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Indoor Air Quality Considerations During Construction and Renovation Projects

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Introduction

Safety and health on construction and renovation sites has always been a challenge due to the dynamic nature of these workplaces. Numerous contractors and trades performing a variety of processes and tasks, varying equipment and tools in use, building materials and configuration changing as the building progresses, and various chemicals being applied all contribute to safety and health hazards. There is a difference between "safety" and "health" and indoor air quality (IAQ) falls under the health category and the "hidden illnesses" that must be prevented.

Indoor air concerns are not just related to everyday office building settings. Construction and renovation projects present numerous IAQ problems that the building owner, design architect and engineer, construction manager, general contractor, and sub-contractors must address. IAQ exposures for construction workers and other employees during these projects need to be identified and addressed using a team approach. A proactive stance to identify and remove IAQ concerns before they affect the workplace is a big part of that approach.

Extensive renovation and construction projects often result in various IAQ concerns including the use of chemicals such as glues and mastics, solvents, sealers, and other products. Equipment and furniture can "off-gas" chemicals such as formaldehyde. The building may contain sources of IAQ concerns such as asbestos or lead-based paint. Processes used to complete the work can result in IAQ concerns such as hexavalent chromium from welding fumes. Any strange odor during renovation projects can set off a series of complaints.

Renovation projects often present the need to complete work in areas closely adjacent to active, non-construction employees who may not be used to the odors, dust and noise associated with these types of projects. The white powder on the desk of an employee may be drywall dust to the construction worker, but in these days of heightened awareness to personal protection, the office worker may perceive that dust to be asbestos, anthrax, or mold.

Due to a variety of reasons including increased regulations, over zealous newspaper and television reporting, the magnitude of information available on the Internet, and the rise of the "social media", employees are more educated on IAQ issues and they have grown to expect good IAQ at work. This mix of increased knowledge, high expectations, and decreased tolerance leads to a psycho-social response that must be addressed early.

In new construction or remodeling, efforts must be made to control poor air quality and to rethink the use of some building materials and techniques. The early identification of these chemicals, products and processes is key to avoiding the delays and liabilities resulting from improper containment of these chemicals. Early identification of the issues will allow for adequate communication and public relations to educate workers, employees and other building occupants about the concerns and precautions in place.

Protection of construction materials and rapid containment and cleanup of spills are essential. During construction, building materials should be kept dry and off the ground. Allowing moisture to enter building materials such as wood or fabric may stimulate the growth of mold. A process should be in place to address water and chemical spills on the site. Any spills need to be cleaned up immediately and saturated materials must be removed from the site and disposed of properly.

As buildings are being remodeled or replaced, the issue of air quality becomes more evident. While older buildings had designs that needed improvement, they had one symptom that actually helped air quality—they were not airtight. These buildings had numerous entry points for air to flow in and out. While this played havoc on heating bills, it sometimes allowed an exchange of air that filtered out pollutants and brought in fresh air. Newer structures are tighter and, thus, the direct exchange of air is reduced or eliminated making the heating, ventilation, and air conditioning (HVAC) system more critical. One way building owners may choose to address energy conservation is to shutdown HVAC systems when the building is not in use. However, the question becomes "What is happening while it is off?" The lack of air filtering and temperature fluctuations could lead to poor IAQ.

New standards for air quality and the exchange of air have been enacted to help eliminate the problem of contaminants. However, the pressure to conserve energy and recent focus on energy efficiency and "green buildings" is affecting IAQ as voluntary standards and building codes are being implemented and revised to meet the often stringent requirements.

The focus has grown to include the concept of indoor environmental quality (IEQ). The concept of IEQ takes into account the overall human responses to pollutants, climatic factors and other stressors such as noise and light that are generally categorized according to the type and degree of responses and the timeframe in which they occur. Contractors need to be aware of IEQ concerns and take measures to ensure that proper processes are in place. The current voluntary standards known as LEED (Leadership in Energy Efficient Design) are setting these goals and it appears that the voluntary aspect of LEED may be replaced as more building codes are being revised to include energy efficient requirements and "smart" building technology. Although the United States Environmental Protection Agency (USEPA) currently regulates most areas of IAQ, it would not be surprising if the Occupational Safety and Health Administration (OSHA) ventures into regulating IAQ more issues in the future.

Design for Health

Many safety and health professionals are familiar with the concept of "Design for Safety", whereby the issues involved with making a building "safe" are identified, discussed, and incorporated very early in the construction process. The same concept can be revised to "Design for Health", whereby the issues related to IAQ and other environmental concerns can be identified, discussed, and incorporated into the early planning stages. One way to accomplish this is to reinforce and communicate your concern about preventing IAQ problems to the engineer,

architect, interior designer or other professionals involved in the project.

New construction requires a concentrated effort to incorporate IAQ goals early in the "building" process at the design and engineering stages. IAQ issues may need to be addressed in bid and construction documents. A 2009 guidance document available from the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) entitled *Indoor Air Quality Guide – Best Practices for Design, Construction, and Commissioning* provides up to date information on a variety of IAQ and IEQ concerns including significant information on how to manage the design and construction process to achieve good IAQ. The first chapter or "objective" of the guidance document covers the following:

- Integrate Design Approach
- Commission to Ensure that the Owner's IAQ Requirements are Met
- Select HVAC Systems to Improve IAQ and Reduce the Energy Impacts of Ventilation
- Employ Project Scheduling and Manage Construction Activities to Facilitate Good IAQ
- Facilitate Effective Operation and Maintenance for IAQ

The architect may not know how to accomplish a specific result, so it is critical that the engineers and project managers discuss the design processes early on, with one goal being the identification of potential IAQ concerns. The plans may show a potential pathway for poor IAQ to affect other parts of the building, so it is important to look at the entire building, not just the immediate area of the renovation or construction work.

Early assessment of potential IAQ issues in renovation and construction projects should include the architects and engineers communicating with the onsite project managers. This early communication should include a review of plans to identify how the building will be affected or built. The plans are detailed enough to provide an overview of the building materials that will be affected. One prime example of "poor" design for safety is placing an emergency generator too close to the building fresh air intake. This can result in occupant complaints when the generator runs during monthly tests or in true emergency situations.

Building Information Modeling (BIM) is a new way of building design. According to Wikipedia, BIM is

> "…the process of generating and managing building data during its life cycle. Typically it uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction. The process produces the Building Information Model (also abbreviated BIM), which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components."

The use of BIM to proactively identify, and resolve, IAQ and health issues (as well as safety issues) in the design plan stage has great potential and hopefully architects and engineers will recognize and use BIM in this manner.

For large renovation projects, depending on the types of IAQ concerns identified, it may be prudent to collect preconstruction air samples to assist in identifying issues as a "baseline" of existing levels and help make comparison measurements during the project, if needed. Pre-sampling of existing asbestos fibers in the air prior to conducting an asbestos abatement project is very common and often required. Qualified IAQ consultants may be needed in larger, complex jobs, but they do provide good third-party liability protection.

A walkthrough of an existing building is another important step in the IAQ identification process. Smoke tests or other means to map out airflow patterns may be required. Particular attention should be paid to areas where air pressure and air flow may be affected such as elevator shafts, doorways, windows and air vents. Identification of existing poor IAQ potential include closed or broken outdoor air dampers, open containers of chemicals or an improperly maintained HVAC system.

A simple yet important goal is to be sure new construction and active renovation areas attached to occupied buildings are properly insulated from building occupants. The work area should have a sealed entrance that would prevent vapors and fumes from adhesives, sealants, or welding from filtering into the occupied space. Contractors should be required to use construction entrances to the project that bypass occupied areas. Construction vehicles can be a source of contaminants and the use and parking of these vehicles should be reviewed.

ASHRAE Standard 62.1-2007, *Ventilation for Acceptable Indoor Air Quality*, is a great resource for issues related to ventilation. In addition, ASHRAE sponsors a training course on the details of "62.1-2007" and safety and health professionals wanting an in-depth look at those related issues may want to take that course.

Health Effects

There are many types of health effects attributable to indoor air quality during construction; these are discussed below.

Acute Effects

Acute effects are those that occur immediately (e.g., within 24 hours) after exposure. Chemicals released from building materials may cause headaches, itchy eyes or runny noses in sensitive individuals shortly after exposure. Generally, these effects are not long-lasting and disappear shortly after exposure ends.

Chronic Effects

Chronic effects are long-lasting responses to long-term or frequently repeated exposures. Long-term exposures to even low concentrations of some chemicals may induce chronic effects. Cancer is the most commonly associated long-term health consequence of exposure to indoor air contaminants. For example, long-term exposures to environmental tobacco smoke, radon, asbestos and benzene increase cancer risk.

Fumes, Vapors, Mists, Dusts & Particles

There is a difference between fume and vapor. The construction process may generate any number of air contaminants, and knowing how and why the particular byproduct (i.e., fumes, vapor, and dust) is generated and how it is dispersed throughout the site can be helpful in understanding potential IAQ problems.

Simply put, a fume is a combination of fine airborne liquids and solids often generated during a heating process (i.e., welding fumes); a vapor is usually generated during a liquid process (i.e., gasoline vapors).

A dust is a suspension of fine solid particles, and a mist is a suspension of fine liquid droplets. It is important for the construction manager to understand these differences in order to identify the potential problems associated with each.

The fairly new science of nanotechnology and nanoparticles and the effects on IAQ during renovation and construction requires further study but the existence of nanoparticles is

something that deserves attention. Nanoparticles in welding fumes, dusts, etc. on a worksite have not been fully measured or identified.

Outdoor Air Quality

Knowing the existing outdoor air quality (OAQ) should be a large part of identifying IAQ issues since the areas of buildings under major renovation and various stages of new construction are open to the outdoors and outdoor contaminants can affect workers health. OAQ includes concern over levels of particulates, lead, ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, dust, volatile organics compounds (VOCs), odors, mold, etc. The published Air Quality Index for ozone is a good example of an indicator of an elevated OAQ concern. Awareness and compliance with National Ambient Air Quality Standards (NAAQS) should be a part of an IAQ program during large renovation and new construction projects. The weather certainly has an effect on workers exposed to hot and cold stressors and could compound the effect of IAQ issues (i.e. ozone in hot weather). Mold levels are often higher on the outside of a building due to filtering of outdoor air entering the building. The best way to measure mold inside a building is to measure and compare indoor levels against outdoor levels.

Discomfort

Discomfort is typically associated with climatic conditions, but building contaminants may also be implicated. People complain of being too hot or too cold, or experience eye, nose or throat irritation because of low humidity. However, reported symptoms can be difficult to interpret. Complaints that the air is “too dry” may result from irritation from particles on the mucous membranes rather than low humidity; “stuffy air” may mean that the temperature is too warm or that there is lack of air movement; “stale air” may mean that there is a mild but difficult to identify odor. These conditions may be unpleasant and cause discomfort among occupants, but there is usually no serious health implication involved. Absenteeism, work performance and employee morale, however, can be seriously affected when building managers fail to resolve these complaints.

Performance Effects

Significant measurable changes in people’s ability to concentrate or perform mental or physical tasks have been shown to result from modest changes in temperature and relative humidity. In addition, recent studies suggest that similar effects are associated with indoor pollution due to lack of ventilation or the presence of pollution sources.

Communication Is the Key

Needless to say, public relations is very important when working in buildings with “sensitive” occupancies such as schools, daycare centers, hospitals, nursing homes and other buildings where an IAQ concern could turn into significant liability issues. These buildings often present a higher density of population than a typical office building.

According to EPA, within the last 15 years, the number of children suffering from asthma has doubled. Nearly 5 million children—or one out of every 13 students in schools—has asthma. While IAQ may not be the cause of all the increase, it can aggravate the symptoms. Besides asthma, poor IAQ contributes to headaches, nausea, dizziness and allergies.

Children in particular are more susceptible to air quality concerns. Smaller air passages allow small infections to restrict breathing. Growing students require more oxygen for their high metabolism rate and thus exchange air at a greater rate than adults. This permits any pollutants to enter their system at a higher rate.

Materials Evaluation & Selection

The following discussion is about evaluating and selecting materials that will minimize the negative effects of construction on IAQ.

Selecting Products and Materials

Specify products and processes that minimize odors and emissions, while maintaining adequate safety and efficacy. Review the general information provided by the product labels and MSDS (Material Safety Data Sheets). Request information from suppliers about the chemical emissions of products under consideration for purchase.

Work with manufacturers to select products with the desired emission profile, and develop a strategy to minimize building contamination during installation. Require information about emissions from manufacturers. Manufacturers have both a marketing and liability motivation to test their products. Testing laboratories and emission testing protocols are rapidly developing.

IAQ issues can affect other construction materials which can create liability concerns. One example of how "bad" materials can enter the construction industry is the application of drywall manufactured in China that entered the United States between 2001 and 2007. The drywall apparently had a high content of sulfur which when released in the air, damaged copper materials (HVAC coils, electrical wiring, etc.). Health effects from this situation were not readily identified, but it is a good example of how a chemical can be released and cause IAQ liability as millions of dollars are being spent to rectify the drywall problems.

In selecting materials, investigate each material's potential to pollute the indoor environment in four key areas:

1. Release of particles, fibers or chemicals inherent in the material selected;
2. Potential ability of chemical molecules or particles in the air to adsorb (physically attached) to the material and be released later (e.g., during warm weather or when disturbed);
3. Potential for microbial growth on material surfaces; and
4. Maintenance or refurbishing requirements requiring chemical treatment that can become pollution sources:

- "Wet-applied" materials such as caulks, paint and adhesives are of particular concern because of the high emission rates experienced while curing.
- Fast-drying materials offer greater flexibility in developing strategies to minimize contamination of other building materials.
- Materials used in areas likely to become moist or wet (e.g., kitchens/ showers, downstream from cooling coil, area around humidifier) can foster microbial growth if a carbon source is available. Easily cleaned, smooth surfaces are recommended.
- Use of fibrous material, including fiberglass insulation in ducts, requires careful consideration of the potential for soiling. Soiled fiberglass will take on moisture much more rapidly than clean fiberglass, creating the potential for microbial growth. Particles provide carbon, and the fiberglass matrix provides self-sheltering surfaces for microbial growth.
- Fleecy materials covering large areas, such as carpeting, fabric upholstery, textile wall coverings or ceiling tiles can adsorb chemical and particle contaminants during the finishing stage of building construction, and release it later after occupancy. When wet, these surfaces also foster microbial growth.

Strategies for Selection & Installation of Materials

The following are strategies for selecting and installing materials to preserve IAQ during construction:

- Identify target products of particular concern, considering potential emission rates, toxicity and quantity used.
- Gather information from manufacturers, suppliers and other sources.
- Require specific testing, if necessary, of emissions over time.
- Select and/or negotiate for materials with low emissions and quick decay rates where possible.

Use this information to determine strategies for the sequence of installation and the ventilation strategies during installation. Negotiate pre-shipment storage techniques that accelerate emissions of partitions, carpets and similar materials before installation. Sometimes, perforated containers can serve to facilitate off-gassing during shipment.

Work Schedules

Activities that produce dust, odors or emissions should be scheduled for unoccupied periods. if possible.

Isolation of Work Areas

Return registers should be blocked so that contaminants are not recirculated from the demolition/construction area into adjoining areas, and install temporary barriers to confine dust and noise. If possible, install temporary local exhaust to remove odors and contaminants, and check to confirm that the temporary ventilation system is operating as planned.

Monitoring the Construction/Renovation Process

Many IAQ problems occur as a result of poor construction practices, change orders or field orders. Monitoring all work is critical to good IAQ.

- Monitor field orders, shop drawings, and change orders impacting IAQ specifications and designs. Check deviations from construction documents.
- Monitor IAQ specifications during progress by inspections, and check that products and materials specified are actually being used.
- Monitor obstacles or construction debris in ventilation airflow paths.
- Ensure proper installation of insulation, HVAC equipment and ductwork,
- Monitor HVAC system testing and balancing as it occurs.
- Monitor contaminant isolation and control strategy during construction/ finishing.

Early Start-Up of HVAC System

General contractors should avoid requiring the HVAC contractor to start up the permanent HVAC system during the construction phase of new construction. The HVAC system often gets contaminated with various construction materials such as drywall dust that is difficult to remove and, therefore, is introduced into the atmosphere once the building is occupied. In addition, in high-humidity areas, the introduction of moisture into the HVAC system before it is commissioned and balanced properly, including humidity controls, could lead to moisture problems. Temporary heating and cooling for construction workers is often a better alternative. In large renovation projects, the same difficulties may be experienced if the existing HVAC system is running during “dirty” phases of the work.

Isolation of Contaminants

When Occupants Are Present

An isolation strategy is usually a necessary condition for effective IAQ control, but it is made more feasible to achieve when pollutant emissions are also controlled through material selection and installation strategies:

- Establish a complete physical enclosure to the construction zone.
- Seal all return ducts to ensure that contaminants do not enter the HVAC system.
- Using existing and temporary exhaust fans (negative air machines), establish a containment zone under significant negative pressure (e.g., 0.02 to 0.04 w.g.). The supply air to the construction area may also need to be shut down.
- Monitor pressure relationships to ensure that the containment zone is under significant negative pressure, and that the construction zone beyond the containment area is under negative pressure relative to all surrounding occupied spaces on the same and on adjacent floors.
- Ensure that exhausted contaminants do not re-enter the building through open windows or the air intake of the HVAC system.
- Maintain the occupied spaces under positive pressure relative to the outside.

Installation of New Furnishings

New furnishings can affect the IAQ as well as construction and demolition; here are suggestions to forestall such effects:

- Ask suppliers to store new furnishings in a clean, dry, ventilated location so that volatile organic compounds will be emitted before installation.
- Minimize the use of adhesives during installation or specify low-emitting products. After new furnishings are installed, increase the ventilation rate to flush the area with outdoor air and dilute emissions.

Smoking

An agreement with outside contractors concerning no smoking should be established in and near the buildings. Environmental tobacco smoke has been one of the most widespread indoor air pollutants, however recent regulations that ban smoking indoors has helped address this issue dramatically.

Occupant Relations

Managing occupant relations to prevent IAQ problems involves: allocating space and monitoring the use of building areas to isolate odor- and contaminant-producing activities and avoid re-entrainment; establishing a communication strategy that is responsive to complaints and provides tenants with information about their role in preventing IAQ problems; and modifying employee manuals or lease agreements as necessary to clarify the responsibilities of occupants and building management. A safety and health committee or joint tenant/management IAQ task force that represents all major interest groups in the building can be very helpful in disseminating information and fostering a cooperative approach to IAQ management.

Recordkeeping

As new practices are introduced into a building (such as equipment), an organized system of recordkeeping will help the start-up to become part of routine operations and forestall to complications that could affect IAQ. The best results can be achieved by taking time to think

about the established channels of communication so that individuals understand that there is some form of recordkeeping and control.

Common Sense and Vigilance

Even though the factors that affect the quality of the indoor environment can be numerous during construction, the good news is that most indoor environmental problems can be prevented or corrected easily and inexpensively through the application of common sense and vigilance on the part of everyone in the building. Success depends on cooperative actions taken by management and occupants to improve and maintain IAQ during these discomforting times. By becoming knowledgeable about indoor air quality, building occupants are in a good position to help facility managers maintain a comfortable and healthy building environment.

Odors from some adhesives can linger for long periods. When new materials such as paint, carpet adhesive, caulking and sealants are used, it is generally advisable to ventilate the areas for at least 72 hours and to use exhaust fans to remove contaminated air from the building. Failure to do this may cause vapors and fumes, through negative air pressure, to be drawn into the occupied area.

Also, equipment that runs on gas, kerosene or oil should not be used during occupied times unless required. Activities that involve this type of equipment need to be completed afterhours and the building properly ventilated when work is completed. Whenever possible, this type of equipment needs to be outside the building.

Contractors should have construction trailers present on site for the storage of any materials, such as paints and adhesives that could leak odors and vapors. Such materials should not be stored in the building. Carpet that has been tested under the Carpet and Rug Institute's Air Quality Carpet Testing Program should be used. When installing HVAC ductwork, extra effort should be taken to prevent insulation from becoming wet. Also, ducts need to be sealed from construction dust during the installation phase. All these efforts require close supervision. Such attention to detail will reduce the number of complaints from the adjoining occupied structure.

Remodeling

Remodeling involves additional safety controls. All the procedures in new construction need to be part of the overall plan. In addition, working inside an occupied building presents another set of challenges. During demolition, contractors need to check for asbestos materials and lead-based paints.

Buildings built between 1950 and 1975 often had asbestos material present. It is advisable that a building have a thorough asbestos review, including the sampling of materials, before renovation begins so contractors will know what they face. In pipe insulation samples need to be removed from joints and "elbows" as well as pipe runs. Again, in some construction, asbestos insulation was only used in joints.

Floor tile is another concern. The old process of breaking up and removing tile could release fibers into the air as well as cleaning the mastic glue. Even low-odor or orange-based mastic removers may emit odors that are offensive to building occupants.

New machines are available that heat and lift the tile, thus preventing any release in the air. The process is so clean that a hygienist report is not required nor do the areas need to be sealed off. Either way, such work needs to be scheduled for off hours or vacation periods where the building is not occupied.

As much as is physically possible, the work areas and the occupied areas need to be separated with solid barriers. Simply stringing caution tape across the hall will not solve IAQ issues. Air ducts need to be sealed off also so contaminants cannot move from the construction area to the areas where occupants are located. Construction debris and dust needs to be frequently removed. Dust control procedures should be used when dust is an issue.

Maintenance for IAQ

After all construction is completed, the job of air quality control falls on the operations and maintenance department. Frequently, low staffing levels do not allow a preventive maintenance program to take place. Sufficient resources must be available for this program since it is an integral part of the overall air quality program. Maintenance departments must be sure that they receive detailed as-built drawings to cover renovations or construction. This allows the maintenance staff to quickly trace and stop moisture problems and address airflow issues.

Allowing for frequent filter changes on HVAC also helps eliminate many contaminants. Regular inspection of air supply outlets and inspection of air plenums for mold growth, excess dirt or obstructions will ensure that contaminants do not get a foothold in the building. Condensate pans need to be cleaned regularly. All schedules of cleaning or replacement need to be documented.

When new HVAC systems are commissioned, it is important that programmers and balancers refer to proper standards in their calculations. Also the temperature and humidity requirements of proper standards need to be followed. Such standards ensure that airflow is sufficient to remove contaminants and provide adequate ventilation in the new or remodeled airtight buildings.

Systems must be set up to bring in sufficient outside air to cleanse the air on a continual basis. In some cases, this may require the room air be exchanged up to five times per hour. Often, this leads to complaints from occupants in rooms with ventilator units that the fan “runs frequently and blows cold air.” Untrained individuals often assume this to mean the unit is not functioning properly when in reality it is doing exactly what it is designed to do. Educating the staff will help to eliminate such complaints.

Conclusion

Poor jobsite construction practices can frustrate even the best design by allowing chemicals, moisture, and other contaminants to become potential long-term problems. Pressures to be energy efficient in the design and application of construction processes and practices will impact IAQ in the near future. Using “Design for Health” strategies and preventive jobsite practices will reduce the potential for residual problems with IAQ in the completed building and reduce undue health risks for workers.

Unfortunately, serious health complaints have resulted from careless acts during construction projects, such as failure to clean up spilled adhesives or to properly ventilate during and after applying sealants in an occupied building. These mistakes have led to unpleasant headlines and costly lawsuits. Good IAQ strategies during construction will help eliminate these potential liabilities.

SH&E professionals and risk managers may be reluctant to take on the added responsibility of IAQ planning and preventive jobsite practices. However, building owners and project architects across the country have experienced litigation related to poor IAQ resulting from construction activities. Addressing these issues before and during construction will reduce

exposure of the owners and designers to potentially expensive litigation in the future.

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