and indoor environmental quality, energy often receives more attention than these other attributes. Given that buildings exist primarily for the occupants, indoor air quality (IAQ) within these buildings merits more serious consideration. ASHRAE/IES/USGBC Standard 189.1, Design of High-Performance Green Buildings, is the only consensus standard for HPBs (except low-rise residential), and valid questions exist as to whether or not it is consistent with high performance IAQ. This paper discusses high performance IAQ and approaches to move Standard 189.1 as well as other programs to higher performance IAQ. In many cases, the formal requirements in standards are inadequate to achieve this goal, and therefore this paper also discusses the role of guidance documents and other information.

Keywords: Green buildings, high-performance buildings, indoor air quality, standards, sustainable buildings

INTRODUCTION

In recent years, the building community has been pursuing the design and construction of sustainable HPBs in order to reduce the environmental impacts of buildings and to provide better conditions for building occupants. These efforts include programs to define criteria for such buildings (BRE 2011, GBI 2010, USGBC 2013); conferences to discuss case studies and design methods (ASHRAE 2014a); and standards and guidance (ASHRAE 2011 and 2014b). While most discussions of HPBs have a broad scope including site impacts, water use, energy, materials and indoor environmental quality, reduced energy use often receives more attention than these other attributes (Teichman et al., 2013). Given that buildings exist to support the activities of their occupants, the treatment of IAQ within sustainable, HPBs merits more serious attention. ASHRAE/IES/USGBC Standard 189.1 is the only consensus-based high performance, sustainability standard covering buildings other than low rise residential (ASHRAE 2011). However, questions exist on how well it provides for high performance in the area of IAQ, leading to the additional question of what is high-performance IAQ.

METHODOLOGIES

This paper discusses how IAQ is dealt with in existing HPBs and explores the definition of high-performance IAQ based on the scope of existing standards, green and sustainable buildings programs, and guidance to improve IAQ. High-performance IAQ as described in this paper is then compared with the requirements of Standard 189.1, and gaps in the standard's requirements are discussed. Suggested approaches to move this and other standards to high-performance IAQ are presented. Given that the formal or minimum requirements of standards limit how issues can be addressed and that many existing standards focus more on design than operation, the role of guidance documents and other information is described.

IAQ in Existing HPBs

While HPB programs and standards cover IAQ, the manner in which they do so varies considerably (Persily and Emmerich 2012). A recent analysis in ASHRAE's HPB Magazine (Teichman et al. 2013) considered 100 case studies, examining how IAQ is addressed in individual HPBs. Table 1 summarizes the prevalence of IAQ features (number of case studies). Note that these features are broadly identified as impacting IAQ, despite the fact their impact on IAQ may be indirect, even negative, e.g. natural and displacement ventilation. The most common feature is the use of low VOC (volatile organic compound) emitting materials. However, the use of such materials is often noted without details of how they were determined to be low emitting, such as a labeling program or measured emission rates. The next most common feature is carbon dioxide based demand control ventilation, which is more likely to have been included to reduce energy consumption than based on any IAQ benefits. Just over one-third of the case studies include a claim of "good IAQ" and nine claim "healthy IAQ," neither of which is particularly meaningful without supporting data (e.g., measured contaminant levels or occupant survey results). However, only 12 mentioned the use of a post-occupancy IAQ survey, and just two reported measured contaminant data. While 12 note the existence of an IAQ monitoring program, those programs are not described.

Table 1 Prevalence of IAQ features mentioned in the 100 HPB magazine case studies (V refers to Ventilation, SC to source control, FAC to filtration/air cleaning, P to process)

Feature	**Category**	**Prevalence**
Low VOC Emitting Materials	SC	60
Carbon Dioxide Demand Control Ventilation	V	51
Hybrid/Natural Ventilation	V	42
Claim of Good IAQ	P	36
Dedicated Outdoor Air System	V	31
Displacement Ventilation (e.g., under-floor air distribution)	V	31
Reference to ASHRAE Standard 62.1	P	25
Filtration Efficiency Cited (e.g., MERV)	FAC	22
Low Emitting Cleaning Materials	SC	16
Formaldehyde-Free Materials	SC	14
Post-Occupancy IAQ Survey	P	12
IAQ Monitoring Program	P	12
Anecdotal Mention of IAQ Improvements	--	10
Nighttime Outdoor Air Purge	P	10
Claim of Healthy IAQ	--	9
IAQ Considered During Construction (e.g., ductwork sealed)	P	8
Gaseous Air Cleaning	FAC	6
Air Leakage or Air Change Measurement	V	5
Carbon Monoxide Sensors (to control garage ventilation)	SC	4
Post-Construction Building Flush Out	P	4
Indoor Contaminant Data Provided	P	2
Monitoring of Outdoor Air Intake Rates	V	1

As part the analysis of these HPB case studies, it was also determined that the frequency of energy features dominated IAQ by roughly a factor of two. While the inclusion of the IAQ features, even general claims, shows a level of awareness of the importance of IAQ, the information provided is limited. One reason for the limited focus on IAQ in these HPBs may be the lack of agreement on what constitutes high performance IAQ, including what design information and performance data should be reported.

IAQ in Standard 189.1

The purpose of ASHRAE/IES/USGBC Standard 189.1 Design of High-Performance Green Buildings (ASHRAE 2011) includes "occupant health and well-being," and its Scope explicitly includes indoor environmental quality (IEQ). The IEQ requirements are covered in section 8 of the standard and are summarized in Table 2. All buildings designed to be in compliance with the standard must implement the mandatory requirements shown in the upper portion of the table. In addition, they must also comply with either the prescriptive requirements or the performance requirements shown in the lower portion.

Table 2 IEQ requirements in Standard 189.1

<table>
<tr><th colspan="3">Mandatory Requirements</th></tr>
<tr><td colspan="3">• Meet all requirements of Standard 62.1-2010
• Minimum outdoor airflow rates no less than 62.1 Ventilation Rate Procedure
• Devices to measure outdoor airflow rates in air handling systems
• MERV 13 particle filters when ambient PM2.5 exceeds U.S. EPA ambient criteria
• Ozone filters in all areas exceeding U.S. EPA ambient air criteria
• No indoor smoking
• Walk-off mats to collect dirt and moisture at building entrances
• Comply with thermal comfort design and documentation requirements in Standard 55
• Provisions to limit sound transmission from exterior and between spaces</td></tr>
<tr><th>Prescriptive Requirements</th><th>OR</th><th>Performance Requirements</th></tr>
<tr><td>Daylighting
• Minimum areas
• Shading of non-north facades
VOCs
• Limits on material VOC emissions or content
• No added urea-formaldehyde resins in wood products</td><td></td><td>Daylighting simulations to demonstrate illuminance level and limitation on direct sun on work surfaces
Model VOC emissions to demonstrate that VOC concentration limits are met</td></tr>
</table>

In this paper, we consider only the IAQ requirements and not those related to thermal comfort, acoustics or lighting. In comparison to ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality (ASHRAE 2010a), the requirements for IAQ in Standard 189.1 can be described as incremental improvements: outdoor airflow monitoring, stricter filtration requirements for ambient air, no indoor smoking, walk-off mats at entrances and material VOC limits. All other aspects of IAQ are covered by requiring compliance with the provisions in Standard 62.1, which purposely contains only minimum requirements consistent with its use as a reference by building codes and regulations. Therefore, the 189.1 IAQ requirements are no stricter that Standard 62.1 in several important areas, i.e., moisture control and separation of outdoor air intakes from outdoor contaminant sources. In addition, Standard 189.1 does not provide for a performance-based design approach, such as the IAQ Procedure in Standard 62.1. Note that most U.S. building codes reference only the ventilation requirements of 62.1, and not the other requirements related to system design, filtration, etc.

Defining High Performance IAQ

The comparison of the IAQ requirements in Standard 189.1 with those in Standard 62.1 highlights the question as to whether or not 189.1 is high performance in terms of IAQ. Given that many of the IAQ requirements in 189.1 are the same as the minimum requirements in 62.1, a strong argument can be made that 189.1 does not contain high performance IAQ requirements. The next logical question is therefore, what is high performance IAQ and what requirements should be included in a standard such as 189.1 to support it? In order to explore a definition of high performance IAQ, it is useful to consider the ASHRAE IAQ Guide (ASHRAE 2009). While not a standard containing requirements for improving IAQ, the IAQ Guide provides a comprehensive collection of information related to IAQ in building design and construction. This information includes covers a range of IAQ issues, case studies of successful and in some cases problematic designs, and discussion of design approaches and technologies that can improve IAQ. Since the guide is not a standard, it intentionally includes information that is not necessarily appropriate for all buildings.

The IAQ features in Table 1 highlight the basic principles of IAQ control in buildings: source control, ventilation, and filtration and air cleaning. These principles serve as the basis for the information in the ASHRAE IAQ Guide, which is organized by the following objectives:

1. Manage the design and construction process to achieve good IAQ
2. Control moisture in building assemblies
3. Limit entry of outdoor contaminants
4. Control moisture and contaminants related to mechanical systems
5. Limit contaminants from indoor sources
6. Capture and exhaust contaminants from building equipment and activities
7. Reduce contaminant concentrations through ventilation, filtration and air cleaning
8. Apply more advanced ventilation approaches

Neglecting objective 1 for the moment, all of the objectives except 7 and 8 address source control, highlighting the key role of source reduction in controlling IAQ. Ventilation strategies are covered by objective 8, while objective 7 covers both ventilation and filtration and air cleaning. Referring back to Table 1, we see that four of the 22 features relate to source control (noted by an "SC" in the table), six relate to ventilation (V), two relate to air cleaning/filtration (FAC) and eight relate to process (P), while the remaining two uncategorized items are general claims of good or healthy IAQ. The process items, which relate to objective 1 of the IAQ Guide, include a variety of strategies to incorporate IAQ into the design and construction process, as well as commissioning and ultimately building operations and maintenance. However, to be effective these process strategies must start at the earliest stages of the building design and not after key design decisions have been made. Regarding process, it is important to note that both Standard 189.1 and the IAQ Guide cover design, construction and commissioning, but do not stress the critical impacts of operation and maintenance once the building is occupied.

These objectives, and the strategies to pursue them, can be used to develop the framework for a definition of high performance IAQ. Such a definition would include the following elements: Design, Construction, Commissioning, and Operations and Maintenance (O&M). Table 3 presents a framework that describes steps to be taken in these four elements.

Table 3 Conceptual Approach to High Performance IAQ

DESIGN	
Incorporate IAQ into earliest design phases	Include IAQ goals in building design objectives Consider IAQ impacts of building use and occupants, building configuration and layout, site and local environment Select heating, cooling and ventilation strategies
General	Document IAQ-related design assumptions Define commissioning requirements and plan Consider O&M impacts of design decisions Develop IAQ O&M plan
Source control	Design envelope and HVAC system to manage moisture Select building materials and furnishings for low emissions Include exhaust systems to control local contaminant sources Filter outdoor air based on local contaminant sources Filter supply air to keep wetted surfaces clean and to reduce occupant exposures to contaminants
Ventilation	Design outdoor air requirements based on space use and occupancy levels; consider potential benefits of rates above minimum requirements in codes and standards Incorporate outdoor air intake monitoring devices and configure ventilation systems for accurate measurements Select air distribution systems for effective delivery to occupants; consider personal benefits of individual control
CONSTRUCTION	
Scheduling	Plan for protection of construction materials from moisture Stage material installations to reduce exposure of sorptive materials to volatile chemicals Consider pre-occupancy building flush out
Contaminant control	Protect equipment and ductwork from contaminants associated with construction activities Isolate occupied spaces from contaminants associated with construction activities
COMMISSIONING	
	Follow commissioning plan developed during design
OPERATIONS AND MAINTENANCE	
Occupant survey	Conduct within 1 or 2 months of occupancy and periodically thereafter; Develop action plan to respond to results
O&M	Follow equipment IAQ O&M plan developed during design
Outdoor airflow rates	Monitor outdoor airflow rates and respond when measured values disagree with design values
Indoor contaminant measurements	Measure selected indoor contaminant levels within 1 or 2 months of occupancy and periodically thereafter

To summarize, the key elements of high performance IAQ as described in Table 3 are as follows: incorporate IAQ considerations into the design process from the very beginning; explicitly plan for IAQ in construction, commissioning, operation and maintenance; source control, with an emphasis on moisture management and building material selection; and use of occupant surveys and indoor contaminant measurements to verify that the intended high level of performance is in fact being achieved. The last element, contaminant measurement, is challenging in terms of defining the contaminants to measure and reference values for comparison of the measurement results. The need for clear objectives, appropriate measurement methods and a plan for using the data have long been noted as critical when considering such measurements (ASHRAE 2009 and 2010b). The development of suggested lists of indoor contaminant measurements for application to HPBs will need to address these issues. Also, IAQ O&M as listed in this table includes more than traditional system O&M, but would also include facility inspections, programs to manage potential contaminant sources brought into a building, and space-use reviews.

Table 3 presents a framework for discussing high performance IAQ. All of these elements require more discussion and details to be useful for actual implementation. In addition, many of these details would necessarily be building specific and therefore hard, if not impossible, to present in general terms applicable to all buildings or for inclusion in a standard.

DISCUSSION

While this paper has made the case as to why HPB programs, including standards, need to include more thorough treatment of IAQ and has offered an initial framework for doing so, additional work is needed to develop an accepted definition of high performance IAQ and the resources needed to support implementation of this definition. In discussing definitions of high performance IAQ it is worth considering the definition of acceptable IAQ from Standard 62.1, which is "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80 % or more) of the people exposed do not express dissatisfaction" (ASHRAE 2013). In considering this definition, it is important to realize that 62.1 is a standard that intentionally includes only minimum requirements. The fact that it is a standard leads to the reliance on contaminant limits from authoritative bodies (i.e., cognizant authorities), which are inherently constrained by the limits of our knowledge of health effects of indoor air pollutants. This approach makes it harder to address contaminants that are suspected but not yet known to be harmful, to consider irritation effects and the effects of mixtures of contaminants, and to apply general principles of risk reduction. The target of 80 % or more of the building occupants, who may be adapted to some odors in the space, is not a particularly ambitious target in the context of high performance, especially when trying to maximize occupant health and productivity.

The ASHRAE IAQ Guide, on the other hand, is not a standard with a target of minimum performance and is therefore less constrained to be exact in its language and in its goals. It describes good IAQ as resulting from "diligent compliance with both the letter and intent of ASHRAE Standard 62.1, technically sound and well-executed efforts to meet or exceed these minimum requirements, and the application of IAQ-sensitive practices in building and system design, construction, commissioning and operations and maintenance throughout the life of the buildings." Basically, the IAQ Guide is saying do everything in 62.1 and do so with diligence, perhaps going beyond those minimum requirements, and to seriously consider IAQ in all decisions related to the building design and beyond. This "definition" is vague in many respects, specifically: What is the difference between compliance and diligent compliance? What does it mean to seriously consider IAQ in designing, construction, commissioning and operating a building? The IAQ Guide does a good job describing many specific aspects of such "serious consideration," but it does not provide a clear definition or set of requirements that can be implemented in practice or enforced by authorities having jurisdiction.

In the context of Standard 189.1, and other HPB standards and programs, the next issue is then how to convert a definition or at least a conceptual approach for high performance IAQ into specific requirements and actions. Several of the elements in Table 3 can be, and in some form already are, included in Standard 189.1, e.g. filtration levels; some aspects of source control; and construction, commissioning and operation requirements. Moisture management, a key factor in IAQ and something that must be addressed for high performance, is currently covered in 189.1 via reference to the minimum requirements of Standard 62.1, but more demanding requirements should presumably be added to 189.1. Other elements could include requirements for occupant surveys and perhaps indoor contaminant monitoring, though defining the contaminants, the measurement methods, and the time and spatial resolution of the measurements will be difficult.

Regardless of what is added to Standard 189.1, or any other standard, in terms of requirements for high performance IAQ, many of the issues covered in Table 3 will be difficult to incorporate into a standard. For example, while it might make sense to require one to document the design goals for IAQ, the construction schedule for better IAQ control, or the O&M plan for IAQ, documenting all the details behind such valuable strategies may not be consistent with how standards and regulations are written and enforced. Therefore, guidance material will be needed to provide supporting information on how one might pursue such strategies, including example approaches, case studies and sample checklists, somewhat like the approach described in the IAQ Guide.

CONCLUSIONS

High-performance, sustainable buildings need to give more attention to IAQ than is currently being done. Current sustainable building standards and programs, while they address IAQ, do little to go beyond minimum requirements to aim for a high level of performance. However, the challenges of defining high performance IAQ and the requirements to meet such a definition make this important goal difficult to achieve. Nevertheless, buildings are built for people, and good (not merely acceptable) IAQ must be prominent in high-performance building discussions and standards.

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Steven Emmerich, Dennis Stanke and Kevin Teichman for their thoughtful reviews of this paper.

REFERENCES

ASHRAE (2009) Indoor Air Quality Guide. Best Practices for Design, Construction, and Commissioning. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

ASHRAE (2010a) ANSI/ASHRAE Standard 62.1-2010 Ventilation for Acceptable Indoor Air Quality, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

ASHRAE (2010b) Performance Measurement Protocols for Commercial Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

ASHRAE (2011) ANSI/ASHRAE/IES/USGBC Standard 189.1-2011, Standard for the Design of High-Performance Green Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

ASHRAE (2013) ANSI/ASHRAE Standard 62.1-2013 Ventilation for Acceptable Indoor Air Quality, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.
ASHRAE (2014a) ASHRAE High Performance Buildings Conference, San Francisco, CA, 7-8 April 2014.
ASHRAE (2014b) ASHRAE Greenguide: The Design, Construction, And Operation Of Sustainable Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.
BRE (2011) Building Research Establishment Environmental Assessment Method, Building Research Establishment, Ltd., Bucknalls Lane, Watford, UK.
GBI (2010) ANSI/GBI 01-2010 Green Building Assessment Protocol for Commercial Buildings, Green Building Initiative, Portland OR.
Persily AK. and Emmerich, SJ (2012) Indoor air quality in sustainable, energy efficient buildings. *HVAC&R Research*, **18**, 4-20.
Teichman KY, Persily AK, and Emmerich SJ (2013). Wealth of Intent, Dearth of Data. IAQ in HPB Case Studies. *High Performance Buildings*, **6**, 34-43.
USGBC (2013) LEED v4 for Building Design and Construction. U.S. Green Building Council, Washington DC.