2_C16

A Holistic Approach to Indoor Environmental Quality Assessment

Alex Reese Mavrelis, CIH, CSP, CIEC

John Earman, CMC, OPMP
ASHRAE Member

ABSTRACT

As the industry shifts focus from indoor air quality (IAQ) to indoor environmental quality (IEQ), the need arises for its field consultants and inspectors to meet the demands of assessment, evaluation and control, particularly in established buildings with a longer history of operation. In the past, IAQ assessments have often remained isolated to specific complaint areas, focused on conditions of concern occurring in the immediate work area at the time of the assessment, and quite commonly provided insufficient comprehensive analysis of the cause and origin of conditions that impact the indoor environment. Given the vast array of factors that contribute to healthy and productive IEQ, a proper assessment truly lies in the intersection of IAQ, building and material sciences, and mechanical system design and operation. These assessment projects best serve building owners and managers by being both expansive horizontally, taking a building as a whole from its exterior skin down to its inner core of structural and mechanical systems, and also vertically by providing ongoing consultation and project management that guides the client from an experience of problematic conditions and loss of environmental control, through repairs, renovations, remediation and verification, and back to the point of proper control and healthy IEQ. A very effective approach is a hybrid assessment that combines industrial hygiene and indoor air quality expertise, beginning inspection at the point of occupant concerns or building material damage, with mechanical system and ventilation expertise that begins the evaluation with an audit of the design, operation and condition of the equipment and automation programs, all supplemented by long-term environmental monitoring and trending. Typically, the findings of these two fields come together in the middle to complement each other and provide a robust understanding of the mechanisms and processes that cause conditions of concern and impact IEQ.

INTRODUCTION

This paper has been developed from the perspective of the field of building and IEQ assessment and consulting in sub-tropical climates, more specifically assessment of the built environment throughout Florida and the Caribbean. The sub-tropical climate in close proximity to ocean coastlines presents a host of unique conditions and concerns relevant to both building owners and operators, as well as building mechanical system designers and manufacturers. In general, these conditions and concerns are reflected in substantial challenges in maintaining control over the indoor environment with respect to the regional climate, often stemming from risky original building design and engineering decisions, ongoing equipment maintenance and degradation, owner and operator interface with equipment and management of buildings and occupants, and a lack of comprehensive understanding and assessment of the built environment that has become more common among inspectors, consultants and other industry professionals. The intention of this paper is to convey our

Alex Mavrelis is an active environmental consultant and the Industrial Hygiene and Indoor Environmental Quality Practice Director – Southeast Region, Gallagher Bassett Technical Services, Miami Lakes, Florida. **John Earman** is a practicing HVAC and mechanical contractor, EE&G Restoration LLC, Melbourne, Florida.

approach to addressing the transition from IAQ assessment to the emerging field of IEQ assessment and management, and to provide meaningful and relevant assessment project findings that may offer insight into the various deficiencies and impacts that buildings undergo in the years after the design and construction phase is completed.

Traditionally, the field of IAQ assessment has focused almost exclusively on the air that building occupants breathe from the perspective of potential health effects or physical reactions and the preservation of building materials and contents. The emerging field of IEQ seeks to build upon IAQ by also addressing the occupant experience from the perspective of wellbeing, prosperity, productivity, and quality of life, and by enhancing that experience through better and more thoughtful design and engineering. The differences between the assessments of IAQ versus IEQ are outlined in Table 1 below. Also included are industry documents or other resources that may be relied upon when interpreting the findings of the various assessment metrics.

Table 1. Potential Components of IAQ and IEQ Assessments

Assessment Metric	IAQ Assessment (exposure and asset preservation focused)	IEQ Assessment (occupant experience focused)	Applicable Industry Standards and Guidelines
Moisture and Microbial Damage	X	X	AIHA Recognition, Evaluation, and Control of Indoor Mold, ASTM D7338-14
Temperature, Humidity, CO_2, Ventilation	X	X	ASHRAE 62.1 and 62.2, EPA's Building Air Quality, AIHA IAQ Investigator's Guide
Dust and Particulates	X	X	OSHA, NIOSH and ACGIH exposure limits
Microbial Amplification	X	X	AIHA Recognition, Evaluation, and Control of Indoor Mold, ASTM D7338-14
Cursory Mechanical System Inspections	X	X	NADCA ACR Standard and HVAC Inspection Manual, ANSI/ASHRAE 180-2018
Comprehensive Mechanical System and Operations Audit		X	NADCA ACR Standard and HVAC Inspection Manual, ANSI/ASHRAE 180-2018
Sound and Vibration, Acoustic Privacy		X	OSHA, NIOSH and ACGIH exposure limits, Professional Judgment
Lighting (both natural and artificial)		X	OSHA, NIOSH and ACGIH exposure limits
Malodors (building materials, cleaning chemicals, deodorizers, etc.)		X	Experience and Professional Judgment
Ergonomics		X	OSHA, NIOSH and ACGIH exposure limits
Occupant Control of Lighting, Air Conditioning and Ventilation		X	Experience and Professional Judgment
Electromagnetic Fields		X	OSHA, NIOSH and ACGIH exposure limits
Potable Water Quality		X	EPA Primary and Secondary Standards
Soil Vapor Intrusion		X	OSHA, NIOSH and ACGIH exposure limits

For the purposes of this paper, the discussions that follow are primarily based on the assessment of mid and high-rise residential and hospitality, commercial, retail, and public buildings that exist across the spectrums of new to old and small to large.

THE STATE OF IAQ ASSESSMENT

Over the years the IAQ assessment has evolved to fit into a more packaged and marketable product that can be quickly and easily completed in large quantities, streamlining the effort and time required to complete them, simplifying the analytical process and methods used in the field, and increasing profitability. This is typically referred to as a limited assessment, which instead of equating to the inherent limitations that would be part of any comprehensive assessment, is more often used to develop a service that functions more like a screening tool, regardless of whether that is of real benefit or value to the client or addresses the known conditions of concern in a building. Although this streamlined and packaged IAQ assessment is generally based on current standards of care in the industry, while at the same time better appealing to building owners and managers, the results and recommendations arising from them often do little to assist owners and managers in the operation, repair and management of their buildings and associated systems. This is not to say that the comprehensive, experienced and dedicated IAQ assessment no longer exists, as it certainly does, only that accessibility to these services for unwitting building owners/operators has become diminished and confused in an abundant pool of potential service providers.

Large commercial and residential structures function more like living, breathing systems that change over time as internal and external forces exert stress on them and management personnel strive to cope with perceived deficiencies and implement repairs and modifications, all in an effort to keep them functioning within original design parameters and in accordance with current industry standards and guidance documents. The indoor environment is a product of the stresses and loads placed on a building and its systems, and it oscillates, sometimes drastically from day to day, or between days and nights, weekdays and weekends, or even mornings and afternoons. For example, catastrophic damage can occur to a structure, which results in clear and significant impacts to indoor air quality and enormous expense to the owner to enact repairs, that is not readily explainable based on data collected during a short-term assessment performed during standard occupied hours. Yet the IAQ assessment is most often defined as a “snapshot in time” which is by design incapable of determining the dynamics in play that contribute to, or even overtly cause such conditions of concern. Even though snapshot IAQ assessments may be successful in identifying the effects of building deficiencies, they often fall short of collecting sufficient data and observations evaluated by professionals with access to a broad understanding of building sciences that is necessary to pinpoint the root causes and origins of the problems. This is because the streamlined IAQ assessment is generally designed to serve a reactive function in response to occupant concerns or complaints, utilized in an effort to capture evidence that may be useful. The observations and data are primarily collected at the point of building-occupant interaction (i.e., the occupied environment) even though the most serious implications for IAQ are often controlled by mechanical and building systems that exist well outside the complaint area. This leaves the limited IAQ assessment disconnected from the larger build-wide dynamics and ill-prepared to draw definitive and valuable conclusions and recommendations that allow a building owner/manager to correct deficiencies and prevent future loss of assets and erosion of tenant/occupant relations.

Occupant Interviews and Building History

One of the fundamental components of a responsible IAQ assessment should be a candid and open discussion with building management and maintenance personnel and the occupants of both complaint and non-complaint areas. While this may seem quite straightforward, the true benefits of these interviews and building research is often lost in the limited IAQ assessment. An initial interview is most helpful when a client is seeking an IAQ assessment and before any field work begins, for the primary purpose of identifying what the complaints or concerns are and tailoring the assessment to meet those needs. Again, the limited IAQ assessment may function to varying degrees of efficacy as a screening tool, but it is typically not developed to address the specific symptomology of health-based complaints, times and frequency of complaints, or the overall goals of the building owner/manager. For example, a request for an IAQ assessment in response to occupant complaints of transient malodors should not inherently mean that bioaerosol sampling is warranted, and in fact may exclude such sampling given that the data collected from it would likely not yield useful information on the pathways and mechanisms for the conveyance of malodors from potential sources to areas of complaint and it should not be used as a means of determining occupant exposures bioaerosols. At the start of an IAQ assessment, interviews with individual occupants or groups of occupants should drive the assessor toward patterns in the complaints. Understanding when complaints started, when and under what conditions they arise, how often they occur, and the ratio locations of occupants who experience issues is often far more revealing than many routine IAQ testing or assessment methods, and it adds little or no cost to the service. For example, complaints of visual evidence of potential mold growth on furnishings and contents would likely lead an assessor to conclude that chronic elevated relative humidity and condensation was occurring, even if indoor air parameter readings at the time of the assessment suggested that there was no issue with dehumidification. However, if occupant interviews revealed that resilient flooring materials in the areas of concern are often slippery and paper products feel damp and wrinkled in the early mornings, one might further conclude that outdoor air dampers are remaining in the open position during overnight hours or in unoccupied modes and relative humidity becomes elevated at these times. On another note, complaints of malodors that have a pattern where little is noted by occupants in the mornings, but are amplified in the mid-afternoon may suggest to an assessor that the source is outside the building and is being drawn in at an increased rate by the outdoor air intakes of the mechanical systems, which operate to a greater degree under full occupant load and at the hottest times of the day. Again, it is not just the basic facts of a complaint or concern that are relevant to the IAQ assessment, but the patterns in the information corroborated across multiple building occupants and staff that drive the investigation to more decisive and comprehensive conclusions, even if the information is based on subjective sources such as personal sensory observations and perceptions.

Aside from occupant interviews, lines of inquiry with long-standing building managers or operators are of great value considering that changes in building design and function over the life of a structure may provide ample explanation in addressing IAQ concerns. The IAQ assessor may enter many investigations under the assumption that the assessed areas and the mechanical systems serving them are approximately the same as the original intended design. However, changes in space usage within a building can result in drastic impacts to IAQ, occasionally with few simple options of recourse to correct the conditions. For example, the conversion of storage areas to occupied office spaces by a building owner may result in issues related to inadequate outdoor air ventilation, chronic malodors, elevated indoor air contaminants, and potentially mechanical equipment that is insufficiently sized to properly control the indoor environment under enhanced occupant and heat loading.

Indoor Air Parameter Testing

The collection of standard air quality parameters that may be interpreted against well-accepted industry standards and guidelines, such as temperature, relative humidity, dew point and carbon dioxide, are a staple of the IAQ assessment. However, since these parameters may vary widely from hour to hour and day to day and larger buildings, such as commercial and public office buildings, may have multiple modes of operation (occupied and unoccupied, weekday and weekend), their collection solely through the use of direct read devices limited to the period of the assessment rules out evaluation of potential problems occurring outside of what is typically normally occupied times. This represents a notable shortcoming of the limited IAQ assessment because indoor air parameters occurring at any period within a building have equal capacity to impact IAQ. This is particularly relevant to moisture control within a building and the potential for mechanical systems to drive indoor parameters well outside of acceptable ranges where microbial growth, moisture damage to building materials, and other allergens such as dust mites are effectively managed.

Bioaerosol Sampling

There is perhaps no other single testing parameter that has become more synonymous with the limited IAQ assessment than bioaerosol fungal sampling. Although this form of sampling is not without some value, the methods commonly employed to collect these samples and interpret them is often neither responsible nor representative of the assessed environment. The limited IAQ assessment has evolved to rely heavily on data from bioaerosol sampling and to a far lesser extent on an informed and exhaustive inspection by a knowledgeable indoor environmental professional. In fact, the results of such sampling cannot be properly interpreted without consideration of the findings of an exhaustive visual inspection, given that the potential sources or causes of indoor fungal amplification may exist in the readily observable assessment areas, hidden areas in the building such as wall and ceiling cavities, on contents and furnishings, and within many parts of the mechanical systems such as supply and return ductwork, variable air volume boxes, return air plenums, and air handling units. At best, bioaerosol sampling may serve to support negative findings of the visual inspection, or in other words to potentially assess for impacts from hidden areas for fungal damage. However, results of bioaerosol sampling that contradict negative findings of conditions of concern in the visual inspection do little to identify the actual sources or locations of damage. This often leads to irresponsible recommendations to building owners/operators to perform misdirected remediation in a vague attempt to discover the source, often at great expense that results in inconsequential corrective measures.

While the indoor air quality industry has begun to recognize the significant limitations of bioaerosol sampling and in many cases no longer recommends its use, it remains one of the most widely recognized metrics of IAQ. Yet the shortcomings of bioaerosol sampling are often related to numbers of test samples that are far too few to properly characterize test and control areas, improper conclusions and recommendations drawn from limited data, and use of sampling data to guide remediation or other corrective actions that may or may not be supported by the visual inspection. The interpretation of sampling data has traditionally been based on comparisons of results between indoor test and outdoor control locations, where lower concentrations of individual fungal varieties with fewer dominant varieties in indoor samples versus outdoor samples is considered as acceptable. However, when one considers that outdoor fungal concentrations of numerous varieties typically fluctuate considerably from hour to hour and day to day and there may or may not be limited correlation between indoor and outdoor trends, comparisons of data between these areas that was based on limited sampling performed over a relatively short period of time is problematic given that results may be considered as acceptable at one point in time and unacceptable, or elevated indoors shortly thereafter. If this is a distinct possibility, then data collected and interpreted by these means becomes unreliable and questionable to some degree. As such, bioaerosol sampling should be secondary to the comprehensive visual inspection, when performed should include sample numbers in both test and control locations that are adequate to characterize these areas, and based on the concerns in the building, potentially excluded from the assessment.

Other forms of fungal sampling, such and surface tape-lifts or swabs have similar limitations. There is no industry concensus on criteria that may be used to interpret testing results, and surface samples are far less representative of a given indoor space than bioaerosol samples. Although with tape-lift sampling, microscopists are able to view the arrangements and orientation of fungal spores and components along with the array of other particulates that have settled onto surfaces, the results of analysis offer little information of any bearing on delineation of conditions of concerns or damage, causes and effects, locations of damage, or corrective actions that should be employed. Fungal remediation does not change based on the fungal varieties that are identified. For these reasons, the primary benefit of surface fungal sampling would be to obtain laboratory verification that conditions of assumed or apparent microbial damage are indeed mold, or to attempt to connect visible microbial damage with potential human exposures that have resulted in specific fungal infections, with both purposes being most relevant in legal matters.

Building Sciences and Mechanical Systems

Indoor air quality is most commonly a product of the structure itself and the mechanical systems within it, yet dedicated consideration of the design of the building, the building materials used, and the design and condition of mechanical systems is often lacking from the limited IAQ assessment. The materials used in construction not only determine the capacity of the building to resist the influx of outdoor air and moisture (as water vapor), but also the capacity and resilience of the building to disperse accumulated moisture without resulting in microbial or other physical damage. The design and performance of mechanical, and to a certain extent the plumbing systems, have the potential to either significantly contribute to or detract from IAQ. They may both remove IAQ contaminants from occupied areas or be a reservoir for them, create both beneficial positive building pressurization or drive detrimental negative building pressurization, and by their very design transport and distribute IAQ contaminants and malodors from their sources to the occupants of a building. In order to address malodor complaints, particularly in large buildings, it is critical to map air flows, local and overall building pressurization, and air conveyance pathways. Given that the IAQ assessment is intended to evaluate the indoor environmental for bioaerosols, gases and vapors, malodors, particulates and several other constituents of concerns, as well as the sources and pathways by which they impact building occupants, analysis of building pressurization differentials and air flows in necessary in the interpretation of testing results and observations and for drawing accurate conclusions that lead to meaningful corrective actions.

As buildings age and a subjected to renovations, modifications and repairs over time, pathways of air flow may change, be created or eliminated. The greatest risk in this consideration is that through improperly planned or executed modifications and renovations to a building over time, new air pathways may be established that unintentionally introduce contaminants into the occupied environment, often from source locations that are remotely located or were previously of little concern to IAQ. A common example would be the installation of unsealed penetrations through the walls in a return air plenum to route new electrical and communications utilities, resulting in new air flows from wall cavities, chases, elevator shafts, or even the outdoors that are driven by negative pressurization created by the mechanical systems. An understanding of the mechanical systems, building pressurization, and the materials used in the building, particular those that comprise the envelope, is necessary to evaluating the interface between indoor and outdoor environments, controlled and uncontrolled influx of outdoor air and moisture, and indoor ventilation and moisture control. Although these conditions are anticipated and for the most part prevented in building design, engineering and construction, they do occur over time and must be anticipated and evaluated in the IAQ assessment. However, given that they can be difficult to evaluate, and in cases involving simpler, smaller scale building concerns they may be unnecessary to the success of the assessment, emphasis on buildings sciences and mechanical system design and performance are often overlooked in the limited IAQ assessment.

TRANSITION TO THE IEQ ASSESSMENT

While the engineering and design phase of construction seeks to anticipate the future uses, stresses (loads), operation and maintenance of a building well into the future, the IEQ assessment evaluates the efficiency, performance, and resilience of the design over time. Design engineers and architects are typically not called upon to perform assessments to address indoor environmental concerns or complaints, at least not to the same degree as IAQ/IEQ consultants, and therefore, may not have the opportunity to develop extensive observations on the unique conditions and deficiencies that arise from the operation of a building over years or decades.

With the emergence of IEQ the interior assessment now not only concerns itself with the long-standing field of IAQ, but also includes evaluation of environmental stressors such as lighting (natural vs. artificial), sound, vibration, housekeeping practices and chemical use in the building, use of deodorizers and air fresheners, relevant construction or renovation activities that may affect complaints areas, and quite importantly the occupants' interface with and control of the environment around them (i.e., control of lighting sources, availability of natural light, access to quiet, productive spaces, and the ability to adjust thermal and air flow comfort parameters). These factors combine with IAQ to comprise the overall experience of occupants in the buildings where they spend a large percentage of their waking hours.

Our approach to the emerging field of IEQ is a hybrid assessment that combines building sciences, indoor air quality, and industrial hygiene with the field of mechanical systems design, construction and maintenance. In our assessment model an industrial hygienist with experience in indoor air quality and building sciences begins the assessment by addressing the complaints and concerns expressed by the client or occupants and by performing an inspection of the occupied environment for observable sources that may impact IEQ. This is the space in which the occupant interacts with and is affected by the environment produced by the building and its systems. Simultaneously, the mechanical systems professional begins the assessment by characterizing the general design and specific construction of the heating, ventilation and air conditioning (HVAC) systems serving the building, including the building automation systems (BAS). The mechanical systems professional will typically begin the assessment in parts of the building that are not known to and likely never seen by the vast majority of building occupants. Initially the goal is to characterize the intended design and function of the mechanical system and then compare it to the existing state of the system. In addition, the BAS is analyzed for frequent alarms, errors and overrides that are indicative of ongoing, and often ignored, mechanical system deficiencies. One advantage that the mechanical systems professional has is the real world experience to anticipate and identify changes or modifications that commonly occur, poor construction practices, equipment and components that are frequently used and fail, and the effects of long-term operation and maintenance of the equipment. Whereas, the experienced industrial hygienist often attempts to anticipate trends in occupant complaints and behavioral patterns and sources of occupant dissatisfaction, in addition to localized stressors that may impact human health or result in damage to the building. The two fields of profession typically begin the assessment in two very parts of the building, but eventually meet in the middle.

This approach incorporates mechanical systems performance evaluation into the enhanced IAQ and building sciences assessment to arrive at the IEQ assessment model, the most significant advantages of which are as follows:

- The causes of wide spread or systemic effects on a building are far more definitively concluded without resulting in recommendations to the client to seek other professionals to perform subsequent assessments. This yields corrective actions that address the issue straight back to the root cause, since they are not based on conclusions that are limited to secondary or tertiary effects that more directly led to the conditions of concern that are the focus of the assessment.
- The building owner/operator is given clear insight into potential future deficiencies and equipment failures that they should plan and budget for.
- The building owner/operator can be informed on the overall improvement in IEQ and operational and energy savings that may be achieved by replacing equipment that is beyond planned obsolescence, which often pays for the purchase of new equipment in a surprisingly short period of time.

The IEQ assessment should build upon the existing IAQ model and incorporate numerous additional parameters and methods to better characterize the building, and should strive to evaluate each structure well beyond the snapshot in time, where possible.

Primary Assessment Methods

The basis of the IEQ assessment should be grounded firmly in a thorough visual inspection by qualified professionals, and rely far less on sample collection and laboratory analysis. There is little that may be revealed by laboratory analysis that cannot be determined by the visual assessment. The inspection phase of the assessment is aided through the use of moisture detection equipment, infrared thermography, a smoke pen to visualize air flows, a digital hygrometer or indoor air quality meter, and a high powered flashlight. There is typically little or no need to test for volatile organic compounds, bioaerosols, particulates, or other gases and vapors such as carbon monoxide or oxygen since interpretation of the data may be precarious or unsupported by industry standards and the results are often nowhere near occupational or other industrial hygiene exposure thresholds. The key to an effective visual inspection is minimizing or eliminating hidden areas and inspecting as many areas and building systems as possible that have the capacity to contribute constituents of concern to the occupied environment.

Environmental Monitoring

In IAQ assessments, the testing of air parameters (temperature, relative humidity, and carbon dioxide most commonly) are used to determine, often inadequately, if the mechanical systems are functioning effectively condition the indoor air and provide sufficient ventilation based on the occupant load. However, conclusions based on short-term data are limited and often incorrect when it comes to the overall performance of the structure and mechanical systems. Short-term testing data does not shed light on how the mechanical systems manage the indoor environment, only on if they have the capacity to hold these parameters to within industry-recommended ranges at some point in time. However, concluding that a mechanical system has the capacity to do something is not the same as concluding that it is actually doing it on a regular basis. The IEQ assessment should seek to monitor or log these parameters, along with others that are not as commonplace, over an extended period of time, producing trend graphs that illustrate how a building is functioning 24-hours a day in both occupied and unoccupied conditions. In addition, there is notable value in recent monitoring systems that have the ability to transmit data in real time through cloud networks to consultants who can set limits and alarms in analytical programming used to process the data so that the building owner/operator can be notified before conditions within the building worsen or damage to assets occurs.

Ambient indoor temperature, relative humidity, dew point and carbon dioxide readings may be logged along with parameters such as overall building pressurization, air handler unit coil temperatures, chilled water supply and return temperatures and chilled water flow rates. These parameters may be particularly critical with regard to buildings equipped with Dedicated Outdoor Air Systems (DOAS) or those that require large quantities of outdoor make-up air to offset significant exhaust sources, as malfunctions or improper cycling can have disastrous effects indoors in relatively short periods of time. Likewise, monitoring of overall building pressurization is critical for the same reasons. In fact, given the implications associated with negative building pressurization, monitoring of this parameter should be engineered into new commercial mechanical systems and tied into the BAS with alarms set to notify building owners and operators when it occurs. In hot and humid climates, it is likely more favorable to have a loss of mechanical system operation than to have continued operation with negative building pressurization.

Visual trending of a multitude of indoor air quality and thermal comfort parameters provides for an in depth analysis of how the indoor environment fluctuates and responds to building occupants and the operation of the mechanical systems, which sheds light on their overall performance and efficiency. This can be particularly valuable in cases where mechanical systems are operating with marginal efficiency. An effective line of inquiry with a client requesting an IAQ or IEQ assessment would indicate a need for long-term monitoring in addition to direct read measurements by potentially revealing symptoms that are suggestive of deficiencies driven by mechanical systems.

Supplemental Assessment Parameters

There are several other test and inspection parameters that set a comprehensive IEQ assessment apart from more limited IAQ assessments. In some cases these supplemental parameters are used strictly in the evaluation of the assessed environment, while others are used to evaluate mechanical systems against the intended design and function. Incorporating the use of absolute humidity or humidity ratio allows the assessor to compare the moisture load in one functional area to that in another, which may be of value when evaluating mechanical systems that may be achieving some cooling, but little dehumidification. Along the same lines, when evaluating chilled water systems in buildings with a history of moisture control, documenting water temperatures and flow rates leaving the Central Energy Plant (CEP) and at the coils of each air handling unit (AHU) can also be used to diagnose systems that may be capable of providing cooling, but with little or no dehumidification. Inspection of cooling coils for dust and particulate loading, as well as physical damage, deterioration or obstruction should be critical to even an IAQ assessment, given the effects of increased air velocity across the coils and loss of dehumidification. However, a cursory visual inspection of the return side of a coil may be unrevealing because obstructions may exist within the coil layers that can't be readily observed. Measuring the air pressure drop across a coil is a more definitive means of assessing its cleanliness and condition.

Beyond the assessment of interior parameters and building materials, in some cases consideration may be made as to the orientation of the building with respect to prevailing winds and season solar exposure. Buildings with long facades that are perpendicular to prevailing winds, particularly in regions known for consistent and significant wind action under normal conditions, or frequent significant weather events may experience chronic high pressure against the windward side and negative pressure along the leeward side. Although this effect is commonly understood in building design and engineering, it also has the capacity to greatly exacerbate indoor pressure differentials, overwhelming backflow prevention devices, overcoming localized positive building pressurization on the windward side, and driving the uncontrolled influx of outdoor air and moisture. Evaluation of the patterns of solar exposure on a building is typically of value in consideration of occupant comfort, but is also worth attention as it relates to localized air flows and pressurization between adjacent portions of a building. In this case, areas receiving greater solar exposure also demand greater supply from the HVAC system, while shaded sides of the building require less. This may result in higher air pressure in sunward portions of the building, with respect to shaded portions, driving air contaminants and odors along with air flow from high to low pressure zones.

REFLECTIONS FROM RECENT IEQ ASSESSMENTS

We have performed the hybrid IEQ assessment on approximately 1.23 million square feet of building space across sixteen sites over a four year period. In that time, distinct patterns have been observed that are revealing and may be informative to professionals involved in the design and construction of new buildings. The overall impression has been that effective indoor air quality and energy savings are typically in conflict. Maintaining exceptional air quality requires increased energy consumption, particularly when one considers cooling and dehumidifying the volumes of air necessary for adequate ventilation and make-up air in large commercial structures. Often, the building owner or manager is more concerned with the annual budgets for energy consumption, maintenance, and capital improvements than for the cost necessary to operate the building in accordance with its intended design, even though the ramifications for ignoring these operating requirement typically equate to greater expense, disruption of business, eroded occupant relations, and potential legal actions. Unfortunately it has been our experience that the IEQ assessment is, for the most part, still performed for reactive reasons, as opposed to proactive ones. Although the Green Building Council has built proactive IEQ management protocols into their accreditations and programs, the vast majority of buildings do not have LEED accreditation and do not follow USGBC guidelines, especially older infrastructure that was designed before the LEED programs and suffer the greatest occurances of IEQ issues.

One troubling trend that has been observed is engineering designs that may or may not have been altered by value engineering decisions, which result in a narrow window of safe operation for the building. In such cases, typically involving more recent construction projects, the mechanical systems are either marginally capable of managing heat and humidity loads placed on the building during the height of the summer season, or fail to maintain control of the indoor environment, resulting in significant damage to interior finishes and contents, remediation costs, of disruption of business. For example, in chilled water systems the chiller plant may be operating at approximately 90-100% capacity, while indoor air parameters (primarily relative humidity, dew points and carbon dioxide) are near the upper limits of industry recommended ranges, moisture control is marginally managed, and building pressurization is slightly positive to neutral. And these conditions remained consistent over a period of two to three months, making them seasonal in nature. Given that in many of these cases some or all of the equipment was recently installed, the design would inherently have little or no buffer to account for the natural wear and tear and loss in efficiency of the equipment that occurs over time, even with diligent operations and maintenance programs in place. It may be anticipated that these buildings will struggle to maintain control of the indoor environment over an extended period of time given the loss of efficiency and capacity, coupled with climate conditions that will almost surely continue to trend upwards.

In other cases, conditions of concern with the building were ultimately related to the user (local operator or building maintenance/engineer) interface with the mechanical systems and the BAS. In some the building owner was not receiving the full benefits of unoccupied modes and the BAS continued to operate beyond what was necessary, providing cooling and outdoor air ventilation at normal operating fan speeds and foregoing the opportunity to perform in a meaningful drying mode that could significantly reduce the daily latent heat load and extract retained moisture from the structure. Often times, building maintenance perceived that they were acting responsibly to manage the building systems, but given a lack of understanding of the effects related to their actions they actually caused significant IEQ impacts. In one building, the maintenance supervisor attempted to meet occupant temperature requests by modulating the chilled water temperature delivered to the AHUs. While this was reasonably successful in meeting occupant service calls, the result was a loss of dehumidification and wide spread microbial impacts to the structure and contents, exacerbating occupant complaints and straining tenant relations. In some cases, commercial building operators or engineering staff thought that by closing outdoor air intakes on the mechanical systems they could increase cooling and dehumidification, essentially by eliminating the energy consumption lost to the process of building ventilation. However, while these actions seemed logical on their face, the misunderstanding of building sciences meant significant negative building pressurization which resulted in unconditioned outdoor air being drawn into the structure through countless pathways, the formation of condensation and decay in the building materials along these pathways, and considerable humidity-driven microbial damage to the finishes and contents within.

Much has been said recently on the changes in building materials and designs used in modern construction projects. As it relates to this subject, building materials have been manufactured to be cheaper and more readily available, but at the expense of quality and resilience. In many structures the building materials used have less capacity to absorb and distribute low levels of moisture intrusion inherent to the regions where they were built, while at the same time incorporating more readily available food sources for microbial growth. Dense wood products from resilient tree varieties that were used decades ago have been replaced by less dense varieties that grow rapidly to produce a greater yield, yet are more susceptible to moisture damage. Sheet plywood has been replaced with compressed strand board or fiberboard products that are treated with chemical agents and bound with adhesives that provide rich nutrient sources for microbial growth. Although these products are cheaper and more readily available, there use may result in a demand on a building's mechanical systems to provide moisture control and extract retained moisture from the structure in order to prevent microbial impacts and decay.

CONCLUSIONS

The IEQ assessment remains an action taken by building owners and operators to address conditions of concern after they have occurred, as opposed to a preventative measure that is incorporated into ongoing operations and maintenance programs. In our assessment, significant deficiencies are typically identified that equate to extensive repairs and costs. Approximately 83% of our client have been willing to take partially or full action to make the necessary repairs, based on our recommendations, while approximately 17% declined. It is possible to interpret this as an approximate 83% participation rate of building owners and operators in the proper management of IEQ in their buildings. The remaining building owners perceive the costs of maintaining proper IEQ as being overly burdensome or more effectively applied to makeshifts corrective actions and reactive remediation and restoration. In essence, the value of proactive IEQ assessments in order to prevent damage to the structure, monitor equipment performance, maintain environmental control, and achieve a prosperous and beneficial indoor environmental experience for the occupants is not overtly recognizable to most building owners, even though the costs to perform these assessments are typically a fraction of the costs to restore a building to acceptable operation and performance.

REFERENCES

ASHRAE. 2019. ASHRAE Standard 62.1-2019 Ventilation for Acceptable Indoor Air Quality. Atlanta: ASHRAE.

ASHRAE. 2018. ASHRAE Standard 180-2018 Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems. Atlanta: ASHRAE.

American Industrial Hygiene Association (AIHA). 2004. Assessment, Remediation and Post-Remediation Verifications of Mold in Buildings. Fairfax, Virginia. American Industrial Hygiene Association.

AIHA. 2020. Recognition, Evaluation, and Control of Indoor Mold. Fairfax, Virginia. American Industrial Hygiene Association.

AIHA. 2006. The IAQ Investigator's Guide. Fairfax, Virginia. American Industrial Hygiene Association.

ASTM. 2014. ASTM International Standard D7338-14 Standard Guide for Assessment of Fungal Growth in Buildings. West Conshohocken, Pennsylvania. American Society for Testing and Materials.

US Environmental Protection Agency (EPA). 1991. Building Air Quality – A Guide for Building Owners and Facility Managers. Washington, D.C. USEPA.

National Air Duct Cleaners Association (NADCA). 2021. ACR – The NADCA Standard for Assessment, Cleaning, and Restoration of HVAC Systems, 2021 Edition. Mt. Laurel, NJ. NADCA.

National Air Duct Cleaners Association (NADCA). 2016. The HVAC Inspection Manual, 2016 Edition. Mt. Laurel, NJ. NADCA.

National Institute of Occupational Safety and Health (NIOSH) website – Indoor Environmental Quality. https://www.cdc.gov/niosh/topics/indoorenv/default.html.